RAMAIAH
Institute of Technology

CURRICULUM

for the Academic year 2019 – 2020

DEPARTMENT OF BIOTECHNOLOGY

V & VI SEMESTER B.E

RAMAIAH INSTITUTE OF TECHNOLOGY
(Autonomous Institute, Affiliated to VTU)
Bangalore – 560054.

About the Institute:

Ramaiah Institute of Technology (RIT) (formerly known as M. S. Ramaiah Institute of Technology) is a self-financing institution established in Bangalore in the year 1962 by the industrialist and philanthropist, Late Dr. M S Ramaiah. The institute is accredited with "A" grade by NAAC in 2014 and all engineering departments offering bachelor degree programs have been accredited by NBA. RIT is one of the few institutes with prescribed faculty student ratio and achieves excellent academic results. The institute was a participant of the Technical Education Quality Improvement Program (TEQIP), an initiative of the Government of India. All the departments have competent faculty, with 100% of them being postgraduates or doctorates. Some of the distinguished features of RIT are: State of the art laboratories, individual computing facility to all faculty members. All research departments are active with sponsored projects and more than 304 scholars are pursuing PhD. The Centre for Advanced Training and Continuing Education (CATCE), and Entrepreneurship Development Cell (EDC) have been set up on campus. RIT has a strong Placement and Training department with a committed team, a good Mentoring/Proctorial system, a fully equipped Sports department, large air-conditioned library with over 1,35,427 books with subscription to more than 300 International and National Journals. The Digital Library subscribes to several online e-journals like IEEE, JET etc. RIT is a member of DELNET, and AICTE INDEST Consortium. RIT has a modern auditorium, several hi-tech conference halls and all are air-conditioned with video conferencing facilities. It has excellent hostel facilities for boys and girls. RIT Alumni have distinguished themselves by occupying high positions in India and abroad and are in touch with the institute through an active Alumni Association. RIT obtained Academic Autonomy for all its UG and PG programs in the year 2007. As per the National Institutional Ranking Framework, MHRD, Government of India, Ramaiah Institute of Technology has achieved 64th rank in 2019 among the top 100 engineering colleges across India.

About the Department:

The department of Biotechnology established in 2002 offers a four year B.E. Biotechnology Program with an intake of 60 students and a two years PG Program, M.Tech in Biotechnology with an intake of 18 students. The department is a recognized Research Centre by VTU, Belgaum, offering M.Sc (Engg.) by research and PhD programs. The Department also offers a Post Graduate Diploma in Biopharmaceutical Technology under the Biotechnology Skill Enhancement Programme (BiSEP), supported by the Department of IT & BT, Government of Karnataka with a sanctioned budget of Rs. 162.5 Lakhs.

The department has 16 faculty members, of them 12 are Ph.D holders and the others are M.Tech pursuing Ph.D. The faculty members have competence in Core areas of Biotechnology viz. Food and Agricultural Biotechnology, Health and Medical Biotechnology & Environmental Biotechnology and Bioprocess Engineering. The department research is focused towards these core areas and funded by national and state funding agencies like DST, KBITS, AICTE, VGST, VTU and RGUHS.

The department faculties and students have publications in Scopus Indexed peer reviewed Journals of Elsevier, Taylor and Francis and Springer. Faculties have published book chapters and presented their research work in National and International conferences. A sizeable number of students have pursued their higher education at various premier institutes in India and abroad after having qualified GATE, GRE & TOEFL exams. The students undergo internships at various premier institutes in India and abroad. Several students receive the Indian Science Academies Summer Internship every year. The department has collaborations with some of the leading biotech industries like: Biocon, Hindustan Unilever Limited (HUL), Bristol Myers Squibb India Ltd, Novozymes South Asia Pvt Ltd, Himalaya Drug Company, Beckman Coulter, Sami Labs, Sartorius AG, Genotypic Technology, Aristogene Biosciences, GangaGen, Connexios Life Sciences, Acquity Labs & Celest Pharma.

VISION OF THE INSTITUTE

To be an Institution of International Eminence, renowned for imparting quality technical education, cutting edge research and innovation to meet global socio-economic needs.

MISSION OF THE INSTITUTE

RIT shall meet the global socio-economic needs through

1. Imparting quality technical education by nurturing a conducive learning environment through continuous improvement and customization.
2. Establishing research clusters in emerging areas in collaboration with globally reputed organizations.
3. Establishing innovative skills development, techno-entrepreneurial activities and consultancy for socio-economic needs.

QUALITY POLICY

We at Ramaiah Institute of Technology strive to deliver comprehensive, continually enhanced, global quality technical and management education through an established Quality Management System complemented by the synergistic interaction of the stakeholders concerned

VISION OF THE DEPARTMENT

To be a leading Biotechnology Engineering department that imparts quality technical education with strong research component, to develop solutions in the field of food, health and environment.

MISSION OF THE DEPARTMENT

To provide quality technical education in a conducive learning environment to produce professionals, researchers with a zeal for lifelong learning and a commitment to society.

Programme Educational Objectives (PEOs) of the program

PEO 1: To impart strong foundation in mathematics, basic and engineering sciences contributing to Biotechnology.

PEO 2: To produce graduates who can pursue higher education and research in biotechnology and allied fields.

PEO 3: To produce graduates with an ability to design, develop and implement research projects and apply to solve problems related to areas of biotechnology.

PEO 4: To provide opportunities to students to work in multidisciplinary teams with professional ethics, good communication, leadership skills and commitment to society.

Programme Outcomes (PO): As per NBA guidelines

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSO)

1. To have thorough grounding in Mathematics, Chemistry and Biology.
2. To be proficient in the principles and practices of advanced biological sciences.
3. To apply engineering principles to biological systems to solve Biotechnology problems.

Curriculum Course Credits Distribution

Batch 2017-2021

Semester	Humanities & Social Sciences (HSS)	Basic Sciences / Lab (BS)	Engineering Sciences/ Lab (ES)	Professional Courses - Core (Hard Core, Soft Core, Lab)	Professional Courses - Electives	Other Electives	Project Work	Internship/ other activities	Total semester load
First	2	9	14						25
Second	4	9	12						25
Third		4		21					25
Fourth		4		21					25
Fifth	2			19	4				25
Sixth				15	4		6		25
Seventh				14	8	4			26
Eighth	2				4		16	4	24
Total	10	26	24	90	20	4	22	4	200

SCHEME OF TEACHING (Batch 2017-2021)

V SEMESTER

Sl. No	Course Code	Course	Teaching Dept.	Component	Credits				
					L	T	P	S	Total
1.	BT51	Immunology	BT	HC	3	0	0	1	4
2.	BT52	Genomics, Proteomics and Bioinformatics	BT	HC	3	1	0	0	4
3.	BT53	Industrial and Environmental Biotechnology	BT	HC	3	0	0	1	4
4.	BT54	Bioreaction Engineering	BT	HC	3	1	0	0	4
5.	BT55	Intellectual Property Rights	BT	HSS	2	0	0	0	2
6.	Elective-A	Departmental Elective	BT	Elective	4	0	0	0	4
7.	BTL56	Immunotechnology Lab	BT	Lab	0	0	1	0	1
8.	BTL57	Biokinetics and Bioreaction Engineering Lab	BT	Lab	0	0	1	0	1
9.	BTL58	Bioinformatics Lab	BT	Lab	0	0	1	0	1
				Total	**18**	**2**	**3**	**2**	**25**

Elective -A								
Sl. No	**Course Code**	**Course**	**Teaching Dept.**	**L**	**T**	**P**	**S**	**Total**
1	BTE01	Bioprocess Engineering	BT	4	0	0	0	4
2	BTE02	Plant and Agricultural Biotechnology	BT	4	0	0	0	4
3	BTE03	Biomaterials	BT	4	0	0	0	4

L – Lecture **T – Tutorial** **P- Practical** **S-Self Study**

HC-Hard Core **HSS-Humanities and Social Sciences**

VI SEMESTER

SI. No	Course Code	Course	Teaching Dept.	Component	Credits				
					L	T	P	S	Total
1	BT61	Enzyme Technology	BT	HC	3	0	0	1	4
2	BT62	Upstream and Downstream Process Technology	BT	HC	3	0	0	1	4
3	BT63	Bioprocess Control and Automation	BT	HC	3	1	0	0	4
4	BT64	Mini-Project	BT	Project	0	0	6	0	6
5	Elective-B	Departmental Elective	BT	Elective	4	0	0	0	4
6	BTL65	Genetic Engineering Lab	BT	Lab	0	0	1	0	1
7	BTL66	Bioprocess control and Automation Lab	BT	Lab	0	0	1	0	1
8	BTL67	Upstream Process Technology Lab	BT	Lab	0	0	1	0	1
				Total	**13**	**1**	**9**	**2**	**25**

Elective -B								
SI. No	**Course Code**	**Course**	**Teaching Dept.**	**L**	**T**	**P**	**S**	**Total**
1	BTE01	Food Biotechnology	BT	4	0	0	0	4
2	BTE02	Metabolic Engineering	BT	4	0	0	0	4
3	BTE33	Programming using CAD and MATLAB	BT	4	0	0	0	4

L – Lecture **T – Tutorial** **P- Practical** **S-Self Study**

HC-Hard Core **HSS-Humanities and Social Sciences**

IMMUNOLOGY

Course Code	**: BT51**	**Credit: 3:0:0:1**
Contact Hours	**: 42T**	
Prerequisite(s)	**: Biochemistry**	
Course Coordinator(s)	**: Dr. Dhamodhar P & Dr. Bindu S**	

UNIT-I

The immune system: Introduction, Cells and Organs of the immune system: Lymphoid cells, Primary and secondary Lymphoid organs, Antigens, antibodies, Classification of immune system - innate and adaptive immunity. Complement and their biological functions**,** cytokines and their role in immune response.

UNIT-II

Humoral and Cell mediated immunity: B-lymphocytes and their activation; Basic structure of Immuno globulins; immunoglobulin classes and biological activity, idiotypes and anti-idiotypic antibodies. Production of monoclonal antibodies. Thymus derived lymphocytes (T cells) and types, MHC Complex, antigen presenting cells (APC), mechanisms of T cell activation, dendritic cells, macrophages, mechanism of phagocytosis, Antigen processing and presentation.

UNIT-III

Immunological disorders: Hypersensitivity and its types. Autoimmune disorders and types, pathogenic mechanisms. Primary and Secondary immunodeficiency disorders (AIDS). Transplantation Immunology: Immunological basis of graft rejection, Types of transplantation, Clinical manifestations.

UNIT-IV

Molecular immunology: Active and Passive Immunization, Immunization protocol, Vaccines and their types. Live, attenuated, inactivated, subunit vaccines, recombinant and DNA vaccines. Catalytic antibodies, application of PCR technology to produce antibodies, immunotherapy with genetically engineered antibodies.

UNIT-V

Immunodiagnosis: Antigen antibody interaction – Precipitation reactions, Agglutination reactions, Blood typing, A, B, ABO and Rh. Principles and applications of ELISA, radio immuno assay (RIA), western blot analysis, immuno-electrophoresis, Immunofluorescence.

Textbooks:

1. Thomas J. Kindt, Richard A. Goldsby and Barbara A. Osborne (2006) Kuby Immunology 6th Edition, W.H. Freeman.
2. Peter J. Delves, Seamus J. Martin, Dennis R. Burton and Ivan M. Roitt (2011) Roitt's Essential Immunology, Wiley-Blackwell.

Reference Books:

1. IanTizard (2006) Immunology – An Introduction, Cengage Learning (RS).
2. Eli Benjamini, Geoffrey Sunshine and Sidney Leskowitz (2000) Immunology: A short course, 3rd Revised edition, Wiley-Blackwell.
3. Chakravarthy AK (2006) Immunology & Immunotechnology. Oxford University Press.

Course outcome (COs):

On completion of the course, student will have improved ability to:

1. Classify and describe the functions of the major components of the immune system in human. (PO-1; PSO-1)
2. Differentiate the humoral and cell mediated response against infectious antigens. (PO-1; PSO-1)
3. Analyze the basis for Immunological disorders and understand the pathogenesis. (PO-1; PO-2; PSO-1)
4. Analyze the recent advancement in molecular immunology. (PO-3; PO-5; PSO-2, PSO-3)
5. Identify the appropriate Immunological technique for diagnosis of infectious diseases. (PO-5; PSO-2, PSO-3)

GENOMICS, PROTEOMICS & BIOINFORMATICS

Course Code	**: BT52**	**Credit: 3:1:0:0**
Contact Hours	**: 42L+14T**	
Prerequisite(s)	**: Biochemistry, Molecular Biology.**	
Course Coordinator(s)	**: Dr. Sravanti V & Mr. Krishna Murthy T P**	

UNIT-I

Genome Sequencing & Genome Projects: DNA sequencing methods: Sanger dideoxy method, Maxam Gilbert method, Pyrosequencing, Automated Fluorescence method, Nanopore. Introduction to Next Generation Sequencing technology (NGS). Methods of sequencing genomic DNA: Shotgun and Clone contig. Genome size and C-value paradox. Human Genome Project. Organelle genome: Mitochondria. Translational Genomics: applications in medicine and agriculture

UNIT-II

Functional Genomics & Proteomics: cDNA library and EST library. SAGE, Microarrays in functional genomics. Introduction to Structural genomics, Comparative genomics, Metagenomics and Transcriptomics. Proteomics analysis pathway, 2D Gel electrophoresis, Mass spectrometry, MALDI-TOF, Peptide mass fingerprinting, Yeast-two hybrid interaction screens, protein chips/microarray. Case study of pharmaceutical and clinical applications of Proteomics.

UNIT-III

Protein engineering and Applications: Introduction and need for protein engineering, Rational and De Novo protein design, Protein engineering by Directed evolution, Phage display. Applications of protein engineering in Protein therapeutic development, agriculture and food industry.

UNIT-IV

Bioinformatics: Introduction, History, Scope, Application, Limitations- Data mining and analytical tools for OMICS studies-Sequence alignment and database similarity searching. Multiple sequence alignment-molecular phylogeny-computational gene prediction.

UNIT-V

Structural Bioinformatics: Protein Structure Visualization, Comparison, and Classification-Secondary and tertiary structure Prediction. Bioinformatics in Drug discovery and design: Molecular targets, Structure based drug design, principles of molecular docking-Molecular dynamics and simulations (basic concepts including force fields, protein-protein, protein-nucleic acid, protein-ligand interaction)- protein – protein interactions.

Textbooks:

1. T A Brown (2017), Genomes, 4th edition, Garland Science.
2. Daniel C Liebler (2002), Introduction to proteomics: Tools for the new biology, Humana Press.
3. Jonathan Pevsner (2015), Bioinformatics and Functional Genomics, 3rd edition, John Wiley & Sons, Inc.
4. Arthur Lesk (2013), Introduction to Bioinformatics, Fourth Edition, Oxford University Press.

References:

1. Aurther M Lesk (2012), Introduction to Genomics, Oxford University Press.
2. Nawin Mishra (2010), Introduction to Proteomics: Principles and Applications, John Wiley & Sons Publications
3. Richard M. Twyman (2013) Principles of Proteomics, Garland Science.
4. Arthur Lesk (2016), Introduction to Protein Science: Architecture, Function, and Genomics, 3rd Edition, Oxford University Press.
5. Michael Agostino (2012), Practical Bioinformatics, 1st edition, Garland Science publisher.

Course Outcomes (COs):

On completion of this course student will have improved ability to:

1. Apply DNA/genome sequencing techniques to genome projects. (PO-1, 5, 11; PSO-2)
2. To correlate the relationship between Genome, Transcriptome and Proteome. (PO-2, 3, 4, 5, 6, 9; PSO-2)
3. Design steps for engineering proteins. (PO-2, 3, 4, 5, 10; PSO-3)
4. Compare various bioinformatics tools used for sequence alignment and phylogenetic studies. (PO-2, 4, 5, 9; PSO-3)
5. To predict protein structure and apply bioinformatics for drug discovery (PO-2, 4, 5, 9 ; PSO-3)

INDUSTRIAL & ENVIRONMENTAL BIOTECHNOLOGY

Course Code	**: BT53**	**Credit: 3:0:0:1**
Contact Hours	**: 42L**	
Prerequisite(s)	**: Microbiology**	
Course Coordinator(s)	**: Mr. Krishna Murthy T P and Dr. Sravanti V**	

UNIT-I

Basics of Bioprocessing

History and development of industrial biotechnology-Objectives and Scope-Characteristics and comparison of bioprocessing with chemical processing- Industrial bioprocess and biorefinery-Substrates for bioconversion processes and design of media-Isolation, preservation and improvement of industrial microorganisms-Metabolic basis for product Formation- Environmental Control of Metabolic Pathways-Cell culture techniques and aseptic transfers.

UNIT-II

Process Technologies-I

Bulk organics (Acetone, Ethanol and Butanol), organic acids (Citric acid, Lactic acid, gluconic acid etc.) specialty chemicals (1,3-Propanediol), enzymes (industrial Enzymes and therapeutic enzymes), vaccines, amino acids, Antibiotics, Extremophiles in industrial bioprocess.

UNIT-III

Process Technologies-II

Fermented foods and beverages, vitamins and growth stimulants, microbial cells, microbial transformations, Mushroom and algae cultivation, healthcare products, Biological control agents, legume inoculants, Biosurfactants, Cosmetics, Dyes and Pigments.

UNIT-IV

Waste water treatment & Bioremediation: BOD, COD of waste water. Primary, secondary and tertiary treatment of waste water- *In situ* and *ex situ* Bioremediation-Phyto-remediation: Classification of Phyto-remediation-Bioleaching of Copper and Gold-Microbial enhanced oil recovery mechanism-Biosorption-mechanisms, Xenobiotic compounds: Sources, Properties, Degradation. Environmental Standards and Environmental laws in India.

UNIT-V

Bioenergy & Bioplastics: Biodiesel: Types and production, advantages over fossil-fuel- Microbial Fuel Cells: Types and applications of MFC, Geobacter based MFC-Alternatives to plastics, Bioplastics: Types-Degradable, Biodegradable, Compostable plastics. Properties and production of PHA, PHB, Productions of plastics from plants.

Textbooks:

1. Ashok Pandey (2016), Current Developments in Biotechnology and Bioengineering series. Elsevier.
2. Wim Soetaert, Erick J. Vandamme (2010). Industrial Biotechnology: Sustainable Growth and Economic Success. John Wiley & Sons, Inc.
3. Michael C. Flickinger (2013) Upstream Industrial Biotechnology, John Wiley & Sons, Inc.
4. Indu Shekhar Thakur (2010) Environmental Biotechnology: Basic Concepts and Applications, I K Publishers
5. Hans-Joachim Jördening and Josef Winter (2004), Environmental Biotechnology Concepts and Applications, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim

References:

1. Devarajan Thangadurai, Jeyabalan Sangeetha (2016) Industrial Biotechnology: Sustainable Production and Bioresource Utilization, Elsevier.
2. Christoph Wittmann, James C. Liao, Sang Yup Lee, Jens Nielsen, Gregory Stephanopoulos (2017) Industrial Biotechnology: Microorganisms & Products and Processes, John Wiley & Sons, Inc.
3. Gareth G. Evans, Judy Furlong (2011) Environmental Biotechnology: Theory and Application, John Wiley & Sons, Inc.

Course Outcomes (COs):

On completion of this course student will have improved ability to:

1. Describe the steps involved in the production of bioproducts and methods to improve modern biotechnology. (PO-2, 3; PSO-2)
2. Choose and manage appropriate mechanism of microbiological processes to produce industrially important products. (PO-2, 3, 4; PSO-2)
3. Apply the bioprocess technology in production of important products for better health human. ((PO-2, 3, 4; PSO-2)
4. Apply microbial technology for Bioremediation and Bioleaching processes. (PO-2, 4, 6; PSO-3)
5. Compare & analyze various forms of Biofuels, Microbial fuel cells and degradable varieties of plastic. (PO-2, 4, 6; PSO-3)

BIOREACTION ENGINEERING

Course Code	**: BT54**	**Credit: 3:1:0:0**
Contact Hours	**: 42L+14T**	
Prerequisite(s)	**: Bioprocess Principles & Calculations**	
Course Coordinator(s)	**: Mr. M. Gokulakrishnan & Dr. Chandraprabha MN**	

UNIT-I

Kinetics of Homogeneous Bioreactions: Basic Concepts of Bioreaction and bioprocess engineering, Concentration dependent term of a rate equation. Rate Constant. Representation of elementary reaction and Non elementary reactions, Kinetic Models of Non elementary Reactions, Testing Kinetic Models. Temperature-dependent term of a rate equation: Temperature dependency from Arrhenius law, Collision theory, Transition state theory, Thermodynamic approach, Activation Energy.

UNIT-II

Interpretation of Batch Bioreactor Data: Constant volume batch reactor, Integral method of analysis of data -first order, second order, zero order reactions, fractional life, homogenous catalyzed reactions, irreversible reaction in series, irreversible reactions in parallel, reactions of shifting order, autocatalytic reactions, reversible reactions, differential method of analysis of data.

UNIT-III

Ideal Bioreactor and bioprocess models: Ideal Batch Reactor, Batch cycle time, Space-Time and Space-Velocity, Mixed flow reactor, Plug flow Reactor, General features of reactors, Holding time and space time for flow reactors Design for Single Reactions: Size comparison of single reactors. Growth kinetics quantification- Unstructured models for microbial growth- Substrate limited growth-models with growth inhibitors, product formation kinetics. Monod kinetics.

UNIT-IV

Heterogeneous Biocatalysis and Non Ideal reactors:
Immobilized enzyme systems: Methods of Immobilization, Requirements and choice of immobilization methods, Diffusional limitations in immobilized enzyme systems. Various types of reactors for immobilized cell and enzyme systems Non ideal flow, Residence time distribution, step and impulse response, conversion in non-ideal flow reactors.

UNIT-V

Analysis of Bioreactors: Scale-up and scale down of bioreactors and its difficulties, Bioreactor instrumentation and control, bioreactor considerations for animal cell cultures and plant cell cultures. Novel Bioreactors: Packed bed bioreactors, Air lift bioreactors, loop bioreactors, Hollow fiber Bioreactors. Solid state fermentation Bioreactors.

Textbooks:

1. Scott Fogler, H (2009) Elements of Chemical Reaction Engineering, 4th edn., Prentice Hall India Pvt. Ltd.
2. Levenspiel O (2006) Chemical Reaction Engineering, Wiley Eastern, 3rd edn, New Delhi.
3. Kargi and Shuler (2001) Bioprocess Engineering. 2nd edn., Prentice Hall PTR.

Reference Books:

1. Bailey JE and Ollis DF (2010) Biochemical Engineering Fundamentals, 2nd edn. McGraw- Hill.
2. Charles D. Holland (1990) Fundamentals of Chemical Reaction Engineering, John Wiley and Sons.
3. Pauline M Doran., Bioprocess Engineering Principles, 2nd Edition, Academic Press, USA, 2013.
4. Tapobrata Panda., Bioreactors: Analysis and Design, 1st Edition, Tata McGraw Hill Education Private Limited, New Delhi, 2011.

Course Outcomes (COs):

Course Outcome: On completion of this course student will be able to:-

1. Predict the order and rate of the different reactions. (PO-1, 2; PSO-1)
2. Analyze the batch bioreactor data for different reactions. (PO-2, 3, 9; PSO-3)
3. Design the suitable bioreactor for different biochemical reactions.(PO- 2, 3, 4, 9; PSO-3)
4. Predict the residence time distribution to determine the conversion in non ideal flow reactors (PO-3,4; PSO-2).
5. Analyze bioreactors for various cell cultures. (PO-4, 5, 9; PSO-2)

INTELLECTUAL PROPERTY RIGHTS

Course Code	**: BT55**	**Credit: 2:0:0:0**
Contact Hours	**: 28L**	
Prerequisite(s)	**: Nil**	
Course Coordinator(s)	**: Dr. Y S Ravikumar**	

UNIT-I

Introduction to IPR: History of IPR. Need of IP. International organization for IP control: GATT, WTO, WIPO & TRIPS. Introduction to different forms of IPR: Copyrights, Trademarks, Industrial designs, Patents, Geographical Indications, Traditional Knowledge, Plant varieties, Trade Secrets.

UNIT-II

Trade Marks: Nature, Essentials, Protection, Trademarks, Service marks and Laws. Procedure for trade mark registration, Case studies on trademarks: Related to Biotechnology and allied industries.

Copy Right: Characteristics and Requirements; Copyright law in India Subject matter of copyright, Procedure for copyright registration, Infringement of Copyright. Case Studies on Copyrights: Related to Biotechnology and allied industries.

UNIT-III

Patents: Patent as an intellectual property, Principles underlying Patent law. Patentable Subject Matter, Patent is a Negative Right, Patent granting authority, Infringement of patents, Literature scanning for possibility of IP rights, Disclosure, Inventors Interview, Process and Product Patents.

UNIT-IV

Patent application procedure & drafting: Patent Drafting: Filing requirements. Patent application Indian and global scenario, Types of patent and patent application, Patents and Patent search, Invention record, Public disclosure, Processing of Patent application, Patent Drafting, Patent Examination Patent Co-operation Treaty Patent attorney and Agent. Patent Revocation. Role of patent agents and attorneys, possibility of IPR as a career. Case studies Related to Biotechnology and allied industries.

UNIT-V

Origins of patent law in biotechnology, Bio-piracy: case study, Diamond versus Anand Chakra borty etc. Patenting biotech products. National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Patenting Biotechnological inventions-Microorganisms, Plant varieties protection and Protection of Traditional Knowledge.

Text Books:

1. Acharya NK (2007) Text book on Intellectual Property Rights, Asia Law house, 4th edn.
2. Deborah E Bouchoux (2005) Intellectual Property Rights, Delmar Cengage learning.
3. Thomas T Gordon and Arthur S Cookfair (1995) Patent Fundamentals for Scientists and Engineers, CRC Press.

Reference Books:

1. Wadehhra BL (2002) Intellectual Property Law Handbook, Universal Law Publishing Co. Ltd.
2. Manish Arora (2007) Guide to Patents Law, Universal Law Publishing, 4th Ed.
3. Singh K (2000) Intellectual Property Rights on Biotechnology. BCIL, New Delhi.
4. Intellectual Property Laws (Bare Act with short comments), Professional Book Publishers, 2007

Course Outcomes (COs):

On completion of this course students will have improved ability to:

1. Identify the different types of IP and scope of protection, and discuss the role of the international intellectual property rights system. (PO-6, 10, 12, PSO-1, 2)
2. Distinguish the key differences between trade mark and copy right and conversant with the procedures used to protect copyright and trademark. (PO-6, 10, 12, PSO-1, 2)
3. Understants the importance of patents in modern scientific and industrial research (PO-6, 10, 12, PSO-1, 2)
4. Apply the procedure involved in drafting patent application and identify activities that constitute patent infringement and discuss the remedies available to the patent owner. (PO-6, 10, 12, PSO-1, 2)
5. Discuss the crucial role of IP in biotechnological organizations for the purpose of product and technology development. (PO-6, 10, 12, PSO-1, 2)

BIOPROCESS ENGINEERING

Course Code	**: BTE 01**	**Credit: 4:0:0:0**
Contact Hours	**: 56L**	
Prerequisite(s)	**: Unit operations and Heat & Mass Transfer**	
Course Coordinator(s)	**: Dr. Chandraprabha M N & Mr. Krishna Murthy T P**	

UNIT-I

Introduction to Bioprocess Engineering:

The origins and domains of (bio)process engineering, early history of (bio)process engineering, Industrial era of (bio)process engineering, green and clean technologies, sustainable bioprocessing, types of bioprocess and bioproducts. Presentation and analysis of bioprocess data, Conservation laws, steady and unsteady sate mass and energy balances. Analogies between transport of momentum, heat and mass, Solution of transport equations.

UNIT-II

Hydrodynamics in Bioprocess Systems:

Rheological properties of fermentation broths, factors affecting broth Viscosity-Functions of mixing, mixing equipment, flow patterns in stirred tank, impellers, stirrer power requirements, power input by gassing, impeller pumping capacity, suspension of solids, mechanism of mixing, assessing mixing effectiveness, scale up of mixing systems, improve mixing in bioreactors, multiple impellers, retrofitting effect of rheological properties on mixing, role of shear in stirred bioreactors.

UNIT-III

Gas-liquid mass transfer in bioprocessing:

Role of diffusion in bioprocessing, film theory, convective mass transfer, oxygen uptake in cell cultures-factors affecting oxygen transfer in bioreactors, measuring dissolved oxygen concentration, estimating oxygen solubility, mass transfer correlations for oxygen transfer, measurement of kLa, measurement of specific oxygen uptake rate, practical aspects of oxygen transfer in large bioreactors, alternative methods for oxygenation without sparging, oxygen transfer in shake flasks.

UNIT-IV

Mass transfer in heterogeneous Bioprocess systems:

Heterogeneous reactions in bioprocessing, concentration gradients and reaction rates in solid catalysts, mass transfer considerations in heterogeneous systems.

Heat transfer Applications in Bioprocess Engineering:
Heat transfer equipment, mechanism of heat transfer, heat transfer between fluids, design equations for heat transfer systems, applications of design equations, hydrodynamic considerations with cooling coils. Sterilization of media, kinetics of thermal death of Microorganisms-Batch and Continuous Sterilizers-Heat transfer in agitated tank and Columns-Heat transfer to dense suspension.

UNIT-V

Cell Culture Bioprocessing & Biomanufacturing:
Brief review on biopharmaceutical industry, Cell culture, cell culture products, cellular properties critical to biologics production, nutritional requirements, cell line development, bioreactors, Overview of continuous biomanufacturing, Facility Design and Process Utilities, Quality, validation, and regulatory aspects in biomanufacturing. Scale up and scale down of bioprocess systems.

Textbooks:

1. Pauline M Doran (2013) Bioprocess Engineering Principles, 2nd Edition, Academic Press.
2. Michael L Shuler, Fikret Kargi (2017) Bioprocess Engineering: Basic Concepts, 3rd Edition, Pearson publishers.
3. Stanbury, P. F., Whitaker, A., & Hall, S. J. (2013). Principles of fermentation technology. 3rd Edition, Elsevier.
4. Wei-Shou Hu (2017) Engineering Principles in Biotechnology, John Wiley & Sons, Inc.
5. Ganapathy Subramanian (2017) Continuous Biomanufacturing: Innovative Technologies and Methods, 1st Edition, John Wiley & Sons, Inc.

Reference Books:

1. Koltuniewicz, A. B. (2014). Sustainable process engineering: prospects and opportunities. Walter de Gruyter GmbH & Co KG.
2. Murray Moo-Young (2011) Comprehensive Biotechnology, 2nd edition, Elsevier B.V
3. Michael C. Flickinger (2013) Upstream and Downstream Industrial Biotechnology, 1ST edition, John Wiley & Sons, Inc.
4. El-Mansi, E. M. T., Bryce, C. F., Allman, A. R., & Demain, A. L. (2018). Fermentation Microbiology and Biotechnology. 4th Edition, CRC press.
5. Gunter Jagschies Eva Lindskog Karol Lacki Parrish Galliher (2017) Biopharmaceutical Processing: Development, Design, and Implementation of Manufacturing Processes, 1st Edition, Elsevier B.V.

6. John Villadsen, Sang Yup Lee, Jens Nielsen, Gregory Stephanopoulos (2016) Fundamental Bioengineering, John Wiley & Sons, Inc.
7. Odum, J., & Flickinger, M. C. (Eds.). (2018). Process Architecture in Biomanufacturing Facility Design. John Wiley & Sons.

Course Outcomes (COs):

On completion of this course students will have improved ability to

1. Understand the role of bioprocess engineering in modern chemical technology for sustainable production of industrial products (PO-2, 3; PSO-2)
2. Apply knowledge of momentum transfer in solving complex problem in industrial bioprocess. (PO-2, 3, 4; PSO-2)
3. Apply the principles of mass transfer in bioprocessing. (PO-2, 4, 6; PSO-3)
4. Understand the importance of heat transfer in industrial bioprocess (PO-2, 4, 6; PSO-3)
5. Apply the principles of bioprocess engineering in manufacturing of biopharmaceuticals. (PO-2, 4, 6; PSO-3)

PLANT AND AGRICULTURAL BIOTECHNOLOGY

Course Code	**: BTE 02**	**Credit: 4:0:0:0**
Contact Hours	**: 56L**	
Prerequisite(s)	**: Molecular Biology**	
Course Coordinator(s)	**: Dr. Sharath R**	

UNIT-I

Introduction to Plant tissue culture: Introduction and historical developments and applications of Plant tissue and cell culture. Laboratory Design and Developments. Instrumentation. Sterilization techniques, Plant Tissue Culture Media, Cellular totipotency, Factors affecting Tissue Culture success: (Media explant, light, Temperature, Polarity, Subculture, Genotype, Season), Hormones.

UNIT-II

Plant Tissue and cell culture techniques: Organogenesis organ culture, Establishing callus and cell culture,. Micropropagation for large scale production of plantlets: - banana, Acclimatization of micro propagated plant. Somaclonol variation, Somatic embryogenesis in plant. Synthetic seeds and their commercial potential. Protoplast isolation and culture. Cell suspension culture for production of secondary metabolites. Hairy root culture.

UNIT-III

Genetic Engineering in Plants: Transfer of DNA to plant cells- Direct transformation by electroporation and particle gun bombardment. Agrobacterium, Ti plasmid vector Theory and techniques for the development of new genetic traits, Transgenic plants and their importance. Transgenic crop plants: - herbicide tolerances, insect resistance. Marker assisted selection. Methods for crop improvement.

UNIT-IV

Introduction to Agricultural Biotechnology: Introduction, history and scope of agriculture in India. Agro-climatic zones and cropping pattern of India. Conventional crop improvement programs- Introduction, Selection and Hybridization, Mutation, Haploidy and Polyploidy Breeding. Modern agriculture biotechnology for food security and national economy. Green-revolution. Industries that based on agricultural raw materials. Impact of biotech-products on national economy and trade. Improvements of raw material for food processing industry.

UNIT-V

Organic agriculture and genetic conservation: Modernization of agricultural practices and national food security. Sustainable food production: organic farming for improvement of food quality and soil fertility. Composting, Biofertilizers. Integrated pest management. Renewable bio-fuels: - Biogas an alternative fuel, Importance and strategies of Biodiversity Conservation. Impact of Biotechnology on Biological diversity and genetic conservation.

Text Books:

1. Singh BD (2014) Biotechnology- Expanding Horizons. Kalyani Publishers, Rajindernagar, Ludhiana.
2. Reinert J and Bajaj YPS (2013) Applied and Fundamental aspects of Plant Cell, Tissue and organ Culture. Springer Verlag, Berlin.
3. Narayanaswamy S (2008) Plant Cell and Tissue Culture. Tata McGraw Hill, New Delhi.
4. Sathyanarayana B. N. and Varghese, D.B. (2007) Plant Tissue Culture: Practices and New Experimental Protocols. I. K. International Pvt Ltd.

References:

1. Bengochea T and Doods JH (2012) Plant Protoplasts: A Biotechnological Tool for Plant Improvement. Chapman and Hall. London.
2. Gamborg OL and GC Phillips (2013) Plant Cell, Tissue and organ culture. Narosa Publishing House, New Delhi.
3. Razdan MK (2003) An Introduction to Plant Tissue Culture, Oxfsord & IBH Pub. Co, Pvt., Ltd., New Delhi
4. Bhojwani SS and Razdan MK (2003) Plant Tissue Culture: Theory and Practice, a revised edition. Elsevier Publication.
5. Dodds JH and Roberts LW (1995) Experiments in plant Tissue Culture. Cambridge University Press, Cambridge.

Course Outcomes (COs):

On completion of this course student will have improved ability:

1. Understand the basic concept of plant tissue culture, media formulation, and its importance. (PO-2, 3, 4; PSO-2)
2. Understand the concept of different techniques involved in plant tissue culture. (PO-3, 4; PSO-2)
3. To analyze the developments of crop production by using plant breeding and hybridization techniques. (PO-3, 4, 7; PSO-2)
4. To apply knowledge of molecular markers for the identification of traits in various genomes. (PO-3, 4, 7; PSO-2)
5. Apply modern agricultural techniques and understand the importance of bioresources (PO-5, 7; PSO-2).

BIOMATERIALS

Course Code	**: BTE 03**	**Credit: 4:0:0:0**
Contact Hours	**: 56L**	
Prerequisite(s)	**: Nil**	
Course Coordinator(s)	**: Dr. Lokesh and Dr. Y.S Ravikumar**	

UNIT-I

Introduction: Importance of biopolymers and biomaterials. Classes and Forms - Biotechnology derived polymers and composites and their applications. Characterization of Materials. Overview of metal and polymer biomaterials, Bioceramics and composites.

UNIT-II

Biopolymers: Polymers as biomaterials. Microstructure and mechanical properties. Sterilization and disinfection of polymeric materials. Biocompatibility of polymers as biomaterials.

UNIT-III

Biomedical applications: Biomedical application of materials obtained from natural and synthetic sources. Metallic, Ceramic, Polymeric materials and composites as medical implants. Cardiovascular Applications- Treatments of atherosclerosis; Stents, Heart Valves, Blood Substitutes; balloon angioplasty and pacemakers. Artificial skin, Artificial Organs, soft implants. Case studies. Orthopedic Applications: Requisite properties, materials selection, issues of wear, case studies. Dental applications: Implants, coatings, mechanical fixation.

UNIT-IV

Tissue response to biomaterials: Interaction of cells and tissues with synthetic and natural biomaterials. Soft tissue response, Metrology/Testing of Biomaterials, Blood Compatibility, Materials Failure. Immunological consequences of polymeric implants and devices, Issues of biocompatibility and biodegradability.

UNIT-V

Miscellaneous applications and regulatory issues: Role of polymers in gene therapy and DNA vaccination. Skin-graft polymers, biodegradable polymers in drug delivery and drug carrier systems, imaging, Overview of biomaterials and implant regulatory issues, Tissue engineering: Ethical and regulatory aspects: Current issues and future directions.

Textbooks:

1. Buddy D. Ratner et al. (Ed.) (2004) Biomaterials Science: An Introduction to Materials in Medicine, 2nd edn., Academic Press.
2. Park JB and Lakes RS (1992) Biomaterials. Plenum.

Reference Books:

1. Lanza RP, Langer R, Chick WL (1997) Principles of Tissue Engineering. Academic Press.
2. Gebelein CG and Carraher Jr. CH (1994) Biotechnology and Bioactive Polymers. Plenum Press.
3. An YH and Draughn RA (2000) Mechanical Testing of Bone and The Bone-Implant Interface. CRC Press.

Course Outcomes (COs):

On completion of the course, the student should be able to:

1. Demonstrate in-depth knowledge of the mechanical and biological properties of both natural and synthetic biomaterials. (PO-1, 4, 5; PSO-2)
2. Assessing the compatibility and physiochemical properties of biomaterials (PO-2, 3, 5; PSO-3)
3. To apply the concepts to orthopedic and dental applications. (PO-1, 4, 5; PSO-2)
4. Describe the methods of testing for biomaterials biocompatibility and to distinguish the events that lead to the degradation of materials in the biological environment. (PO-1, 4, 5; PSO-2)
5. To apply the knowledge to a variety of delivery systems, including chemotherapy, gene therapy and antibacterial therapy. (PO-1, 4, 5; PSO-2)

IMMUNO TECHNOLOGY LAB

Course Code	**: BTL56**	**Credit:**	**0:0:1:0**
Contact Hours	**: 14P**		
Prerequisite(s)	**: Microbiology**		
Course Coordinator(s)	**: Dr. P. Dhamodhar & Dr. Y.S. Ravikumar**		

LIST OF EXPERIMENTS

1. ABO Blood grouping & Rh typing
2. Radial Immuno diffusion
3. Ouchterlony Double Immuno Diffusion (ODD)
4. Immunoelectrophoresis (IEP)
5. Counter Immunoelectrophoresis (CIEP)
6. Rocket Immunoelectrophoresis
7. Widal & VDRL tests
8. Total count of RBC.
9. Differential count of WBC
10. Enzyme linked Immunosorbent assay (ELISA)
11. Precipitation of Immunoglobulins
12. Separation of Lymphocytes from blood.
13. Total count of WBC
14. Latex Agglutination

Note: Any 12 experiments must be performed

Reference Books:

1. Channarayappa (2010) Cell Biology: Universities Press (India) Pvt. Ltd.
2. Rastogi SC (1996) Immundiagnostics. New Age International

Course outcomes (COs):

On completion of the course, student will have improved ability to:

1. Design and analyze the key concepts in immunological reactions, and to interpret the data. (PO-1, 2, 3, 4; PSO-1)
2. Select the appropriate Immunological technique for diagnosis of infectious diseases. (PO-1, 2; PSO-2)
3. Analyze and interpret various components of blood sample.PO-1, 2, 4; PSO-2)
4. Apply the knowledge of Immunological techniques in implementing research projects.(PO-1, 2, 3; PSO-2)
5. Distinguish various types of blood groups in humans. .(PO-1, 2, 3; PSO-2)

BIOKINETICS AND BIOREACTION ENGINEERING LAB

Course Code	**: BTL57**	**Credit: 0:0:1:0**
Contact Hours	**: 14P**	
Prerequisite(s)	**: Nil**	
Course Coordinator(s)	**: Mr. Gokulakrishnan M & Dr. Chandraprabha MN**	

LIST OF EXPERIMENTS

1. Analysis of batch reactor
2. Analysis of Plug flow reactor
3. Analysis of mixed flow reactor
4. RTD of Plug flow reactor
5. RTD of mixed flow reactor
6. Effect of temperature on reaction rate constant
7. Analysis of Semi Batch Reactor
8. Determination of Enzyme activity
9. Study the effect of substrate concentration on enzyme activity (K_m and V_{max})
10. Fermenter performance
11. Effect of temperature/pH on reaction rate kinetics
12. Enzyme immobilization kinetics
13. Batch growth kinetics (Evaluation of doubling time and decay time)
14. Effect of dissolved oxygen on growth kinetics

Note: Any 12 experiments must be performed

Reference Books:

1. Rao DG (2005) Introduction to Biochemical Engineering, Tata McGraw Hill.
2. Bailey JE and Ollis DF (2010) Biochemical Engineering Fundamentals, 2nd edn. McGraw- Hill.
3. Charles D. Holland (1990) Fundamentals of Chemical Reaction Engineering, John Wiley and Sons.
4. Sadashivam and Manikam (1992) Biochemical Methods, Wiley Eastern Ltd, New Delhi.

Course Outcomes (COs):

Students will be able to:

1. Predict the kinetics of reaction using different reactors. (PO-1, 2, 3, 4; PSO-1)
2. Evaluate the residence time distribution of MFR & PFR. (PO-4, 9; PSO-1)
3. Predict the effect of pH and temperature on reaction rate kinetics. (PO-2, 3, 4; PSO-2)
4. Predict the kinetics of enzyme reaction and apply for reactor studies. (PO-3, 9; PSO-3)
5. Determine the batch growth kinetics and evaluate fermentor performance. (PO-3, 9; PSO-3)

BIOINFORMATICS LAB

Course Code	**: BTL58**	**Credit: 0:0:1:0**
Contact Hours	**: 14P**	
Prerequisite(s)	**: Fundamentals of computing and Molecular Biology**	
Course Coordinator(s)	**: Mr. Krishna Murthy T P and Dr. Sravanti V**	

LIST OF EXPERIMENTS

1. Introduction to major biological and bibliographic databases
2. Sequence retrieval and pair wise comparison of sequences
3. Database similarity searching using BLAST tool
4. Comparison of Multiple Sequence alignment algorithms
5. Molecular phylogenetics
6. Identification of functional sites in genes and genomes
7. Retrieval of structure data of macromolecules and their molecular visualization
8. Secondary structure prediction of proteins
9. Tertiary structure prediction of proteins
10. Bioinformatics tools for laboratory: Restriction mapping and Primer designing
11. *In silico* pharmacokinetics and molecular docking studies
12. Prediction of deleterious SNPs using *in silico* tools
13. Data analysis using Microsoft Excel®
14. Working with MATLAB® functionalities and Bioinformatics Toolbox

Note: Any 12 experiments must be performed

Reference Books:

1. Jonathan Pevsner, Bioinformatics and Functional Genomics, 3rd edition, John Wiley & Sons, Inc, 2015.
2. Arthur Lesk., Introduction to Bioinformatics, Fourth Edition, Oxford University Press, 2013
3. Michael Agostino, Practical Bioinformatics, 1st edition, Garland Science publisher, 2012.

Course outcomes (COs):

On completion of the course, student will have improved ability to:

1. Perform sequence alignment to identify the regions of similarity in DNA/RNA/protein sequences using appropriate sequence alignment methods (PO-2, 4, 5, PSO-2)
2. Construct and analyze the phylogenetic tree to understand the evolutionary relationships of organisms using appropriate phylogeny tools (PO-2, 4, 5, PSO-2)

3. Predict the functional sites in DNA sequence using online gene prediction tools (PO-4, 5, PSO-2)
4. Predict Secondary and tertiary of proteins and visualize using available open-source tools (PO-4, 5, PSO-2)
5. Apply the computational tools to address important problems of biotechnology (PO-4, 5, PSO-2)

ENZYME TECHNOLOGY

Course Code	**: BT61**	**Credit: 3:0:0:1**
Contact Hours	**: 42L**	
Prerequisite(s)	**: Biochemistry**	
Course Coordinator(s)	**: Dr. P. Dhamodhar & Dr. Sharath R**	

UNIT-1

Introduction to enzymology: Introduction to enzymes, Advantages of enzymes *vs* chemical catalysts, Classification, Active site, Mechanism of enzyme action, enzyme specificities, Strategies of purification of enzymes, criteria of purity, molecular weight determination. Introduction to coenzymes & co-factors.

UNIT-2

Enzyme kinetics: Enzyme substrate reaction, Derivation of Michaelis and Menten equation, Lineweaver Burk plot, Units of enzyme activity, Enzyme inhibition, Competitive, Non-Competitive, Uncompetitive, and Irreversible inhibition, Multisubstrate reactions, ping-pong, Sequential, ordered and random mechanism. Regulation of enzyme activity: Allosteric enzymes, Feedback inhibition, Covalent modification, Proteolytic cleavage.

UNIT-3

Enzymatic techniques: Enzyme and isoenzyme measurement methods with two examples; Methods for investigating the kinetics of enzyme catalyzed reactions – Initial velocity studies, rapid-reaction techniques. Design and construction of novel enzymes, artificial enzymes, Catalytic antibodies.

UNIT-4

Medical applications: Enzymes of Biological Importance, Importance of enzymes in diagnosis, Enzyme pattern in diseases like Myocardial infarctions (SGOT, SGPT, & LDH). Isoenzymes (CK, LD, ALP). Use of isozymes as markers in diseases. Enzymes in immunoassay techniques, Therapeutic enzymes.

UNIT-5

Industrial applications: Techniques of enzyme immobilization, applications of immobilized enzyme technology, Economic argument for immobilization. Enzymes used in detergents, use of proteases in food and leather industries; methods involved in production of glucose syrup from starch (using starch hydrolyzing enzymes),production of glucose from cellulose and sucrose, uses of lactase in dairy industry, glucose oxidase and catalase in food industry.

Textbooks:

1. Nicholas C. Price and Lewis Stevens (2006), Fundamentals of Enzymology, 3rd Edition, Oxford University Press.
2. Trevor Palmer and Philip Bonner (2008) Enzymes: Biochemistry, Biotechnology and clinical Chemistry. 2nd Edition, East West Press Pvt. Ltd.

Reference Books:

1. David L. Nelson, Michel M. Cox (2008) Lehninger Principles of Biochemistry,4th Edn., Palgrave Macmilan, W H Freeman Publisher, Newyork, USA
2. Chaplin MF and Bucke C (1990) Enzyme technology. Cambridge University Press.
3. Gerhatz W (1990) Enzymes in Industry Production and Applications, VCH publishers.
4. Dordrick JS (1991) Biocatalysts for Industry. Plenum Press.

Course Outcome (COs):

On completion of this course student will have improved ability to:-

1. Classify the enzymes, understand their general properties and select the appropriate analytical technique for purification and characterization of enzymes. (PO-1; PO-2; PSO-1)
2. Integrate the practical aspects of enzymology with the kinetic theories to provide a mechanistic overview of enzyme activity and regulation in cells. (PO-1; PO-3; PSO-1)
3. Apply enzymatic techniques for measurement of enzymes and methods for enzyme engineering. (PO-2; PO-3; PSO-1)
4. Identify the role and use of various enzymes in diagnosis and treatment of diseases. (PO-1; PO-2; PSO-2, PSO-2)
5. Identify the current and possible future industrial applications of enzymes. (PO-1; PO-2; PSO-2, PSO-3)

UPSTREAM AND DOWNSTREAM PROCESS TECHNOLOGY

Course Code	**: BT62**	**Credit: 3:0:0:1**
Contact Hours	**: 42L**	
Prerequisite(s)	**: Cell Biology, Microbiology**	
Course Coordinator(s)	**: Dr. Lokesh K N & Dr. Ahalya N**	

UNIT-I

Upstream processing of microbial and plant cells: Overview of fermentation process. Microbial and plant media constituents, formulation and optimization. Batch and continuous sterilization process. Mode of cell culture & concept of dual culture system. Somatic embryogenesis & Artificial seed production. Bioprocess consideration in using plant cell cultures: Bioreactors for suspension cultures, immobilized cells reactor technology. Production of industrially important metabolites vinca alkaloids, Shikonin, penicillin, Vit B12, ethanol.

UNIT-II

Animal cell technology: Characteristics of animal cells. Media for culturing animal cells and tissues; development of animal cell lines, maintenance and cryopreservation of animal cell lines and viability assessment. Specialized animal cell culture techniques: Fibroblast cultures, lymphocyte culture, stem cell isolation and culture. Bioreactors considerations for animal cell cultures and reactors. Production of Monoclonal antibodies.

UNIT – III

Basics of downstream processing and Separation techniques: Role & Importance of downstream processing in biotechnological processes. Characteristics of biological mixtures, process design criteria for various classes of bioproducts (high volume, low value products and low volume, high value products), physicochemical basis of bio separation processes. . Cell disruption methods for intracellular products,removal of insolubles, biomass (and particulate debris) separation techniques; flocculation and sedimentation, centrifugation and filtration methods.

UNIT- IV

Product Enrichment operations and Membrane Separation: Precipitation methods with salts, organic solvents, and polymers, extractive separations. Aqueous two-phase extraction, supercritical extraction; In situ product removal/integrated bio processing. Solute polarization and cake formation in membrane ultra filtration – causes, consequences and control techniques; enzyme processing using ultra filtration membranes; separation by solvent membranes.

UNIT-V

Final product formulation and finishing operations: Hybrid Separation Techniques (Membrane chromatography, Electrochromatography, etc). Crystallization – Principles, Nucleation, CrystalGrowth – Kinetics, crystallization of proteins. Drying and lyophilization in final product formulation. Quality Assurance and Regulatory affairs in Downstream Processing.

Text Books:

1. Peter Stanbury, Allan Whitaker, Stephen Hall (2017) Principles of Fermentation Technology, 3rd Edition, Butterworth-Heinemann.
2. S.S. Bhojwani M.K. Razdan (1996) Plant Tissue Culture: Theory and Practice, Elsevier Science.
3. B Sivasankar (2005) Bioseparations: Principles and Techniques, Prentice Hall India Learning Private Limited
4. Mukesh Doble (2015), Principles of Downstream Techniques in Biological and Chemical Processes, Apple Academic Press

Reference Books:

1. Michael C. Flickinger (2013) Upstream and Downstream Industrial Biotechnology, 1st edition, John Wiley & Sons, Inc.
2. Roger G. Harrison, Paul W. Todd, Scott R. Rudge, and Demetri P. Petrides (2015) Bioseparations Science and Engineering, Oxford University Press.

Course Outcomes (COs):

1. Apply appropriate strategy for scale up of microbes, plants and animals to obtain product of interest. (PO-1, 2, 5, 7, 8, 9, 10; PSO-1)
2. Identification and implementation of animal cell culture techniques for scale up. (PO-1, 2, 5; PSO-2)
3. Identify appropriate unit operations based on nature of biomolecules or complex bioprocess parameters.(PO-1, 2, 3, 4, 6, 7, 10; PSO-1)
4. Apply appropriate unit operation for isolation, purification and characterization of bioproduct. (PO-1, 3, 5, 6, 8, 9, 10; PSO-2)
5. 4: Evaluate different unit operations for product crystallization and Drying. (PO-1, 3, 5, 6, 8, 9, 10; PSO-3)

BIOPROCESS CONTROL AND AUTOMATION

Course Code	**: BT63**	**Credit: 3:1:0:0**
Contact Hours	**: 42L+14T**	
Prerequisite(s)	**: Bioreaction Engineering**	
Course Coordinator(s)	**: Mr. Gokulakrishnan M & Dr. Chandraprabha MN**	

UNIT-I

Introduction: Biochemical process, Industrial control problem- example, variables of a process, control configuration types, hardware for a process control system, Process characteristics, Laplace transform, Monitoring and control of bioreactors, Biochemical Reactor Instrumentation, principles of measurement and classification of process control instruments- physical, chemical and bio-chemical parameters, Introduction to flow, pressure, temperature and level measurements, sensors for medium and gases. Online and offline measurements of cells, substrates and products.

UNIT-II

Systems and Process Dynamics: Development of mathematical model- CSTR, I order system-examples, mercury in glass thermometer, level, mixing. Linearization, I order system in series, interacting and non-interacting systems. Second order system with under damping, derivation of transfer function for various systems, dead time, response of I and II order over damped and under damped systems, to step, ramp, impulse (pulses) and sinusoidal changes. Numericals

UNIT-III

Controllers and Final Control Elements: Controllers-discontinuous and continuous, two position control, proportional, derivative, integral control; proportional Reset (integral) (P+I); proportional +rate (derivative (P+D); proportional+reset+rate controller (PID), actuators, positioners, valve body, valve plugs, Valve characteristics, final control elements. Transfer functions for controllers and final control element, Numericals.

UNIT-IV

Transient Response of Closed Loop Systems: Block diagram reduction, block diagram & Transfer functions for servo and regulator problems. Transient response of I and II order processes for set point changes and load changes with proportional, PI, PD and PID controllers, Numericals.

UNIT-V

Stability of Closed Loop Control Systems Concepts of stability, stability criteria, Routh test for stability, Root-locus method, Bode plots and stability criteria, tuning of controllers, Numericals.

Text Books:

1. Donald R. Coughanowr (2013) Process Systems Analysis and Control, McGraw-Hill, 3rd ed.,
2. Pauline MD (2013) Bioprocess engineering principles, 2nd edition, Reed Elsevier India.

Reference Books:

1. Bailey and Ollis (2010) Biochemical engineering fundamentals. McGraw Hill (2nd Ed)
2. Shuler and Kargi (2002) Bioprocess engineering, 2nd ed., Prentice Hall.
3. Tarun K Ghosh (ed.) (1984) Biotechnology and bioprocess engineering: Proceedings, VII international biotechnology symposium. Delhi.
4. Wankat PC (2005) Rate controlled separations, 1st ed., Springer.
5. George Stephanopoulos (2009) Chemical process control 1st ed., Prentice Hall of India.

Course Outcomes (COs):

On completion of this course student will have improved ability:-

1. Determine the parameters to be measured and controlled in the bioreactor. (PO-2, 3, 4, 9; PSO-2)
2. Predict the response of first order, second order and first order system in series for various input changes.(PO-1, 2; PSO-1)
3. Determine and analyze the different control actions involved in the bioreactor. (PO-2, 3, 4, 9; PSO-3)
4. Evaluate the transient response of first and second order systems for load and set point change and to predict the stability of the control system.(PO-2, 3; PSO-3)
5. Predict the stability of the closed loop control system (PO-3, 4; PSO-3)

MINI PROJECT

Course Code	**: BT 64**	**Credit: 0:0:6:0**
Contact Hours	**: 84P**	
Prerequisite(s)	**: Nil**	
Course Coordinator(s)	**: Project Coordinators**	

Course outcomes (COs):

1. Able to analyze scientific data. (PO-1, 2, 8, 9; PSO-3)
2. Able to apply concepts in research work. (PO-1, 2, 4, 6, 8, 9, 10, 11; PSO-1)
3. To evaluate team work or independent work skills. (PO-1, 2, 4, 5, 6, 8, 10, 11; PSO-2)
4. Able to apply research methodology for formulation of research design. (PO-6, 10, 11; PSO-3)
5. Develop effective communication and research report writing skills (PO-6, 10, 11; PSO-3).

FOOD BIOTECHNOLOGY

Course Code	**: BTE 04**	**Credit: 4:0:0:0**
Contact Hours	**: 56L**	
Prerequisite(s)	**: Nil**	
Course Coordinator(s)	**: Dr. Bindu S**	

UNIT-I

Microorganisms in foods: History of microorganisms in food. The role and significance of microorganisms, Intrinsic & extrinsic factors of spoilage, Primary sources of microorganisms found in foods, Types of microorganisms in foods. Synopsis of common food-borne bacteria, Synopsis of genera of molds common to foods, Synopsis of genera of yeasts common to foods.

UNIT-II

Determining microorganisms and their products in foods: Culture, microscopic and sampling methods, Conventional; SPC, Membrane filters, Microscope colony counts, Agar droplets, Dry films, Most probable Numbers (MPN), Dye-reduction, Roll tubes, Direct microscopic count (DMC), Microbiological examination of surfaces, Air sampling, Enumeration and detection of food-borne organisms.

UNIT-III

Food spoilage and preservation: Microbial spoilage of vegetables, fruits, fresh and processed meats, poultry, Food preservation using irradiation, Legal Status of Food Irradiation, Effect of Irradiation of food constituents; Food preservation with low temperatures: Slow & quick freezing, Effect of freezing on microorganisms. Food preservation with high temperatures: Blanching, Pasteurization, Sterilization , Aseptic Packaging, Canning , Factors affecting heat resistance in microorganisms thermal destruction-D, Z & F values. Preservation of foods by drying: Factors influencing evaporation, Factors of relevance in control of drying, Changes brought about in food by drying, Freeze drying.

UNIT-IV

Biotechnology in food industry: Common additives, Organic foods, Prevention of spoilage, Storage and preservation through biotechnological means, Food packaging: Packaging methods and materials: Controlled atmosphere packaging and Modified atmosphere packaging. Factors influencing food product development. Introduction to: Nutrition value, Basal metabolic rate, Dietary strategies for individuals, Ecologically sustainable production, Risks and benefits of biotechnology to food industry.

UNIT-V

Nutraceuticals and Phytoceuticals: Water soluble and fat soluble vitamins, Functions and nutritional importance of vitamins. Deficiency diseases, prevention. Estimation of vitamins from the sample, Assay of vitamins: Fat soluble & water soluble Essential amino acid, fatty acids, Electrolytes, Anti obesity nutraceuticals, Golden rice.

Textbooks:

1. James M Jay Martin J Loessner and David A Golden (2006) Modern Food Microbiology. 7th edition, Springer, US.
2. Norman N. Potter and Joseph H.Hotchkiss (2007) Food Science , 5th edition, CBS publishers and distributors
3. King RD and Cheetham PSJ, Ed., (1988) Food Biotechnology - 2. Elsevier NY.

Reference Books:

1. Dietrick Knorr, Ed., (1987) Food Biotechnology. Marcel Dekker, Inc., NY.
2. Owen R. Fennema, Ed., (1985) Food Chemistry. Marcel Dekker, Inc., NY.
3. Rogers PL and Fleet GH, Ed., (1989) Biotechnology and the Food Industry.

Course Outcomes (COs):

On completion of the course, the student should be able to:

1. List, identify & distinguish the commonly found microorganisms in food, correlate them to their role & routes of entry into food. (PO-2; PSO-2)
2. Differentiate types of spoilages seen in various food categories & suggest methods of preservation. (PO-2, 3, 4, 5; PSO-2)
3. Identify & describe the processing & preservation methods practiced in the food industry (PO-2,3,4,5; PSO-2)
4. TO understand biotechnological methods of food preservation & sustainable food production. (PO-2, 3, 4, 5; PSO-2)
5. Identify & classify minor food components, nutraceuticals & relate them to their roles. (PO-2, 4, 5; PSO- 2)

METABOLIC ENGINEERING

Course Code	**: BTE 05**	**Credit: 4:0:0:0**
Contact Hours	**: 56L**	
Prerequisite(s)	**: Biochemistry**	
Course Coordinator(s)	**: Mr. Krishna Murthy T P and Dr. Chandraprabha M N**	

UNIT-I

Cellular Metabolism

Solute transport processes in the cell- transporter classification system- catabolism and metabolic fuelling: thermodynamics of fuelling processes, products of fuelling processes, redox potentials and mobile electron carriers-biosynthesis of cellular building blocks-polymerization of building blocks to macromolecules-rare metabolic conversions-transcriptional regulation of metabolism.

UNIT-II

Balances and Reaction Models

Growth nutrients and diversity- rates and mass balances-biomass specific conversion rates-mathematical models for the batch experiment from mass balances and q-based kinetics-data reconciliation and error detection peter-black box models for growth and product formation-metabolic models for growth and product formation-thermodynamic description of microbial growth and product formation.

UNIT-III

Modelling in Metabolic Engineering

Metabolic flux analysis-metabolic flux quantification methods-metabolic control analysis: definitions and structure of metabolic reaction networks, mathematical models of metabolic-structure and flux analysis of metabolic networks-constraint based genome-scale models of cellular metabolism-multiscale modeling of metabolic regulation-validation of metabolic models.

UNIT-IV

Tools in Metabolic Engineering

Improving Protein Functions by Directed Evolution-Engineering DNA and RNA Regulatory Regions through Random Mutagenesis and Screening-Evolving Pathways and Genomes for the Production of Natural and Novel Compounds-Models Predicting Optimized Strategies for Protein Evolution-Application of Emerging Technologies to Metabolic Engineering: Genome-Wide Technologies: DNA Microarrays, Phenotypic Microarrays, and Proteomics, Monitoring and Measuring the Metabolome- *In Silico* Models for Metabolic Systems Engineering

UNIT-V

Developing Appropriate Hosts for Metabolic Engineering: Escherichia coli, Yeast, Bacillus subtilis, Streptomyces, Mammalian Cells.

Future Applications of Metabolic Engineering: Energy and Cofactor Issues in Fermentation and Oxyfunctionalization- Microbial Biosynthesis of Fine Chemicals-Applications of Metabolic Engineering for Natural Drug Discovery-Metabolic Engineering for Alternative Fuels.

Textbooks:

1. George Stephanopoulos Aristos Aristidou, Jens Nielsen (1998). Metabolic Engineering: Principles and Methodologies, 1st edition, Academic Press.
2. Christina D. Smolke (2009), The Metabolic Pathway Engineering Handbook: Fundamentals, 1st edition, CRC Press.
3. Christina D. Smolke (2009), The Metabolic Pathway Engineering Handbook: Tools and Applications, 1st edition, CRC Press.

References:

1. S Y Lee and E T Papoutsakis (1999). Metabolic Engineering, Marcel Dekker, NewYork, 1999.
2. Néstor V Torres, Eberhard O. Voit (2002). Pathway Analysis and Optimization in Metabolic Engineering, 1st Edition, Cambridge University Press.
3. Stephen Van Dien (2016) Metabolic Engineering for Bioprocess Commercialization, Springer International.

Course Outcomes COs):

1. Understand the central metabolic reactions and regulations in cellular metabolism. (PO-2, 3; PSO-2)
2. Describe the various models for regulation of metabolic pathways at different levels. (PO-2, 3, 4; PSO-2)
3. Analyze the metabolic flux for real time industrial applications. (PO-2, 4, 6; PSO-3)
4. Utilize various scientific tools for engineering microbial pathway. (PO-2, 4, 6; PSO-3)
5. Development of effective solutions for various industrial and environmental problems using metabolic engineering. (PO-2, 4, 6; PSO-3)

PROGRAMMING USING CAD & MATLAB

Course Code	**: BTE 06**	**Credit: 4:0:0:0**
Contact Hours	**: 56L**	
Prerequisite(s)	**: Fundamentals of Computing**	
Course Coordinator(s)	**: Dr. Sharath R**	

UNIT-I

Introduction to Aspen: Basics of Aspen software's, Graphic user interphase, defining properties, NRTL, model libraries, flow sheet drawing and process parameters estimation using ASPEN software's

UNIT-II

Properties Estimation: Introduction to Aspen properties, Physical properties of compounds, Thermodynamic properties of gases and binary mixtures, Viscosity, Vapour pressure and K-values.

UNIT-III

Basic Design Concepts: Process design of reactors, various batch reactors, plug flow and mixed flow reactors, distillation columns and heat exchangers, Case studies

UNIT-IV

Matlab: Introduction to MATLAB Environment, Defining Matrices, Matrix Manipulation, Data Structures, 2D Graphics, 3D Graphics, Editor/Debugger window, Creating MATLAB functions, Improving code performance, Error Correction.

UNIT-V

Applications: How do mathematical problems arise in biology? Prevalence of differential equations, a practical approach to biological mathematics, Models in biology, Types of models - deterministic, stochastic, mixed. Uses for models - heuristic, predictive, mixed. How are models, the physical world, and biology related? When and why should we build models? How should we treat models that exist already?, Mathematical modeling of biochemical and biotechnological systems using the MATLAB scientific computing environment. Estimation & plotting in MATLAB.

Text Books:

1. Aspen and Hysys (2007) Manual, AspenTech, Inc.
2. Arnold / Wiley (1999) Essential MATLAB for Scientists and Engineers, NY
3. Rudra Pratap (1999) Getting Started with MATLAB

Reference Books:

1. Andrew Knight (1999) Basics of MATLAB and Beyond, Chapman & Hall/CRC
2. Jay B. Brockman (2009) Introduction to Engineering: Modeling and Problem Solving, John Wiley & Sons, Inc.

Course Outcomes (COs):

On completion of the course, the student should be able to:

1. Apply fundamental computing concepts related to processing, memory and data organization as related to engineering. (PO-2, 4, 5, 9; PSO-3)
2. Formulate succinctly and correctly the input and output relationship of computational problems. (PO-2, 4, 5, 9; PSO-3)
3. Use computer-based programming solutions for problems using MATLAB. (PO-2, 4, 5, 9; PSO-3)
4. Evaluate theoretical and computational skills with the syntax and functionality of MATLAB. (PO-2, 4, 5, 9; PSO-3)
5. Utilize computational tools for solving bioprocess engineering problems. (PO-2, 4, 5, 9; PSO-3)

GENETIC ENGINEERING LAB

Course Code	**: BTL65**	**Credit: 0:0:1:0**
Contact Hours	**: 14P**	
Prerequisite(s)	**: Molecular Biology**	
Course Coordinator(s)	**: Dr. Bindu S & Mrs. Bhavya S G**	

LIST OF EXPERIMENTS

1. Introduction to PCR – working of PCR equipment and programming.
2. Preparation of DNA for PCR applications- Isolation, purity & quantification
3. Gene/DNA amplification by random/specific primers.
4. Preparation of cDNA
5. Amplification of known gene/s using cDNA
6. Preparation of competent cells
7. Gene Transformation.
8. Southern hybridization.
9. Transfer of gus A reporter gene into plant cells by leaf disc method.
10. Isolation of total RNA by Trizol method.
11. Isolation of fusion proteins using expression vectors.
12. Maintenance of animal cell culture
13. Eukaryotic Cell Transformation

Note: Any 12 experiments must be performed

Reference Books:

1. Channarayappa (2010) Cell Biology: Universities Press (India) Pvt Ltd.
2. David S Latchman (1994) From Genetics to Gene Therapy – the molecular pathology of human disease by, BIOS scientific publishers.
3. Berger SL and Kimmel AR (1987) Methods in enzymology, Vol.152, Academic Press.
4. Sambrook J et. al. (2000) Molecular cloning: a laboratory manual. Volumes I - III. Cold Spring Harbor laboratory Press, New York, USA.
5. Old RW and Primrose SB (1993) Principles of gene manipulation, an introduction to genetic engineering. Blackwell Scientific Publications.

Course outcomes (COs):

On completion of this course student will have improved ability to:-

1. Choose appropriate method to isolate & quantify DNA/RNA. (PO-1, 4; PSO-1)
2. Amplify DNA/gene(s) using PCR & RT-PCR. (PO-1, 2, 4; PSO-2)
3. Compare, analyse and interpret the agarose gel electrophoresis results (PO-3, 4; PSO-2)
4. Perform gene transformation using the appropriate method. (PO-3, 4, 5; PSO-3)
5. Identify of transformed cells by appropriate screening technique (PO- 4, 5; PSO-3)

BIOPROCESS CONTROL AND AUTOMATION LAB

Course Code	**: BTL66**	**Credit: 0:0:1:0**
Contact Hours	**: 14P**	
Prerequisite(s)	**: Nil**	
Course Coordinator(s)	**: Mr. Gokulakrishnan M & Dr. Chandraprabha MN**	

LIST OF EXPERIMENTS

1. Characteristics of Transducers (Temperature, Pressure, Flow)
2. Dynamics of First order –Thermometer- system for step input
3. Dynamics of First order -Liquid level system - for step input
4. Dynamics of first order systems -Liquid level- for impulse input
5. Dynamics of first order systems-thermometer- for pulse input
6. Dynamics of second order system (Manometer)
7. Non-interacting systems
8. Interacting systems
9. Control of temperature in a bioprocess.
10. Control of pH in a bioprocess.
11. Control of Pressure in a bioprocess.
12. Control of Flow rates in a bioprocess.
13. Control of level
14. Study of Valve characteristics

Note: Any 12 experiments must be performed

Reference Books:

1. Bailey and Ollis (2010) Biochemical engineering fundamentals. McGraw Hill (2nd Ed)
2. George Stephanopoulos (2009) Chemical process control 1st ed., Prentice Hall of India.

Course Outcomes: On completion of this course student will be able to:

1. Determine the control parameters of control system. (PO-1, 2, 3, 4, 9; PSO-3)
2. Predict the response of first order systems. (PO-2, 3, 4; PSO-1)
3. Predict the response of first order system in series. (PO-2, 4; PSO-1)
4. Evaluate the transducer characteristics. (PO-2, 3, 4, 9; PSO-3)
5. Predict the response of the second order system (PO-2, 3, 4; PSO-1)

UPSTREAM PROCESS TECHNOLOGY LAB

Course Code	**: BTL67**	**Credit: 0:0:1:0**
Contact Hours	**: 14P**	
Prerequisite(s)	**: Cell Biology, Microbiology**	
Course Coordinator(s)	**: Dr. Sravanti V. & Mr. Lokesh K. N.**	

LIST OF EXPERIMENTS

1. Media Preparation and sterilization
2. Organ culture-Stem/node/internodes/Leaf
3. Callus Induction Techniques
4. Development of suspension culture from callus
5. Lycopene estimation
6. Production of Secondary metabolite – Anthocyanin
7. Encapsulation of artificial seed
8. Shake flask studies; Comparison of yield in synthetic and complex media
9. Estimation of DNA (by diphenyl method)
10. Preparation & validation of the Fermenter
11. Single Cell Protein (SCP) production
12. Preparation of seed culture
13. Study of effect of substrate inhibition on cell growth
14. Replica plating for screening of auxotrophs/antibiotic resistant strain

Note: Any 12 experiments must be performed

Reference Books:

1. Dixon RA and Gonzales (1989) Plant Cell Culture: A Practical Approach, IRL Press.
2. Channarayappa (2006) Molecular Biotechnology: Principles and practices. Universities Press (India) Private Limited and CRC Press World-wide.
3. John H. Dodds and Lorin W. Robert (1985) Experiments in Plant Tissue Culture, Second Edition Cambrige University Press

Course Outcomes (COs):

On completion of this course student will have improved ability to:-

1. Design plant tissue culture and microbiological technology experiments. (PO-1, 2,9; PSO-2)
2. To grow, screen and isolate auxotrophs. (PO-4, 5, 6, 10; PSO-2)
3. To isolate, estimate, and quantify secondary metabolites. (PO-1, 4, 6, 10; PSO-3)

4. Correlate the applications of biochemical and microbiological principles in upstream process technology. (PO-1, 2, 6, 8; PSO-3)
5. Apply appropriate methods for scale up of microbes and plants to obtain products of interest (PO-2, 4, 5, 6; PSO-2)