NATIONAL INSTITUTE OF TECHNOLOGY, DURGAPUR

DEPARTMENT OF BIOTECHNOLOGY

Revised Curriculum and Syllabi for the Degree of 2 Yr. M. Sc. in LIFE SCIENCES

(To be effective from the batches admitted in the Academic Session 2020-2021 Onwards)
Approved in PGAC meeting on 28/08/2020

Date: 28th August, 2020

Curriculum

First Semester

Sl. No.	Subject Code	Subject	L	T	P	CP/CH
1	BT1101	Biochemistry	3	1	0	4
2	BT1102	Microbiology	3	0	0	3
3	BT1103	Cellular & Molecular Biology	3	1	0	4
4	BT1104	Classical & Molecular Genetics	3	0	0	3
5	BT1105	Chemistry for Biologists	3	0	0	3
6	BT1151	Biochemistry Laboratory	0	0	3	2
7	BT1152	Microbiology Laboratory	0	0	3	2
8	BT1153	Cellular & Molecular Biology Laboratory	0	0	3	2
		Total Credit				**23/26**

Second Semester

Sl. No.	Subject Code	Subject	L	T	P	CP/CH
1	BT2101	Omics & Bioinformatics	3	1	0	4
2	BT2102	Immunology	3	1	0	4
3	BT2103	Biophysics & Structural Biology	3	1	0	4
4	BT2104	Genetic Engineering	3	0	0	3
5	BT2105	Plant & Animal Biotechnology	3	0	0	3
6	BT2151	Omics & Bioinformatics Laboratory	0	0	2	2
7	BT2152	Immunology Laboratory	0	0	3	2
8	BT2153	Genetic Engineering Laboratory	0	0	3	2
		Total Credit				**24/27**

Third Semester

Sl. No.	Subject Code	Subject	L	T	P	CP/CH
1	BT91**	Elective I	3	0	0	3
2	BT91**	Elective II	3	0	0	3
3	BT3101	Methods in Biology	3	0	0	3
4	BT3102	IPR, Biosafety & Bioethics	3	0	0	3
5	BT3103	Scientific Communications	2	1	0	3
6	BT3151	Recombinant DNA Technology Laboratory	0	0	3	2
7	BT3152	Protein Purification Laboratory	0	0	3	2
8	BT3153	Project Work - I	0	0	4	4
9	BT3154	Project Seminar - I	0	0	1	1
		Total Credit				**24/26**

Fourth Semester

Sl. No.	Subject Code	Subject	L	T	P	CP/CH
1	BT91**	Elective III	3	0	0	3
2	BT91**	Elective IV	3	0	0	3
4	BT4151	Project Work – II	0	0	10	10
5	BT4152	Project Seminar - II	0	0	3	3
		Total Credit				**19/19**

Total Program Credit: 90

List of Electives:

Elective I:

Sl. No.	Code	Course Title
1	BT9111	Cancer Biology
2	BT9112	Enzymology & Bioenergetics
3	BT9113	Physiology, Ecology & Evolution
4	BT9114	Protein Structure, Folding & Misfolding
5	BT9115	Programming for Biologists

Elective II:

Sl. No.	Code	Course Title
1	BT9121	Developmental & Stem Cell Biology
2	BT9122	Molecular Virology
3	BT9123	Host – Pathogen Interactions
4	BT9124	Infection Biology

Elective III:

Sl. No.	Code	Course Title
1	BT9131	Nano-biotechnology
2	BT9132	Nutraceuticals & Nutrigenomics
3	BT9133	Metabolic Engineering
4	BT9134	Drug Discovery and Development

Elective IV:

Sl. No.	Code	Course Title
1	BT9141	Bioprocess Engineering & Technology
2	BT9142	Environmental Biotechnology
3	BT9143	Industrial Microbiology
4	BT9144	Protein Engineering

First Semester

<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>BT1101</td><td>Biochemistry</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Students will gain fundamental knowledge in biochemistry.
• CO2: Students will understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.
• CO3: Will be able to apply knowledge of biochemistry in other areas of study like genetics, cell and molecular biology and microbiology.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">History of Biochemistry. Diversities of biomolecules: carbohydrates (Monosaccharides and derivatives of sugars, polysaccharides), nucleic acids, lipids (Fatty acids, triacylglycerols, glycerophospholipids, sphingolipids, cholesterol lipid bilayers), proteins (glycoproteins, nucleoproteins, lipoproteins etc.). Role of small molecules and trace elements in biology. Structure of amino acids, peptide bonds, Ramachandran Plot, Structural organization of Proteins: Motifs, domains, super secondary structures of proteins.
Basic concepts, Central role of ATP in metabolism, Carbon fuel and its oxidation, Concept of energy rich compounds and intermediates, Common types of reactions involved in metabolism, Glycolysis and gluconeogenesis, Energetics and ATP productions, Regulation of glycolysis, glycogen synthase, metabolic flux and its regulation by various metabolic intermediates, TCA cycle, its regulation, its role in energy generation, its role in generating biosynthetic intermediates, Redox reaction, mitochondrial structure and its role in energy metabolism, electron transport system, ATP synthesis and chemo-osmotic hypothesis of ATP generation, Pentose phosphate pathway and its importance in biosynthetic reactions, Glycogen synthesis, breakdown and its regulation, Fatty acid biosynthesis and degradation, Synthesis and degradation of steroids, Amino acid metabolism, Urea cycle, one carbon reaction, non-protein amino acids, amines and their role in cell function, Nucleotide biosynthesis and metabolism, salvage pathways, its regulation and diseases, Special topics in biochemistry. Mechanisms of hormone action, Role of post-translation modifications in regulation of cell function.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books: 1. Biochemistry (5th Edition) by Jeremy Berg, John Tymoczko and Lubert Stryer. 2. Biochemistry (3rd Edition) by Donald J. Voet and Judith G. Voet. 3. Lehninger Principles of Biochemistry (4th Edition) by David L. Nelson and Michael M. Cox.</td></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT1102</td><td>Microbiology</td><td>PCR</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To identify major categories of microorganisms and analyse their classification, diversity, and ubiquity.
• CO2: To identify and demonstrate structural, physiological, genetic similarities and differences of major categories of microorganisms.
• CO3: To identify and demonstrate how to control microbial growth; Demonstrate and evaluate interactions between microbes, hosts and environment.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">History of microbiology: Theory of spontaneous generation Experiments of Pasteur and Tyndall, Koch's Postulates, Isolation of bacteria, methods of sterilization. Role of bacteria in human welfare: Biological concepts – Immunization (Pasteur experiment Antibiosis), (penicillin story), The Microbial cell: General organization of cell, Prokaryotes Eukaryotes and Archaea, Cell wall organization on Prokaryotes, Eukaryotes and Archaea, Cell surface appendages pilli, locomotion by flagella chemotactic Movement, Peptidoglycan synthesis inhibitors in different steps. Changing concepts in microbiology taxonomy, Earlier systems, Molecular taxonomy, Jackard's similarly coefficients. Growth and nutrition: Growth kinetics, Batch and continuous cultures, Nutritional classification of microorganisms, Nutritional uptake by microorganisms (C.N.P). Metabolic Pathways: Metabolic versatility of microbes, Anaerobic Carbon metabolism: Aerobic Carbon metabolism: Nitrogen metabolism; Nitrogen Fixation, Regulation of 'nif'. Energy Metabolism: Chemo autotrophs, Hydrogen bacteria, Phototrophic bacteria/Cyanobacteria. Microbial Genetics: Modes of genetic exchange in microbes, Transformation, Transduction, Conjugation, Evolutionary Significance. Microbes in Extreme Environment: The basis of extremophiles and their applications, Life of a thermophile (Thermus, Pyrococcus). Microbes and Agriculture: Symbiotic nitrogen fixation, Rhizobium, Cyanobacteria (Anabaena, Azolla etc.), Mycorrihiza, Clinical Microbiology, Survey of disease causing microbes, Mechanisms of Pathogenesis, Antibiotics and their targets, Immune response elicited by microorganisms. Industrial Microbiology: Major industrial products from microbes, Beverages, Antibiotics, Secondary metabolites, Recombinant products. Environmental Microbiology: Nature of anthropogenic wastes, Municipal wastes and xenobiotics, Enrichment cultures, Xenobiotic degrading consortia, Bioremediation.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Microbiology, J.G. Cappuccino, N. Sherman, Pearson Education Publications. 2. Essential Microbiology, Stuart Hogg, John Wiley and Sons Limited. 3. Microbiology: A Human Perspective, E.W. Nester, D.G. Anderson, C.E. 4. Roberts, N.N. Pearsall, M. T. Nester McGraw Hill Higher Education. 5. Culture of Animal Cells, A Manual of Basic Technique. R. I. Freshney, Wiley. 6. Manual of</td></tr>
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	Environmental Microbiology, C. J. Hurst, R.L. Crawford, G. R. Knudsen, M. J. McInerney, L. D. Stetzenbach, ASM Press. 7. Microbiology, L.M. Prescott, J. P. Harley, D.A., Klein, McGraw Hill. 8. General Microbiology. H.G. Schlegel, Cambridge University Press. 9. Microbiology by Pelczar.

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<tr><td>BT1103</td><td>Cellular & Molecular Biology</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To understand the concepts of structure, organization and molecular signalling of cells which govern its function.
• CO2: To learn the application of experimental methods and designs to solve cell biology questions in basic cell biology and human diseases.
• CO3: To understand the central dogma in molecular biology.
• CO4: To understand the detailed mechanisms of regulations of gene expression.</td></tr>
<tr><td>Topics Covered</td><td colspan="7"><u>Cell Biology</u>
Introduction to the Cell: The evolution of the cell, From molecules to first cell, From Prokaryotes to eukaryotes, From single cells to multicellular organisms. The Plasma membrane, Membrane structure: The Lipid bilayer, Membrane proteins, Membrane carbohydrates, Membrane transport of small molecules, Membrane transport of macromolecules and particles. The Cell nucleus and subnuclear organization: Organelles to the eukaryotic cell: The lysosomes, The peroxisomes, The Golgi apparatus, The endoplasmic reticulum. Mitochondria and chloroplast, Structure of the mitochondria and chloroplast, Protein sorting in different cellular compartments and locations organelle biogenesis and protein secretion. vesicular traffic and secretary pathway, exocytosis and endocytosis. The cytoskeleton, the nature of cytoskeleton, Intermediate filaments, Microtubules, Actin filaments, Cilia and centrioles, Organization of the cytoskeleton. Cell growth and division, Overview of the Cell cycle and its control, the molecular mechanisms for regulating mitotic events, Cell cycle control in mammalian cells, Checkpoints in cell cycle regulation. Cell adhesions, cell junctions and the extracellular matrix, Cell to cell adhesion and communication. Stem cells and cellular differentiation.

<u>Molecular Biology</u>
Genetic material (Classical experiments: Griffith’s experiment, Avery and McCarty’s experiment). Macromolecules and Organization: DNA, RNA Structure, Conformation, Denaturation, Renaturation, Chromatin structure, Nucleosome. Genes and genome organization. Transposons and retrotransposons. Processes: DNA Replication-mechanism-Prokaryotes/eukaryotes, DNA damage repair. RNA world and RNA Replication.</td></tr>
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	Mechanism of transcription- Prokaryotes/eukaryotes. RNA processing: capping, polyadenylation, splicing, editing. Genetic code and translation. Regulation: Transcriptional regulation- Prokaryotes/eukaryotes. Translational regulation. Epigenetics. Genetic Engineering. Gene silencing and Gene editing.
Text Books, and/or reference material	Text Books: **Cell Biology:** 1. Essential Cell Biology: An Introduction to the Molecular Biology of the Cell, B. Alberts, D. Bray, A. Johnson, J. Lewis, M. Roff, K. Robert, P. Walter and K. Roberts, Garland Publishing Company. 2. Cell and Molecular Biology, De Robertis, B. I. Publication Pvt. Ltd. 3. Molecular Cell Biology, H. Lodish, A. Berk, S.L. Zipursky, P. Matsudaura, D. Baltimore and J. Danell, W.H. Preeman and Company. 4. Essential Cell Biology: An Introduction to the Molecular Biology of the Cell, B. Alberts, D. Bray, A. Johnson, J. Lewis, M. Roff, K. Robert, P. Walter and K. Roberts, Garland Publishing Company. **Molecular Biology** 1. Genes IX. Lewin (2008) 2. Molecular Biology of the Gene. Watson et. al. (6th edn., 2009) 3. Molecular Cell Biology. Lodish et. al. (6th edn., 2008) 4. Molecular Biology of the Cell. Alberts et. al. (5th edn.,2007).

Department of Biotechnology							
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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT1104	Classical & Molecular Genetics	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: To describe fundamental molecular principles of genetics. • CO2: To understand relationship between phenotype and genotype in human genetic traits.						
Topics Covered	Mendelian Genetics: An overview Law of segregation and independent assortment, chromosome theory of inheritance. Allelic and non-allelic interactions: Concept of alleles, types of dominance, lethal alleles, multiple alleles, test of allelism, complementation, epistasis, Linkage and recombination, nondisjunction, gene mapping in Drosophila. Changes in chromosome number and structure: Polyploidy, aneuploidy, deletion, inversion, duplication, and translocation. Sex-linked inheritance and extrachromosomal inheritance. Non-Mendelian/quantitative genetics: Genes and environment, heritability, penetrance and expressivity. Mutation: Types, mechanism and role in creating genetic variation/evolution. Bacterial genetics: Transformation, conjugation, and transduction. Human Genetics, Plant Genetics- including molecular markers, Population Genetics.						

Text Books, and/or reference material	Text Books: 1. An introduction to Genetic Analysis by Griffiths et al. 2. Genetics: Analysis of Genes and Genomes by Hartl and Ruvolo. 3. Genetics: A conceptual approach by Pierce et al.

Department of Biotechnology							
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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT1105	Chemistry for biologists	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: Students will be able to gain clear understanding of fundamental laws of chemistry. • CO2: Students will be able to learn to associate biological problems with chemical properties.						
Topics Covered	Basic constituents of matter - elements, atoms, isotopes, atomic weigts, atomic numbers, basics of mass spectrometry, molecules, Avogadro number, molarity, gas constant, molecular weights, structural and molecular formulae, ions and polyatomic ions; chemical reactions, reaction stoichiometry, rates of reaction, rate constants, order of reactions, Arrhenius 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); light and matter interactions (optical spectroscopy, fluorescence, bioluminescence, paramagnetism and diamagnetism, photoelectron spectroscopy; chemical bonds (ionic, covalent, Vander Walls forces); electronegativity, polarity; VSEPR theory and molecular geometry, dipole moment, orbital hybridizations; states of matter - vapour pressure, phase diagrams, surface tension, boiling and melting points, solubility, capillary action, suspensions, colloids and solutions; acids, bases and pH -Arrhenius theory, pH, ionic product of water, weak acids and bases, conjugate acid-base pairs, buffers and buffering action. Redox reactions and electrochemistry - oxidation-reduction reactions.						
Text Books, and/or reference material	Text Books: 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. Mahan, B. H. (1965). University Chemistry. Reading, MA: Addison-Wesley Pub. 4. Cantor, C. R., & Schimmel, P. R. (2004). Biophysical Chemistry. San Francisco: W.H. Freeman.						

Department of Biotechnology							
Course Code	Title of the course		Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT1151	**Biochemistry Laboratory**		0	0	3	3	2
Student Learning Outcomes	• CO1: To elaborate concepts of biochemistry with easy to run experiments. • CO2: To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in biochemistry.						
Topics Covered	1. To Prepare various stock solutions and working solutions that will be needed for the course. 2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation. 3. Quantitative Estimation of carbohydrate. 4. To determine an unknown protein concentration by different methods (by plotting a standard curve of BSA using UV-Vis Spectrophotometer and validating the Beer- Lambert's Law, Bradford's dye-binding method, Lowry method). 5. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography. 6. Extraction, separation and estimation of lipids. 7. Kinetic study of enzymes (Determination of Km, Vmax and Kcat) and Inhibition kinetics of enzymes 8. Identification of an unknown samples of DNA, RNA or protein using spectrophotometric method. 9. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy).						

Department of Biotechnology							
Course Code	Title of the course		Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT1152	**Microbiology Laboratory**		0	0	3	3	2
Student Learning Outcomes	Students will be able to: • CO1: Isolate, characterize and identify common bacterial organisms. • CO2: Determine bacterial load of different samples. • CO3: Perform antimicrobial sensitivity tests. • CO4: Preserve bacterial cultures.						
Topics Covered	1. Sterilization, disinfection and safety in microbiological laboratory. 2. Preparation of media for cultivation of bacteria. 3. Isolation of bacteria in pure culture by streak plate method. 4. Study of colony and growth characteristics of some common bacteria: *Bacillus, E. coli, Staphylococcus, Streptococcus, etc.* 5. Preparation of bacterial smear and Gram's staining.						

	6. Enumeration of bacteria: standard plate count. 7. Antimicrobial sensitivity test and demonstration of drug resistance. 8. Maintenance of stock cultures: slants, stabs and glycerol stock cultures 9. Determination of phenol co-efficient of antimicrobial agents. 10. Determination of Minimum Inhibitory Concentration (MIC).

Department of Biotechnology							
Course Code	Title of the course		Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT1153	**Cellular & Molecular Biology Laboratory**		0	0	3	3	2
Student Learning Outcomes	• CO1: Students will learn basic animal cell culture techniques. • CO2: Students will learn basic molecular biology techniques. • CO3: Students will get exposure to ideal practices and standards in animal cell culture and nucleic acid manipulation. • CO4: Students will get exposure to safety and ethical issue related to handing animal cells and manipulating nucleic acid.						
Topics Covered	1. Counting of cells and check their viability. 2. Prepare culture media with various supplements for cell culture. 3. Monitor and measure doubling time of animal cells. 4. Chromosome preparations from cultured animal cells. 5. Isolate DNA from cells by SDS method. 6. Cell migration and invasion assay. 7. Concept of lac-operon: a) Lactose induction of □-galactosidase. b) Glucose Repression. c) Diauxic growth curve of *E. coli.* 8. UV mutagenesis to isolate amino acid auxotroph. 9. Plasmid DNA isolation and DNA quantitation. 10. Restriction Enzyme digestion of plasmid DNA. 11. Agarose gel electrophoresis. 12. Polymerase Chain Reaction and analysis by agarose gel electrophoresis.						

Second Semester

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT2101</td><td>Omics & Bioinformatics</td><td>PCR</td><td>3</td><td>1</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 (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NA</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: In depth understanding of genomes, transcriptomes and proteomes and methods to probe them.
• CO2: Understanding of concepts for functional analysis of genes and proteins.
• CO3: Learning bioinformatics to analyse nucleic acid and protein sequence and structure.
• CO4: Learning bioinformatics to analyse genomes, transcriptomes and proteomes.
• CO5: Development of comprehensive understanding of Omes, Omics and bioinformatics to apply them to solve existing problems in biology.</td></tr>
<tr><td>Topics Covered</td><td colspan="7"><u>Omics</u>

Definition, classification, and scopes. The emergence of proteome concept: structural and functional proteomes, protein structure related to functional kinetics. Proteome analysis: 2-D PAGE, mass spectrometry and mass fingerprinting, LC-MS/MS and PTM analysis. Quantitative Proteomics, Proteomics in relation to animal and plant health and welfare. Transcriptomes: measurement of gene expression. Genome and genome analysis. Bridging genomics to proteomics. Metagenomics. Metabolomics. Protein-protein interaction and interactome. Systems biology.

<u>Bioinformatics</u>

Brief description of the Course, biological data, data mining, databases. Examples of different databases, Database searching, Boolean operators, SRS. Practical on databases and database searching. Nucleic acid sequences, simple sequence features, such as GC content, skew ness, Motifs, manipulation of sequences. Practical on nucleic acid sequences. Amino acid sequences of proteins and their manipulation, motifs and domains, Practical on proteins. Concept of sequence alignment and similarity, different algorithms, global and local alignment, scoring systems, Practical on sequence alignment. Multiple sequence alignment, theory and practical. Phylogenetic tree construction, theory and practical. Protein structure, 3D viewer, simple structure manipulation both theory and practical. Introduction to Biostatistics: hypothesis testing, ANOVA, t-test, correlation, and regression.</td></tr>
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Text Books, and/or reference material	Text Books: **Omics** 1. A Textbook of Protein and Proteomics, C Subramanian and Nandan Hazare, Dominant Pub. 2. Discovering Genomics, Proteomics and Bioinformatics (2nd Edition), by A. Malcolm Campbell and Laurie J. Heyer. **Bioinformatics** 1. Bioinformatics, edited by Des Higgins and Willie Taylor; Oxford University Press. 2. Bioinformatics by Orpita Basu and Simminder K Thukral, Oxford Higher Education. 3. Introduction to Bioinformatics by Arthur M Lesk, Oxford University Press.

Department of Biotechnology							
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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT2102	Immunology	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: To understand basic concepts of innate and adaptive immunity. • CO2: To apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in the setting of infection (viral or bacterial). • CO3: To understand the application of immunological techniques in pathology labs and clinical studies.						
Topics Covered	Introduction to Immune System, organs, cells and molecules involved in Innate and Adaptive Immunity. Mechanisms of barrier to entry of microbes/pathogens. Hematopoiesis and its regulation: Differentiation of stem cells to different cellular elements in blood, role of cytokines. Introduction to inflammatory reaction: chemokines, adhesion molecules, migration of leukocytes to the site of infection, phagocytosis and microbicidal mechanisms. Immediate hypersensitivity: role of eosinophils, and mast cells. Asthma. IgE receptor, prostaglandins and leukotrienes. Receptors of innate immunity: Toll-like receptors and sensing of PAMPs, signal transduction, opsonization, Fc receptors. Antigens, antigenicity, and immunogenicity. B and T cell epitopes. Antibody structure and function (classification of immunoglobulins, immunoglobulin domains, concept of variability, isotypes, allotypes and idiotypic markers). Antigen-antibody interactions. Immunoglobulin genes, VJ/VDJ rearrangements and genetic mechanisms responsible for antibody diversity, affinity maturation, allelic exclusion. Class switching, receptor and soluble forms of immunoglobulin. Hybridoma, monoclonal antibodies, and antibody engineering. The complement system: classical and alternative pathways. Major Histocompatibility Complex: genetic organization of H2 and HLA complexes. Class I and class II MHC molecules, structure and function. Antigen processing and presentation pathways. Differentiation and activation						

	of B cells, BCR and pre BCR, receptor editing. T cell receptors, αβ and γδ T cells, receptor diversity. Activation of T cells, APC-T cell interaction, Th1/Th2 cells and cytokines. T cell differentiation in thymus, thymic selection and tolerance to self, MHC restriction, super antigens. Cell-mediated effector functions: Cytotoxic T cells, Natural Killer Cells, ADCC, NK cell receptors, inverse correlation with target MHC expression, missing self hypothesis, cytotoxicity reaction. Topics like Applications of immunological principles (vaccines, and diagnostics); tumor and transplantation Immunology; and diseases of relevance to the immune system (autoimmunity and immunodeficiency) etc.
Text Books, and/or reference material	Text Books: 1. Roitt's Essential Immunology. 2. Immunobiology: The immune system in health and disease by Charles Janeway et. al. 3. Kuby Immunology. 4. Relevant review articles/research papers/handouts provided in the course.

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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	
BT2103	Biophysics & Structural Biology	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: To understand biophysical parameter governing structure of biomolecules. • CO2: To analyse the structure of biomolecules. • CO3: To apply the knowledge of biophysical technique and methods to solve questions on structure of biomolecules.						
Topics Covered	Introduction. Structure of Biomolecules and conformations of protein and nucleic acids. Secondary, tertiary and quaternary structure of protein. Primary and secondary structure of RNA and DNA. Method of conformational analysis and prediction of conformation. Thermodynamics and kinetics of conformational transition of proteins. Protein folding, techniques for studying Macromolecular structure. Ultra centrifugation Sedimentation velocity and equilibrium determination of molecular weights. Electron microscopy. UV Visible Spectroscopy, Fluorescence Spectroscopy. Circular Dichroism Spectroscopy. Symmetry, space group crystal lattices, brag's law in real & reciprocal space. Nuclear Magnetic Resonance.						
Text Books, and/or reference material	Text Books: 1. Biophysical Chemistry by Cantor & P. Schimmel. Vol. I & II. 2. Physical Biochemistry by David I Reifelder. 3. Protein: Structure & Molecular Properties by TE Creighton, 4. Introduction to Protein structure by Branden and Tooze. 5. Introduction to experimental biophysics by Jay L Nadeau.						

	Reference books: 1. Textbook of structural biology by Liljas Anders. 2. Principles of Protein structure by G E Schulz and Schirmer. 3. Fundamentals of Protein Structure and function by Engelbert Buxbaum. 4. Protein structure: A practical approach by Creighton. 5. Proteins: Structure and function by James J L'ltalien. 6. Biomolecular Crystallography: Principles, Practice and application to structural Biology by Bernhard Rupp. 7. Introduction to Protein Architecture: The structural Biology of proteins by A M Lesk. 8. The physics of proteins by Robert H Austin and Charles E Schulz. 9. Structure and mechanism in protein science by Alan R Fersht.

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<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>BT2104</td><td>Genetic Engineering</td><td>PCR</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To gain a strong theoretical base of manipulation of nucleic acid.
• CO2: To get exposure of advanced genetic engineering and molecular biology tools.
• CO3: To apply the knowledge in designing experiment or strategy to solve problems of basic science and industry applications.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction and tools for genetic engineering: Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes, hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence in situ hybridization.
Different types of vectors: Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, hagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression vectors; pMal; GST; pET-based vectors; Protein purification; Histag; GST-tag; MBP-tag etc.; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and Pichia vectors system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.
Different types of PCR techniques: Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing;</td></tr>
</table>

	chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP. **Gene manipulation and protein-DNA interaction**: Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display. **Gene silencing and genome editing technologies:** Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics- gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.
Text Books, and/or reference material	Text Books: 1. Old, R. W., Primrose, S. B., & Twyman, R. M. (2001). Principles of Gene Manipulation: An Introduction to Genetic Engineering. Oxford: Blackwell Scientific Publications. 2. Green, M. R., & Sambrook, J. (2012). Molecular Cloning: A Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. 3. Brown, T. A. (2006). Genomes (3rd ed.). New York: Garland Science Pub. 4. Selected papers from scientific journals, particularly Nature & Science. 5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

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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	
BT2105	Plant & Animal Biotechnology	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: Gain understanding of cell and tissue culture and their applications in research and industry. • CO2: Gain understanding of methods for genome editing and generation of transgenic organisms. • CO3: Develop strategies to answer a basic question or a biotech industrial applications.						
Topics Covered	**Plant tissue culture and animal cell culture** **Plant tissue culture**: historical perspective; totipotency; organogenesis; Somatic						

	embryogenesis; establishment of cultures – callus culture, cell suspension culture, media preparation – nutrients and plant hormones; sterilization techniques; applications of tissue culture - micropropagation; somaclonal variation; androgenesis and its applications in genetics and plant breeding; germplasm conservation and cryopreservation; synthetic seed production; protoplast culture and somatic hybridization - protoplast isolation; culture and usage; somatic hybridization - methods and applications; hybrids and somatic cell genetics; plant cell cultures for secondary metabolite production. **Animal cell culture**: brief history of animal cell culture; cell culture media and reagents; culture of mammalian cells, tissues and organs; primary culture, secondary culture, continuous cell lines, suspension cultures; application of animal cell culture for virus; isolation and *in vitro* testing of drugs, testing of toxicity of environmental pollutants in cell culture, application of cell culture technology in production of human and animal; viral vaccines and pharmaceutical proteins. **Plant genetic manipulation** Genetic engineering: Agrobacterium-plant interaction; virulence; Ti and Ri plasmids; opines and their significance; T-DNA transfer; disarmed Ti plasmid; Genetic transformation Agrobacterium-mediated gene delivery; cointegrate and binary vectors and their utility; direct gene transfer - PEG-mediated, electroporation, particle bombardment and alternative methods; screenable and selectable markers; characterization of transgenics; chloroplast transformation; marker-free methodologies; advanced methodologies - cisgenesis, intragenesis and genome editing; molecular pharming - concept of plants as biofactories, production of industrial enzymes and pharmaceutically important compounds. **Animal reproductive biotechnology and vaccinology** Animal reproductive biotechnology: structure of sperms and ovum; cryopreservation of sperms and ova of livestock; artificial insemination; super ovulation, embryo recovery and *in vitro* fertilization; culture of embryos; cryopreservation of embryos; embryo transfer technology; transgenic manipulation of animal embryos; applications of transgenic animal technology; animal cloning - basic concept, cloning for conservation endangered species; Vaccinology: history of development of vaccines, introduction to the concept of vaccines, conventional methods of animal vaccine production, recombinant approaches to vaccine production, modern vaccines. **Plant and animal genomics** Overview of genomics – definition, complexity and classification; need for genomics level analysis; methods of analyzing genome at various levels – DNA, RNA, protein metabolites and phenotype; genome projects and bioinformatics resources for genome research – databases; overview of forward and reverse genetics for assigning function for genes. **Molecular mapping and marker assisted selection** Molecular markers - hybridization and PCR based markers RFLP, RAPD, STS, SSR, AFLP, SNP markers; DNA fingerprinting-principles and applications; introduction to mapping of genes/QTLs; marker-assisted selection - strategies for Introducing genes of biotic and abiotic stress resistance in plants: genetic basis for disease resistance in animals; molecular diagnostics of pathogens in plants and animals; detection of meat adulteration using DNA based methods.

Text Books, and/or reference material	Text Books: 1. Chawla, H. S. (2000). Introduction to Plant Biotechnology. Enfield, NH: Science. 2. Razdan, M. K. (2003). Introduction to Plant Tissue Culture. Enfield, NH: Science. 3. Slater, A., Scott, N. W., & Fowler, M. R. (2008). Plant Biotechnology: an Introduction to Genetic Engineering. Oxford: Oxford University Press. 4. Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). Biochemistry & Molecular Biology of Plants. Chichester, West Sussex: John Wiley & Sons. 5. Umesha, S. (2013). Plant Biotechnology. The Energy And Resources. 6. Glick, B. R., & Pasternak, J. J. (2010). Molecular Biotechnology: Principles and Applications of Recombinant DNA. Washington, D.C.: ASM Press. 7. Brown, T. A. (2006). Gene Cloning and DNA Analysis: an Introduction. Oxford: Blackwell Pub. 8. Primrose, S. B., & Twyman, R. M. (2006). Principles of Gene Manipulation and Genomics. Malden, MA: Blackwell Pub. 9. Slater, A., Scott, N. W., & Fowler, M. R. (2003). Plant Biotechnology: The Genetic Manipulation of Plants. Oxford: Oxford University Press. 10. Gordon, I. (2005). Reproductive Techniques in Farm Animals. Oxford: CAB International. 11. Levine, M. M. (2004). New Generation Vaccines. New York: M. Dekker. 12. Portner, R. (2007). Animal Cell Biotechnology: Methods and Protocols. Totowa, NJ: Humana Press.

Department of Biotechnology							
Course Code	Title of the course		Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT2151	**Omics & Bioinformatics Laboratory**		0	0	3	3	2
Student Learning Outcomes	Students will be able to: • CO1: Describe contents and properties of most important bioinformatics databases. • CO2: Perform text- and sequence-based searches and analyze and discuss results in light of molecular biological knowledge. • CO3: Explain major steps in pairwise and multiple sequence alignment, explain principle and execute pairwise sequence alignment by dynamic programming. • CO4: Predict secondary and tertiary structures of protein sequence.						
Topics Covered	1. Using NCBI and Uniprot web resources. 2. Introduction and use of various genome databases. 3. Sequence information resource: Using NCBI, EMBL, Genbank, Entrez, Swissprot/TrEMBL, UniProt. 4. Similarity searches using tools like BLAST and interpretation of results. 5. Multiple sequence alignment using ClustalW. 6. Phylogenetic analysis of protein and nucleotide sequences. 7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).						

	8. Using RNA structure prediction tools. 9. Use of various primer designing and restriction site prediction tools. 10. Use of different protein structure prediction databases (PDB, SCOP, CATH). 11. Construction and study of protein structures using Deepview/PyMol. 12. Homology modelling of proteins. 13. Use of tools for mutation and analysis of the energy minimization of protein structures. 14. Use of miRNA prediction, designing and target prediction tools.

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BT2152	**Immunology Laboratory**		0	0	3	3	2
Student Learning Outcomes	Students will be able to: • CO1: Detect different antigen and antibody interactions. • CO2: Identify and isolate different immune cells. • CO3: Design simple experiments and interpret data. • CO4: Understand the application of immunological techniques in pathology labs and clinical studies.						
Topics Covered	1. Selection of animals, preparation of antigens, immunization and methods of blood collection, serum separation and storage. 2. Antibody titre by ELISA method. 3. Double diffusion, Immuno-electrophoresis and Radial Immuno diffusion. 4. Complement fixation test. 5. Isolation and purification of IgG from serum or IgY from chicken egg. 6. SDS-PAGE, Immunoblotting, Dot blot assays. 7. Blood smear identification of leucocytes by Giemsa stain. 8. Separation of leucocytes by dextran method. 9. Demonstration of Phagocytosis of latex beads and their cryopreservation. 10. Separation of mononuclear cells by Ficoll-Hypaque and their cryopreservation. 11. Demonstration of ELISPOT. 12. Demonstration of FACS.						

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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
BT2153	**Genetic Engineering Laboratory**		0	0	3	3	2
Student Learning Outcomes	Students will be able to: • CO1: Clone a piece of DNA or a ORF. • CO2: Over express a protein and purify by affinity chromatography. • CO3: Gain ideas to trouble shoot problems with gene cloning and protein						

	expression.
Topics Covered	1. Vector and Insert Ligation. 2. Preparation of competent cells. 3. Transformation of *E. coli* with standard plasmids, Calculation of transformation efficiency. 4. Confirmation of the insert by Colony PCR and Restriction mapping. 5. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in *E. coli*, SDS-PAGE analysis. 6. Purification of His-Tagged protein on Ni-NTA columns: a) Random Primer labeling b) Southern hybridization

Third Semester

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT3101</td><td>Methods in Biology</td><td>PCR</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Students will learn theoretical basis and basic understanding of latest technologies in area of biotechnology.
• CO2: Students should also be able to learn about various applications of these technologies.
• CO3: Students will be able to design experiments with correct application of the technology and methods.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Microscopic techniques and its applications: Principles and application of following microscopes and microscopy techniques: Light and phase contrast; Fluorescence; Confocal; FRET; FRAP; TIRF; Electron (TEM and SEM); Electron tunnelling and Atomic Force Microscopy.
Centrifugation techniques and its applications: Basic principles and calculations (RCF, Sedimentation coefficient etc.); Centrifuges and rotor designs and safety measures for operation (micro-centrifuge, high speed & ultracentrifuges; fixed angle, swing bucket and continuous flow rotors); Preparative centrifugation (differential & density gradient) and its applications (cell fractionation); Analytical centrifugation and its application (sedimentation velocity and sedimentation equilibrium).
Chromatographic techniques and its applications: General principles of chromatography; TLC and Paper chromatography; Chromatographic methods for macromolecule separation – Gel-permeation, Ion exchange, Hydrophobic, Reverse-phase and Affinity chromatography; HPLC and FPLC; Criteria of protein purity, Ultrafiltration and other membrane techniques, dialysis.
Electrophoretic techniques and its applications: Principles and application of gel electrophoresis, Agarose gel electrophoresis; SDS PAGE; Capillary gel electrophoresis; Isoelectric focusing and 2D-PAGE; Pulse field electrophoresis; Micro-electrophoresis.
Radioisotope techniques and its applications: Principles of radioisotopes and radiations; Units of radioactivity; Radioactive & stable isotopes; Measurement of radioactivity (Geiger-Muller counter; Solid & Liquid scintillation counters); Autoradiography; Measurement of stable isotopes. Use of radioactivity in biochemistry.
Immunological Techniques: antibody generation, detection of molecules using ELISA, RIA, Western blot, immunoprecipitation, flow cytometry, immunofluorescence microscopy.
Advanced Techniques: Mass Spectrometry: API-electrospray and MALDI-TOF; LC MS/MS; Enzyme and cell immobilization techniques; DNA & Peptide Synthesis.</td></tr>
</table>

Text Books, and/or reference material	Text Books: 1. Keith Wilson and John Walker, Principles and Techniques of Practical Biochemistry, 8th Edition, Cambridge University Press, 2018. 2. Freifelder D., Physical Biochemistry, Application to Biochemistry and MolecularBiology,2nd Edition, W.H. Freeman & Company, San Fransisco, 1982. 3. Debajyoti Das. Biophysics & Biophysical Chemistry.

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BT3102	IPR, Biosafety & Bioethics	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: The students will understand the rationale for and against IPR and especially patents. • CO2: Students will understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations. • CO3: The students will gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations. They will also understand ethical aspects related to biological, biomedical, health care and biotechnology research.						
Topics Covered	**Intellectual Property Rights (IPR)** Introduction to IPR Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT,WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of 'prior art': invention in context of "prior art"; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation. Patenting Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting requirement, procedures and costs; financial assistance for patenting introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research						

	students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives. **Biosafety** Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools. **National and international regulations** International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures -guidelines of state governments; GM labelling – Food Safety and Standards Authority of India (FSSAI). **Bioethics** Introduction, ethical conflicts in biological sciences - interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research – cloning and stem cell research, Human and animal experimentation, animal rights/welfare, Agricultural biotechnology - Genetically engineered food, environmental risk, labelling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – biopiracy.
Text Books, and/or reference material	Text Books: **IPR:** 1. Ganguli, P. (2001). Intellectual Property Rights: Unleashing the Knowledge Economy. New Delhi: Tata McGraw-Hill Pub. 2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI. 3. Complete Reference to Intellectual Property Rights Laws. (2007). Snow White Publication Oct. **Biosafety & Bioethics** 1. Kuhse, H. (2010). Bioethics: an Anthology. Malden, MA: Blackwell. 2. Karen F. Greif and Jon F. Merz, Current Controversies in the Biological Sciences -Case Studies of Policy Challenges from New Technologies, MIT Press 3. Recombinant DNA Safety Guidelines, 1990 Department of Biotechnology,

	Ministry of Science and Technology, Govt. of India. Retrieved from http://www.envfor.nic.in/divisions/csurv/geac/annex-5.pdf 4. Craig, W., Tepfer, M., Degrassi, G., & Ripandelli, D. (2008). An Overview of General Features of Risk Assessments of Genetically Modified Crops. Euphytica, 164(3), 853-880. doi:10.1007/s10681-007-9643-8 5. Guidelines for Safety Assessment of Foods Derived from Genetically Engineered Plants. 2008. 6. Guidelines and Standard Operating Procedures for Confined Field Trials of Regulated Genetically Engineered Plants. 2008. Retrieved from http://www.igmoris.nic.in/guidelines1.asp 7. Alonso, G. M. (2013). Safety Assessment of Food and Feed Derived from GM Crops:Using Problem Formulation to Ensure "Fit for Purpose" Risk Assessments. Retrieved from http://biosafety.icgeb.org/inhouse publications collection biosafety reviews.

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BT3103	Scientific Communications	PCR	2	1	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: To understand and practice scientific reading, writing and presentations. • CO2: To appreciate scientific ethics through case studies. • CO3: To develop communication skills and prepare the students to present their topic of research and its importance to the audience.						
Topics Covered	The course provides a systematic review of the principles and practice of the various modes and forms of scientific communication including scientific papers, technical reports, presentations, and proposal writing. The objective of this course is to develop effective skill for: 1. Scientific or technical presentation (or poster); 2. Writing technical reports; 3. Writing scientific papers; 4. Writing research or project proposals. Topics are likely to include: What is science communication for, and why is it important in our society now? Defining science in the public sphere. Contemporary issues in science communication. Public attitudes and social representations. Health and medical communication. Environmental communication. Ethics in science communication. Science and entertainment media. Digital media.						

	Popular Science Books and magazines.
Text Books, and/or reference material	Science Communication: A Practical Guide for Scientists 1st Edition by Laura Bowater nand Kay Yeoman The Oxford Handbook of the Science of Science Communication (Oxford Library of Psychology) 1st Edition 2017, by Kathleen Hall Jamieson, Dan Kahan, and Dietram A.Scheufele

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BT3151	**Recombinant DNA Technology Laboratory**	PCR	0	0	3	3	2
Student Learning Outcomes	• CO1: Students should be able to perform the basic experiments required for recombinant DNA technology						
Topics Covered	Transformation methods, genomic DNA isolation, Plasmid DNA isolation, restriction digestion of Plasmid and genomic DNA, elution of DNA by low melting gel agarose, Ligation, insert analysis, isolation of RNA, northern blotting, PCR, RT-PCR, Recombinant protein expression, purification and refolding.						

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BT3152	**Protein Purification Laboratory**	PCR	0	0	3	3	2
Student Learning Outcomes	• CO1: Students should be able to perform the basic protein purification techniques for biochemical and molecular biological experiments						
Topics Covered	a) Preparation of cell-free lysates b) Ammonium Sulfate precipitation c) Ion-exchange Chromatography d) Gel Filtration e) Affinity Chromatography f) Generating a Purification Table g) Assessing purity by SDS-PAGE Gel Electrophoresis h) Assessing purity by 2-D gel Electrophoresis						

ELECTIVE SUBJECTS
(Elective I)

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<tr><td>BT9111</td><td>Cancer Biology</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">NA</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To gain knowledge about the classification of cancer, types and phenotypic characteristics.
• CO2: To understand differentiation and apoptosis, Biology of metastasis, Carcinogenesis, Cancer genetics.
• CO3: To understand the Host tumor interactions, Gene rearrangements, detecting oncogene abnormalities in clinical specimens.
• CO4: To learn about Principles of chemotherapy, Concepts in cancer therapy - Mechanisms of cytotoxic drug action, Cancer Immunotherapy.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Cancer incidence and mortality; origin of neoplastic cells; cancer as cellular disease; tumor cell growth kinetics. Oncogenes and tumor suppressor genes. Environmental carcinogens; carcinogen metabolism. Chemical carcinogenesis; initiation, promotion and progression. Mechanism of ultraviolet radiation carcinogenesis (melanoma and non melanoma skin cancer). Animal models of cancer research; athymic nude mice model; syngeneic mouse model, transgenic mouse model etc. Heredity and cancer; genetic basis of carcinogenesis (e.g. APC mutation and colon cancer). Viral carcinogenesis mechanism. Immunological aspects of cancer; leukemia. Deregulated cell cycle progression in cancer.
Aberrant cell signaling in cancer. Antiapoptotic mechanisms for the survival of cancer cells. Tumor angiogenesis and its molecular mechanisms. Mechanisms of cancer invasion and metastasis. Cancer therapeutics: surgery, radiation and chemotherapy. Chemoprevention of cancer. Immunotherapy of cancer.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Molecular Biology of Cancer by F. Macdonald, C.H.J. Ford, and A.G. Casson; Garland Science / Bios Scientific Publishers 2. Molecular Biology of Human Cancers by Wolfgang Arthur Schulz Springer.</td></tr>
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<tr><td>BT9112</td><td>Enzymology & Bioenergetics</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Gain clear understanding of function of enzymes, principle of enzyme catalysis and enzyme kinetics.
• CO2: Acquire knowledge about isolation, purification and characterization of enzymes.
• CO3: Gain concept of free energy and measurement of free energy.
• CO4: Apply the concept of Chemical mechanisms of biological energy conversion in different cellular organelles.</td></tr>
<tr><td>Topics Covered</td><td colspan="7"><u>Enzymology</u>
Rate accelerations in biological systems; Catalysis and historical perspective on enzymes; Overview of applied enzymology and enzyme technology; Enzyme nomenclature; Origins of enzyme catalytic power; Structural basis of enzyme action and characterization of active site residues; Kinetic approaches to understand enzyme action; Michaelis-Menten kinetics; Evaluation of Km, kcat and enzyme inhibition analysis; Concept of an efficient catalyst; Elucidation of kinetic mechanism through initial velocity, product inhibition, pH and isotopic analysis; Role of metal ions in enzyme catalysis; Integration of kinetic, chemical and structural data to describe enzyme action; Control of enzyme activity and its role in regulating metabolism – in vivo enzymology; Frontiers in enzymology: Rational design of an enzyme catalyst, directed evolution, abzymes, non-protein catalysts.

<u>Bioenergetics</u>

Molecular basis of entropy, concept of free energy, standard free energy and measurement of free energy, significance in metabolism. Application of first and second law of thermodynamics to biological systems. Energy rich bonds - ATP and interconversions of nucleotide phosphates. Phosphorylation potential. Biochemical reaction mechanism; Temperature dependency from Arrhenius law; Theoretical prediction of rate constant: Interpretation of batch kinetic data; analysis of intra-particle diffusion and reaction; Kinetics of substrate utilization, product formation and biomass production; Chemical mechanisms of biological energy conversion in mitochondria and chloroplasts, Photosynthesis energy transfer kinetics.</td></tr>
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<tr><td>BT9113</td><td>Physiology, Ecology & Evolution</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Understand how evolutionary questions are linked with physiology and environment and how they influence selection pressure.
• CO2: Analyse evidence, form inferences, evaluate strength of inferences.</td></tr>
<tr><td>Topics Covered</td><td colspan="7"><u>Evolution and physiology</u>

Introduction:
Introduction to evolutionary physiology and its role in medicine; Evolutionary physiology toolkit (understanding how genotype and environment influence physiological traits; the comparative method).

Interactions among genotype, phenotype, physiological performance, and fitness:
Enzyme polymorphisms –controlling nutrient flow through pathways.
Regulatory polymorphisms –controlling when, where and how much genes are expressed.

Role of evolutionary processes in engendering or limiting physiological evolution:
Detecting adaptation; Physiological plasticity; Trade-offs and constraints in physiological evolution; Mapping genotype to phenotype using evolutionary physiology.

Ecological and phylogenetic patterns of physiological evolution:
Major physiological transitions (endothermy, flight, multicellularity); Evolution of quantitative traits (locomotor performance, growth and development, energetics).

<u>Environmental influences on physiological evolution</u>

Oxygen and carbon dioxide:
Physiological and evolutionary responses to oxygen and carbon dioxide; Hypoxia and hyperoxia; Ocean acidification.

Temperature:
Thermal physiology; Thermal tolerances; Thermal effects on energetics.

Seasonality:
Physiological responses to seasonal fluctuations; Regulation of dormancy; Cross seasonal consequences of fluctuating selection.

Water balance:
Osmoregulation and water balance physiology; Desiccation tolerance in terrestrial organisms; Osmoregulation in aquatic animals.</td></tr>
</table>

	<u>Global change – can evolutionary physiology help predict the future?</u> Global change predictions and impact on physiological; Mechanistic models; Predicting biotic impacts of climate change; Case study: Willow leaf beetles in the Sierra Nevada mountains.
Text Books, and/or reference material	Text Books: 1. An Introduction to Molecular Evolution and Phylogenetics 2 nd UK ed. Edition by Lindell Bromham. 2. Integrative Organismal Biology 1st Edition by Lynn B. Martin, Cameron K. Ghalambor, H. Arthur Woods.

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	
BT9114	Protein Structure, Folding & Misfolding	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		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: 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. DNA structures. DNA recognition in prokaryotes by helix-turn-helix motifs. DNA recognition by eukaryotic transcription factors, specific transcription factors. Structural feature of common proteins involved in enzyme catalysis, signal transduction and immunity. Protein Structure determination. Protein folding: thermodynamics, kinetics and chaperones. Protein misfolding and Disease.						
Text Books, and/or reference material	Text Books: Introduction to Protein Structure: Second Edition by Carl IV Branden, Routledge. Reference book: Structure and Mechanism in Protein Science A Guide to Enzyme Catalysis and Protein Folding: Alan Fersht.						

<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>BT9115</td><td>Programming for Biologists</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To learn about scripting and programming
• CO2: To learn and write programs to analyse vast amount of biological data
• CO3: To acquire knowledge about Artificial Intelligence and Machine learning approaches in the field of Biology.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to Linux operating system, Kernel system, benefits of Linux for computational biology.
Bash programming for bioinformatics: Shell scripting, working in terminal with different commands, use of important commands such as sed, grep, awk
C programming for bioinformatics: Introduction to C, Identifiers, 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)
Python scripting for bioinformatics: File handling in python, numpy, pandas etc
Basics of Machine Learning and its applications in biological data analysis.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Computational Biology —Unix/Linux, Data Processing and Programming by Röbbe Wünschiers
2. Learning Python, 5th Edition by Mark Lu
3. Machine Learning For Absolute Beginners: A Plain English Introduction (Second Edition) by Oliver Theobald</td></tr>
</table>

(Elective II)

<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>BT9121</td><td>Developmental & Stem Cell Biology</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• 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 remodelling 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">An Introduction to Stem Cells.
Adult Stem Cells.
Embryonic Stem Cells.
Induced Pluripotent Stem Cells.
Hematopoietic Stem Cells.
Mesenchymal stem cells, cord blood cells, Lessons from Medipost company products like Neurostem, Cardiostem, Cartistem, Pneumostem.
Molecular and Cellular Bases of Organ Development.
Cloning of Somatic Cells by Nuclear Transfer, iPSC based cloning, Production of chimera animals.
Molecular Bases of degenerative disease.
Therapeutic Uses of Stem Cells with examples.
In vivo Regeneration of Tissues by Cell Transplantation.
IPS Cells as Experimental Models of Neurodegenrative Disorders: use of them as disease modelling platform, novel drug testing and tissue renerarative therapy and implantation studies.
Studies of Patients Treated with Stem Cells, The modalities of treatment, Preperation of cells/tissues/scaffolds and Trnasplantation procedure.
Tissue Regeneration Driven by Growth Hormones.
Organ of dish, Orgnoid culture, Tissue Bioprinting to develop transplantation quality organs, Bioartificial Organs.
Biobanking of stem cells and the ethical considerations in regenerative medicine.</td></tr>
</table>

Text Books, and/or reference material	Text Books 1. Stem Cells, Tissue Engineering And Regenerative Medicine By: David Warburton 1st Edition. 2. Principles of Regenerative Medicine byAnthony Atala Robert Lanza Tony Mikos Robert Nerem , 3rd Edition. 3. Translational Regenerative Medicine by Anthony Atala and Julie G. Allickson Reference Books: 1. The Developping Human by Keith L. Moore/T.V.N. Persaud/ Mark G. Tenth edition. 2. Encyclopedia of Tissue Engineering and Regenerative Medicine by Rui Reis, Ist Edtion

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	
BT9122	Molecular Virology	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: To acquire an understanding of virus life cycle and host-virus interactions. • CO2: To acquire an idea about detection, prevention and treatment of virus infections. • CO3: To learn about the use of virus in biotechnology.						
Topics Covered	Brief history and principles of virology. (1) Principles of virus classification. (2) General structure of viruses; Viroids, Virusoids, Satellite viruses, and Prions. (2) Genome of plant and animal viruses. Mobile genetic elements. (4) Replications of RNA viruses. (5) Replication of DNA viruses. (5) Virus-cell interactions: cytopathology; virus entry and egress; host cell shut off and IRES; viral persistence and latency. (6) Methods to diagnose virus infections. (3) Antiviral vaccines. (3) Antivirals: interferons and its mechanisms of action. (2) Gene silencing. (2) Culture and purification of viruses. (2) Viral vectors and gene therapy. (2) New and emerging viruses (3)						

Text Books, and/or reference material	Text Books Principles of Virology: 4th Edition. By S. Jane Flint, Vincent R. Racaniello, Glenn F. Rall, Anna Marie Skalka, and Lynn W. Enquist. Reference Books: Fields Virology by Lippincott Williams and Wilkins.

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	
BT9123	Host – Pathogen Interactions	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	• CO1: Account for structure and function of infectious viruses, bacteria and parasites. • CO2: Explain the interplay between pathogen functions and host immune responses. • CO3: Account for the most common diagnostic methods and treatments within infection biology and for the mechanisms of antibiotic resistance • CO4: Analyse infection biological research data, draw conclusions, and propose testable • hypotheses from the analysed data.						
Topics Covered	The fundamental structure of bacteria, especially structures and mechanisms important for pathogenicity and virulence. Components and structures of viral particles and the basis of virus classification. General and specific properties of infectious protozoa and worms. Adaptive and innate immunity. Virulence factors: Description of the most common virulence mechanisms. Bacterial, viral and parasitological infections and host immune modulation. Diagnostics and vaccination: Basal principles for diagnosis and vaccination. The basis for PCR, RT-PCR, immunofluorescence, ELISA, FACS and Western blotting. Antibiotics and antibiotics resistance: Principles of antibiotic mechanisms. Mechanisms of the origin of antibiotics resistance.						
Text Books, and/or reference material	Text Books 1. Roitt's Essential Immunology 2. Immunobiology: The immune system in health and disease by Charles Janeway et al 3. Kuby Immunology 4. Relevant review articles/research papers/handouts provided in the course. Reference: Fields Virology by Lippincott Williams and Wilkins.						

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<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>BT9124</td><td>Infection Biology</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• 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="7">Origin of Infection; Evolution of infectious diseases; Concept of Infection: Immunity, Immune surveillance, Virulence, Pathogenesis.
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.
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.
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.
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; Infection and life style- Concepts of Microbiome; Neglected diseases.
Spread of Infectious diseases; Disease epidemiology, Steps involved in epidemiology and epidemiological case studies; Purpose of infection control, Regulations, policy and practice; Roles and responsibilities in infection control; Risk assessments; Principles of infection control procedures.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases-
8thEdition; Volume I and II. By John E. Bennett, Raphael Dolin, Martin J. Blaser.</td></tr>
</table>

	SaudersPublication. 2. Immunology of Infectious Diseases. Edited by Stephan Kaufmann, Alan Sher, and Rafi Ahmed. American Society for Microbiology. 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.

(Elective III)

<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>BT9131</td><td>Nano-biotechnology</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">NA</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Book:
1. Understanding Nanomedicine - An Introductory Textbook by Rob Burgess.

Refrences 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.</td></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT9132</td><td>Nutraceuticals & Nutrigenomics</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">NA</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Understand the role of nutraceuticals in cellular physiology.
• CO2: Understand basics of genetics, genomics and gene regulation with relation to diet.
• CO3: Understand the application of nutraceuticals and its market potentials.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books
1. 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.
2. Nutraceuticals by Lisa Rapport, Brian Lockwood, Pharmaceutical press.

References:
1. Nutragenomics and Proteomics in Health Promotion and Disease Prevention by
Mohamed M. Rafi, FereidoonShahidi, CRC Press
2. Nutraceuticals: The Complete Encyclopedia of Supplements, Herbs, Vitamins, and Healing Foods by Arthur J. Roberts, GenelleSubak-Sharpe, Mary E. O'Brien (Designer), Perigee Trade
3. Regulation of Functional Foods and Nutraceuticals: A Global Perspective by Clare Hasler, Blackwell Publishing Professional.</td></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT9133</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="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To learn about the basic concepts of Metabolic Engineering.
• CO2: To understand the manipulation of metabolic pathways to enhance the yield and quality of the products.
• CO3: To learn and understand the models and the concepts required for the purpose of metabolic flux analysis.
• CO4: To study the methods and application of metabolic flux analysis.
• CO5: To analyze metabolic networks.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Importance of metabolic engineering.
Review of cellular metabolism, Regulation of metabolic pathways, Examples of pathway manipulations: metabolic engineering in practice – enhancement of product yield and productivity.
Extension of product spectrum and novel products (antibiotics, biopolymers, polyketides, vitamins etc), Improvement of cellular properties.
Metabolic modeling: Introduction to models for cellular reactions-stoichiometry,
rates, and yield coefficients of cellular reactions, black box stoichiometries.
Material balance & data consistency: Black box model; elemental balances, degree of reduction balances, Heat balance.
Biochemical reaction networks: simple metabolic networks, flux analysis in metabolic networks; Metabolic control analysis.
Xenobiotic degradation.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Metabolic Engineering: Principles and Methodologies, Gregory N. Stephanopoulos, Aristos A. Aristidou, Jens Nielsen, Academic Press.
2. Bioreaction Engineering Principles, Jens Nielsen, John Villadsen, Gunnar Liden, Springer.

Reference Books:
1. Pathway Analysis and Optimization in Metabolic Engineering, Néstor V. Torres, Eberhard O. Voit, Cambridge University Press.
2. An Introduction to Metabolic and Cellular Engineering, S. Cortassa, M. A. Aon, A.A. Iglesias, D. Lloyd, World Scientific Publishing Company.</td></tr>
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<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>BT9134</td><td>Drug Discovery and Development</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of this course, students should be able to understand basics of R&D in drug discovery and should be able to apply knowledge gained in respective fields of pharmaceutical industry.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Target identification and molecular modelling
Identification of target or drug leads associated with a particular disease by a number of different techniques including combinations of molecular modeling, combinatorial libraries and high-throughput screening (HTS); Conceptualizing the automation of the HTS process and the importance of bioinformatics and data processing in identification of lead compounds; Rational drug design, based on understanding the three-dimensional structures and physicochemical properties of drugs and receptors; Modelling drug/receptor interactions with the emphasis on molecular mechanisms, molecular dynamics simulations and homology modelling; Conformational sampling, macromolecular folding, structural bioinformatics, receptor-based and ligand-based design and docking methods, in silico screening of libraries, semi-empirical and ab-initio methods, QSAR methods, molecular diversity, design of combinatorial libraries of drug-like molecules,
macromolecular and chemical databases.
Lead optimization
Identification of relevant groups on a molecule that interact with a receptor and are
responsible for biological activity; Understanding structure activity relationship; Structure modification to increase potency and therapeutic index; Concept of quantitative drug design using Quantitative structure–activity relationship models (QSAR models) based on the fact that the biological properties of a compound are a function of its physicochemical parameters such as solubility, lipophilicity, electronic effects, ionization, stereochemistry, etc.; Bioanalytical assay development in support of in vitro and in vivo studies (LC/MS/MS, GC/MS and ELISA).
Preclinical development
Principles of drug absorption, drug metabolism and distribution - intestinal absorption, metabolic stability, drug-drug interactions, plasma protein binding assays, metabolite profile studies, Principles of toxicology, Experimental design for preclinical and clinical PK/PD/TK studies, Selection of animal model; Regulatory guidelines for preclinical PK/PD/TK studies; Scope of GLP, SOP for conduct of clinical & non clinical testing, control on animal house, report preparation and documentation Integration of non-clinical and preclinical data to aid design of clinical studies.
Drug manufacturing</td></tr>
</table>

	Requirements of GMP implementation, Documentation of GMP practices, CoA, Regulatory certification of GMP, Quality control and Quality assurance, concept and philosophy of TQM, ICH and ISO 9000; ICH guidelines for Manufacturing, Understanding Impurity Qualification Data, Stability Studies. **Clinical trial design** Objectives of Phase I, II, III and IV clinical studies, Clinical study design, enrolment, sites and documentation, Clinical safety studies: Adverse events and adverse drug reactions, Clinical PK, pharmacology, drug-drug interaction studies, Statistical analysis and documentation. **Fundamentals of regulatory affairs and bioethics** Global Regulatory Affairs and different steps involved, Regulatory Objectives, Regulatory Agencies; FDA guidelines on IND and NDA submissions, Studies required for IND and NDA submissions for oncology, HIV, cardiovascular indications, On-label vs. off-label drug use GCP and Requirements of GCP Compliance, Ethical issues and Compliance to current ethical guidelines, Ethical Committees and their set up, Animal Ethical issues and compliance.
Text Books, and/or reference material	Text Books: 1. Krogsgaard-Larsen et al. Textbook of Drug Design and Discovery. 4th Edition. CRC Press. 2. Kuhse, H. (2010). Bioethics: an Anthology. Malden, MA: Blackwell. 3. Nally, J. D. (2006) GMP for Pharmaceuticals. 6th edition. CRC Press 4. Brody, T. (2016) Clinical Trials: Study Design, Endpoints and Biomarkers, Drug Safety, and FDA and ICH Guidelines. Academic Press.

(Elective IV)

<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>BT9141</td><td>Bioprocess Engineering & Technology</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">NA</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">Students should be able to:
• CO1: Appreciate relevance of microorganisms from industrial context.
• CO2: Carry out stoichiometric calculations and specify models of their growth.
• CO3: Give an account of design and operations of various fermenters.
• CO4: Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products.
• CO5: Calculate yield and production rates in a biological production process, and also interpret data.
• CO6: Calculate the need for oxygen and oxygen transfer.
• CO7: Critically analyse any bioprocess from market point of view.
• CO8: Give an account of important microbial/enzymatic industrial processes in food and fuel industry.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Basic principles of biochemical engineering
Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.
Stoichiometry and models of microbial growth
Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.
Bioreactor design and analysis
Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformation; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.
Downstream processing and product recovery
Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.</td></tr>
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	Fermentation economics Isolation of micro-organisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling; effluent treatment and disposal. **Applications of enzyme technology in food processing** Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions *e.g.* starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein *etc.* and their downstream processing; baking by amylases, deoxygenation and desugaring by glucoses oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing. **Applications of microbial technology in food process operations and production, biofuels and biorefinery** Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria–production and applications in food preservation; biofuels and biorefinery.
Text Books, and/or reference material	Text Books: 1. Shuler, M. L., & Kargi, F. (2002). *Bioprocess Engineering: Basic Concepts.* Upper Saddle River, NJ: Prentice Hall. 2. Stanbury, P. F., & Whitaker, A. (2010). *Principles of Fermentation Technology*. Oxford: Pergamon Press. 3. Blanch, H. W., & Clark, D. S. (1997). *Biochemical Engineering.* New York: M. Dekker.

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	
BT9142	Environmental Biotechnology	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	Students will be able to: • CO1: Understand the use of basic microbiological, molecular and analytical methods, which are extensively used in environmental biotechnology. • CO2: Apply microbiological, molecular and analytical methods to solve issues related to cleaning up environment, development of sustainable technology and agriculture.						
Topics Covered	**Introduction to environment** Introduction to environment; pollution and its control; pollution indicators; waste						

	management: domestic, industrial, solid and hazardous wastes; strain improvement; Biodiversity and its conservation; Role of microorganisms in geochemical cycles; microbial energy metabolism, microbial growth kinetics and elementary chemostat theory, relevant microbiological processes, microbial ecology. **Bioremediation** Bioremediation: Fundamentals, methods and strategies of application (biostimulation, bioaugmentation) – examples, bioremediation of metals (Cr, As, Se, Hg), radionuclides (U, Te), organic pollutants (PAHs, PCBs, Pesticides, TNT etc.), technological aspects of bioremediation (in situ, ex situ). **Role of microorganisms in bioremediation** Application of bacteria and fungi in bioremediation: White rot fungi vs specialized degrading bacteria: examples, uses and advantages vs disadvantages; Phytoremediation: Fundamentals and description of major methods of application (phytoaccumulation, phytovolatilization, rhizofiltration phytostabilization). **Biotechnology and agriculture** Bioinsecticides: Bacillus thuringiensis, Baculoviruses, uses, genetic modifications and aspects of safety in their use; Biofungicides: Description of mode of actions and mechanisms (e.g. Trichoderma, Pseudomonas fluorescens); Biofertilizers: Symbiotic systems between plants – microorganisms (nitrogen fixing symbiosis, mycorrhiza fungi symbiosis), Plant growth promoting rhizobacteria (PGPR) – uses, practical aspects and problems in application. **Biofuels** Environmental Biotechnology and biofuels: biogas; bioethanol; biodiesel; biohydrogen; Description of the industrial processes involved, microorganisms and biotechnological interventions for optimization of production; Microbiologically enhanced oil recovery (MEOR); Bioleaching of metals; Production of bioplastics; Production of biosurfactants: bioemulsifiers; Paper production: use of xylanases and white rot fungi.
Text Books, and/or reference material	Text Books: 1. G. M. Evans and J. C. Furlong (2003), Environmental Biotechnology: Theory and Applications, Wiley Publishers. 2. B. Ritmann and P. L. McCarty, (2000), Environmental Biotechnology: Principle & Applications, 2nd Ed., McGraw Hill Science. 3. Scragg A., (2005) Environmental Biotechnology. Pearson Education Limited. 4. J. S. Devinny, M. A. Deshusses and T. S. Webster, (1998), Biofiltration for Air Pollution Control, CRC Press. 5. H. J. Rehm and G. Reed, (2001), Biotechnology – A Multi-volume Comprehensive Treatise, Vol. 11, 2nd Ed., VCH Publishers Inc. 6. H. S. Peavy, D. R. Rowe and G. Tchobanoglous, (2013), Environmental Engineering, McGraw-Hill Inc.

<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>BT9143</td><td>Industrial Microbiology</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">NA</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">Students will be able to:
• CO1: Describe the main steps and processes used to produce biological products in industry.
• CO2: Discover new useful microorganisms and store them reliably for later use.
• CO3: Evaluate which molecular techniques are applicable to improve production.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Characteristics of microbes: Introduction to Microbiology and Microbes, Morphology, Structure and Growth, Bacterial and other Microbial growth curves.
Isolation of microbes from nature and screening of biological activities: Actinomycetes, Bacteria, Fungi, Developing and Semi-automating Screening Tests.
Culture preservation and inoculum development: Culture Preservation, Cryopreservation, Inoculum Development.
Small scale liquid fermentation: Introduction and Scope, Fermentation Vessels, Shakers, Media /Composition and Gas Exchange, Sampling and Analysis.
Small scale solid state fermentation: Advantages/Disadvantages of Solid State Fermentation, Growth and Production of Enzymes, Small Scale Process Control.
Experimental designs for improvement of fermentation: Sequential Nature of Design Experiments, Screening Designs, Optimization Designs and Verification of Models.
Cell and enzyme immobilization: Different types of Immobilizations (entrapment, cross linking, covalent etc.), Performance and case studies.
Strain improvements by recombinant and non-recombinant methods: Recombinant Methods, Non recombinant (Mutagenesis, fusion, recombination etc.), Operational Conditions, Statistical analysis.
Culture and analysis using gel microdrops: GMD’s for Culture and Assays, Open
GMD’s, Closed GMD’s.
Culture of extremophiles: Culture strategies and Challenges, Preservation, Batch and Continuous cultivation etc.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. M.T. Madigan and J.M. Martinko, (2006), Brock Biology of Microorganisms, 11th Ed, Pearson Prentice-Hall.
2. J. M. Willey, L. Sherwood, C.J. Woolverton, L.M. Prescott, (2011), Prescott’s Microbiology, McGraw Hill, New-york.
3. A.L. Demain and J. Davies, (2004), Manual of Industrial Microbiology and Biotechnology, 2nd Ed.ASM Press.</td></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>BT9144</td><td>Protein Engineering</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="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">Students should be able to:
• CO1: Describe structure and classification of proteins.
• CO2: Design strategies to alter protein sequence to alter properties and function of proteins.
• CO3: Analyse purity and stability of proteins and explain how to store them in best way.
• CO4: Gain understanding of structure driven drug designing.
• CO5: Analyse structure and construction of proteins by computer-based methods.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to protein engineering
Protein engineering – definition, applications; Features or characteristics of proteins that can be engineered (definition and methods of study) – affinity and specificity;
Spectroscopic properties; Stability to changes in parameters as pH, temperature and amino acid sequence, aggregation propensities, etc. Protein engineering with unnatural amino acids and its applications.
Stability of protein structure
Methods of measuring stability of a protein; Spectroscopic methods to study physicochemical properties of proteins: far-UV and near-UV CD; Fluorescence; UV absorbance; ORD; Hydrodynamic properties–viscosity, hydrogen-deuterium exchange; Brief introduction to NMR spectroscopy – emphasis on parameters that can be measured/obtained from NMR and their interpretation.
Applications
Forces stabilizing proteins – Vander waals, electrostatic, hydrogen bonding and weakly polar interactions, hydrophobic effects; Entropy – enthalpy compensation; Experimental methods of protein engineering: directed evolution like gene site saturation mutagenesis; Module shuffling; Guided protein recombination, etc., Optimization and high throughput screening methodologies like GigaMetrix, High throughput microplate screens etc., Application to devices with bacteriorhodopsin as an example; Engineering antibody affinity by yeast surface display; Applications to vaccines, Peptidomimetics and its use in drug discovery.
Computational approaches
Computational approaches to protein engineering: sequence and 3D structure analysis, Data mining, Ramachandran map, Mechanism of stabilization of proteins from psychrophiles and thermophiles vis-a-vis those from mesophiles; Protein design, Directed evolution for protein engineering and its potential.</td></tr>
</table>

Text Books, and/or reference material	1. Edited by T E Creighton, (1997), Protein Structure: a Practical Approach, 2nd Edition, Oxford university press. 2. Cleland and Craik, (2006), Protein Engineering, Principles and Practice, Vol 7, Springer Netherlands. 3. Mueller and Arndt, Protein Engig Protocols, 1st Edition, Humana Press. 4. Ed. Robertson DE, Noel JP, (2004), Protein Engineering Methods in Enzymology, 388, Elsevier Academic Press. 5. J Kyte; (2006), Structure in Protein Chemistry, 2nd Ed, Garland publishers.

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