NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF BIOTECHNOLOGY

Revised Curriculum and Syllabi

Program Name
Master of Technology in Biotechnology
Effective from the Academic Year: 2021-2022

Recommended by DPAC	: 29.06.2021
Recommended in PGAC	: 16.08.2021
Approved by the Senate	: 22.08.2021

DETAILED CURRICULUM

Semester - I							
Sl. No.	**Code**	**Subject**	**L**	**T**	**P**	**C**	**H**
1	BT1001	Molecular Biology & rDNA Technology	3	0	0	3	3
2	BT1002	Bioprocess Engineering	3	1	0	4	4
3	BT1003	Bio-separation Technology	3	1	0	4	4
4	BT90XX	Specialization Elective - I	3	0	0	3	3
5	BT90XX	Specialization Elective - II	3	0	0	3	3
6	BT1051	Bioprocess Engineering Lab.	0	0	4	2	4
7	BT1052	Bio-separation Technology Lab.	0	0	4	2	4
		TOTAL	**15**	**2**	**8**	**21**	**25**
Semester - II							
Sl. No.	**Code**	**Subject**	**L**	**T**	**P**	**C**	**H**
1	BT2001	Genomics, Proteomics & Bioinformatics	3	1	0	4	4
2	BT90XX	Specialization Elective - III	3	0	0	3	3
3	BT90XX	Specialization Elective - IV	3	0	0	3	3
4	BT90XX	Specialization Elective - V	3	0	0	3	3
5	BT90XX	Specialization Elective - VI	3	0	0	3	3
6	BT2051	Molecular Biology and rDNA Technology Lab.	0	0	4	2	4
7	BT2053	Omics and Bioinformatics Lab.	0	0	4	2	4
8	BT2054	Seminar	0	0	2	1	2
		TOTAL	**15**	**1**	**10**	**21**	**26**
Semester - III							
Sl. No.	**Code**	**Subject**	**L**	**T**	**P**	**C**	**H**
1	BT907X	Audit Lectures/Workshops	0	0	0	0	2
2	BT3051	Dissertation-I	0	0	24	12	24
3	BT3052	Seminar –Non Project/ Evaluation of Summer Training	0	0	4	2	4
		TOTAL	**0**	**0**	**28**	**14**	**30**
Semester - IV							
Sl. No.	**Code**	**Subject**	**L**	**T**	**P**	**C**	**H**
1	BT4051	Dissertation II/ Industrial Project	0	0	24	12	24
2	BT4052	Project Seminar	0	0	4	2	4
		TOTAL	**0**	**0**	**28**	**14**	**28**
Grand Total			**30**	**3**	**74**	**70**	**109**

List of Specialization Electives

BT9031 Human Molecular Genetics
BT9032 Cancer Biology
BT9033 Signal Transduction
BT9034 Molecular Cell Signalling
BT9035 Food Biotechnology
BT9036 Biopharmaceutical Technology
BT9037 Biomaterials
BT9038 Biomettalurgy
BT9039 BioEnergy
BT9040 Bioprocess & Plant Design
BT9041 Advanced rDna & Cellular Biotechnology
BT9042 Animal Biotechnology
BT9043 Immunotechnology
BT9044 Molecular Modelling & Drug Design
BT9045 Regenerative Medicine & Translational Research
BT9046 Microbial Biotechnology
BT9047 Environmental Biotechnology
BT9048 Protein structure,folding & misfolding
BT9049 Methods in Computational Biology
BT9050 Nanobiotechnology
BT9051 Plant Biotechnology
BT9052 Metabolic Engineering
BT9053 Nutraceuticals & Nutrigenomics
BT9054 Molecular Plant Pathogen Interactions
BT9055 Cell Biology of Human Diseases
BT9056 Infectious Diseases & Infection Control
BT9057 Project Engineering in Biotechnology
BT9058 Biological Computation
BT9059 Quality by Design for Biopharmaceuticals
BT9060 Medical Biotechnology
BT9061 Biological Chemistry
BT9062 BioEntreupreneurship

Detailed Syllabus for the
M.Tech. Proposed Curriculum 2021-22 (DPAC dated June 29, 2021)

<table>
<tr><td colspan="8">Department of Biotechnology</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT1001</td><td>Molecular Biology & rDNA Technology</td><td>PCR</td><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods {Continuous Test (CT) and end assessment (EA)}</td></tr>
<tr><td colspan="2">Cell Biology, Genetics & Biochemistry</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the basics of central dogma in molecular biology
CO2: To understand the detailed mechanisms of regulations of gene expression
CO3: To learn methods in molecular biology and genetic engineering
CO4: To evaluate and apply the knowledge in order to develop new microbial, plant & animal products</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Unit – I: Nucleic Acids, Genes & Chromosomes
Nucleic acid structure and chemistry including denaturation & renaturation kinetics, Organization of prokaryotic and eukaryotic chromosomes, Content of the genomes, Gene structure, Genomic sequences, clusters, repeats, mutations in the genetic material (10).

Unit – II: DNA Replication, Repair & Recombination
DNA Replication, Replicon, Extrachromosomal Replicons, Transposable elements and Retroviruses, Homologous and site-specific recombination, DNA Repair systems (11).

Unit – III: Transcription & Post-transcriptional Mechanisms
Prokaryotic transcription, Eukaryotic transcription, RNA splicing and processing, mRNA stability and localization, Catalytic RNA, Translation, Post-translational modifications (11).

Unit – IV: Regulation of Gene Expression
The Operon, Phage Strategies, Regulation of eukaryotic transcription, Epigenetics, chromatin remodelling, non-coding RNA, regulatory RNA (12).

Unit – V: Methods in Molecular Biology & Recombinant DNA Technology
Vectors, enzymes in molecular biology, cloning and identification of recombinant clones, gDNA / cDNA libraries, Hybridization experiments, mutagenesis, PCR techniques, sequencing, DNA fingerprinting, gene targeting, gene silencing, gene therapy, genetic engineering, Recombinant products, gene knockouts, transgenics, genome editing (12)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
Lewin’s Genes XII by Jocelyn E. Krebs, Elliot S. Goldstein and Stephen T. Kilpatrick, Jones & Bartlett Learning
Molecular Biology of the Gene by James D. Watson, Tania A. Baker, Stephen P. Bell, Alexander Gann, Michael Levine, Richard Losick.
Molecular Biology of the Cell by Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts , Peter Walter.
Molecular Cell Biology by Harvey Lodish, Arnold Berk, Chris A. Kaiser, Monty Krieger, Matthew P. Scott, Anthony Bretscher, HiddePloegh, Paul Matsudaira.
Reference Books:
Biochemistry by LubertStryer. W. H. Freeman & Company, NY
Biochemistry by Lehninger. McMillan publishers</td></tr>
</table>

	Molecular Cloning: A Laboratory Manual (3 Volume Set): 4th Edition hael R Green, Cold Spring Harbor laboratory Molecular Biology: A Comprehensive Introduction to Prokaryotes and Eukaryotes by David Freifelder

CO-PO mapping:

Course Code	Title of the course	COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT1001	**Molecular Biology & rDNA Technology**	CO 1	3	2	3	3	3	1
		CO 2	3	2	3	3	3	1
		CO 3	3	2	3	3	3	1
		CO 4	3	2	3	3	3	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT1002	**Bioprocess Engineering**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes	CO1: Strengthening of basic concepts of stoichiometry, kinetics, heat and mass transfer CO2: In depth learning of reactor design and operation for free and immobilized cells CO3: Learning of detailed processes of large scale mammalian cell and plant cell culture						
Topics Covered	Recapitulation: Stoichiometry of Growth and Product formation. Heat transfer for biochemical processes. Kinetics of Growth and Product formation in Batch, Continuous and Fed batch systems. 12 Media Sterilization and Air Sterilization. Design of Stirred Tank Bioreactors. 4 Mass transfer studies in stirred tank reactor and in free and immobilized cell bioreactors. 5 Design of Immobilized biocatalytic reactor, perfusion reactor, membrane reactor, Hollow fibre reactor, airlift reactor. Reactors for solid state fermentation. 5 Large scale mammalian cell culture – non perfused attachment system, fed-batch and perfusion for cell cultivation, suspension culture, microcarrier culture system, microencapsulation, large scale stirred tank and air lift reactors for cultivation of animal cell. Discussion on single use technologies. 10 Plant cell bioreactors – their design and operation. 3 Scale up, Instrumentation and Control of Bioreactors. 3						

Text Books, and/or reference material	**Books** Large-scale Mammalian Cell Culture Technology, Lubiniecki, CRC Bioreactors: Analysis & Design, Tapobrata Panda, McGraw Hill Doran PM, '*Bioprocess Engineering Principles'*, Academic Press Reference: Bioprocess Engineering: Basic Concepts (2nd Edition), Shuler and Kargi, Prentice Hall International. International Cell Culture Technology for Pharmaceutical and Cell-Based Therapies, Sadettin Ozturk, Wei-Shou Hu, CRC Bioprocess Engineering: Kinetics, Biosystems, sustainability and reactor design by Shijie Liu, Elsvier Publisher.

CO-PO mapping

Course	Title of the course	COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT1002	**Bioprocess Engineering**	CO 1	1	1	3	2	2	1
		CO 2	2	1	3	2	2	1
		CO 3	3	2	3	3	3	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT1003	**Bioseparation Technology**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic Physics, Mathematics including basics of Differential & Integral Calculus, Basic concepts of Biochemistry		CT+EA					
Course Outcomes	CO1: To learn the concepts of separation of a biological product from a crude mixture. CO2: To analyze the various unit operations in bioseparations CO3: To understand the design aspects of unit operations in bioseparations. CO4: To learn the aspects of continuous processing, scale up and single use technology CO5: To apply the concepts learned to recovery of typical biological products.						
Topics Covered	**Removal of Insolubles** – Flocculation; Filtration- batch filtration at constant pressure & at constant rate, continuous filtration; Sedimentation at low acceleration; Centrifugation (including ultracentrifugation) , continuous centrifugation; Scale up of the processes [6] **Cell Disruption -** by mechanical and non-mechanical means including enzymatic methods [1] **Precipitation** - protein solubility (effect of size and charge, solvent, ionic strength), precipitate formation phenomena, precipitate growth, aging, & breakage; continuous operation & scale up [4]						

	Adsorption - Adsorption equilibria; adsorption in batch mode & in fixed bed & agitated bed; Desorption; continuous operation & scale up [5] **Chromatography** – theoretical concepts & methods including gel filtration, ion exchange chromatography, affinity chromatography, hydrophobic interaction chromatography. Continuous Chromatography; scale up [5] **Extraction** – single stage & multiple stage counter-current flow systems & their analysis, scale up and design of extractors; Supercritical fluid extraction; Reverse micellar extraction [4] **Membrane separations** – dialysis, reverse osmosis & ultrafiltration along with flux equations; concentration polarization; cross-flow filtration; continuous operation & scale up [4]
	Crystallization - principles, nucleation and growth aspects, batch crystallization and its control – cooling curve, process crystallization of proteins, crystallizer scale up and design; continuous crystallization [4] **Drying** – Drying Principles, Drying Equipment basics, Heat and Mass Transfer in Conduction Drying (with analysis of tray drying) & Adiabatic Drying (constant rate drying & falling rate drying), Undesirable Effects of Drying; continuous operation & scale up [4] **Analytical techniques used for Bioseparation –** HPLC, mass spectrometry, coupling of HPLC with mass spectrometry. [3] Bioseparation strategies of some typical products including case studies [2]
Text Books, and/or reference material	**Text Books:** 1. Bioseparations Science and Engineering, Roger G. Harrison, Paul W. Todd, Scott R. Rudge, Demetri Petrides, Oxford University press, USA 2. Practical Biochemistry Principles and techniques: Editor Wilson and Walker, Cambridge University Press 3. Bioseparations – Downstream Processing for Biotechnology, Paul A. Belter, E.L. Cussler, Wei-Shou Hu, Wiley Interscience Coulson & Richardson, Chemical Engineering, Vol- II, Butterworth Heinemann **Reference Books:** 1. Bioseparations Engineering: Principles, Practice, and Economics, Michael R. Ladisch, Wiley-Interscience 2. Doran P. Bioprocess Engineering Principles. Elsevier, Academic Press 3. Transport Processes & Unit Operations. Christine John Geankoplis, Prentice-Hall International Inc.

CO-PO mapping:

Course Code	Title of the course	COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT1003	**Bioseparation Technology**	CO 1	3	1	3	2	1	2
		CO 2	3	1	3	3	-	1
		CO 3	3	1	3	3	-	2
		CO 4	3	1	3	3	-	2
		CO 5	1	2	3	2	3	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT 1051	**Bioprocess Engineering Laboratory**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Bioprocess Engineering							
Course Outcomes	**CO1**: To study the growth kinetics of E.coli and Saccharomyces cerevisiae in shake flasks and bioreactor **CO2:** To study the substrate utilization kinetics in a fermentation system **CO3:** To study the **S**terilization of a Bioreactor **CO4:** To determine Volumetric Oxygen Transfer Coefficient (K_La) in a Bioreactor						
	CO5: To estimate Residence Time **D**istribution (RTD) in a Bioreactor **CO6:** To determine the correlation of Mixing Time with Reynold's Number in a fermentation system						
Topics Covered	1. Microbial Growth Kinetics 2. Determination Reducindg Sugar (Glucose) by Dinitrosalicylic acid (DNS) method 3. Media Sterilization and Air Sterilization 4. Aeration and Agitation in Bioreactors 5. Non ideal Flow in Bioreactors 6. Concept of Mixing Time determination						
Text Books, and/or reference material	**Text Books:** **Reference Books:** Mukhopadhyay S.N 2007. Experimental Process Biotechnology Protocols New Delhi Viva Books						

CO-PO mapping:

Course Code	Title of the course	COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT 1051	**Bioprocess Engineering Laboratory**	CO 1	3	3	3	2	2	2
		CO 2	3	3	3	2	1	2
		CO 3	3	3	3	2	1	2
		CO 4	3	3	3	1	1	2
		CO 5	3	3	3	1	1	2
		CO 6	3	3	3	1	1	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT 1052	**Bioseparation Technology Laboratory**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Bioseparation Technology		CT+EA					

Course Outcomes	**CO1:** To determine the specific cake resistance & filter medium resistance by constant pressure filtration/pressure-time variation in constant rate filtration **CO2:** To construct a binodial diagram and study the extraction of a protein in an aqueous two-phase system. **CO3:** To recover a protein such as an enzyme from a microbial culture & carry out its laboratory bioseparation including salt precipitation & dialysis **CO4:** To separate out a protein from a mixture by gel filtration/ion exchange chromatography and to concentrate a protein by ultrafiltration/diafiltration and to study tangential flow filtration **CO5:** To carry out adsorption in batch mode/column/gradient separation studies **CO6:** To prepare a cell-free extract by sonication/homogenization for recovering intracellular proteins or other compounds **CO7:** To learn about instrumental techniques such as HPLC/GC analysis and rotary vacuum evaporator and lyophilizer
Topics Covered	1. Filtration (constant pressure/constant rate filtration) 2. Aqueous two phase separation 3. Recovery of protein (such as enzyme) from microbial culture and its laboratory bioseparation including salt precipitation &dialysis. 4. Separation of proteins by gel filtration /ion-exchange chromatography 5. Separation/concentration of proteins by Ultrafiltration/diafiltration. 6. Study of tangential flow filtration 7. Adsorption in batch/column/gradient separation studies 8. Preparation of cell-free extract: by sonication/homogenization 9. Chromatographic separation by HPLC/GC 10. Demonstrations of rotary vacuum evaporator and lyophilizer
Text Books, and/or reference material	**Reference Books:** 1. Bioseparations Science and Engineering, Roger G. Harrison, Paul W. Todd, Scott R. Rudge, Demetri Petrides, Oxford University press, USA 2. Principles and Techniques of Biochemistry & Molecular Biology: Editor Wilson and Walker, Cambridge University Press 5. Transport Processes & Unit Operations. Christine John Geankoplis, Prentice-Hall International Inc.

CO-PO mapping:

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT 1052	**Bioseparation Technology Laboratory**	CO 1	3	3	3	1	-	2
		CO 2	3	3	3	1	1	2
		CO 3	3	3	3	2	2	2
		CO 4	3	3	3	1	1	2
		CO 5	3	3	3	1	1	2
		CO 6	3	3	3	2	2	2
		CO 7	2	3	3	2	1	1

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT2001	**Genomics, Proteomics & Bioinformatics**	PCR	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA)
Molecular Biology & rDNA Technology	CT+EA

Course Outcomes	CO1: In depth understanding of genomes, transcriptomes and proteomes to address relevant problems. CO2: Understanding of concepts for functional analysis of genes and proteins. CO3: Learning bioinformatics to analyse genomes, transcriptomes and proteomes. CO4: Development of comprehensive understanding of "Omes& Omics" to solve the existing problems of the society.
Topics Covered	Introduction to genomics; Importance of genomics; (2) Sequencing of genomes; Assembly of genome sequences; (2) The human genome project; (2) Locating the genes in the genome; (2) Determination of gene functions; (3) Structural, comparative and functional genomics; (2) Lessons from various prokaryotic and eukaryotic genomes; (3) Comparative genomics in evolution and medicine; Genomic variations. (2) Introduction to proteomics: (1) Expression proteomics, Functional proteomics, Structural proteomics; (2) Two-dimensional gel electrophoresis (2-DGE); Sample Preparation; Isoelectric focusing (IEF); (3) Equilibration of the IPG strip, the second dimension and detection of proteins on the 2-DGE gel; (2) Introduction to mass spectrometry; Mass spectrometry (MS) - based methods of protein identification: (3) MALDI-MS, ESI-MS; (3) Analysis of phosphoproteins by MS; Glycobiology and proteomics; (2) Protein microarrays; Protein 3D structures; (2) Protein interaction networks; Measuring proteins. (2) Introduction to bioinformatics; (2) Data acquisition; Databases and data retrieval; (2) Searching sequence database; Multiple sequence alignment, (2) phylogenetics and sequence annotation; (2) Structural informatics; (2) Microarray, 2DGE and MS data analysis; (2)
Text Books, and/or reference material	**Text Books:** S. B. Primrose and R. M. Twyman; *Principles of Genome Analysis* A. *M. Campbell and L. J. Heyer; Discovering Genomics, Proteomics & Bioinformatics; Pearson ducation; Second Edition.* *T. A. Brown; Genomes; Wiley-Liss; Third Edition.* Mount "Bioinformatics" Cold Spring Harbour Arthur Lesk "Introduction to Bioinformatics" Bioinformatics Sequences and Genome Analysis,2nd edition 2004 by David W. Mount, CBS Publishers and Distributors . **Reference Books:** S. B. Primrose and R. M. Twyman; *Genomics: Applications in Human Biology* Bioinformatics. (A.D.Baxevanis&B.F.F.Ouellette, eds.) Wiley Interscience, 1998.

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CO-PO mapping:

Course Code	Title of the course	COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6

BT2001	**Genomics, Proteomics & Bioinformatics**	CO 1	3	2	3	3	3	1
		CO 2	3	2	3	3	3	1
		CO 3	3	2	3	3	3	1
		CO 4	3	2	3	3	3	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT2051	**Molecular Biology & rDNA Technology Lab**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Molecular Biology & rDNA Technology		CT+EA					

Course Outcomes	CO1: To learn basic techniques in molecular biology & recombinant DNA technology CO2: To learn how to make the experimental plans in molecular biology CO3: To evaluate and analyse the results of various experiments CO4: To formulate strategies for project – related laboratory work
Topics Covered	Isolation of plasmid DNA Isolation of purification of genomic DNA Restriction digestion Ligation & bacterial transformation Screening for recombinant clones Amplification of DNA fragments by Polymerase chain reaction (PCR) Southern blotting. Isolation & visualization of RNA Study of protein expression in bacteria
Text Books, and/or reference material	Reference Books: Molecular Cloning: A Laboratory Manual (3 Volume Set): 4th Editionby Michael R Green, Cold Spring Harbor laboratory RNA Methodologies: A Laboratory Guide for Isolation and Characterizationby Robert E. Farrell Jr. PCR Protocols: 687 (Methods in Molecular Biology)by Daniel J. Park

CO-PO mapping:

Course Code	Title of the course	COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT2051	**Molecular Biology & rDNA Technology Lab**	CO 1	3	2	3	3	3	2
		CO 2	3	2	3	3	3	2
		CO 3	3	2	3	3	3	2
		CO 4	3	2	3	3	3	2

Department of Biotechnology				
Course	Title of the course	Program	Total Number of contact hours	Credit

Code		Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT2053	**Omics & Bioinformatics Laboratory**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Genomics, Proteomics & Bioinformatics		CT+EA					
Course Outcomes	CO1: To acquire knowledge of most important bioinformatics databases and learn text- and sequence-based searches to retrieve biological data in different file formats. CO2: Understanding pairwise and multiple sequence alignment using various softwares. CO3: Perform phylogenetic analysis to understand evolutionary relationships. CO4: To learn prediction of secondary and tertiary structures of protein and RNA sequences						
Topics Covered	1. Introduction and use of various sequence and structure databases. 2. Sequence information resource: Using NCBI, EMBL, Genbank, Entrez, UniProt. 3. Pairwise Sequence Alignment: BLAST tool and interpreting the results 4. Multiple Sequence Alignment: Clustal, Muscle etc 5. Phylogenetic analysis of protein and nucleotide sequences and phylogenetic tree constructions using softwares like Mega, Phylip 6. Use of different protein family databases (SCOP, CATH). 7. Visualization of protein structures using Rasmol and PyMol. 8. Aligning protein structures. 9. Secondary structure prediction of proteins using DSSP, Pispred. 10. Homology modelling of proteins. 11. Using RNA structure prediction tools.						
Text Books, and/or reference material	Text Books: The Linux Command Line: A Complete Introduction 1st Edition by William E. Shotts Jr. Python Crash Course by Eric Matthews Reference Books: A Byte of Python by C.H. Swaroop A Practical Guide to Linux Commands, Editors and Shell Programming 3rd Edition by Mark G. Sobell						

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT2053	**Omics & Bioinformatics Laboratory**	CO 1	3	1	3	2	2	1
		CO 2	3	1	3	3	2	1
		CO 3	3	1	3	3	2	2
		CO 4	3	1	3	3	3	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9031	**Human Molecular Genetics**	PEL	3	0	0	0	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					

Genetics and Molecular Biology	CT+EA
Course Outcomes	1. Learn about classical human genetics. 2. Learn about Mutation and diseases. 3. Learn about genetics of Neoplasia. 4. Learn about genomic imprinting and human disease 5. Learn about X-inactivation and DNA methylation. 6. Learn about gene mapping and positional cloning. 7. Learn about genetics of behavioral disorders 8. Learn about pharmacogenetics and biochemical genetics. 9. Learn about animal models in human genetics 10. Learn about methods used for diagnosis and detection of gene mutations
Topics Covered	1.Simple Mendelian traits. Loss-of-function mutations; Gain-of-function mutations; Gene interactions; Dynamic mutations. 3. Genetics of neoplasia. 4. Genomic imprinting and human disease. 5. X-inactivation and DNA methylation 6. Gene mapping and positional cloning tics of behavioral disorders. nacogenetics and biochemical genetics. nal models in human genetics. thods used for diagnosis and detection of gene mutations.
Text/ References	1. Human Molecular Genetics : Tom Strachan and Andrew P Read 2. Thompson and Thompson Genetics in Medicine 3. An Introduction to Human Molecular Genetics: Jack J. Pasternak 4.Molecular Biology of the Gene: James D Watson 5. Genes IX: Benjamin Lewin 6.Concept of Genetics: Klug, Cummings and Spencer 7. Molecular Cell Biology: James E. Darnell 8. Molecular Biology of Cancer: Pecorino

CO-PO mapping

Course Code	Title of the course	*COs*	*PO1*	*PO2*	*PO3*	*PO4*	*PO5*	*PO6*
BT9031	**Human Molecular Genetics**	*CO1*	*1*	*1*	*2*	-	*3*	-
		CO2	*1*	*1*	*2*	-	*3*	-
		CO3	*1*	*1*	*2*	-	*3*	-
		CO4	*1*	*1*	*2*	-	*3*	-
		CO5	*1*	*1*	*2*	-	*3*	-
		CO6	*1*	*1*	*2*	-	*3*	-
		CO7	*1*	*1*	*2*	-	*3*	-
		CO8	*1*	*1*	*2*	*1*	*3*	*1*
		CO9	*1*	*1*	*2*	*1*	*3*	*1*
		CO10	*1*	*1*	*1*	*1*	*3*	*1*

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

BT9032	**Cancer Biology**	PEL	3	0	0	0	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Genetics and Molecular Biology	CT+EA

Course Outcomes	1. Learn about classification of cancer, types and phenotypic characteristics. 2. Learn about DNA polymerase and DNA damage repairing mechanisms. 3. Learn about differentiation and apoptosis, Biology of metastasis, Carcinogenesis, Cancer genetics 4. Learn about Oncogenes and Tumor suppressor genes 5. Learn about Growth factors and signal transduction 6. Learn about Cell cycle regulation and check point. 7. Host tumor interactions, Gene rearrangements, detecting oncogene abnormalities in clinical specimens 8. Principles of chemotherapy, Concepts in cancer therapy - Mechanisms of cytotoxic drug action, Cancer Immunotherapy
Topics Covered	1. Phenotypic characteristics of cancer cells 2. DNA replication and Repair mechanisms 3. Role of differentiation and apoptosis, Biology of metastasis, Carcinogenesis, Cancer genetics 4. Oncogenes ,Tumor suppressor genes 5. Growth factors and signal transduction 6.Cell cycle regulation and check point.
	7. Host tumor interactions, Gene rearrangements, detecting oncogene abnormalities in clinical specimens 8. Principles of chemotherapy, Concepts in cancer therapy - Mechanisms of cytotoxic drug action, Cancer Immunotherapy.
Text/ References	1. The Biology of Cancer: Robert Weinberg 2. Principles of Cancer Biology: LJKleinsmith 3. Cancer: A Beginner's Guide (Beginner's Guides): Paul Scotting 4.Molecular Biology of the Gene: James D Watson 5. Genes IX: Benjamin Lewin 6.Concept of Genetics: Klug, Cummings and Spencer 7. Molecular Cell Biology: James E. Darnell 8. Molecular Biology of Cancer: Pecorino

CO-PO mapping

Course Code	Title of the course	*CO*	*PO1*	*PO2*	*PO3*	*PO4*	*PO5*	*PO6*
BT9032	**Cancer Biology**	*CO1*	*1*	*1*	*2*	-	*3*	-
		CO2	*1*	*1*	*2*	-	*3*	-
		CO3	*1*	*1*	*2*	-	*3*	-
		CO4	*1*	*1*	*2*	-	*3*	-
		CO5	*1*	*1*	*2*	-	*3*	-
		CO6	*1*	*1*	*2*	-	*3*	-
		CO7	*1*	*1*	*2*	-	*3*	-
		CO8	*1*	*1*	*2*	*1*	*3*	*1*

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9033	**Signal Transduction**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous assessment (CA) and end-term examination (ET))					
Molecular Biology, Biochemistry, Cell biology and Genetics		CA+ET					
Course Outcomes	CO1: Acquire an understanding on fundamental components of signal transduction processes. CO2: Acquire an understanding on various signaling steps in different physiological and developmental processes of bacteria, plants and animals. CO3: To be able to design experiments to investigate new signaling pathways and regulation of gene expression.						
Topics Covered	Bacterial two-component regulatory systems (2) Ligands, Receptors, Second messengers and Effectors (3) Carriers and channels of membrane (1) G protein-coupled signal transmission (3) Protein tyrosine kinase (2) Ras/MAP Kinase pathways (2) Transcription factors and regulators (3) Chromatin remodeling (2) Ethylene signaling (1) Light perception and photoreceptors (2)						
	Signal transducers and master regulators (3) Photomorphogenesis (2) Transcriptional networks of seedling development (2) Light regulated gene expression (2) Identification of novel signaling molecules (2) Functional characterization of new components (2) Cross talks among various signaling pathways (2)						
Text Books, and/or reference material	Text Books: Lewin's Genes X by J.E. Krebs, E.S. Goldstein and S.T. Likpatrick Research Articles on the said topics (usually given to the students)						

CO-PO mapping

Course Code	Title of the course		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9033	**Signal Transduction**	CO 1	2	0	3	1	0	0
		CO 2	1	0	3	1	2	1
		CO 3	3	2	3	3	2	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

BT9034	**Molecular Cell Signaling**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Cell Biology, Molecular Biology and Biochemistry		CT+EA					
Course Outcomes	CO1: To understand the concepts of molecular signaling of cells which regulate its function. CO2: To understand the deregulation of these pathways leading to functional defects at cellular and molecular level. CO3: To identify the molecules than can be targeted therapeutically for the treatment of human diseases at cellular and molecular level.						
Topics Covered	• Introduction of cellular signaling [4] • Signaling molecules – Interferons, Interleukins and others [4] • Receptor-mediated signaling in cells, Receptor associated and non-receptor tyrosine kinases and their involvement in different signal transduction pathways [5] • Role of different transcription factors and kinases (MAP kinases and other ser/thr kinases) [7] • Activation of various signalling pathways (Jak-Stat, MAPK, PI3K-Akt, NF-kB etc.) in different cells by extracellular stimuli [10] • Involvement of signal transduction pathways in many important cellular processes like Cell migration, cancer, angiogenesis etc. [10]						
Text Books, and/or reference material	Text Books: Molecular Biology of the Cellby Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts, Peter Walter.6th Edition, 2014.Garland Science. olecular Cell Biologyby Harvey Lodish, Arnold Berk, Chris A. Kaiser, Monty Krieger, Matthew P. Scott, Anthony Bretscher, HiddePloegh, Paul Matsudaira. 8th edition, 2016.						
	Publisher: WH Freeman. Reference Books: 1. Cell and Molecular Biology: Concepts and Experiments by Gerald Karp. 6th Edition, 2010. Wiley. Essential Immunology, Roitt, I.M., 9th Ed. (1997), Blackwell Scientific, Oxford, UK 2. Immunology, Kuby, J. 3rd Ed. (1997), Freeman, W.H,Oxford,UK 3. Weir, Immunology, 8th ed, W.B. Saunders& Co. 4. K.A. Abbas, Immunology, 4th ed, W.B. Saunders& Co. 5. Relevant publications from many peer-reviewed journals.						

CO-PO mapping:

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9034	**Molecular Cell Signaling**	CO 1	1	1	3	1	1	-
		CO 2	2	1	3	1	2	-
		CO 3	3	2	3	2	2	1

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9035	**Food Biotechnology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					

Bioseparation Technology	CT+EA
Course Outcomes	CO 1: To understand the concept of metabolic Engineering in food and apply it to increase the quality and productivity of food products CO-2: To increase the efficiency of enzyme by protein engineering. CO-3: To formulate associations between specific nutrients and genetic factors and to study how a food/food ingredient influence gene expression. CO-4: To learn the concept of nutratceuticalsand help in the prevention of lifestyle related disorders. CO-5: To study the application of nutratceutical in food based system and to develop delivery strategies for the nutraceutical. CO-6: To learn about heat transfer,mass transfer and reaction kinetics in foods CO-7: To learn aboutdetails of thermal processing of foods, dehydration operations and filtration operations art commercial level CO-8: Studies on Food quality management and concept of HACCP CO-9: Studies on design of a food processing plant
Topics Covered	Introduction to Food Biotechnology – Food Microbiology- Metabolic Engineering of Bacteria for food ingredients, Metabolic engineering of Saccharomyces cerevisae (4] Biotechnological Modifications of S. cerevisae and its effect in wine production, genetic Engineering of baker's yeast, [2] Recombinant Lactic Acid Bacteria [1] Plant and Animal Food applications and functional food- Introduction to Nutraceutical and Nutigenomics, Probiotics, Bioavailability and delivery of nutraceuticals using nanotechnology Food and food component preventing cancer, Antiobesity effect of Allenic carotenoid, fucoxanthin, Encapsulation of probiotic bacteria, Antioxidant [10] Improvement in Food Quality- Enzymes & Recombinant lipooxygenases and oxylipin metabolism for food quality [4]
	Heat transfer in food, microwave operation, ultrasound assisted processing [4] Kinetics of chemical reactions in foods [2] Dehydration of foods, Mass transfer in dehydration, Drying rate curve, Pychrometry [4] Physical separation processes in foods – filtration operation, membrane filtration [5] Food quality management, HACCP [3] Design of food processing plant [3]
Text Books, and/or reference material	Text Books Food Biotechnology by Kalidas Shetty Fundamentals of Food Biotechnology by Lee Fundamentals of Food Process Engineering, Romeo Toledo , Springer Fundamentals of Food Engineering, D G Rao, PHI References: 1. Bioprocesses and Biotechnology for Functional Foods and Nutraceuticals by Jean-Richard Neeser, J. Bruce German, CRC Press

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9035	**Food Biotechnology**	CO 1	-	-	*2*	*3*	*3*	-
		CO 2	-	-	-	*3*	*3*	-
		CO 3	-	-	*3*	-	*3*	*1*
		CO 4	-	-	*3*	*3*	*3*	*1*
		CO 5	-	-	-	*3*	-	-
		CO 6	1	1	2	3	2	2
		CO 7	3	2	3	3	3	2
		CO 8	3	3	3	3	3	3
		CO 9	3	3	3	3	3	3

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9036	**Biopharmaceutical Technology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Bioprocess Engineering, Bioseparation Technology		CT+EA					
Course Outcomes	CO 1: To learn about the manufacturing processes of drug substance and drug products CO 2: To learn about the detailed design of a GMP compliant plant CO 3: To learn about downstream processing of biopharmaceutical products at commercial level CO 4: To learn about biopharmaceutical process start up CO 5: To learn about quality management in a biopharmaceutical industry						

Topics Covered	Manufacturing process - Drug substance manufacturing, drug product manufacturing, key factors for process evaluation. Manufacturing and storage of cell bank. Comparison of batch and continuous process for fermentation. Difference between suspension fermenters for cell culture and microbial fermentation. [6] Design and construction of manufacturing facilities for mammalian cell derived pharmaceuticals. Detailed design of a GMP compliant plant with process flow diagram along with utilities, water treatment, waste management and location selection [6] Downstream processing - Harvest of therapeutic proteins from high cell density fermentation broths – centrifugation and filtration. Expanded bed adsorption for separating the biopharmaceutical product from crude solution. Ultrafiltration process design and implementation for biopharmaceutical product recovery. Virus filtration process design for biopharmaceutical product recovery. Product recovery of biopharmaceutical products from transgenic sources – aqueous two phase extraction [14] Role of process development group and manufacturing group in biopharmaceutical process start up. [2] Making changes to a biopharmaceutical manufacturing process during development and commercial manufacturing – acase study [2] Biosimilars and non-innovator biotherapeutics in India – an overview of current situation [2] Fundamental of Quality assurance, Structure of Quality Management Systems, Responsibility of Management and Training of Personnel, Quality Assurance in Development. [4] Quality assurance in manufacturing, GMP, Process validation for cell culture derived pharmaceutical proteins. Regulation [4] Concepts of understanding controlling factors regulating cost of production of a biopharmaceutical product. [2]
Text Books, and/or reference material	Text Process Scale Bioseparations for the Biopharmaceutical Industry, Abhinav A. Shukla, Mark R. Etzel, ShishirGadam, CRC Press Manufacturing of Pharmaceutical Proteins, Stefan Behme, Wiley-VCH References Pharmaceutical Production Facilities: Design and Applications, Graham Cole, Informa Healthcare Large-scale Mammalian Cell Culture Technology, Lubiniecki, CRC Press

CO-PO mapping

Course Code	Title of the course	COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9036	**Biopharmaceutical Technology**	CO 1	*2*	*1*	*2*	*2*	*2*	*2*
		CO 2	*3*	*3*	*3*	*3*	*3*	*3*
		CO 3	*3*	*2*	*3*	*3*	*3*	*2*
		CO 4	*3*	*3*	*3*	*3*	*3*	*3*
		CO 5	*3*	*3*	*3*	*3*	*3*	*3*

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9037	**Biomaterials**	PEL	3	0	0	3	3

Biochemistry, cell biology, Chemistry	Course Assessment methods (Continuous (CT) and end assessment (EA))
	CT+EA
Course Outcomes	CO1: Classify the biomaterials and recognize their production and properties. CO2: Explain the application areas of biomaterials CO3: To realize the important basic properties and requirements for biomaterials CO4: Recognize the importance of relationships between living tissues and biomaterials
Topics Covered	Definition of biomaterials – biologically derived materials or materials compatible with biology. **(2)** Common biomaterials: some proteins, many carbohydrates and some specializedpolymers. **(4)** Collagen (protein in bone and connective tissues): Structure production and its use. **(3)** Fibroin (protein in silk): Production and its use. **(2)** Production of these proteins by conventional cloning methods. **(3)** Carbohydrates: Modified carbohydrates acting as lubricants for biomedical applications; Polydextrose; Carbohydrates modified by enzymes; **(8)** Biopolymers: Synthesis from a simple biological monomer (eg., hyaluronate polymers); Dextrans (used in chromatography columns); Rubber Like materials produced by bacteria and fungi (Polyhydroxybutyrate PHB), Polycaprolactone(PCL); Production of a copolymer of PHB and PHV(polyhydrovaleric acid), sold as Biopol by fermentation by Alcaligeneseutrophus; Biodegradable polymers **(8)** Industrial biopolymers: Production of polyphenol resins by the enzyme soybean peroxidase; Evaluation of the properties of biopolymers to make good biomaterials; Tensile strength (both elasticity and breaking strength); Hydration, visco – elastic properties; viscosity. **(8)** Biomaterials for Organ Replacement; Tissue Engineering; tissue replacements, cardiovascular; biodegradable and bioactive materials, drug delivery systems.**(4)**
Text Books, and/or reference material	Text Book: 1. Biomaterials: Principles and Applications by J.B. Park and J.D. Bronzino. 2. Biomaterials: SUJATA V. BHATT, Second Edition, Narosa Publishing House,2005. 3. Biomaterials Science: An introduction to Materials in Medicine, Edited by Ratner, Hoffman, Schoet and Lemons, Second Edition: Elsevier Academic Press, 2004. Reference book: 1. Biomaterials Science and Biocompatibility, Fredrick H. Silver and David L. Christiansen, Piscataway, Springer, New Jersey.

CO-PO mapping

Course Code	Title of the course	COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9037	**Biomaterials**	CO 1	3	3	3	2	2	-
		CO 2	3	3	3	2	2	-
		CO 3	3	3	3	3	2	-
		CO 4	3	3	3	2	3	1

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9038	**Biometallurgy**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Microbiology, Chemical Kinetics	CT+EA
Course Outcomes	**1:** To recapitulate the basics of bioenergetics and to understand the relevant biogeochemistry & microbiology. **2:** To learn about the concepts of bioleaching and biobeneficiation along with the microbiological aspects **3:** To learn about bioleaching processes with typical examples. **4:** To analyze the kinetics of bioleaching **5:** To understand the enzymatic mechanism of bioleaching.
Topics Covered	Recapitulation of basics of bioenergetics (ATP as an energy-rich molecule, oxidation- reduction reactions), Biogeochemical cycles – sulphur, iron, and manganese cycles. Nature and characteristics of biogeochemically important micro-organisms. (9) Bioleaching: definition, scope, advantages & disadvantages; Types: direct, indirect, & indirect contact. Types of bioleaching with respect to reaction intermediates (thiosulphate & polysulphide mechanisms). Autotrophs & heterotrophs as candidate microorganisms for bioleaching. Bioleaching by aerobic and anaerobic microorganisms. (9) Bioleaching processes: in situ, heap & dump, & reactor bioleaching. Bioleaching of copper by *Acidithiobacillus* from chalcopyrites, chalcocite, & covellite. Dump & heap and reactor bioleaching of copper. Uranium bioleaching & biobeneficiation of gold. Environmental pollution control in gold recovery processes. (9) Kinetics of pyrite bioleaching – two-subprocess mechanism-ferric leach kinetics & kinetics of bacterial oxidation of ferrous iron. Modelling of continuous tank bioleaching of pyrite – unsegregated and segregated models. (9) Oxidation of iron by Acidithiobacillus – enzymatic mechanism; role of cytochromes & rusticyanin, elements of electron transport pathways in iron & sulphur oxidation. (6)
Text Books:	Text Books, and/or reference material Pillai Abhilash, B. D. Pandey, K. A. Natarajan. Microbiology for Minerals, Metals, Materials and the Environment, CRC Press, 2018 Ross W. Smith & Manoranjan Misra, ed. Mineral Bioprocessing, The Minerals, Metals & Materials Society, 1991 **Reference Books:** L. M. Prescott, J.P.Harley, D.A.Klein. Microbiology 5th edn. Mc-Graw Hill, 2002. . M.E. Curtin, Microbial mining and metal recovery biotechnology (1), pp 229-235, 1983 Woods D, Rawling D.E., Bacterial leaching and biomining in Marx J.L. (ed), A Revolution in biotechnology, Cambridge University Press

CO-PO mapping:

		COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9038	**Biometallurgy**	CO 1	-	1	2	2	2	-
		CO 2	1	2	3	2	2	-
		CO 3	1	2	3	2	3	1
		CO 4	1	-	3	-	-	-
		CO 5	1	1	3	2	-	-

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9039	**BioEnergy**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes	CO1: To learn about present energy scenario in the world and importance of alternate energy CO2: Detailed study on biological solid fuels CO3: Detailed study on biological liquid fuels to replace petrol and diesel CO4: Detailed study on biological gaseous fuels CO5: To learn about Indian scenario and approach to solve the problem						
Topics Covered	Energy and fossil fuel use – fossil fuel use, fossil fuel reserves, sustainable fuel sources [4] Consequences of burning fossil fuel – effects of industrial (anthropogenic) activity on greenhouse gases, sources of greenhouse gases [3] Mitigation of global warming – Kyoto protocol, reduction in global greenhouse gases, fuel cells, sequestration of carbon dioxide, alternative energy sources, energy storage. [4] Biological solid fuels – 1st, 2nd and 3rd generation biofuels, types of biomass available, energy and fuel generation using biomass. [5] Gaseous biofuels – methane production using anaerobic digestion process, sewage sludge and from landfill sites, use of methane as transport fuel.Hydrogen production from biological material, biological production of hydrogen, photosynthetic hydrogen production, hydrogen storage, use as transport fuel. Diethyl ether production [6] Liquid biofuels to replace petrol – methanol production.Large scale ethanol production from biomass, use of lignocellulosics for ethanol production, ethanol extraction after production, use of ethanol as fuel.Butanol production and use. [6] Liquid biofuel to replace diesel – synthetic diesel (FT synthesis), bio-oil (pyrolysis), microalgal biodiesel, biodiesel from plant oils and animal fats, properties of biodiesel, glycerol utilization. [5]						

	The benefits and deficiencies of biofuels – reduction in fossil fuel use, fuel economy, reduction in carbon dioxide emission from biofuels, improvement in biodiesel quantity and quality, life cycle analysis of biofuels. [6] Jatropha cultivation, National hydrogen energy road map. [3]
Text Books, and/or reference material	**Text Books:** 1. Biofuels production, application and development. Alan Scragg, CABI. 2. Research articles

CO-PO mapping:

Course Code	Title of the course	COs	PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9039	**BioEnergy**	CO 1	-	-	-	1	-	-
		CO 2	-	-	3	3	3	-
		CO 3	-	-	3	3	3	-
		CO 4	-	-	3	3	3	-
		CO 5	3	2	3	3	3	1

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9040	**Bioprocess & Plant Design**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Bioprocess Engineering, Bioseparation Technology		CT+EA					

Course Outcomes	CO1: Learn about mass balance and energy balance in Bioprocess Engineering and Cell growth kinetics CO2: Learn about media sterilization and air sterilization including kinetics, design of batch and continuous media sterilizers and air sterilizer**s.** CO3: Study of bioreactors and their design aspects related to microbial, plant and animal cell culture products CO4: Study of Scale-up, Operation, Instrumentation and control of Bioreactors. CO5: Bioreactor design supporting systems; Pumps, Refrigeration, Boilers and Effluent treatment plants. CO6: plant design aspects
Topics Covered	**Introduction to Bioprocess Engineering and Systems: (10)** Mass balance and energy balance in Bioprocess Engineering, kinetics of microbial growth, batch, continuous and fed batch systems, components of bioreactors, material of construction, vessel size, Aseptic operations in bioreactors, Mass Transfer and Heat transfer Bioreactors Mechanical fittings in bioreactors ,Project planning in Bioprocess Engineering **Sterilization of Bioreactors: (6)** Media sterilization, kinetics of media sterilization, Arrhenius equation. Design of batch and continuous sterilizers Air sterilization, kinetics of air sterilization, Design of Air Filters **Bioreactors and their Design: (8)** Batch, continuous stirred tank Bioreactors (CSTR), Plug flow Bioreactors (PFR). Enzyme immobilized bioreactors ,Fluidized bed bioreactors, Bubble column bioreactors, Air- lift bioreactors, Hollow- fibre bioreactors, Membrane bioreactors Bioreactors for plant and animal cell culture systems **Scale-up, Operation, Instrumentation and control of Bioreactors: (4)** Scale up criteria, Measurement systems and their control in Bioreactors, Feedback control, Computer control Bioreactors. **Bioreactor design supporting systems: (6)** Reciprocating and Centrifugal Pumps; Boilers for Steam generation-Water Tube and Fire Tube boilers; Refrigeration systems; Effluent treatment systems-Aerobic and Anaerobic. **Plant Design (8)** Plant Location and Site Selection, Site layout, Utilities, Environmental considerations, Equipment cleaning, Culture cell bank, cGMP aspects, Bioprocess validation, Safety Considerations, Process economics.
Text Books, and/or reference material	Text Books: 1. Shuler M.L, Kargi F, '*Bioprocess Engineering-Basic Concepts'*, Prentice Hall of India Ltd. 2. Aiba S, Humphrey A E and Millis N F, '*Biochemical Engineering'* , Academic Press *3.* Stanbury P F and Whitaker A, *'Principles of Fermentation*

	Technology', Pergamon Press 4. Bailey J E and Ollis D F, *Biochemical Engineering Fundamentals*,' McGraw Hill Reference Books: 1. Doran P M, '*Bioprocess Engineering Principles'*, Academic Press 2. Sinnott, R.K, '*Coulson and Richardson's Chemical EngineeringVol.3& Vol.6*,', Butterworth- Heinemann

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9040	**Bioprocess & Plant Design**	CO 1	3	2	3	2	2	1
		CO 2	3	2	3	2	2	1
		CO 3	3	2	3	2	2	1
		CO 4	3	2	3	2	2	1
		CO 5	3	2	3	2	2	1
		CO 6	3	3	3	2	2	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9041	**Advanced rDNA & Cellular Biotechnology**	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Cell Biology, Biochemistry, Immunology, Molecular Biology & rDNA Technology, Microbiology		CT+EA					
Course Outcomes	CO1 :Learn the concept about working of Host system , vectors.specfic enzymes CO2 : Formulate the strategies for r proteins from specific cells,media selection and their modification. CO3: By applying knowledge of cellular technologies, purification specific bioreactors can be setup for commercial level production of valuable compounds for mankind.						

Topics Covered	**Module 1** : **Tools and general Methodology Recombinant DNA Technology**: Vectors types and their importance. Selection of host and its characteristics, Cloning and screening strategies for gene and gene expression with specific examples. (**6)** **Module 2** : **Manipulation in Gene Expression and Protein Production in Prokaryotes and Eukaryotes**;Regulatable promoters role; Vector design for increasing protein, Fusion protein , protein stability ; overcome oxygen limitation ,DNA integration into host chromosome, Metabolic load, Increasing Secretion ;Yeast espression system Cultured insect cell expression systems;Microbial Cell factories for insulin production.Modified microorganisms for waste degradation, Synthesis of commercial from recombinant microorganisms Ascorbic acid , Indigo, amino acids antibiotics, Engineering human interferon , Human growth hormones, DNAse I and Aginate lyase. **(10)** **Module 3 : Animal cells as Bioreactor**: Cultivation systems for cell and tissue culture: Animal cell cultures maintenance and modifications. Vector design for mammalian gene expression ; CHO cells and its modification to enhance its potential in production of
	recombinant proteins; Animal cell culture fermenter. Cell immobilization techniques. Large Scale Production of r Protein, Types of Fermenter ,Two stage fermentation in Tandem air lift reactor for T4 DNA Ligase. Separation of products**.(10)** **Module 4**: **Plants as bioreactors** for bio Pharmaceuticals production:Plant tissue culture techniques Cell suspension cultures and bioreactor technology, secondary metabolites, plant biosynthesis of alkaloids, flavonoids, terepenes, phenols, regulation and commercial importance.Plant and plant cell culture derived r Therapeutics and its purification**.(10)** **Module 5** : **Recent advanced tools** for Forensic studies,Molecular Diagnostics, Gene therapy. Environment cleaning programme**.(6)**
Text Books, and/or reference material	**Text/ Reference Books :** 1. Principles of Gene Manipulation. Old and Primrose- Blackwell scientific Pub. 2. Recombinant DNA Technology. Watson JD et al., Scientific American Book Series 3. Molecular biotechnology Principles and applications of r DNA technology. Bernard R.Glick.Jack J Pasternak. ASM Press ; Washington DC 4. Culture of Animal Cells: A Manual of Basic Technique. R. Ian Freshney Wiley-Liss. 5.Principles of Gene Manipulation. Sandy B. et al., Blackwell Publishers

CO-PO mapping:

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9041	**Advanced rDNA & Cellular Biotechnology**	CO 1	3	2	2	3	-	3
		CO 2	3	-	2	-	2	2
		CO 3	3	2	-	1	-	-

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9042	**Animal Biotechnology**	PEL	3	0	0	0	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Genetics and Molecular Biology		CT+EA					

Course Outcomes	1. Learn about animal cell culture technique in laboratory scale. 2. Learn about technique for animal in large scale. 3. Learn about various techniques in animal biotechnology. 4. Learn about transgenic and knock animal techniques and its application. 5. Learn about techniques and importance of gene therapy 6. Learn about IVF technique and its importance. 7. Learn about stem cells and its applications.
Topics Covered	1. History scope and prospect of animal cell culture: History of animal cell culture and development, Development of primary culture, Development of cell line by enzymatic disaggregation, Culture media and growth conditions.Cell type and characterization, origin of animal cell line, maintenance and characterization of different cell lines, Marker gene characterization. 2. Growth and scale up: Cell growth characteristics and kinetics, Micro-carrier attached growth, Cell culture in continuous, perfusion and hollow fiber reactor, Mass transfer in mammalian cell culture. 3. Technology – Present and future: Hybridoma technology/Monoclonal antibody technology, Vaccine production, Organ culture, Transfection of animal cells, Future tissue engineering. 4. Transgenic and Konck out Animals: Methodology, Embryonic Stem Cell method,
	Microinjection method, Retroviral vector method, Applications of transgenic animals 5. Gene Therapy: Ex-vivo gene therapy, In vivo gene therapy, Viral gene delivery system,Retrovirus vector system, Adenovirus vector system, Adeno-Associated virus vectorsystem, Herpex simplex virus vector system, Non-viral gene delivery system, Prodrug activation therapy, Nucleic acid therapeutic agents. 6.In Vitro Fertilization and Embryo Transfer:Composition of IVF media, Steps involved in IVF, Fertilization by means of micro insemination, PZD, ICSI, SUZI, MESA. 7.Stem cells: Classification and types, Sources, Markers, Differentiation signals, application, IPSC
Text/ References	1. Animal Cell Culture by John R.W. Masters; Oxford University Press 2. Introduction to Cell and Tissue Culture by Jennie P. Mather and Penelope E. Roberts Plenum Press, New York and London 3. Molecular Biotechnology: Primrose. 4. Animal Cell Biotechnology: R.E. Spier and J.B. Griffiths (1988), Academic press. 5. Balasubramanian, Bryce, Dharmalingam, Green and Jayaraman (Eds.), Concepts in Biotechnology, University Press, 1996 6. Hood L.E., Weissman I., Wood W.B. and Wilson J.H. Immunology, Benjamin Cummings, 1989 7. Biotol Series – Butterworth and Heineman, Oxford, 1992

CO-PO mapping

Course Code	Title of the course	***CO***	***PO1***	***PO2***	***PO3***	***PO4***	***PO5***	***PO6***
BT9042	**Animal Biotechnology**	*CO1*	*1*	*1*	*2*	*1*	*3*	*1*
		CO2	*1*	*1*	*2*	*1*	*3*	*1*
		CO3	*1*	*1*	*2*	*1*	*3*	*1*
		CO4	*1*	*1*	*2*	*1*	*3*	*1*
		CO5	*1*	*1*	*2*	*1*	*3*	*1*
		CO6	*1*	*1*	*2*	*1*	*3*	*1*
		CO7	*1*	*1*	*2*	*1*	*3*	*1*

Department of Biotechnology				
Course	Title of the course	Program	Total Number of contact hours	Credit

Code		Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9043	**Immunotechnology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Immunology, Cell biology		CT+EA					
Course Outcomes	**CO 1.** The students will gain insight into the immune response to various infectious and non-infectious and autoimmune diseases. **CO 2.** In depth understanding of the impact of different receptors cell signaling pathways in immune response will allow their knowledge to apply for future application. **CO 3.** The latest technologies used in disease detection and antibody production **CO 4.** To apply the concept and strategies for immunotherapeutics production from cell lines at higher scale.						
Topics Covered	**Fundamental and cell signaling in immune system:** Components of innate and acquired immunity; major histocompatibility complex and immune responsiveness, molecular basis of antibody diversity, self–non-self discrimination and immunological memory. Immunoglobulin superfamily; B and T cell activation B-cell receptor; T-cell receptor; cytokines, chemokines and their receptors; signal transduction pathways. **(8)** **Host-Pathogen interaction**; Molecular basis of Immune diversity, Immunity and infection to bacteria, virus, protozoa, fungi. tumor. Cancer, Auto immune disease, Inflammation. Discussion with examples for each category.Research on progress for immunotherapy **(8)** **Principles and applications of laboratory tests in Immunology:** Principles of antigen-antibody interactions;production and purification of polyclonal antibodies; antibody assays - precipitation, agglutination, immunoelectrophoresis advanced immunological techniques - RIA, ELISA, Western blotting, immunofluorescence, immunoelectron microscopy, flow cytometry and ELISPOT assay, surface plasmon resonance; total and differential counts in human peripheral cells, separation of monocytes from peripheral cells; lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, HLA typing **(6)** **Cellular technologies and animal cell bioreactors** : Large scale production of interferon, therapeutic agents. Generation of monoclonal antibodies through Hybridoma technology,. Use of specific cells and cell lines for therapeutic purpose. Genetic engineering techniques to make human antibodies- chimeric antibodies & humanized antibodies, clinical use of monoclonal antibodies. **(8)** **Vaccinology:** Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines; mRNA based vaccine, Peptide vaccines; conjugate vaccines, Dendritic cell vaccine; **(4)** **Clinical Immunology**- Hypersensitivity; Types of autoimmune diseases and their treatment; Transplantation and immunosuppressive therapy; Tumor immunology – Tumor antigens; Therapeutic uses of cytokines. **(8)**						

Text Books, and/or reference material	**Text Book**: Kuby Immunology By Owen, Punt, & Stranford, 7th, Seventh Edition, 2013, Macmillan press. 2. Abul K. Abbas, Andrew K. Lichtman & Jordan S. Pober (Eds.). Cellular and Molecular Immunology. 3rd Edn. W.B. Saunders Company, 2001 **Reference books:** 2. The Elements of Immunology by FahimHalim Khan, Pearson Education, 2009. 3. Essentials of Immunology: Ivan Riot- Blakswell Scientific Publications, Oxford, 6th Edition. 4. Infection and immunity by John Playfair and Gregory Bancroft, 3rd edition, Oxford Univ.press. 2008. 5. Monoclonal antibodies: Principles and practice by J.W. Goding. 3rd edition, Academic Press.

CO-PO mapping

Course Code	Title of the course		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9043	**Immunotechnology**	CO 1	3	3	3	3	2	2
		CO 2	3	3	2	2	3	3
		CO 3	3	2	3	3	3	3
		CO 4	**3**	**2**	**3**	**3**	**2**	**3**

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9044	**Molecular Modeling & Drug Design**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Biochemistry, Proteomics, Protein Engineering		CT+EA					
Course Outcomes	CO1: To understand the physical basis of the structure, the dynamic evolution of the system, and the function of biological macromolecules. CO2: To learn the fundamental concepts of structure-activity relationships CO3: To elucidate the mechanism of action of drugs (drug-receptor interaction) CO4: To learn rational design of novel, biologically active compounds.						
Topics Covered	Introduction to molecular Simulation Techniques (5) Quantum chemistry for Modeling of small molecules (5) Molecular Dynamics Methods- Molecular Dynamics of rigid non linear polyatomic molecules in ensembles, Structural information from M.D. (5) Force fields for molecular modeling: Choice of functional form. Parametrization of a force field, Distributed multipole and polarizable force fields, Hydrophobic effect and solvation energy. Potentials of mean force. (10) Conformational analysis: Geometry optimization using steepest descent and conjugate gradients. Restrained and constrained molecular dynamics. Distance geometry. Case studies: Prediction of protein-protein interactions. DNA conformation. (10) Principles of ligand based drug design: SAR, QSAR and 3D-QSAR. Receptor based drug design: Principles of receptor based de novo ligand design. Rigid body molecular Docking. (7)						
Text Books, and/or reference material	Text Books: A R Leach-Molecular Modelling,. Principles and application 2nd edition–Prentice Hall. Krogsgaard, L-Text Book of Drug Design and Discovery-2002, Taylor and Francis, London Reference Books: G.Walsh-Biopharmaceuticals-Biochemistry and Biotechnology-2003, Wiley Scolnick.J.(2001) Drug Discovery and Design Academic Press, London N. R. Cohen, Editor. *Guidebook on Molecular Modeling in Drug Design.* Academic Press, San Diego, 1996.						

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9044	**Molecular Modeling & Drug Design**	CO 1	3	2	3	3	3	-
		CO 2	3	-	3	3	2	-
		CO 3	3	-	3	3	3	2
		CO 4	3	-	3	3	3	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

BT9045	**Regenerative Medicine &**	PEL	3	0	0	3	3
	Translational Research						
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Cell Biology, Biochemistry, Genetics, Molecular Biology		CT+EA					
Course Outcomes		CO1: To understand the basic mechanisms of how cells differentiate into specific tissues in response to a variety of biologic signaling molecules and the use of such factors for tissue production in-vitro. CO2: To acquire knowledge on the molecular basis of cellular and functional changes of different organs that occur in disease and treatments that cause tissue remodeling to correct these changes CO3: To gather insights on how studies of the developmental, cellular and molecular biology of regeneration have led to the discovery of new drugs/therapy for regenerative therapy. CO4: To understand the recent advances on application the regenerative therapy from well characterized case studies.					
Topics Covered		An Introduction to Stem Cells(2) Adult Stem Cells (1) Embryonic Stem Cells (1) Induced Pluripotent Stem Cells (1) Hematopoietic Stem Cells (1) Mesenchymal stem cells , cord blood cells, Lessons from Medipost company products like Neurostem, Cardiostem, Cartistem, Pneumostem (4) Molecular and Cellular Bases of Organ Development (6) Cloning of Somatic Cells by Nuclear Transfer, iPSC based cloning, Production of chimera animals(4) Molecular Bases of degenerative disease (1) Therapeutic Uses of Stem Cells with examples (2) In vivo Regeneration of Tissues by Cell Transplantation (2) IPS Cells as Experimental Models of Neurodegenerative Disorders: use of them as disease modelling platform, novel drug testing and tissue regenerative therapy and implantation studies(2) Studies of Patients Treated with Stem Cells, The modalities of treatment, Preparation of cells/tissues/scaffolds and Transplantation procedure(3) Tissue Regeneration Driven by Growth Hormones (2) Organ of dish, Orgnoid culture, Tissue Bioprinting to develop transplantation quality organs, Bioartificial Organs(8) Biobanking of stem cells and the ethical considerations in regenerative medicine. (2)					
Text Books, and/or reference material		Text Books: Stem Cells, Tissue Engineering And Regenerative MedicineBy: David Warburton 1st Edition. Principles of Regenerative Medicine by AnthonyAtala Robert Lanza Tony Mikos Robert Nerem,3rd Edition. Translational Regenerative Medicine byAnthony Atala and Julie G. Allickson Reference Books: The Developping Human by Keith L. Moore/T.V.N. Persaud/ Mark G.Tenth edition. Encyclopedia of Tissue Engineering and Regenerative Medicine by Rui Reis, IstEdtion.					

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9045	**Regenerative Medicine & Translational Research**	CO 1	3	3	3	3	2	1
		CO 2	3	1	2	3	3	2
		CO 3	3	2	3	2	3	3
		CO 4	3	2	3	3	2	2

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9046	**Microbial Biotechnology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Cell Biology and Genetics Biochemistry and Enzyme Technology, Microbiology and Fermentation Technology		CT+EA					
Course Outcomes	CO1: To acquire knowledge on microbial based products of commercial importance at environmental ,industrial and clinical relevance. CO2:To Apply knowledge based skills in developing strategies to improve yield and reduce cost of the microbial process and or derived products CO3:To generate pilot plant design via understanding in microbial kinetic studies. and scale up approaches. CO4:Able to impart the knowledge in synthesis and separation of microbial products at highest level of purity as per the required demand.						

Topics Covered	UNIT 1:An overview of traditional and modern applications of microbial products. Concept of Overproduction of metabolites. Strain improvement strategies for improved production of valuables via Classical (Random Mutagenesis)and advanced approches(Genetic engineering, Site directed mutagenesis, Protoplast fusion). Case studies on strategies for enhanced production of Insulin, Penicillin, and enzymes of microbial origin with emphasis onhost cell engineering ;vector design, optimization of media and process parameters. Concepts on cost analysis for better yield using improved technology (10) UNIT 2: Process technology for the production of microbial biomass. , primary metabolites and secondary metabolites. Growth and product kinetics .Fermentation, raw materials for fermentation, submerged, surface and solid-state systems, whole cell and enzyme immobilized systems.Technological processes for industrial manufacture of Yoghurt, acidophilus milk, Koumis, kefir, cheese, bread, alcoholic beverage, vinegar. Lactic acid and oriental fermented food of commercial importance. Equipment involved in the commercially important food processing methods.(10) UNIT 3: Different regulatory mechanisms involved in controlling the catabolic and anabolic processes of microbes, Induction, nutritional repression, carbon catabolite repression, Crabtree effect, feedback inhibition and feedback repression, with respect to biomass and valuables production.Case studies on Heterologous gene expression and secretion in Gram-positive bacteria with industrial applications. Biotechnology of protein secretion systems in Escherichia coli.(10) UNIT4:Environmental factors and stress in Bacterial community and their response.Microbial waste degradation (Heavy metal ,phenolics,and hydrocarbon); Microbes in bioenergy production (bioethanol , biobutanol,algal biofuel); Application based perspectives of Metagenomics. Plant microbe interaction microbe-mediated enhancement of nitrogen and phosphorus content for crop improvement; Genetic control of the cell cycle and microbial pathogenesis.(10) UNIT 5: Primary & secondary separation process for recovery of microbial products - Biomass removal . Biomass disruption , Membrane based techniques. Extraction -solvent, aqueous two phases, super critical, and Adsorption. Chromatography, Precipitation
	(Ammonium Sulfate, solvent), Electrophoresis, Crystallization, Drying and Freeze drying. (6)
Text/ References	1. Bioprocess Engineering Principles" by Pauline M.Doran, Academic Press 2. A Text book of Industrial Microbiology 2nd Edition. Crueger, W. and Cruger, A. (2000) Panima Publishing Corporation, New Delhi. 4. 3. Manual of Industrial Microbiology and Biotechnology 2nd Edition. Ed. Arnold L. Demain and Julian E. Davies (1999) ASM Press Washington D.C. 4..Bailey J.E. & Ollis, D.F. Biochemical Engineering Fundamentals, 2nd ed., McGraw Hill, 1986 5.Michael Shuler and FikretKargi. “Bioprocess Engineering: Basic Concepts”, 2nd Edition, Prentice Hall, and Englewood Cliffs, NJ, 2002.

CO-PO mapping

Course Code	Title of the course		**PO1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**
BT9046	**Microbial Biotechnology**	CO 1	3	2	3	3	2	-
		CO 2	3	-	3	-	-	-
		CO 3	3	-	3	3	1	1
		CO4	3	2	3	2	-	2

Department of Biotechnology				
Course Code	Title of the course	Program Core	Total Number of contact hours	Credit

		(PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9047	**Environmental Biotechnology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Microbiology, Molecular Biology, Biochemistry		CT+EA					
Course Outcomes	Learn about scope, applications (pollution prevention and abatement) and different parameters in the field of Environmental Biotechnology. Learn about different modes of microbial interaction with inorganic and organic pollutants. Learn about aerobic and anaerobic biotransformation mechanisms and about the scope of genetically engineered organisms in bioremediation. Learn about role and requirements of microorganisms, Microbial community composition and the interactions between community members for enhanced bioremediation. Learn about different strategies of bioremediation – in-situ bioremediation approaches, ex-situ bioremediation approaches, biostimulation, bioaugmentation, monitored natural attenuation, phytoremediation. Learn about different factors regulating bioremediation. Learn about waste water characteristics. Learn about effluent treatment processes. Learn about various suspended growth Aerobic effluent treatment processes. Learn about various attached growth Aerobic effluent treatment processes. Learn about Anaerobic digestion process. Learn about design of reactors for effluent treatment processes.						
Topics Covered	Unit 1-Introduction to Environmental Biotechnology: definition, scope of applications; Biotechnology for pollution prevention and pollution abatement (green technologies – bioleaching of metals, microbially enhanced oil recovery, biodegradable polymers, biobleaching, biodesulphurization, biofuel production, biogas, bioremediation, etc.) (3) Unit 2 -Types of pollutants, sources of pollutants, magnitude of contamination problem, merits and limitations of bioremediation, bioremediation of organic and inorganic pollutants. Microbial interactions with heavy metals/radionuclides – bioaccumulation, biosorption,						

	biotransformation, bioprecipitation, applications of metal-microbe interactions, biomining, engineering microorganisms for metal bioremediation (3) Unit 3 - Biodegradation principles – microbial processes, biotransformation, mineralization, detoxification, activation, cometabolism and growth associated degradation. Requirements for biodegradation, cooperation between different microbial species for enhanced biodegradation, Implications of recalcitrance, acclimation, biotransformation mechanisms – genes, enzymes, reactions, Biodegradation pathways and metabolites, effect of contaminant structure on biodegradability. (8) Unit 4 -Bioremediation strategies – microbial community composition and interactions between community members for enhanced bioremediation, natural attenuation and accelerated bioremediation, aerobic, anaerobic, ex-situ bioremediation approaches, in-situ bioremediation approaches, biostimulation, bioaugmentation, Phytoremediation - phytoextraction, rhizofiltration, phytodegradation, phytovolatilization, rhizoremediation, phytostabilization. (8) Unit 5 -Waste Water & Sludge treatment:Characteristics and analysis of waste water, Treatment of waste water of sewage & Industry. Bio-kinetics coefficient and its application in waste water treatment. Basic design concepts and calculations for waste water treatment of:Preliminary treatment units – screening,grit removal , removal of oil and grease; Primary treatment units- settling tank, flotation.Biological treatment:Aerobic: Activated sludge process, secondary settling tank, trickling filter, waste stabilization pond.Anaerobic : Anaerobic reactors for treatment of waste water- Anaerobic Digesters, Upflow Anaerobic Sludge Blanket Reactor(UASB), Fluidized Bed Biofilm Reactor(FBBR), Treatment and disposal of sludge, Solid waste management , Advanced Waste Water Treatment-Limitations of conventional treatment, pathogen removal, toxic substances removal, phosphorous and nitrogen removal (12) Unit 6 -Industrial Waste:Approach to design, process design parameters - Characteristics, analysis and treatment of wastes from different Industry like: dairy industry, fermentation, slaughter house, tanning, dye, pulp and paper, distillery, petroleum, heavy metal pesticides, food and beverage, antibiotics etc. Treatment of biological industry wastes, Treatment & disposal of radioactive waste.(8)
Text/ References	i) ediation and Natural Attenuation: Process fundamentals and mathematical models by P J J Alvarez and W A Illman, Wiley-Interscience vater treatement: Concepts & design approach, G L Karia, R A Christian, PHI supply & waste water engineering, B S N Raju, Tata Mc Graw Hill Publications ial wastes, Their disposal & Treatment; Willem Rudolfs, Reinhold Publishing Corporation, American series icrobiology; N S Subba Rao; Oxford & IBH Publishing Co. Pvt Ltd. water Engineering: Treatment, disposal, reuse, by Metcalf & Eddy, Tata Mc Graw Hill nmental Engineering: A design Approach, Sincero, Arcadio. P, Sr. & Greogia; PHI & wastewater Technology; Hammer, Mark J, Mark J Hammer; PHI radation & Bioremediation (1999), Martin Alexander, Academic press. Bioremediation engineering; design and application 1995 John. T. cookson, Jr. Mc Graw Hill, Inc. Foster C.F., John Ware D.A., Environmental Biotechnology, Ellis Horwood Ltd., Environmental Pollution Control Microbiology by Ross E Mc Kinney, Dekker publisher Environmental Engineer's Mathematics Handbook by Frank R Spellman & Nancy E Whiting. CRC Publication Biology of wastewater treatment by N F Gray; Imperial College Press.

CO-PO mapping

Course Code	Title of the course	*CO*	*PO1*	*PO2*	*PO3*	*PO4*	*PO5*	*PO6*
BT9047	**Environmental Biotechnology**	*CO1*	*1*	*2*	*2*	*1*	*3*	*1*
		CO2	*2*	*3*	*3*	*2*	*3*	-
		CO3	*2*	*3*	*3*	*3*	*3*	*3*
		CO4	-	*3*	*3*	*3*	*3*	*3*
		CO5	*3*	*3*	*3*	*3*	*3*	-
		CO6	*3*	*3*	*3*	*3*	*3*	-

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9048	**Protein structure, folding & misfolding**	PEL	3	0	0	3	3
Biochemistry, Cell Biology, Molecular Biology		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes	CO1: To learn about protein structures and its classification into structural groups. CO2: To understand protein-DNA interactions and the origin of selectivity and specificity in this process CO3: To learn how to determine protein structure CO4: Understanding of protein folding mechanism and how protein misfolding is related to several human diseases.						
Topics Covered	Basic structural principles - The building blocks, motifs of protein structure, alpha-domain structures, alpha/beta structures, beta structures, fibrous proteins. (10) DNA structures. DNA recognition in prokaryotes by helix-turn-helix motifs. (6) DNA recognition by eukaryotic transcription factors, specific transcription factors. (6) Structural feature of common proteins involved in enzyme catalysis, signal transduction and immunity. (8) Protein Structure determination (4) Protein folding: thermodynamics, kinetics and chaperones. (4) Protein misfolding and Disease. (4)						
Text Books, and/or reference material	Text Book: 1. Introduction to Protein Structure: Second Edition by Carl IV Branden, Routledge Reference book: 1. Structure and Mechanism in Protein Science A Guide to Enzyme Catalysis and Protein Folding: Alan Fersht						

CO-PO mapping

Course	Title of the course		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9048	**Protein structure, folding & misfolding**	CO 1	3	3	3	-	-	-
		CO 2	3	2	3	-	-	-
		CO 3	3	3	3	3	-	-
		CO 4	3	2	3	2	1	1

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9049	**Methods in Computational Biology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Biochemistry, Bioinformatics, C programming		CT+EA					
Course Outcomes	CO1: Learning computational skills to examine biological information CO2: Learning and developing computational tools for analysis of large biological data CO3: To understand the models of biological systems constructed from experimental measurements CO4: Learn about machine learning and statistical tools to construct models from large existing datasets						
Topics Covered	Algorithms in Computing: Biological and Computer algorithm, Fibonacci problem, Dynamic Programming, Time and space complexity of algorithms (7) Programming languages- Algorithm, Flowchart, Compiling, Testing and Debugging (7) C programming – C language Introduction, Identifier , Variables, Constants, Operators, Input statement, Output statement, Conditional and Unconditional Control Statement, Looping Statement: while, do-while, for loop, Arrays. Read, write files (biological data) (10) Clustering and Trees: Hierarchical Clustering, k-Means Clustering, Evolutionary Trees, Distance-Based Tree Reconstruction, Reconstructing Trees from Additive Matrices, Character-Based Tree Reconstruction, Small and large Parsimony Problem. (10) Hidden Markov Models: Markov processes and Markov Models, Hidden Markov Models (8)						
Text Books, and/or reference material	Text Books: Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins" by A D Baxevanis and B F F Ouellette Protein Bioinformatics: An Algorithmic Approach to Sequence and Structure Analysis by Ingvar Eidhammer, Inge Jonassen, William R. Taylor Reference Books: Introduction to Computational Biology by Bernhard Haubold Bioinformatics: Genes, Proteins and Computers by Christine Orengo, David Jones, Janet Thornto						

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9049	**Methods in Computational Biology**	CO 1	3	2	3	3	3	2
		CO 2	3	2	3	3	2	2
		CO 3	3	-	3	3	3	1
		CO 4	3	-	3	3	3	1

Department of Biotechnology				
Course	Title of the course	Program	Total Number of contact hours	Credit

Code		Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9050	**Nanobiotechnology & Nanomaterials**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basic understanding of biology, Chemistry and Physics	CT+EA
Course Outcomes	CO1: Acquire advanced idea about nanoscale phenomenon CO2: To learn about the different investigation tools for the nanobiotechnology CO3: To learn about synthesis of diverse classes of nanomaterials CO4: To get comprehensive understanding of applications of nanotechnology in biology
Topics Covered	Nanotechnology; introduction to miniaturization. (4) Investigation tools: experimental methods and probes; basic principles of scanning force microscopy; scanning electron microscopy; transmission electron microscopy. investigation tools: nanoimprint lithography (8) Nanomaterials: organic and inorganic nanoparticles. (6) Molecular self-assembly and bottom up synthesis of nanomaterials. (6) Nanoparticles and cancer therapeutics; nanoparticle-based drug delivery. (6) Nanofiber-based scaffolds and tissue engineering; nanodiagnostics and biosensing. (6) Nanotoxicology. (4) Future Concepts in Nanobiotechnology. (2)
Text Books, and/or reference material	Text Book: 1. Understanding Nanomedicine - An Introductory Textbook by Rob Burgess. References Books 1. Springer Handbook of Nanotechnology, by Bharat Bhushan Springer 2. Nanobiotechnology: Concepts, Applications and Perspectives, by Christof M. Niemeyer, Chad A. Mirkin, John wiley 3. Introduction to Nanotechnology, by Charles P. Poole, Frank J. Owens, Wiley-Interscience 4. Nanofabrication and Biosystems : Integrating Materials Science, Engineering, and Biology, by Harvey C. Hoch, Lynn W. Jelinski, Harold G. Craighead, Cambridge University Press

CO-PO mapping

Course Code	Title of the course		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9050	**Nanobiotechnology & Nanomaterials**	CO 1	3	3	2	3	2	-
		CO 2	3	1	1	3	-	-
		CO 3	3	2	1	3	-	-
		CO 4	3	3	2	3	3	1

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

BT9051	**Plant Biotechnology**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Biochemistry, Cell Biology, Genetics, Molecular Biology & rDNA Technology	CT+EA
Course Outcomes	CO1: To understand the concepts and techniques of plant tissue culture. CO2: To understand the basic methods of mapping and cloning plant genes. CO3: To learn the methodologies of genetic transformation of plants. CO4: To generate the ability to create genetically modified plants by means of plant breeding and genetic engineering with improved quality traits.
Topics Covered	History of Plant Tissue Culture (1) Lab requirements and general techniques (1) Tissue Culture Media (1) Hormones in plant tissue culture (4) Cellular Totipotency (1) Somatic embryogenesis (1) Cell Suspension Culture (1) Haploid Production, (1) Somaclonal variation (1) Protoplast Isolation and Culture (1) Micropropagation in plants(1) Morphological Markers, Biochemical Markers, (1) molecular markers (DNA / protein) – RFLP, RAPD,AFLP, SSLPs, ESTs, SNPs etc., (6) Molecular mapping, Map-based cloning, (2) marker-assisted selection, marker-aided breeding, (1) Cloning of plant genes using activation tagging, transposon tagging etc. (2) Direct and indirect methods of genetic transformation of plants, (2) *Agrobacterium* mediated gene transfer, Ti Plasmid, (3) vectors for plant transformation, selectable and screenable markers, (1) gene constructs, strategies for genetic transformation of plants,(2) gene silencing, RNA interference, (1) genome editing in plants, (1) resistance to biotic stresses, tolerance to abiotic stresses, genetically modified crops (5)
Text Books, and/or reference material	**Text Books:** H.S.Chawla, Introduction to Plant Biotechnology, Oxford &IBH Publishing co.Pvt..Ltd Slater.A.,NigelW.S,Flower.R.Mark , Plant Biotechnology: The Genetic Manipulation of Plants, 2003, Oxford Univesity Press. Buchaman, Gursam, Jones, Biochemistry and Molecular Biology of Plants, 1ed, 2000, L.K.International. Bhojwani and Razdan –PlantTissue Culture: Theory and Practice 1996 Elsevier **Reference Books:** Butterworth & Heineman, Invitro Cultivation of Plant Cells, Biotol Series. H.E Street(ed): Tissue culture and Plant science, Academic press, London, 1974 GamborgO.L.,.Phillips G.C, Plant Cell, Tissue and Organ Culture, Narosa Publishing House

CO-PO mapping:

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9051	**Plant Biotechnology**	CO 1	3	2	3	3	3	2
		CO 2	3	2	3	3	3	2
		CO 3	3	2	3	3	3	2
		CO 4	3	2	3	3	3	2

<table>
<tr><td colspan="8">Department of Biotechnology</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT9052</td><td>Metabolic Engineering</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Basic concepts of chemical reaction kinetics & stoichiometry; matrices, Biochemistry, recombinant DNA Technology</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To learn about the basic concepts of Metabolic Engineering
2:To learn about the models of cellular reactions and to understand the regulation of metabolic pathways
3: To understand the manipulation of metabolic pathways to enhance the yield and quality of the products
4: To learn and understand the models and the concepts required for the purpose of metabolic flux analysis
CO 5: To study the methods and application of metabolic flux analysis
CO 6: To analyze metabolic networks</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Importance of metabolic engineering [1]

Review of cellular metabolism, Regulation of metabolic pathways, Examples of pathway manipulations: metabolic engineering in practice – enhancement of product yield and productivity [10]
Extension of product spectrum and novel products (antibiotics, biopolymers, polyketides, vitamins etc), Improvement of cellular properties [7]

Metabolic modeling: Introduction to models for cellular reactions- stoichiometry, rates, and yield coefficients of cellular reactions, black box stoichiometries [7]

Material balance & data consistency: Black box model; elemental balances, degree of reduction balances, Heat balance [7]

Biochemical reaction networks: simple metabolic networks, flux analysis in metabolic networks; Metabolic control analysis [7]

Xenobiotic degradation [3].</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
Metabolic Engineering: Principles and Methodologies, Gregory N. Stephanopoulos, Aristos A. Aristidou, Jens Nielsen, Academic Press
Bioreaction Engineering Principles, Jens Nielsen, John Villadsen, Gunnar Liden, Springer
Reference Books:
Pathway Analysis and Optimization in Metabolic Engineering, Néstor V. Torres, Eberhard O. Voit, Cambridge University Press
An Introduction to Metabolic and Cellular Engineering, S. Cortassa, M. A. Aon , A. A. Iglesias, D. Lloyd, World Scientific Publishing Company</td></tr>
</table>

CO-PO mapping:

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9052	**Metabolic Engineering**	CO 1	-	-	1	2	1	-
		CO 2	-	-	2	2	-	-
		CO 3	2	2	3	2	3	2
		CO 4	3	-	3	2	-	-
		CO 5	3	-	3	2	-	-
		CO 6	3	-	3	2	-	-

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9053	**Nutraceuticals & Nutrigenomics**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes	CO1: To establish the correlation between nutraceuticals with cell signaling pathway. CO2: To target nutraceuticals from different sources. CO3: To understand the interaction between gut microbiota with functional food components and nutraceuticals. CO4: To formulate the concept of nutrient gene interaction.						
Topics Covered	Nutraceuticals : General concepts of cell apoptosis/proliferation and molecular targets of nutraceuticals. Nutraceutical role in host immune response, in cancer, infection and chronic/acute inflammations. Mechanism of action of Nutraceutical-signaling events, proteomics and transcription factors. Nutraceuticals from food and herbs I: Polyphenols, flavonoids and other phenolic compounds. Nutraceuticals from food and herb -II: Saponins, terpenoids and sulphur compounds, Probiotic food with therapeutic applications, Prebiotics, Genomics of Lactic Acid Bacteria Nutragenomics: An introduction, Nutrient gene interaction- Structure of nuclear receptors with reference to carbohydrate, fat and vitamin A, Type 2 Diabetes Mellitus and nutrigenomics, PPAR-γ and Diabetes Mellitus, Bioactive Peptides and its role in Nutrigenomics						
Text Books, and/or reference material	**Books** Nutritional Genomics: Discovering the Path to Personalized Nutrition by James Kaput, Raymond L. Rodriguez, Wiley Functional Food Ingredients and Nutraceuticals by John Shi , CRC Press Nutraceuticals by Lisa Rapport, Brian Lockwood , Pharmaceutical press **References:** Nutragenomics and Proteomics In Health Promotion and Disease Prevention by Mohamed M. Rafi, FereidoonShahidi, CRC Press Nutraceuticals: The Complete Encyclopedia of Supplements, Herbs, Vitamins, and Healing Foods by Arthur J. Roberts, GenelleSubak-Sharpe, Mary E. O'Brien (Designer) , Perigee Trade Regulation of Functional Foods and Nutraceuticals: A Global Perspective by Clare Hasler, Blackwell Publishing Professional						

CO-PO Mapping

Course Code	Title of the course		PO1	PO2	PO3	PO4	PO5	PO6
BT9053	**Nutraceuticals & Nutrigenomics**	CO1	3	1	3	3	3	3
		CO2	3	1	3	3	3	3

		CO3	3	1	3	3	3	3
		CO4	3	1	3	3	3	3

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9054	**Molecular Plant Pathogen Interactions**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Molecular Biology & rDNA Technology		CT+EA					
Course Outcomes	CO1: Development of basic concept of plant diseases and contribution of environment toward plant disease development. CO2: Understanding the genetics of plant pathogen interactions. CO3: Learning about mechanisms of host defense & pathogenesis. CO4: Development of knowledge toward developing control measures against phytopathogens.						
Topics Covered	Introduction to molecular plant pathology, Plant diseases, (4) Plant disease development and environment, (3) Effects of pathogen on plant physiology, (2) Biochemistry of plant defense reactions, (3) Plant-pathogen interactions, (3) Genetic regulation of resistance in host plants, (4) Genetic regulation of virulence in pathogen, (4) Mechanisms of host defense, (3) Mechanisms of pathogenesis, (3) Hormone signaling pathways, (7) Biotechnological approach for plant protection; (3) Genetically modified plants to protect against pathogens. (3)						
Text Books, and/or reference material	**Text Books:** Plant Pathology; Fifth Edition, Elsevier; By Geroge N. Agrios. Biochemistry and Molecular Biology of Plants; American Society of Plant Biologists; By Bob Buchanon, Wilhelm Gruissem and Russel Jones. **Reference Books:** Plant Immunity; Methods in Molecular Biology, 2011, 712, Springer. Plant-Pathogen Interactions; Methods in Molecular Biology; By Pamela Ronald, 2007, 354, Springer. Plant-Pathogen Interactions; Annual Plant Reviews; By Nick Talbot, 2004, 11, Blackwell Publishing.						

CO-PO mapping:

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9054	**Molecular Plant Pathogen Interactions**	CO 1	3	2	3	3	3	2
		CO 2	3	2	3	3	3	2
		CO 3	3	2	3	3	3	2
		CO 4	3	2	3	3	3	2

<table>
<tr><td colspan="8">Department of Biotechnology</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT9055</td><td>Cell Biology of Human Diseases</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Cell Biology, Molecular Biology and Biochemistry</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the concepts of structure, organization and molecular signaling of cells which govern its function.
CO2: To understand cellular defects leading to human diseases and apply such understanding to explain any given phenotype at the cellular or organism level.
CO3: To learn the application of experimental methods and designs to solve cell biology questions in human diseases.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Overview of cell organizations and functions. (3)
Experimentations in cell biology: Microscopy, genetic screens, cell fractionations and biochemical assays. (6)
Cytoskeleton and extracellular matrix. Hypertrophic and dilated cardiomyopathies,epidermolysis bullosa simplex (EBS), muscular dystrophy, neurodegeneration, progeria, hearing defects. (4)
Cell polarity, cell junctions and changes in cell shape. Neural Tube Defects.(2)
Cell transport, endocytosis, exocytosis, membrane channels. Cholera and cystic fibrosis. (3)
Cell migration during development and chemotaxis. Developmental defects and cancer.(1)
Cilia structure and function and specialized sensory cells. Ciliopathies.(1)
Protein processing, trafficking and transport. Microbial immune evasion,lysosomal storage disease, and diabetes.(4)
Neurons, astrocytes and oligodendrocytes. Demyelinating diseases.(1)
Mitochondrial function andmitochondrial genome. Mitochondrial diseases.(2)
Cell cycle, cell proliferation, apoptosis.Cancer.(4)
Stem cells and cell differentiation. Cancer.Regenerative medicine. (3)
Nuclear organization and gene expression.Cancer.(2)
Paper presentations (in group).(4)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
Molecular Biology of the Cellby Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts, Peter Walter.6th Edition, 2014.Garland Science.
Reference Books:
. Molecular Cell Biologyby Harvey Lodish, Arnold Berk, Chris A. Kaiser, Monty Krieger, Matthew P. Scott, Anthony Bretscher, HiddePloegh, Paul Matsudaira. 8th edition, 2016. Publisher: WH Freeman.
. Cell and Molecular Biology: Concepts and Experiments by Gerald Karp. 6th Edition, 2010. Wiley.</td></tr>
</table>

CO-PO mapping:

Course	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9055	**Cell Biology of Human Diseases**	CO 1	1	1	3	1	1	0
		CO 2	2	1	3	2	2	0
		CO 3	3	1	3	3	2	1

<table>
<tr><td colspan="8">Department of Biotechnology</td></tr>
<tr><td>Course Code</td><td colspan="2">Title of the course</td><td>Program Core (PCR) / Electives (PEL)</td><td>Total Number of contact hours
Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td><td>Credit</td></tr>
<tr><td>BT9056</td><td colspan="2">Infectious Diseases & Infection Control</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Cell Biology, Immunology</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">CO1: To understand about the spread of infectious diseases, the social impact and means of infection control
CO2: To learn about bacterial infections and ways to tackle different bacterial diseases
CO3: To learn the viral infections, vaccine development and challenges
CO4: To learn about the protozoan and fungal infections and methods to combat them</td></tr>
<tr><td>Topics Covered</td><td colspan="8">Origin of Infection; Evolution of infectious diseases; Concept of Infection: Immunity, Immune surveillance, Virulence, Pathogenesis (4)
Introduction to pathogenic and non-pathogenic bacteria; Common bacterial diseases in humans; Basic mechanism of Bacterial pathogenesis; Bacterial survival in host cells- Quorum sensing; Bacterial virulence factors: Microbial structures and Toxins; infection; Bacterial immune evasion: Molecular Mimicry; Strategies for antibacterial therapy: Antibiotics, Other antibacterial compounds, and Antibiotic resistance- MDR and XDR strains. Bacterial vaccines. Case study: E. coli infection and diarrhoea (9)
History of viral infections; Different viral diseases; Viral pathogenesis; Viral life cycle; Virus genomes and structure; Host –virus interactions; Host Immune reaction against viruses; Viral evasion of host immune surveillance; Antiviral pathways; Mutations in viral genome; Viral diseases and antibody response; Vaccine against viral diseases; Antivirals compounds for viral infections; Challenges in vaccine production against certain virtues; Case study: Influenza (9)
Introduction to Protozoan Diseases; Different protozoan diseases, General mode of action of protozoa; Pathogenesis of protozoan diseases; Host response to Protozoans; Molecular signalling against Protozoa; Hypersensitivity and autoimmunity associated with Protozoan infections; Antimalarial drug development ; Case study: Plasmodium (7)
General fungal diseases; Mode of action of fungal diseases; Immune response against fungal infection; Case study: Candidiasis; Infection caused by Yeast; Mode of action of Yeast infection; Case study: Ring worm (4) ; Infection and life style- Concepts of Microbiome; Neglected diseases (2)
Spread of Infectious diseases; Disease epidemiology, Steps involved in epidemiology and epidemiological case studies; (3) Purpose of infection control, Regulations, policy and practice; Roles and responsibilities in infection control; Risk assessments; Principles of infection control procedures (4).</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="8">Text Books:
1. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases- 8th Edition; Volume I and II. By John E. Bennett , Raphael Dolin, Martin J. Blaser. SaudersPublication.
2. Immunology of Infectious Diseases. Edited By Stephan Kaufmann, Alan Sher, and Rafi Ahmed. American Society for Microbiology.</td></tr>
</table>

	Reference Books: 1. Principles of Virology: 4th Edition. By S. Jane Flint, Vincent R. Racaniello, Glenn F. Rall, Anna Marie Skalka, and Lynn W. Enquist. American Society for Microbiology 2. Practical Healthcare Epidemiology, 4th Edition. By Ebbing Lautenbach. Cambridge University press. 3. Principles and practice of clinical bacteriology-2nd Edition. By Stephen Gillespie, Peter

	M. Hawkey. John Wiley &Sons.

CO-PO mapping:

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9056	**Infectious Diseases & Infection Control**	CO 1	1	2	2	3	3	3
		CO 2	3	2	3	2	2	1
		CO 3	3	2	3	2	2	1
		CO 4	3	2	3	2	2	1

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9057	**Project Engineering in Biotechnology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Bioprocess Engineering, Bioseparation Technology		CT+EA					
Course Outcomes	CO1: Learning about process flow diagram and basic concepts of plant design CO2: Learning about cleaning of process equipment and design of pipes and valves CO3: Learning about facility design and project planning CO4Learning about Planning, construction and commissioning of a biopharmaceutical manufacturing plant CO5: Learning about process economics CO6: Learning about production concepts						

Topics Covered	Introduction Basic considerations in plant design, project identification, preliminary techno-economic feasibility. Process flow Diagrams and symbols: Symbols of Process Equipments& their concepts, types of flow diagrams, Importance of Laboratory development, pilot plant, scale up methods (6) Piping and valves for biotechnology: design, piping materials, polishing, passivation, sizing of pipes and tubes, connections and cleanability, piping applications, supporting and insulating sanitary tubing, in-line instruments, hoses, valves. (5) Cleaning of process equipment: design and practice, sterilization of process equipment, pharmaceutical water systems: design and validation, utilities for biotechnology production plant, biowaste decontamination systems, Heating, ventilating & air conditioning (HVAC) (4) Programming & facility design, project planning, containment regulations affecting the design and operation of biopharmaceutical facilities. (4) Planning, construction and commissioning of a biopharmaceutical manufacturing plant: planning, construction, commissioning, qualification, validation, project schedules, cost estimates, organization of an engineering project, role & selection of contractors, legal aspects of facility engineering, health, safety and environmental law, building law. (6) Product sales and manufacturing costs: basic principles of cost calculation, fixed cost, variable cost, depreciation, interest, typical costs of biotechnological manufacturing processes, profit and loss calculation. (6) Investments: investment targets, types of investments, investment appraisal, cost comparison, profit comparison, internal rate of return, dynamic payback time. (5) Production concepts: capacity planning, dilemma of in-house manufacturing, aspects of
	manufacturing out-sourcing, contractual agreements, technology transfer, process optimization after market launch, supply chain management. (6)
Text Books, and/or reference material	Text Books: Bioprocess engineering: system, equipment and facilities, B K Lydersen, N AD'Elia, K M Nelson. Wiley Manufacturing of pharmaceutical proteins, Stefan Behme, Wiley Reference Books: 1. Plant design and Economics for chemical engineers, peter M. S. Timmerhaus, K. D. McGraw Hill. 2. Project Engineering with CPM and PERT, Modes J. Philips, Rheinhold publishers.

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9057	**Project Engineering in Biotechnology**	CO 1	2	2	2	2	2	1
		CO 2	2	2	2	2	2	1
		CO 3	2	2	2	2	2	2
		CO 4	3	3	3	3	3	3
		CO 5	3	3	3	3	3	3
		CO 6	3	3	3	3	3	3

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9058	**Biological Computation**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					

Cell Biology, Biochemistry, Programming and Data Structure	CT+EA
Course Outcomes	CO1: Learning about different biological databases and the biological data stored in them CO2: To learn UNIX operating system to run bioinformatics resources CO3: To acquire knowledge of Bash scripting and programming skills for analyzing biological data CO4: To learn how to store and visualize biological data using computational methods
Topics Covered	**Biological data and different file formats:** Introduction to biological databases, sources of biological data, genbank, fasta file formats, interchanging of file formats (3) **Introduction to Linux operating system:** What is Linux OS, Kernel system, benefits of Linux for computational biology (3) **Bash programming for bioinformatics:** Shell scripting, working in terminal with different commands, use of important commands such as sed, grep, awk (8) **C programming for bioinformatics:** introduction to C, Identifier , Variables, Constants, Operators, Input statement, Output statement, Conditional and Unconditional Control Statement, Looping Statement: while, do-while, for loop, Arrays. Read, write files (biological data) (10) **Python scripting for bioinformatics:** File handling in python, numpy, pandas etc (8) **Database management:** Designing databases using SQL (5) **HTML and web-designing:** Designing web-pages using HTML and java scripts (5)
Text Books, and/or reference material	Text Books: Computational Biology —Unix/Linux, Data Processing and Programming by Röbbe Wünschiers Learning Python, 5th Edition by Mark Lu
	Reference Books: Introduction to Bioinformatics by Arthur M Lesk Introduction to Bioinformatics computer Skills by Cynthia Gibas and Per Jambeck

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9058	**Biological Computation**	CO 1	3	1	3	3	2	1
		CO 2	3	1	3	3	2	1
		CO 3	3	-	3	3	2	1
		CO 4	3	-	3	3	2	1

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9059	**Quality by Design for Biopharmaceuticals**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Bioprocess Engineering, Bioseparation Technology	CT+EA
Course Outcomes	CO1: Learning about the concept of QbD and importance in Biotechnology CO2: Learning about QbD for Biopharma production process CO3: Learning about QbD for Biopharma purification process CO4: Learning about QbD in biologics formulation and product development CO5: Learning about PAT tools CO6: Learning about integration of PAT with QbD
Topics Covered	1. QbD: Basic Concepts (2) 2. Considerations for Biotech Product QbD (3) 3. Risk Assessment to determine criticality of product quality attributes (3) 4. Case study on definition of process design space for a microbial fermentation step (4) 5. Application of QbD for Tangential Flow Filtrationprocess (4) 6. Applications of design space for biopharmaceutical purification processes (4) 7. Viral Clearance: A Strategy for QbD and the design Space (4) 8. Application of Quality by Design and risk assessment principles for the development of formulation design space (4) 9. Application of QbD principles to biologics product: formulation and process development (4) 10. QbD for Raw Materials (2) 11. PAT Tools for Biologics (4) 12. Evolution and Integration of QbD and PAT (4)
Text Books, and/or reference material	Text Books: Anurag S Rathore, 2009, Quality by Design for Biopharmaceuticals: Principles and Case Studies, Wiley.

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9059	**Quality by Design for Biopharmaceuticals**	CO 1	1	1	2	2	3	2
		CO 2	2	2	2	3	3	2
		CO 3	2	2	2	3	3	2
		CO 4	3	2	3	3	3	3
		CO 5	3	3	3	3	3	3
		CO 6	3	3	3	3	3	3

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9060	**Medical Biotechnology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Immunology, Molecular Biology, rDNA technology		CT+EA					

Course Outcomes	CO1: To provide an understanding about Inborn errors of metabolism and genetic disorders and their consequence. CO2: Able to analyze the key features therapeutics and drugs in current scenario. CO3: Able to apply the knowledge for commercial production of pharmaceuticals and place it in market for marketing approvals. CO4: Able to understand the ethical issues and the different competent regulatory authorities globally associated with clinical Biotechnology.
Topics Covered	Module 1: Biochemical diagnostics in Medical Biotechnology 10 Clinical diagnosis of diseases: Inborn errors of metabolism and genetic disorders. Preimplantation diagnosis, pre-natal diagnosis-chorionic villus sampling, Amniocentesis. Molecular techniques for analysis of diseases: DNA polymorphism; 'disease' gene vs. 'susceptibility' gene; SNP detection: hybridization based assays; Polymerization based assays; Ligation based assays; Polymorphism detection without sequence information: Single nucleotide polymorphism and disease association; High throughput DNA sequencing and diagnosis; and Array based techniques in diagnosis. Module 2: Drug Discovery and targeting: 10 Overview of inherited and acquired diseases for gene therapy; Identification of disease biomarkers and selection of drug targets; Proteomics and High throughput DNA screening for drug discovery; Gene silencing technology: therapeutic applications in treatment of influenza and HIV/AIDS; Tissue and organ transplantation; Transgenics and their uses. Delivery system development: Intracellular barriers to gene delivery; virus, Liposome and nanoparticles mediated gene delivery. Module 3: Production of pharmaceuticals: 12 Production of pharmaceuticals by genetically engineered cells. Microbial transformation for production of important pharmaceuticals. Techniques for development of new generation antibiotics; Pharmacogenomics and pharmacogenetics of pharmaceuticals; Cellular and genotoxicity of pharmaceuticals.
	Module 4:Clinical research: 10 Introduction and importance of clinical research, Drug development and phases of clinical trials: Designing clinical trials, Protocol designing, Ethical, safety and regulatory issues in clinical research, Drug regulatory concepts and accrediting agencies of the world (USFDA, TGA, ICH, WHO, ISO etc.), ICH-GCP Guidelines, Informed consent process, Role of CRC and CRA in clinical trials, Standard operating procedures, Guidelines to undertake clinical trials in India.
Text Books, and/or reference material	**Books** Lewis, Human Genetics, 7th Edition, WCB & McGraw, 2007. Maroni, Molecular and Genetic Analysis of Human Traits, 1st Edition, Wiley-Blackwell, 2001. Alberts et al, Molecular Biology of The Cell, 2nd Edition , Garland 2007 Biopharmaceuticals- Biochemistry and Biotechnology: Gary Walsh; John Wiley & Sons S. P. Vyas, V. Dixit, Pharmaceutical Biotechnology, CBS Publishers Cedric A and Mim S. et al.: Medical Microbiology, Mosby USA An Introduction to Medicinal Chemistry; Graham L.Patrick, Oxford Reference: Pharmaceutical Biotechnology ; Sambhamurthy & Kar , New Age Publishers Epenetos A.A.(ed), Monoclonal antibodies: applications in clinical oncology, Chapman and Hall Medical, London V.Venkatesharalu -Biopharmaceutics and Pharmacokinetics-Pharma Books Syndicate Diagnosis: A Symptom-Based Approach in Internal Medicine; C.S.Madgaonkar, Publisher: JPB

CO-PO mapping

Course Code	Title of the course		PO1	PO 2	PO 3	PO 4	PO 5	PO 6

BT9060	**Medical Biotechnology**	CO 1	3	1	3	3	2	1
		CO 2	3	1	3	2	2	1
		CO 3	2	2	3	2	1	2
		CO 4	3	3	3	3	3	3

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9061	**Biological Chemistry**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic understanding of biology, chemistry and physics		CT+EA					
Course Outcomes	CO1: Understanding of the basic thermodynamic and kinetic aspect of biology. CO2: Getting familiarity with common principle of chemistry and chemical bonds CO3: To have a deeper understanding of energy flow in biology. CO4:To learn about the chemical reactions relevant to biological processes.						
Topics Covered	Chemical reactions, reaction stoichiometry, rates of reaction, rate constants, order of reactions, Arrhenious equation, Maxwell Boltzmann distributions, rate determining steps, catalysis, free-energy, entropy and enthalpy changes during reactions; kinetic versus thermodynamic controls of a reaction, reaction equilibrium (equilibrium constant). (8) Chemical and Biological Synthesis-Introduction to synthesis in biology. Chemical synthesis of peptides and proteins. Chemical synthesis of nucleic acids. Chemical synthesis of oligosaccharides. Chemical synthesis of lipids. Biological synthesis of biological macromolecules. Directed biological synthesis of proteins. Biological synthesis of nucleic acids, oligosaccharides and lipids. (6)						
	Advance chemical and physical tools for Biology-Electronic and vibrational spectroscopy in biology, Circular dichroism spectroscopy, Vibrational spectroscopy, Fluorescence spectroscopy, X-ray crystallography, Mass spectrometry for proteomics. (8) Chemical thermodynamics - internal energy, heat and temperature, enthalpy (bond enthalpy and reaction enthalpy), entropy, Gibbs free energy of ATP driven reactions, spontaneity versus driven reactions in biology; redox reactions and electrochemistry - oxidation-reduction reactions, standard cell potentials, Nernst equation, resting membrane potentials, electron transport chains (ETC) in biology, coupling of oxidative phosphorylations to ETC; theories of ATP production and dissipation across biological membranes. (8) Bond rotations and molecular conformations - Newman projections, conformational analysis of alkanes, alkenes and alkynes; functional groups, optically asymmetric carbon centers, amino acids, proteins, rotational freedoms in polypeptide backbone (Ramachandran plot). Types of organic reactions in biology; addition reactions-electrophilic, nucleophilic and free radical. Substitution reactions – electrophilic, nucleophilic and free radical. Elimination and Rearrangement reactions; Chemical insight of enzyme catalyzed reactions – proteases, polymerases, ribosomes. (12)						
Text Books, and/or reference material	Text Book: 1. Ebbing, D. D., &Wrighton, M. S. (1990). General Chemistry. Boston: Houghton Mifflin. 2. Averill, B., &Eldredge, P. (2007). Chemistry: Principles, Patterns, and Applications. San Francisco: Benjamin Cummings. 3. Cantor, C. R., &Schimmel, P. R. (2004). Biophysical Chemistry. San Francisco: W.H. Freeman.						

CO-PO mapping

Course	Title of the		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6

Code	course							
BT9061	**Biological Chemistry**	CO 1	3	3	1	2		
		CO 2	3	2	1	2		
		CO 3	3	3	1	2		
		CO 4	3	2	1	2		

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT9062	**Bioentrepreneurship**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic understanding of Biosafety guidelines		CT+EA					
Course Outcomes	**CO1.** To educate about various societal, governance and regulatory issues in biotechnology. **CO 2**. To educate about entrepreneurial skill attainment in customer development, customer validation, competitive analysis of the real-world problems and projects and market survey. **CO 3**. To build managerial capacity in value creation through company formation, intellectual property licensing of biopharmaceutical products. **CO 4.** To raise awareness about the ethical implications and safety rules in biopharma and GMO production management.						
Topics Covered	**Introduction to Bioentrepreneurship**: Fundamentals of Marketing of biotechnological products, patent rules regarding product licensing. (4)						

	Entrepreneurship traits & motivation: Growth of entrepreneurship, The marketing and selling of Biotechnology, Creating and marketing the image of the biotechnology company, Effective advertising and marketing.(8) **Entrepreneurial development:** Training, institution in aid of entrepreneur, Power and importance of Positioning of a company name and product. (6) **Capacity building**: **Regulatory systems for health products in India**: Regulatory authority India central (federal) and state (provincial) authorities. Central Licensing Authority. International collaboration of India with South East Asia Regulatory Network (SEARN). Quality management system (QMS). Regulatory functions : Control of clinical trials. Marketing Authorization, Registration Certificate for Import, Manufacturing Licence, Non-Objection Certification (NOC). Licence to manufacture Pre-approval batches, Import Licence, Export NOC for Biological Samples Pharmacovigilance for medicines, vaccines and blood products. (3) Setting of a small industry, location of an enterprise, steps of starting small industry, Incentive & subsidies for industry, Problems of entrepreneurship, The Art of Negotiation, Workable marketing and the strength of distribution. Opportunities in international marketing. (8) **Risk & benefit assessment:** Steps involved in product licensing and technology transfer for commercialization of a biotechnological product. (6) **Ethical issues and Biosafety guidelines:** Food safety and environmental safety evaluation of genetically modified microbes, crops, animals (GMO & LMOs); Roles of Institutional Biosafety Committee, WHO, DBT guideline for institutional biosafety . Primary Containment for Biohazards; Biosafety Levels; Biosafety Levels of Specific Microorganisms. Ethical implications of biotechnological products and techniques over human health. (7)
Text Books, and/or reference material	Text Book: 1. Dynamics of Entrepreneurial development & management; Vasant Desai, Himalay Publications. 2. Entrepreneurship reflection & investigation; M.S. Bisht & R.C. Mishra, Chugh Publication. 3. Entrepreneurship development in India; Samiuddin, Mittal Publication References: • Innovation, Product Development and Commercialization: Case Studies and Key Practices for Market • Science Business: The Promise, the Reality, and the Future of Biotech by Gary P. Pisano Harvard Business School Press: 2006. • Design and Marketing of New Products by Urban and Hauser,ISBN 0-13-201567-6 • Putting Biotechnology to Work: Bioprocess Engineering (1992) Commission on Life Sciences The national academy press

CO-PO mapping

Course Code	Title of the course	COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
BT9062	**Bioentrepreneurship**	CO 1	3	3	1	2	3	2
		CO 2	3	2	2	1	2	2
		CO 3	2	2	3	3	2	3
		CO 4	3	2	3	3	3	3