CURRICULUM & SYLLABI

M.Tech. BIOTECHNOLOGY

Effective from AY: 2024-25

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION
Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION
- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department
Biotechnology

VISION
To become a global centre of excellence for quality education, research, technological services and entrepreneurship in emerging areas of biotechnology.

MISSION
- Providing a quality education in pursuit of knowledge that establishes a strong foundation for understanding developments in the rapidly advancing field of biotechnology through research and instruction.
- Promoting scientific discovery and development in diversified fields of Biotechnology through a fusion between engineering and life sciences.
- Fostering relationships with institutes of higher learning and research, alumni and industries.

Program: M.Tech. Biotechnology

Program Educational Objectives

PEO-1	Pursue successful industrial, academic and research careers in specialized fields of Biotechnology.
PEO-2	Apply the knowledge of advanced topics in Biotechnology to meet industrial and research needs.
PEO-3	Use modern computational, analytical tools and techniques to address biotechnological challenges.
PEO-4	Identify issues related to ethics, society, safety and environment in the context of biotechnology applications.
PEO-5	Engage in lifelong learning for career and professional growth for society and the environment.

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4	PEO-5
Providing a quality education in pursuit of knowledge that establishes a strong foundation for understanding developments in the rapidly advancing field of biotechnology through research and instruction.	2	2	3	3	3
Promoting scientific discovery and development in diversified fields of biotechnology through a fusion between engineering and life sciences.	2	2	2	3	3
Fostering relationships with institutes of higher learning and research, alumni and industries.	1	1	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: M.Tech. Biotechnology

Program Outcomes

PO-1	Carryout independent research, investigation and development work to solve practical problems.
PO-2	Write and present a substantial technical report and document.
PO-3	Design modern Biotechnological methods for bioprocess plant and allied processes.
PO-4	Apply research-based knowledge and biotechnological methods to investigate complex biological problems.
PO-5	Identify measures for energy, environment, health, safety and society following ethical principles.
PO-6	Pursue life-long learning to enhance knowledge and skills for professional advancement.

CURRICULUM
M.Tech. Biotechnology

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	BT16001	Bioprocess Engineering and Process Biotechnology	3-0-0	3
2	BT16003	Molecular and Cellular Biology	3-0-2	4
3	BT16005	Biocomputing and Computational Biology	4-0-0	4
4	BT16XXX	Professional Elective - I	3-0-0	3
5	BT16XXX	Professional Elective - II	3-0-0	3
6	BT16007	Plant Cell and Bioprocess Technology Lab	0-0-3	2
7	BT16009	Biocomputing and Computational Biology Lab	0-0-3	2
			Total Credits	**21**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	BT16002	Bioprocess Modelling and Simulation	3-0-0	3
2	BT16004	Biomaterials and Tissue Engineering	3-0-0	3
3	BT16XXX	Professional Elective – III	3-0-0	3
4	BT16XXX	Professional Elective – IV	3-0-0	3
5	BT16XXX	Professional Elective - V	3-0-0	3
6	BT16006	Bioprocess Modelling and Simulation Lab	0-0-3	2
7	BT16008	Cell Culture and Tissue Engineering Lab	0-0-3	2
8	BT16096	Minor Project	0-0-0	2
			Total Credits	**21**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	BT17089	Seminar and Technical Writing	0-0-0	2
2	BT17091	Summer Internship / Research Experience	0-0-0	2
3	BT17093	Comprehensive Viva-Voce	0-0-0	2
4	BT17097	Dissertation: Part-A	0-0-0	8
			Total Credits	**14**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	BT17098	Dissertation: Part-B	0-0-0	12
			Total Credits	**12**

Professional Elective Courses:

Professional Elective - I, II		
S.No.	**Code**	**Course Title**
1	BT16021	Recombinant DNA Technology
2	BT16023	Systems and Synthetic Biology
3	BT16025	Bioeconomy and Biorefineries
4	BT16027	Bioseparation Technology
5	BT16029	Drug and Vaccine Informatics
6	BT16031	Fermentation and Enzyme Technology
7	BT16033	Plant Cell and Tissue Culture

Professional Elective - III, IV, V		
S.No.	**Code**	**Course Title**
1	BT16022	Quantitative Biology
2	BT16024	Applied Environmental Microbiology
3	BT16026	AI and Machine Learning
4	BT16028	Nanotechnology for Medicine and Healthcare
5	BT16030	Molecular Therapeutics
6	BT16032	Animal Cell Culture
7	BT16034	Biotechnology for Waste Management
8	BT16036	Genomics and Proteomics

The Overall Credit Structure

Course Category	Credits
Program Core	25
Professional Elective	15
Minor Project	2
Seminar and Technical Writing	2
Summer Internship / Research Experience	2
Comprehensive Viva-Voce	2
Dissertation	20
Total Graded Credit Requirement	**68**

SYLLABI

M.Tech. Biotechnology

1st Semester

BT16001 **3-0-0 (3)**

Bioprocess Engineering and Process Biotechnology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the material balances for biological systems
CO-2	Comprehend the thermal death kinetics of microorganisms
CO-3	Know and understand the Rheological behavior of fermentation fluids
CO-4	Understand the applications of heat and mass transfer in bioprocesses
CO-5	Design and analyze various types of bioreactors for the production of metabolites

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	3	–	–
CO-2	1	3	2	2	–	–
CO-3	1	2	2	2	–	–
CO-4	2	2	–	2	–	–
CO-5	2	3	1	3	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Engineering principles of biological systems: Material balances of biological processes, Recycling, and purge processes, Kinetics of batch and continuous microbial kinetics. Stoichiometry of microbial growth and elemental balances. Role of a bioprocess engineer, kinetics of microbial growth, substrate utilization, and product formation; Batch and continuous culture.

Thermal Death Kinetics: Media formulation and sterilization; Thermal death kinetics of cells, Design of batch and continuous thermal sterilization, Air sterilization.

Rheology of Fermentation fluids: Nature and types of fluids, The Reynolds number and fluid flow types, velocity profile and boundary layer concept, Agitation in bioreactors, Power calculation for aerobic and anaerobic processes.

Heat and Mass Transfer in Bioreactors: Types of heat transfer, Fourier law of heat transfer, individual and overall heat transfer coefficients, LMTD, Heat transfer of Boiling and condensation, Heat exchangers, Diffusion mass transfer, Theories of mass transfer, Gas-Liquid mass transfer, Measurement of K_La, Oxygen transfer methodology, Maximum cell concentration.

Bioreactor analysis: Types of Bioreactors, Bioreactors in plant and animal cell culture. Bioprocess technology for the production of biomass, primary and, secondary metabolites.

Learning Resources:

Text Books:

1. Paulin M. Doran, Bioprocess Engineering Principles, Elsevier Science & Technology Books, 2008, 2nd Edition

2. James E. Bailey, David F. Ollis, Biochemical Engineering Fundamentals, Mc Graw Hill, 2004, 2nd Edition
3. Michael Shuler, Fikret Kargi, Bioprocess Engineering Basic Concepts, Prentice-Hall India, 2006, 2nd Edition

Reference Books:

1. Wolf. R. Vieth, Bioprocess Engineering: Kinetics, Mass Transport, Reactors and Gene Expression, A Wiley-Inter science Publication, 2009, 1st Edition
2. P F Stanbury and A Whitaker, Principles of fermentation technology, Pergamon press, 2005, 3rd Edition

Other Suggested Readings:

1. https://www.kgi.edu/news/what-is-bioprocess-engineering/
2. https://www.labmanager.com/big-picture/bioprocessing-overview-and-trends/the-basics-of bioprocess-engineering-25963

BT16003 **3-0-2 (4)**

Molecular and Cellular Biology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Illustrate mechanisms of Intracellular compartments and protein sorting in the cell
CO-2	Describe the intracellular molecular signaling pathways
CO-3	Explain the molecular mechanisms of cell cycle and cell division
CO-4	Compare the molecular mechanism of cell death and cell renewal process

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	–	–	1	2
CO-2	–	–	2	1	–	–
CO-3	3	2	2	3	1	3
CO-4	3	2	2	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

The molecular membrane structure of the cell: The molecular mechanisms of Intracellular compartments and protein sorting, The transport of molecules between the nucleus and the cytosol, The molecular mechanisms of endocytosis, and exocytosis.

Cell signaling: Principles of cell signaling, signaling through G-protein-coupled receptors, signaling through enzyme-coupled receptors, alternative signaling routes in gene regulation secondary messengers, signal integration.

Cell cycle progression: Overview of cell cycle; the molecular mechanism of cell-cycle control system: G1 phase, S phase, G2 phase, mitosis, cytokinesis, meiosis, control of cell division and cell cycle checkpoints.

Cell death and cell renewal: Programmed cell death by apoptosis, Cell-surface death receptors activate the extrinsic pathway of cell death, Molecular basis of cancer, cell division and cancer development, Stem cells and cell differentiation.

List of Experiments:

1. Isolation and Quantification of RNA.
2. cDNA Preparation.
3. Amplification of cDNA.
4. Studies of Gene Expression using qPCR.
5. Restriction Mapping.
6. Protein Expression and Purification.
7. Apoptosis studies using a Fluorescence microscope.

Learning Resources:

Text Books:

1. Berk A, Kaiser CA, Harvey L, Amon A, Ploe H, Bretscher A, Krieger, M, Martin KC, Molecular Cell Biology, WH Freeman, 2021, 9th Edition

Reference Books:

1. Geoffrey M. Cooper, Robert E. Hausman, The Cell: A Molecular Approach, Oxford University Press, 2022, 9th Edition

BT16005 **4-0-0 (4)**

Biocomputing and Computational Biology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Accomplish the data retrieval process from various sources
CO-2	Comprehend the implications of sequence bioinformatic techniques in biotechnology
CO-3	Execute programs in Python language for bioinformatic applications
CO-4	Implement and Analyze the data in Biology

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	2	3	2
CO-2	2	2	2	3	3	2
CO-3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Data mining: Introduction to data mining, text mining, string mining, Knowledge Discovery in Databases (KDD), web search engines, diversity of database types, efficiency and scalability, Applications of data mining and society. Data warehouse(s).

Programming in Python: Introduction to python, history of python, python features, writing python program, values and variables; numeric values, expressions, variables; legal variables, assigning values to variables, operators; arithmetic, assignment, comparison, logical and bitwise. List Methods, Tuples: Immutable Sequences, The tuple Function, Basic Tuple Operations. Control flow statements: simple if statement, if/else statement, if/elsif statement, nested if statement, conditional expressions, while loop, for loop, continue and break statements.

Big Data: Volume, variety, combining multiple data sets, velocity, veracity, data quality, data availability, data discovery. Privacy in bigdata, benefits of bigdata analytics in healthcare sector and benefits. How data commons are changing the way that large biomedical dataset. Molecular diagnostics in the era of big data and precision medicine.

Learning Resources:

Text Books:

1. Mount, David W., Bioinformatics: sequence and genome analysis, Cold Spring Harbor Laboratory Press, 2001
2. Jason Kinser, Python for Bioinformatics, Jones and Bartlett Publishers, Sudbury, Massachusetts 2009
3. JinXiong, Essential Bioinformatics, Cambridge University Press, 2006, 1st Edition
4. Rajendra Akerkar, Big Data Computing, CRC Press, Taylor & Francis Group, 2014

Reference Books:

1. Arthur M. Lesk, Introduction to Bioinformatics, Oxford University Press, 2019, 5th Edition
2. Richard L., Halterman, Learning to Program with Python, 2011

BT16007 **0-0-3 (2)**

Plant Cell and Bioprocess Technology Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Find the effect of pH and temperature on enzyme activity
CO-2	Measure the Monod parameters in batch, fed-batch and continuous cultures
CO-3	Estimate MM constants
CO-4	Prepare nutrient media and learn sterilization methods in plant tissue culture
CO-5	Develop the *in vitro* techniques to regenerate plants and produce synseeds from somatic embryos

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	2	3	3	2	2
CO-2	3	2	3	2	1	3
CO-3	1	1	2	1	3	3
CO-4	3	1	1	2	3	3
CO-5	3	2	1	3	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Bioprocess Technology Lab: Effect of Enzyme concentration on kinetics of invertase enzyme; Measurement of cell biomass concentration; Effect of Substrate concentration on kinetics of invertase enzyme; Yogurt fermentation**;** Effect of pH on kinetics of invertase enzyme**;** Effect of Temperature on kinetics of invertase enzyme.

Plant Cell Lab: Preparation of tissue culture media (MS and B5); Surface sterilization of plant explants; Micropropagation through induction of multiple shoots by using shoot tips and auxiliary buds; Callus propagation, organogenesis, transfer of plants to soil; Encapsulation of somatic embryos and synseed production.

Learning Resources:

Text Books:

1. Paulin M. Doran, Bioprocess Engineering Principles, Elsevier Science & Technology Books, 2008
2. Reinert J and Yeoman MM, Plant Cell and Tissue Culture: A Laboratory manual, Springer, 2000

Reference Books:

1. Shuler M. and Kargi F, Bioprocess Engineering: Basic Concepts, PHI, 2012
2. M.K Razdhan, Introduction to Plant Tissue Culture, Oxford & Ibh, 2010

Other Suggested Readings:

1. https://nptel.ac.in/courses/102/103/102103016/

BT16009 **0-0-3 (2)**

Biocomputing and Computational Biology Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze biological sequence data using various computational biology tools
CO-2	Prepare basic programs in Python
CO-3	Apply the basics of SQL to programming

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	–	2	–	1	–
CO-2	–	–	2	–	1	–
CO-3	3	2	–	2	–	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

1. Sequence analysis with BLAST Suite, Multiple sequence alignment and phylogenetic analysis.
2. Basic of python programming: arithmetic calculations, if-else, for loop, while loop, array, list, tuple, dictionary, function etc.
3. Program to analyze DNA sequence: length of a sequence, GC-content, Tm value, stop, and start codon.
4. Program to complement and reverse complement of DNA sequence.
5. Program to develop restriction-mapping tool.
6. Program to translate the mRNA sequence to protein sequence.
7. UCSC Genome Browser for genomic data analysis.
8. Analysis of biological pathways.
9. Analysis of primary and secondary structure of protein.
10. Homology modelling.
11. Biomolecule visualization software.
12. Protein ligand docking.
13. Structure based virtual screening.
14. Molecular Dynamics Simulations-Basic calculations.
15. Develop a Program for creation of biological database (Accession number, gene name, protein name, expression system, sequence length).
16. Exploratory data analysis with python.

Learning Resources:

Text Books:

1. Michael Agostino, Practical Bioinformatics, Garland Science, 2012, 1st Edition
2. Jason M. Kinser, Python for Bioinformatics, Jones and Bartlett Publishers, 2020
3. Steve Conger, Hands-On Database: An Introduction to Database Design and Development, Pearson Education, Inc., 2012

Reference Books:

1. Shawn T. O'Neil, A Primer for Computational Biology, PHI, 2012

Other Suggested Readings:

1. http://38.100.110.143/model/index.html
2. https://www.youtube.com/watch?v=gAMhDOFdW3g
3. https://nptel.ac.in/noc/courses/noc21/SEM2/noc21-cs75/

2nd Semester

BT16002 **3-0-0 (3)**

Bioprocess Modelling and Simulation

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the Modelling Principles
CO-2	Evaluate kinetic parameters for Biological models
CO-3	Generate models for batch, semi continuous or fed batch operations
CO-4	Develop regression models and neural networks models
CO-5	Perform Design of Experiments

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	1	3	3	3
CO-2	2	1	2	2	3	3
CO-3	3	3	3	2	3	2
CO-4	3	2	2	2	1	1
CO-5	1	2	3	3	1	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Bioreactor Modeling: Introduction of Bioprocess modeling, Use of models, Classification of models, Definition of Lumped and Distributed Parameter Models, Modeling Principles, Steps in Modeling, Fundamental Laws Used in Process Modeling, First-Order Systems, Second-Order Systems, Complexity of the Model, Parameter Sensitivity.

Modeling approaches: General aspects of the modelling approach, general modelling procedure, simulation tools. Mass balance models: Batch operation, semi continuous, continuous operation, summary and comparison, biological kinetics, Michaelis-Menten equation, other enzyme kinetic models, kinetics of anaerobic degradation. biomass productivity.

Simulation examples: Biological reaction Dynamic simulation of batch, fed-batch steady and transient culture metabolism, Simulation of biological models using Berkeley Madonna, batch fermentation, chemostat fermentation, fed batch fermentation, kinetics of enzyme action, repeated fed batch culture, Lineweaver-Burk plot, steady-state chemostat, variable volume fermentation.

Optimization of Bioprocess: OFAT method, Response Surface Methodology and Neural network modeling and validation. Evaluation of model kinetic parameters, Bioprocess modeling using Superpro designer – Case studies.

Learning Resources:

Text Books:

1. Panda, Tapobrata, Bioreactors: Analysis and design, McGraw-Hill Education, 2011

2. I. J. Dunn, E. Heinzle, J. Ingham, J. E. Pfenosil, Biological Reaction Engineering: Dynamic Modelling Fundamentals with Simulation Examples, Wiley-Vch Verlag GmbH & Co. KGaA, Weinheitn, 2003

Reference Books:

1. J.R. Leigh, Modeling and Control of Fermentation Processes, Peter Peregrinus, London, 2000
2. Shyam S. Sablani et al., Handbook of food and bioprocess modelling techniques, Taylor & Francis Group, LLC, 2006

Other Suggested Readings:

1. http://38.100.110.143/model/index.html
2. https://www.youtube.com/watch?v=qAMhDOFdW3g
3. https://www.youtube.com/watch?v=OhFot__I_x8
4. https://www.youtube.com/watch?v=cSUPrSkemgo

BT16004 **3-0-0 (3)**

Biomaterials and Tissue Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	To understand the fundamental principles of biomaterials and their applications in tissue engineering
CO-2	To learn about the design, fabrication, and characterization of biomaterials
CO-3	Select the process for isolation and identification of stem cells
CO-4	To study the principles and applications of tissue engineering
CO-5	To explore the interactions between biomaterials and biological systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	1	–	1	–
CO-2	1	3	–	1	2	–
CO-3	2	–	3	1	–	2
CO-4	–	2	–	1	3	–
CO-5	–	1	–	2	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Definition and Scope of Biomaterials: Classification of Biomaterials: Metals, Ceramics, Polymers, and Composites. Properties of Biomaterials: Biological, Mechanical, Chemical, Electrical and Thermal properties. Surface Properties of Biomaterials, Degradation, and Stability. Biocompatibility, Bioactivity Characterization Techniques: Microscopy (SEM, TEM), Spectroscopy (FTIR, NMR), Mechanical Testing

Scaffold Fabrication Techniques: Solvent Casting and Particulate Leaching, Freeze-Drying, Electrospinning,3D Printing and Bio printing, Hydrogels and Injectable Scaffolds.

Scope of Tissue Engineering: Cells in Tissue Engineering: Stem Cells, different types of stem cells, source, isolation and identification and maintenance methods. Cell Adhesion, Proliferation, and Differentiation on Natural and Synthetic Scaffolds

Bioreactors and Tissue Culture Techniques: Bioreactor Design and Function, Static and Dynamic Culture Systems, Nutrient and Oxygen Transport in Bioreactors.

Learning Resources:

Text Books:

1. Bikramjit Basu, Biomaterials Science and Tissue Engineering, Cambridge, 2012
2. Robert Lanza, Anthony Atala, Essentials of Stem Cell Biology, 2013

Reference Books:

1. Clemens Van Blitterswijk, Tissue Engineering, Academic Press Inc, 2014
2. Mary Clarke, Stem Cells: Biology, Application, CRC Press, 2020

Other Suggested Readings:

1. https://www.sciencedirect.com/science/article/pii/S1672022915000029
2. https://www.nibib.nih.gov/science-education/science-topics/tissue-engineering-and-regenerative-medicine

BT16006 **0-0-3 (2)**

Bioprocess Modelling and Simulation Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Write and execute a program in Berkeley Madonna software
CO-2	Develop program & simulate Batch, Semi continuous and Fed Batch reactors
CO-3	Design & simulate models for bioreactors using SuperPro designer

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	–	2	–	1	–
CO-2	–	–	2	–	1	–
CO-3	3	2	–	2	–	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Simulation of Bioreactor models by Berkeley Madonna software; Demonstration of SuperPro Designer Software; flow sheet development; Material and Energy balance calculations for the production of a bio-product; Designing, Modelling and Simulation of Batch, continuous Stirred Tank Bioreactor; Economic analysis.

Learning Resources:

Text Books:

1. Panda, Tapobrata, Bioreactors: Analysis and design, McGraw-Hill Education, 2011
2. I. J. Dunn, E. Heinzle, J. Ingham, J. E. Pfenosil, Biological Reaction Engineering: Dynamic Modelling Fundamentals with Simulation Examples, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheitn, 2003

Reference Books:

1. J.R. Leigh, Modeling and Control of fermentation Processes, Peter Peregrinus, London, 2000
2. Shyam S. Sablani et al., Handbook of food and bioprocess modelling techniques, Taylor & Francis Group, LLC, 2006

Other Suggested Readings:

1. http://38.100.110.143/model/index.html
2. https://www.youtube.com/watch?v=qAMhDOFdW3g
3. https://nptel.ac.in/noc/courses/noc21/SEM2/noc21-cs75/

BT16008 **0-0-3 (2)**

Cell Culture and Tissue Engineering Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Prepare animal cell culture media and perform basic animal cell culture techniques
CO-2	Evaluate the cytotoxicity of drugs in animal cell culture systems
CO-3	Generate genetically engineered animal cells by gene transfer
CO-4	Demonstrate scaffold fabrication
CO-5	Perform characterization studies on the fabricated scaffolds
CO-6	Evaluate the biocompatibility of scaffolds

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	–	3	–	2
CO-2	3	2	–	3	1	2
CO-3	3	2	–	2	1	2
CO-4	3	2	–	3	–	2
CO-5	2	–	–	–	1	3
CO-6	–	1	–	2	1	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

1. Preparation of cell culture media.
2. Subculturing of adherent cells.
3. Cryopreservation of cells.
4. Measurement of cellular metabolic activity by MTT assay.
5. Detection of apoptosis by immunofluorescence.
6. Genetic manipulation of cells by transfection.
7. Fabrication of Scaffolds Using the Salt Leaching Method.
8. Fabrication of Scaffolds Using the Freeze-Drying Method.
9. Biodegradation Studies of Fabricated Scaffolds.
10. Analysis of Mechanical Strength and Porosity of Scaffolds.
11. Evaluation of Scaffold Biocompatibility.
12. Trypsinization and Viability Testing.

Learning Resources:

Text Books:

1. R. Ian Freshney, Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications, Wiley-Blackwell, 2021, 8th Edition

Reference Books:

1. M. Butler, Animal Cell Culture and Technology, Taylor & Francis, 2003, 2nd Edition
2. Robert Lanza, Principles of Tissue Engineering, Academic Press Inc, 2020, 5th Edition

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc20_me04/preview

BT16096 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	3	3	3
CO-2	2	–	1	1	1	3
CO-3	2	–	1	1	1	3
CO-4	2	2	1	1	1	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	20 marks
II	Study of Existing Systems and establishing clear objectives	20 marks
III	Planning of project and work distribution within the team	10 marks
IV	Proper Documentation and Technical Writing	20 marks
V	Presentation and Response to questions	30 marks

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II	X			
III		X	X	
IV				X
V				X

3rd Semester

BT17089 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	2	2	3
CO-2	2	3	–	–	–	3
CO-3	2	3	1	–	–	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	15 marks
II	List of lectures attended	15 marks
III	Report	15 marks
IV	Presentation	30 marks
V	Response to questions	25 marks

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3
I	X		
II	X		
III		X	
IV			X
V			X

BT17091 **0-0-0 (2)**

Summer Internship / Research Experience

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3	3	3	3
CO-2	2	1	1	2	3	3
CO-3	1	–	–	1	3	3
CO-4	–	3	–	–	–	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Every student has to undergo either a Summer Internship / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Relevance of the area of work	25 marks
II	Performance of the Task	20 marks
III	Crucial learnings from the work	20 marks
IV	Report Preparation	15 marks
V	Presentation and Response to questions	20 marks

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

BT17093 **0-0-0 (2)**

Comprehensive Viva-Voce

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	3	3	1	3
CO-2	3	–	3	3	1	3
CO-3	2	2	2	2	–	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

BT17097 **0-0-0 (8)**

Dissertation: Part- A

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in advanced areas of Biotechnology
CO-2	Review literature to identify gaps and define objectives and scope of the work
CO-3	Employ the ideas from literature and develop research methodology
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	3	3	2	3
CO-2	3	2	3	2	1	3
CO-3	3	–	3	3	3	3
CO-4	3	–	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages (%)
I	Selection of Topic	20
II	Literature Survey	20
III	Defining the Objectives and Solution Methodology	30
IV	Performance of the Task	30

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

4th Semester

BT17098 **0-0-0 (12)**

Dissertation: Part- B

Pre-Requisites: **BT17097**

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyze, discuss and justify the results/trends and draw valid conclusions
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference proceedings without plagiarism

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	–	3	3	2	3
CO-2	2	–	3	3	2	3
CO-3	3	–	3	3	2	3
CO-4	3	3	3	3	3	3
CO-5	3	3	3	–	–	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.

ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.

iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part - A.

Task	Description	Weightages (%)
IV	Performance of the Task	20
V	Dissertation Preparation	25
VI	Review (Presentation & Understanding)	30
VII	Viva-Voce	15
VIII	Publications /Possibility of publication	10

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	X	X			
V				X	
VI			X		
VII				X	
VIII					X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

Professional Electives – I, II

BT16021 **3-0-0 (3)**

Recombinant DNA Technology

Pre-Requisites: **Molecular Biology, Genetic Engineering**

Course Outcomes:

CO-1	Design suitable cloning strategies for bacteria, plant and animal cells
CO-2	Apply appropriate mutagenesis approach to generate desired genetic combination
CO-3	Devise cloning strategies for heterologous gene expression in bacteria and yeast
CO-4	Use appropriate gene transfer techniques for animals and plants
CO-5	Develop transgenic organisms for the benefit of society

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	3	1	3
CO-2	3	2	2	3	3	3
CO-3	3	2	2	3	1	3
CO-4	3	2	2	3	3	3
CO-5	3	2	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Molecular cloning and advanced vectors: Plasmids and Phage Vectors, Cosmids, phagemid and other advanced vectors: phage-derived PACs, BACs, YACs and gateway cloning vectors—cloning strategies.

Mutagenesis strategies: Changing genes – site directed mutagenesis, reverse mutagenesis, cassette mutagenesis, gene knockout, RNA interference, CRISPR-Cas9, transposon mutagenesis.

Cloning strategies in bacteria other than *E. coli* and yeasts: Cloning in gram negative and gram-positive bacteria—Different vectors and suitable cloning strategies. Integrative vectors for fungi, Yeast promoter systems for overexpression of genes, multipurpose vectors.

Gene transfer strategies: Gene transfer strategies and generation of transgenic plants and animals—Transfection techniques and use of suitable selectable markers, overexpression of transgenes, Agrobacterium mediated transformation, Direct DNA transfer method and use of viral vectors for plants and animals, Advance transgenic technologies.

Learning Resources:

Text Books:

1. Old RW and Primrose SB, Principles of gene manipulation and Genomics, Blackwell Scientific Publications, 2006, 7th Edition
2. Kelly T. Hughes and Stanley R. Maloy, Advanced Bacterial Genetics: Use of Transposons and Phage for Genomic Engineering, Methods in Enzymology, Vol. 421, Academic Press, 2007

Reference Books:

1. Brown TA, Gene Cloning and DNA Analysis: An Introduction, Blackwell Publishing, 2016, 7th Edition
2. Green, M. R. and Sambrook, J, Molecular Cloning: A Laboratory Manual (3 volume set), Cold Spring Harbor Lab Press, 2012, 4th Edition

Other Suggested Readings:

1. https://nptel.ac.in/courses/102/103/102103013/

BT16023 **3-0-0 (3)**

Systems and Synthetic Biology

Pre-Requisites: **Bioreaction Engineering, Numerical Methods in Mathematics**

Course Outcomes:

CO-1	Understand the basic systems modelling and synthetic biology principles
CO-2	Identify the basic network biology concepts and principles
CO-3	Apply the modelling techniques to Develop systems biology based mathematical models independently
CO-4	Develop predictive systems models and synthetic networks independently
CO-5	Design Systems and Synthetic Biology Research Studies

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	–	3	–	–	2	1
CO-2	–	3	–	–	2	2
CO-3	–	3	–	3	2	3
CO-4	–	3	3	3	2	3
CO-5	–	3	3	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Systems biology basics; High throughput experimental techniques and data; Model development, Kinetics and Ultrasensitivity; Dynamic (spatial-temporal) and stochastic models in system biology; steady state analysis; Nonlinear Dynamics and Stability Analysis.

Molecular Interaction Networks: Types; Network Motifs and Dynamics; Simple network, Feed forward Loops, Single input modules, Emergent properties of networks: adaptation, homeostasis, bistability, oscillation.

Systems Models and Advancements: *E. coli* chemotaxis, Robustness patterning in fruit fly, Biological time keeping and Oscillatory systems - Circadian rhythm, Cell cycle, Synthetic oscillator; Bistable systems – Lac/ Trp Operon, Type II diabetes model, Synthetic switch, SIR models for disease; Whole cell modelling, Systems pharmacology, Personalized models, Systems Biology and Artificial Intelligence.

Synthetic biology: Introduction, application, and tools; Simple synthetic networks – building and analysis; Synthetic switch and oscillators; Programmed population control, Synthetic chromosome, Synthetic bacterial cell; Synthetic Metabolic Pathway Engineering of microbes for various applications.

Learning Resources:

Text Books:

1. Uri Alon, Introduction to Systems Biology, Chapman & Hall/CRC Mathematical and Computational Biology, 2019, 2nd Edition
2. Eberhard O. Voit, A First course on Systems Biology, Garland Science, 2017, 2nd Edition

Reference Books:

1. Zoltan Szallasi, Jörg Stelling, Vipul Periwal, Systems Modeling in Cellular Biology: From Concepts to Nuts and Bolts, Princeton Hall of India, ISBN: 978-81-203-3172-3, 2007, 1st Edition
2. Karthick Raman, An Introduction to computational Systems Biology: System-level modelling of cellular networks, CRC press, Taylor, and Francis Group, 2021, 1st Edition
3. James Ferrel, Systems Biology of cell signaling: Recurring themes and quantitative models, CRC Press Inc, 2021, 1st Edition

Other Suggested Readings:

1. https://nptel.ac.in/courses/102/106/102106068/
2. https://www.ibiology.org/playlists/synthetic-biology/
3. Relevant research articles

BT16025 **3-0-0 (3)**

Bioeconomy and Biorefineries

Pre-Requisites: **None**

Course Outcomes:

CO-1	Compare oil and bioeconomy
CO-2	Analyze the biomass composition and structure
CO-3	Apply the concept of bio refinery to take over the oil dependent economy
CO-4	Utilize the synthetic biology and metabolic engineering principles for biofuels and biochemicals production
CO-5	Evaluate the standards and life cycle assessment of biofuels

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	3	2	1
CO-2	3	2	3	3	3	1
CO-3	3	1	3	3	3	1
CO-4	3	2	3	3	3	2
CO-5	1	2	2	2	2	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

I**ntroduction to Biofuels:** Oil economy Vs Bio economy, working principle of IC engines, Biofuels in the global energy scene, National biofuel policy and law. Biofuel Feedstocks.

Biomass conversion and Bioprocess technologies: Classification of biofuels, Biomass composition and analysis. Biomass conversion technologies. First, second, third and advanced biofuels production technologies/process and challenges. Consolidated bioprocess engineering (CBP) for biofuels. Concept of Bio refinery: Biomass to value added compounds, Bioelectricity.

Synthetic biology and metabolic engineering for biofuels: Biomass converting enzymes and manipulations, Synthetic biology and metabolic engineering approaches (case studies) for biofuels production.

Analysis and assessment of Biofuels: Life cycle assessment of biomass and biofuels, Standards of biofuels, Exergy analysis of biofuels.

Learning Resources:

Text Books:

1. Caye M. Drapcho, Nhuan Ph Nghim, Terry H. Walker, Biofuels Engineering Process Technology, McGraw Hill: New York, 2020, 2nd Edition
2. Anju Dahiya, Bioenergy Biomass to Biofuels and Waste to Energy, Academic Press, 2020, 2nd Edition

Reference Books:

1. Vijai K. Gupta, Maria G. Tuohy, Christian P. Kubicek, Jack Saddler, Feng Xu, Bioenergy Research: Advances and Applications, Elsevier B.V. Netherlands, 2014, 1st Edition
2. Krzysztof J Ptasinski, Efficiency of Biomass Energy: An Exergy Approach to Biofuels, Power and Biorefineries, John Wiley & Sons, 2015, 1st Edition

Other Suggested Readings:

1. https://nptel.ac.in/courses/102/104/102104057/

BT16027 **3-0-0 (3)**

Bioseparation Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Categorize techniques used in bioseparation processes
CO-2	Design optimal bioseparation processes
CO-3	Analyze the principles of major unit operations and analytical techniques used in Bioseparations
CO-4	Select appropriate technique and equipment for a given bioseparation process

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	1	–	2	–
CO-2	1	–	3	1	–	–
CO-3	1	2	–	3	2	2
CO-4	–	1	2	2	1	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Bioseparation Process: Role and importance of bioseparations in biotechnological processes-Problems and requirements of bioproduct purification- Cost- cutting strategies- Classification of bioproducts - Biological activity, Analysis of purity-Process economics. A few case studies.

Isolation of Products: Cell disruption methods for intracellular products – physical methods (osmotic shock, grinding with abrasives, solid shear, liquid shear) – chemical methods and enzymatic methods. Centrifugation, different types of centrifuges and their application.Membrane based separations, Design and configuration of Membrane separation equipment and applications.

Chromatography: Classification of chromatographic techniques, size exclusion, ion exchange,affinity chromatography – Scale-up of chromatography – Process considerations in Preparative liquid chromatography and HPLC, FPLC, Precipitation, Dialysis; Extraction andDrying and storage of purified protein. A few case studies.

Purified Protein Identification and Visualization: UV-Visible Spectroscopy, detection of protein in gel, 2D gel electrophoresis, MALDI-TOF, Enzyme assays.

Learning Resources:

Text Books:

1. Nikolaos E. Labrou, Protein Downstream Processing, Humana, 2020
2. Sivasankar, Bioseparations: Principles and Techniques, Prentice Hall India Learning Private Limited, 2013

Reference Books:

1. Roger G. Harrison, Paul W. Todd, Scott R. Rudge, Demetri P. Petrides, Bioseparations Science and Engineering, Oxford University press, 2013
2. Ronald & J. Lee, Principles of Downstream processing, Wiley Publications, 2021

Other Suggested Readings:

1. https://onlinelibrary.wiley.com/doi/10.1002/elsc.201600033

BT16029 **3-0-0 (3)**

Drug and Vaccine Informatics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the main components of a drug development project
CO-2	Design and analyze the lead molecules against the drug target
CO-3	Appraise the principles and concepts of protein structure, molecular dynamics simulations, and computer-aided drug discovery
CO-4	Learn and use various tools for in silico drug designing
CO-5	Perform and understand the interpretation of basic (statistical) analysis techniques on the resulting MD trajectories

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	–	3	3	3
CO-2	3	2	–	3	3	3
CO-3	2	–	–	3	–	3
CO-4	3	–	–	3	–	3
CO-5	3	3	–	3	–	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Insights into the Drug Design Process: Drug design process for a known protein target – Structure based drug design process, finding initial hits, Compound refinement, Ligand based drug design process, finding initial hits using online/offline software.

Installation of various drug design software, Introduction to protein structure and visualization tools: Pymol, VMD, Coot & Chimera. Generation and preparation of 3D optimized structure of “Ligand” and “Receptor” for Docking.

Molecular Docking: “Virtual library Preparation” of lead molecules, Docking of ligands into a receptor molecule, Flexible docking of ligand and target, Pharmacophore modelling of ligands, Pharmacophore-based database searching and de novo design of ligand against an active site.

Introduction to molecular dynamics simulation methods**,** Energy minimization and molecular dynamics (MD) target molecule**,** Force fields and parameterization**,** Estimates binding free energy of ligands and receptor, Introduction to molecular dynamics analysis methods.

Learning Resources:

Text Books:

1. Povl Krogsgaard-Larsen, Ulf Madsen, Kristian Stromgaard, Textbook of Drug Design and Discovery, CRC Press, 2017, 5th Edition

2. Gerhard Edwin Seibold, Alexander Hillisch & Rolf Hilgenfeld, Modern Methods of Drug Discovery, Springer, 2003, 2nd Edition

Reference Books:

1. Alan Hinchliffe, Molecular Modelling for Beginners, Wiley & Sons Inc, 2008, 2nd Edition
2. Tamar Schlick, Molecular Modeling and Simulation – An interdisciplinary Guide, Springer, 2000, 1st Edition

Other Suggested Readings:

1. https://nptel.ac.in/courses/102/106/102106070/

BT16031 **3-0-0 (3)**

Fermentation and Enzyme Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understanding the basic fermentation process and bioreactor design
CO-2	Understand Strain isolation and media formulation for production
CO-3	Apply the concept for the process development of novel enzymes
CO-4	Illustrate enzymatic assays and enzyme reaction kinetics
CO-5	Identify molecular tools for improving the performance of enzymes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	–	1	–	2
CO-2	3	3	3	3	–	2
CO-3	3	–	2	3	–	2
CO-4	3	2	–	3	–	2
CO-5	–	–	2	–	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Overview of fermentation industry: General requirements of fermentation processes, Basic configuration of fermenter and ancillaries, Main parameters to be monitored and controlled in fermentation processes, Gaden's Fermentation classification, Isolation, selection and improvement of cultures, Screening methods, Culture preservation.

Design and operation of fermenters: Basic concepts for selecting a reactor; Fermentation Kinetics; continuous fermentation: advantages and limitations; media formulation and preparations: Complex Media and Synthetic media; sterilization.

Studies on growth kinetics in culture: Batch Process, Fed-Batch Process, Continuous Process, Multistage system, Biomass productivity, Metabolite productivity, Instrumentation and control, Aeration and agitation.

Basic concepts of enzymes and Kinetics: Introduction and chemical nature of enzymes, specificity of enzyme action, monomeric and oligomeric enzymes, chemical nature of enzyme catalysis. Michaelis-Menten equation for single substrate, Inhibitor Kinetics, Exposure to multi-substrate enzymes catalyzed reactions, Kinetics of allosteric enzymes and enzyme regulation, factors affecting enzyme activity, and Immobilized enzymes.

Production of enzymes and improvement of enzyme performance: fermentation and separation process of various enzymes, Regeneration of cofactors, enzymes in nonconventional media. Protein engineering of enzymes: site-directed mutagenesis, random mutagenesis, rational design, de novo enzyme design, designer enzymes, engineering substrate specificity.

Learning Resources:

Text Books:

1. Stanbury, P.E., Whitaker, A., Hall, S., Principles of Fermentation Technology, Butterworth-Heinemann, 2002, 2nd Edition
2. Palmer, T., Bonner, P., Enzymes Biochemistry, Biotechnology, Clinical chemistry, Wood Head Publishing, 2008, 2nd Edition

Reference Books:

1. Bailey, J.E. and Ollis D.F., Biochemical Engineering Fundamentals, Mcgraw Hill Higher Education; 2001, 2nd Edition
2. Yoo, Y.J., Feng, Y., Kim, Y.-H., Yagonia, C, Fundamentals of Enzyme Engineering, Springer Netherlands, 2017, 1st Edition

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/102/106/102106053/
2. https://nptel.ac.in/courses/102/102/102102033/

BT16033 **3-0-0 (3)**

Plant Cell and Tissue Culture

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the nutrient requirements and factors influencing the plant tissue culture
CO-2	Illustrate the Invitro techniques and transgenic approach for improving the crop quality, secondary metabolites
CO-3	Demonstrate the importance of transgene technologies for applications
CO-4	Comprehend the plant molecular application industrial applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	1	2	1	3
CO-2	3	1	3	3	2	3
CO-3	3	–	–	3	1	3
CO-4	3	1	–	3	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Plant Technology: Introduction to plant cell and tissue culture, types of tissue culture media composition and preparation. Cytodifferentiation *in-vitro*, Callus and Organogenesis, Micropropagation, Somaclonal variation and application in crop improvement, Applications of genetic engineering in plants, concept of totipotency, Somatic Embryogenesis and Artificial Seed Production, Cell Suspension Cultures, Cryopreservation of plant cells.

Plant transformation technologies: Direct methods of gene transfer, Agrobacterium Mediated Gene Transfer in plants, Ti and Ri Plasmids, Biotransformation using plant cell cultures, Secondary Metabolite production, Transgenic plants for disease resistance, Chloroplast transformation

Plant cell transgene technology: Screening of high yielding Cell Lines and extraction of Valuable Industrial Products, Bioreactors used in Plant Engineering, Advantages of plant cell, tissue, organ culture and Hairy root cultures, as source of secondary metabolites, manipulation in production profile by abiotic and biotic Elicitation, Biotransformation using plant cell cultures

Applications in molecular farming: Production of Antibodies (Plantibodies), Production of Industrial Enzymes and Biodegradable Plastics, Metabolic Engineering for Production of Terpenoids and Flavonoids

Learning Resources:

Text Books:

1. Bhojwani. S.S. & Razdan. M.K, Plant Tissue Culture: Theory and Practice, Elsevier Science Publishers, New York, 2005, 5th Edition
2. B.R.Glick, Methods in Plant Molecular Biology and Biotechnology, 2014

Reference Books:

1. RJ Henry, Practical Application of Plant Molecular Biology, Garland Science, 2012, 2nd Edition
2. R.J. Henry, Practical Application of Plant Molecular Biology, Chapman and Hall, 1997

Other Suggested Readings:

1. https://nptel.ac.in/courses/102/103/102103016/

Professional Electives – III, IV, V

BT16022 **3-0-0 (3)**

Quantitative Biology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Summarize biological data using statistical methods
CO-2	Explain the application of statistical models in biology
CO-3	Analyze genome data using statistical methods
CO-4	Apply the principles of quantitative genetics to understand the complex traits

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	–	2	–	3
CO-2	3	–	–	2	–	3
CO-3	3	–	–	2	–	3
CO-4	3	1	–	3	–	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Summarization of biological data and significance test: Visualization of biological data, numerical summary measures of data, dispersion, theoretical probability distributions, Central limit theorem, Testing hypothesis (Parametric and Non-parametric), chi-square test, sign test, Wilcoxon sign rank test, Wilcoxon rank-sum test, methods of sampling.

Statistical model building: Introduction of Bayesian statistic, evaluation of Bayesian model: Sensitivity and Specificity, Finding relationship in biological data: correlation analysis (Pearson and spearman), regression analysis: Linear, multiple and logistic regression, regression analysis with categorical variable; Principal component analysis, cluster analysis.

Quantitative approaches in Genotype-Phenotype prediction: Experimental approach in quantitative biology and high-throughput experiments; Introduction to genomic data, Differential gene expression analysis; Gene set enrichment analysis; concept of genetic correlation. Genotype-Phenotype Relationships, Mendelian Genetics: Patterns of Inheritance and Single-Gene Disorders, beyond Mendelian Genetics.

Linkage analysis and biomarker identification: Linkage analysis, linkage disequilibrium in human genome, quantitative trait locus (QTL), genetic polymorphism and Genome-wide association studies, case study: use of statistical tools for biomarker identification.

*Along with theory classes, Hands-on sessions will be conducted.

Learning Resources:

Text Books:

1. Sanford Bolton, Charles Bon, Pharmaceutical Statistics, Practical and Clinical Applications, Marcel Dekker, Inc. U.S.A. 2004, 4th Edition
2. David J. Balding, Martin Bishop, Chris Cannings, Handbook of Statistical Genomics, Wiley, 2007, 3rd Edition

Reference Books:

1. Nan M. Laird, Christoph Lange, The Fundamentals of Modern Statistical Genetics (Statistics for Biology and Health), Springer, 2011
2. Motulsky H, Intuitive Biostatistics, Oxford University Press, 2013, 3rd Edition

Other Suggested Readings:

1. Biological data sciences in genome research, Genome Res. 2015. 25: 1417-1422 (https://genome.cshlp.org/content/25/10/1417.full)
2. 10 years of GWAS discovery: biology, function, and translation. Am. J. Hum. Genet. 101, 5–22 (2017). https://www.cell.com/ajhg/fulltext/S0002-9297(17)30240-9 (https://www.sciencedirect.com/science/article/pii/S0002929717302409)
3. Chapter 11: Genome-Wide Association Studies, PLoS Comput Biol 8(12): e1002822 (https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1002822).
4. Patterns of linkage disequilibrium in the human genome, Nature Review Genetics, 3, 299–309 (2002) (https://www.nature.com/articles/nrg777).

BT16024 **3-0-0 (3)**

Applied Environmental Microbiology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe environmental challenges by developing a fundamental understanding of the microbial communities and processes in natural and built environments
CO-2	Predict the effect of environmental parameters and operational factors on performance
CO-3	Understand the role of microbes in biological processes in different ecosystems
CO-4	Explain the microbial ecosystem and role of mix culture microbes in the biological wastewater treatment process

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	2	2	2	3
CO-2	2	1	3	2	3	3
CO-3	2	1	2	3	2	2
CO-4	2	2	3	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: cell elements and composition Cell and its composition, cytoplasmic membrane Prokaryotic cell division Microbes and their environmental niches Historical roots of microbiology Nucleic acids and amino acids DNA structure, replication, and manipulation Protein and its structure Regulation Microbial nutrition Light microscopy, 3D Imaging, AFM, Confocal scanning laser microscopy.

Microbial energetics and diversity: Stoichiometry and bioenergetics Oxidation-reduction NAD, energy-rich compounds and energy storage Mathematics of microbial growth Glycolysis Respiration Citric-acid cycle Catabolic Alternatives Phototrophy, Chemolithotrophy, anaerobic respiration (Nitrate and Sulfate reduction; Acetogenesis; Methanogenesis; Metal, Chlorate, and organic electron acceptors).

Microbial ecosystems: Population, guilds, and communities Environments and microenvironments Microbial growth on surfaces Environmental effects on microbial growth.

Environmental genomics and microbial ecology: genetic exchange Environmental genomics Microbial ecology Horizontal and vertical gene transfer: Replication, Transformation Transduction.

Bioremediation and wastewater microbiology: Bioremediation and examples, Acid mine drainage, Enhanced metal recovery, Wastewater microbiology.

Drinking water microbiology: Drinking water microbiome and treatment, Microbial instability, Water borne microbial diseases.

Solid waste microbiology: Antimicrobial resistance, Landfills, Leachate, Anaerobic degradation phases, Antimicrobial resistance.

Learning Resources:

Text Books:

1. Ian L. Pepper, Charles P. Gerba and Terry J Gentry, Environmental Microbiology, Academic Press, 2014, 1st Edition
2. Ralph Mitchell, Ji-Dong Gu, Environmental Microbiology, Wiley-Blackwell, 2010, 2nd Edition

Reference Books:

1. Bruce E. Rittmann, and Perry L. McCarty, Environmental Biotechnology: Principles and Applications, McGraw-Hill, 2017, 2nd Edition
2. Madigan, M, Bender K. S, Buckley D.H, Sattley W. M, and Stahl D.A. Brock, Brock Biology of Microorganisms, Pearson, 2020, 16th Edition

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_ce07/preview

BT16026 **3-0-0 (3)**

AI and Machine Learning

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the concepts involved in Machine learning
CO-2	Demonstrate various classification methods
CO-3	Apply SVM to solve biological problems
CO-4	Develop neural networks to solve classification problems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	1	3	3
CO-2	3	3	2	1	3	3
CO-3	3	2	3	1	3	3
CO-4	3	3	2	2	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Learning Methods: Introduction to Machine learning; why machine learning, when and where should use machine learning, types of systems of machine learning, block diagram of machine learning; Learning procedures; supervised and unsupervised learning, important algorithms in supervised learning, unsupervised learning, important algorithms in unsupervised learning, reinforcement learning, batch learning, online learning, instance-based learning, model-based learning.

Classification of Data: Classification; measures of performance; confusion matrix; recall; recall tradeoff; ROC; multi class classification; training a random forest classifier; multi-label classification; multi-output classification.

Support Vector Machines: Introduction to SVMs; Basic principles of classification; linear classifiers and nonlinear classifiers, regression; function of hyper plane; Kernel trick functions; clustering; law enforcement; computing; K-means clustering; SOM clustering; hierarchical clustering; Fuzzy clustering.

Applications of Neural Networks: Introduction to neural networks; differences between artificial neuron and natural neuron. Concept of perception, firing rules, architecture and topology of the neural networks, the learning process in NNs, transfer functions in neural network, Tensor flow. Artificial intelligence, Applications of Neural Networks to Secondary Structure Prediction, NN applications in Bioinformatics, SVM applications in Bioinformatics.

Learning Resources:

Text Books:

1. Jason Bell, Machine Learning, John Wiley & Sons, Inc, 2015
2. Pierre Baldi and Soren Brunak, Bioinformatics: The Machine Learning Approach, MIT Press, 2nd Edition

Reference Books:

1. Rudolph Russell, Machine Learning, Create Space Publishing, 2018
2. David W. Mount, Bioinformatics Sequence analysis, Cold Spring Harbor Laboratory Press, 2nd Edition

Other Suggested Readings:

1. https://nptel.ac.in/noc/courses/106/

BT16028 **3-0-0 (3)**

Nanotechnology for Medicine and Healthcare

Pre-Requisites: **Elementary Physics, Biochemistry, BT16003**

Course Outcomes:

CO-1	Illustrate the properties, synthesis and characterization of nanomaterials
CO-2	Apply the theories of nanotechnology for medical diagnosis
CO-3	Apply nanomaterials-based drug and gene delivery systems for therapy
CO-4	Understand the current landscape of nanomedicine and its challenges

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	–	–	–	–
CO-2	–	2	–	–	–	–
CO-3	2	3	2	3	1	1
CO-4	2	3	1	3	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Structural and Functional principles of nanobiotechnology: Introduction to nanomaterials, nanomaterial types and properties, bionanomachines, nanomaterial synthesis and characterization, Functionalization of nanomaterials for biological applications.

Nanotechnology for medical diagnosis: Nanomaterials for *in vitro* and *in vivo* diagnostics, luminescent nanoparticles for biological labelling, nanomaterials based medical imaging, nanomaterials-based biosensors, nanotechnology for cancer diagnosis.

Nanotechnology for therapy: Role of Nanotechnology in targeted drug delivery, nanosystems used in gene therapy, cellular uptake mechanisms of nanomaterials, passive and active targeting, drug-photodynamic therapy, nanomaterials as anti-microbial agents, Nanotechnology in regenerative medicine.

Current landscape of nanomedicine: Major nanomaterial use cases in medicine, future demands and common challenges of nanotechnology in medicine: nanotoxicology, regulation and standards.

Learning Resources:

Text Books:

1. M. Ratner and D. Ratner, Nanotechnology –a gentle introduction to the next big idea, Pearson education, 2007, Latest Edition
2. L. E. Foster, Nanotechnology-Science, Innovation and opportunity, Person education inc, 2007, Latest Edition
3. Martin Braddock, Nanomedicines: Design, Delivery and Detection

Reference Books:

1. Christof M. Niemeyer, Chad A. Mirkin, Nanobiotechnology: Concepts, Applications and Perspectives, 2004
2. Clive Jarvis, Nanobiotechnology: An Introduction, 2018

3. Gil Goncalves, Gerard Tobias, Nanooncology: Engineering nanomaterials for cancer therapy and diagnosis (Nanomedicine and Nanotoxicology), 2018

Other Suggested Readings:

1. https://www.nanowerk.com/nanobiotechnology.php

BT16030 **3-0-0 (3)**

Molecular Therapeutics

Pre-Requisites: **BT16003**

Course Outcomes:

CO-1	Develop an ability to use appropriate knowledge to analyze the molecular basis of diseases
CO-2	Implement the tools and techniques of biotechnology which provide a base for human healthcare
CO-3	Contribute to the advancement of knowledge in Medical and Pharmaceutical fields
CO-4	Apply appropriate techniques, resources, and modern tools to the science of the discovery of therapeutics and vaccines
CO-5	Construct recombinant products for therapeutic applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	–	3	3	3
CO-2	3	–	–	3	3	3
CO-3	3	–	–	3	3	3
CO-4	3	–	2	3	3	3
CO-5	3	–	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Gene and Cellular Therapy: Introduction to Genome Editing, ZFN, TALEN, CRISPR, Introduction to Gene Therapy, Types of gene therapy: *In vivo* and *Ex vivo*; Somatic and Germline gene therapy, Suicide Gene therapy - Suicide genes, bystander effect; Viral and non-viral vectors for gene therapy, Clinical applications of gene therapy, Safety and ethical issues in clinical gene therapy, Introduction and Methodologies involved in cellular therapy, Clinical applications of cellular therapy, Cancer stem cell and Therapeutics.

Antisense therapy: Concept of Gene Silencing, Gene silencing techniques, Clinical applications of gene silencing, Method of Antisense Therapy, Therapeutic applications of Antisense Technology.

RNA Therapy: Principal concept of mRNA pharmacology, Improving the translation and stability of mRNA, Immune-stimulatory activity of IVT mRNA, Structural modifications for tuning mRNA pharmacokinetics, Progress in improving mRNA delivery, Preclinical and clinical applications, MiRNA therapeutics.

Immunotherapy and Recombinant Therapy: Preface to Immunotherapy, Techniques involved in immunotherapy: Antibody phage display, Cr51 assay, Types of Vaccines, Construction and Clinical applications of Recombinant vaccines, Introduction and Clinical applications of recombinant therapy, Introduction and Therapeutic applications of Transgenics: Knock-out & Knock-in mouse, XenoMouse technology.

Learning Resources:

Text Books:

1. Judit Pongracz, Mary Keen, Churchill Livingstone, Medical Biotechnology, Elsevier, 2009, 1st Edition
2. Jogdand S.N., Medical Biotechnology, Himalaya publications, 2011

Reference Books:

1. Pamela Greenwell, Michelle McCulley, Molecular Therapeutics, 21st Century Medicine, John Wiley & Sons Ltd, 2007

Other Suggested Readings:

1. https://nptel.ac.in/courses/102/103/102103093/
2. https://nptel.ac.in/courses/102103041

BT16032 **3-0-0 (3)**

Animal Cell Culture

Pre-Requisites: **BT16003**

Course Outcomes:

CO-1	Understand the design and requirements of cell culture laboratory
CO-2	Explain the techniques involved in culture of cells
CO-3	Demonstrate the methods for characterization and genetic manipulation of cells
CO-4	Apply cell culture techniques for *in-vitro* toxicity studies

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	–	2	1	1
CO-2	3	2	–	2	–	–
CO-3	1	1	–	–	–	–
CO-4	2	3	1	–	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Basics of cell culture: Introduction to animal cell culture, types of tissue culture, culture environment, equipment and culture vessels, types of culture media, importance of serum and serum free media, aseptic techniques, advantages and limitations of cell culture.

Handling of cells: Risk groups, biosafety levels, primary and secondary cultures, adherent and suspension cells, subculturing of cells, contamination, mycoplasma: detection and control, cryopreservation, cell counting.

Characterization and Manipulation of cells: Cell line authentication, characterization of cells, transformation, and immortalization, differentiation and dedifferentiation, genetic engineering of animal cells, cloning and selection of cells, stem cells and culture.

Techniques in cell culture: Applications of cell culture, cell viability assays, cell proliferation assays, assays to quantify apoptosis, cell surface markers, flow cytometry in cell-based assays, gene knockout, three dimensional cultures, 3D bioprinting, recent advances in cell culture techniques, safety and ethics.

Learning Resources:

Text Books:

1. R. Ian Freshney, Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications, Wiley-Blackwell, 2021, 8th Edition

Reference Books:

1. M. Butler, Animal Cell Culture and Technology, Taylor & Francis, 2003, 2nd Edition

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc20_me04/preview

BT16034 **3-0-0 (3)**

Biotechnology for Waste Management

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify salient aspects of biological processes for waste management
CO-2	Design of bioreactors for wastewater treatment
CO-3	Apply principles of bioremediation for handling waste
CO-4	Develop suitable biotechnological processes for hazardous waste management

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	2	2	2	3
CO-2	2	1	3	2	3	3
CO-3	2	1	2	3	2	2
CO-4	2	2	3	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Waste collection, Strategies for sustainable waste management, Microbial growth kinetics, Bioreactors for waste treatment, Instrumentation and control, Aeration and agitation, Effluent treatment. Bio-industrial waste management.

Bioreactors for wastewater treatment: Introduction to bioreactor, Aerobic System Biological processes for domestic and industrial wastewater treatments; Aerobic systems - activated sludge process, trickling filters, biological filters, rotating biological contractors (RBC), Fluidized bed reactor (FBR), expanded bed reactor, Inverse fluidized bed biofilm reactor (IFBBR) packed bed reactors air- sparged reactor

Bioremediation: The characterization and bioremediation of contaminated sites, the superfund law, preliminary site assessment, site investigation techniques, and bioremediation technologies; and monitoring requirements. In-situ Bioremediation of Contaminated Ground Water; Phytoremediation of Contaminated Soil and Ground Water at Hazardous Waste Sites.

Hazardous Waste Management: Introduction - Xenobiotic compounds, recalcitrance. Hazardous wastes - biodegradation of Xenobiotics, Biological detoxification - market for hazardous waste management, biotechnology application to hazardous waste management. Introduction to Solid, Hazardous, and Radioactive Waste Disposal and Containment. Design of Landfill, Municipal Solid Waste Landfills.

Learning Resources:

Text Books:

1. Surajbhan Sevda, Solid Waste Management: Biological Approaches, Taylor & Francis Group, 2024, 1st Edition
2. Clifton Vanguilder, Introduction to Hazardous Waste Management, Mercury Learning & Information 2011, 1st Edition

Reference Books:

1. Foster C.F., John Ware D.A., Environmental Biotechnology, Ellis Horwood Ltd., 2007
2. Rittmann, B. E., & McCarty, P. L., Environmental biotechnology: principles and applications, Tata McGraw-Hill Education, 2020, 2nd Edition

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_bt41/preview
2. https://onlinecourses.nptel.ac.in/noc19_ce32/preview

BT16036 **3-0-0 (3)**

Genomics and Proteomics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Appraise the techniques and instrumentation used in genomics research
CO-2	Recognize suitable proteomic techniques and instrumentation for identification, purification, and modifications of proteins
CO-3	Design a biological experiment by applying suitable genomics and proteomics technology
CO-4	Apply the precise proteomics technology to answer a specific biological question
CO-5	Appraise the techniques and instrumentation used in genomics research

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	2	2	2	3
CO-2	2	1	3	2	3	3
CO-3	2	1	2	3	2	2
CO-4	2	2	3	2	2	2
CO-5	2	2	3	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Genomics: Introduction, genes and genomes; human genome in biology and medicine, second and third generation sequencing technologies; evolutionary genomics; genomics and the microbial world; future of genomics.

Proteomics: Introduction: proteomics relation to genomics, bioinformatics; structural and functional proteomics; proteomics of protein modifications, proteomics of protein–protein interactions/interactomes; gel-based proteomics; gel-independent separation & quantitative proteomics; applications of proteomics in human disease and medicine.

Learning Resources:

Text Books:

1. John M. Archibald, Genomics: A Very Short Introduction, OUP Oxford, 2018, Illustrated Edition

Reference Books:

1. Nawin C. Mishra, Introduction to Proteomics: Principles and Applications, Wiley, 2010