SCHEME OF EXAMINATION

&

SYLLABI

For

Bachelor of Technology

In Biotechnology
(III to VIII Semester)

Offered by

University School of Biotechnology
(2021 onwards)

Guru Gobind Singh Indraprastha University
Sector 16C, Dwarka, Delhi – 110 078 [INDIA]

Program Outcomes (POs)

PO1: Apply the knowledge of mathematics, science, engineering fundamentals, and Engineering specialization to the solution of complex engineering problems

PO2: Design solutions for complex engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO3: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO4: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO5: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

PO6: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

PO7: Appreciate and execute their professional roles in society as biotechnology professionals, employers and employees in various industries, regulators, researchers, educators and managers.

PO8: Adopt code of ethics in professional and social context and demonstrate exemplary professional, ethical and legal behaviors in decision making.

PO9: Apply written and oral communication skills to communicate effectively in healthcare, industry, academia and research.

PO10: Apply responsibilities to promote societal health and safety, upholding the trust given to the profession by the society.

Program Specific Outcomes (PSOs)

PSO1: Acquire knowledge on the fundamentals of biotechnology for sound and solid base which enables them to understand the emerging and advanced engineering concepts in life sciences.

PSO2: Empower the students to acquire technological knowhow by connecting disciplinary and interdisciplinary aspects of biotechnology.

PSO3: Recognize the importance of Bioethics, IPR, entrepreneurship, Communication and management skills so as to usher next generation of Indian industrialists.

PSO4: Students will be able to gain fundamental knowledge in animal and plant biotechnology and their applications.

PSO5: Students will be equipped to understand three fundamental aspects in biological

phenomenon: a) what to seek; b) how to seek; c) why to seek?

PSO6: Students will be able to gain hands on experience in gene cloning, protein expression and purification. This experience would enable them to begin a career in industry that engages in genetic engineering as well as in research laboratories conducting fundamental research.

Bachelor in Biotechnology Semester III to VIII – Syllabus
To be Implemented from Academic Session 2021-22

Semester III

Group	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-201	Microbiology	3	1	4
PC	BA-203	Biochemistry	3	1	4
PC	BT-205	Cell Biology	3	1	4
PC	BT-209	Genetics	3	1	4
PC	CT-211	Introduction to Material and Energy Balance	3	1	4
Practical/Viva Voce					
PC	BT-251	Genetics-Lab	0	3	1.5
PC	CT-253	Introduction to Material and Energy Balance - Lab	0	3	1.5
PC	BT-255	Cell Biology – Lab	0	3	1.5
PC	BT-257	Microbiology Lab	0	3	1.5
PC	BA-259	Biochemistry Lab	0	3	1.5
NUES*		NCC/NSS/YFE and other activities	0	2	2
Total			15	22	29.5

*NUES: Comprehensive evaluation of the students by the concerned coordinator of NCC / NSS / Cultural Clubs / Technical Society / Technical Clubs, out of 100.These activities shall start from the 1st semester and the evaluation shall be completed by the end of the 6th semester.

SEMESTER IV

Group	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-202	Immunology and Immunotechnology	3	1	4
PC	BT-204	Molecular Biology	3	1	4
PC	BT-206	Enzyme Technology	3	1	4
PC	BT-208	Techniques in Biotechnology	3	1	4
PC	CT-212	Fundamentals of Heat and Mass Transfer	3	1	4
Practical/Viva Voce					
PC	BT-254	Molecular Biology – Lab	0	3	1.5
PC	BT-256	Enzyme Technology – Lab	0	3	1.5
PC	BT-258	Immunology and Immunotechnology – Lab	0	3	1.5
PC	BT-260	Techniques in Biotechnology-Lab	0	3	1.5
Total			**15**	**17**	**26**

SEMESTER V

Code	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-305	Animal Biotechnology	3	1	4
PC	BT-307	Recombinant DNA Technology	3	1	4
PC	BT-311	Plant Biotechnology	3	1	4
PC	BT-313	Unit Operations and Plant Design for Biomanufacturing	3	1	4
*PCE-1/***EAE-1	BT-315	*Professional Core elective-1/***Elective in Emerging Areas-1	3	1	4
**OAE-1	BT-317	**USBT Open area elective-1 or Elective from other schools	3	1	4
Mandatory course	USMS112	Entrepreneurial Mindset	2		2
Practical/Viva Voce					
PC	BT-353	Unit Operations and Plant Design for Biomanufacturing Lab	0	3	1.5
PC	BT-355	Animal tissue Culture – Lab	0	3	1.5
PC	BT-357	Recombinant DNA Technology-Lab	0	3	1.5
PC	BT-361	Plant Biotechnology – Lab	0	3	1.5
Total			**18**	**18**	**32**

***PCE: Professional Core Elective-1 (Select any one)**

		L	T/P	Credits
PCE-1	Stem Cell Technology	3	1	4
PCE-1	Environmental Sustainability	3	1	4
PCE-1	Pharmacogenomics	3	1	4

****OAE: Open Area Electives-1 Offered by USBT (Select any one)**

		L	T/P	Credits
OAE-1	Biomaterials	3	1	4
OAE-1	Precision Medicine and Wellness	3	1	4
OAE-1	Regenerative Medicine	3	1	4
	MOOCs (Only Govt. approved platforms like SWAYAM, NPTEL, e-PG Pathshala, etc.)			4

***** EAE: Emerging Area Elective-1 offered by USBT (Select any one)**

EAE1-BT	Nanobiotechnology	L	T/P	Credits
EAE1-BT	Rational Drug discovery	3	1	4
EAE1-BT	Artificial Intelligence in Healthcare	3	1	4

SEMESTER VI

Group	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-314	Bioinformatics	3	1	4
PC	BT-316	Intellectual Property Rights, Biosafety and Bioethics in Biotechnology	3	1	4
PC	BT-318	Downstream Processing	3	1	4
PC	BT-322	Bioprocess Engineering	3	1	4
PCE-2*/ EAE-2***	BT-312	*Professional Core Elective-2/ ***Elective in Emerging Areas-2	3	1	4
OAE-2**	BT-320	**Open area elective offered by USBT-1 or Elective from other schools	3	1	4
Practical/Viva Voce					
PC	BT-352	Bioinformatics – Lab	0	3	1.5
PC	BT-360	Bioprocess Engineering – Lab	0	3	1.5
PCE	BT-354	Food and Nutrition Technology -Lab	0	3	1.5
Total			**18**	**15**	**28.5**

***PCE: Professional Core Elective-2 (any one)**

		L	T/P	Credits
PCE-2	Statistical Methods in Biology and Experimental Design	3	1	4
PCE-2	Food and Nutrition Technology	3	1	4
PCE-2	Food and Nutrition Technology- Lab	0	3	1.5
PCE-2	Data Science			

****Open Area Elective-2 (any one)**

		L	T/P	Credits
OAE-2	Plant Secondary Metabolites and Their Applications	3	1	4
OAE-2	Waste Management and Upcycling	3	1	4
OAE-2	Artificial Intelligence for Designing Therapeutics	3	1	4
	MOOCs (Only Govt. approved platforms like SWAYAM, NPTEL, e-PG Pathshala, etc.)			4

SEMESTER VII

Group	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-401	Genome engineering and editing	3	1	4
PC	BT-403	Environmental Biotechnology	3	1	4
PCE-3*	BT-405	*Professional Core Elective-3	3	1	4
PCE-4**	BT-407	**Professional Core Elective-3	3	1	4
OAE-3***	BT-409	***Open area elective-3	3	1	4
Practical/Viva Voce					
PC	BT-453	Environmental Biotechnology-Lab	0	3	1.5
PC	BT-455	Genome Engineering and Editing		3	1.5
PCE-3	BT-451	Protein Biotechnology -Lab	0	3	1.5
PCE-4	BT-457	Computational Biology -Lab	0	3	1.5
Total			**15**	**17**	**26**

***PCE: Professional Core Elective-3: (Select any one)**

		L	T/P	Credits
PCE-3	Protein Biotechnology	3	1	4
PCE-3	Protein Biotechnology -Lab	0	3	1.5
PCE-3	Good laboratory practices and good manufacturing practices	3		3
****Professional Core Electives-4: (Select any one)**				
PCE-4	Computational Biology	3	1	4
PCE-4	Computational Biology-Lab	0	3	1.5
PCE-4	Green Biotechnology	3	1	4
PCE-4	Internet of Things in Agriculture	3	1	4

*****OAE: Open Area Electives-3 (Select any one)**

		L	T/P	Credits
OAE-3BT	Plant Stress Biology	3	1	4
OAE-3BT	Deep Learning in Biotechnology	3	1	4
OAE-BT	Tissue Engineering	2	1	3
	MOOCs (Only Govt. approved platforms like SWAYAM, NPTEL, e-PG Pathshala, etc.)			4

SEMESTER VIII

Group	Paper Code	Paper	L	T/P	Credits
Practical/Viva Voice					
	BT-450	*Project Work			12
	BT-452	**Journal Club/Seminar			2
Total					**14**

%*By default every student shall do a project work under the supervision of USBT faculty. Evaluation shall be conducted of 40 marks (Teachers' continuous evaluation/internal assessment) by the supervisor and 60 marks by an external examiner deputed by examinations division (COE) for a total of 100 marks.
**Evaluation shall be conducted for 40 marks (Teachers' continuous evaluation / internal assessment) by appointed teacher and for 60 marks by a bench comprising of all faculty and an external examiner deputed by examinations division (COE) for a total of 100 marks.

In the absence of any supervisor/faculty, Dean of the school can assign responsibility of the supervisor (for purpose of examinations) to any faculty of the School.

Note:

1) The programme of study shall be governed by ordinance 11 of the university.
2) Total credits for B.Tech. in Biotechnology (1-8 semesters): 214
Minimum credits required: 200

Bachelor in Biotechnology Semester III to VIII – Syllabus
To be Implemented from Academic Session 2021-22
Semester III

Group	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-201	Microbiology	3	1	4
PC	BA-203	Biochemistry	3	1	4
PC	BT-205	Cell Biology	3	1	4
PC	BT-209	Genetics	3	1	4
PC	CT-211	Introduction to Material and Energy Balance	3	1	4
Practical/Viva Voce					
PC	BT-251	Genetics-Lab	0	3	1.5
PC	CT-253	Introduction to Material and Energy Balance - Lab	0	3	1.5
PC	BT-255	Cell Biology - Lab	0	3	1.5
PC	BT-257	Microbiology -Lab	0	3	1.5
PC	BA-259	Biochemistry -Lab	0	3	1.5
NUES*		NCC/NSS/YFE and other activities	0	2	2
Total			15	22	29.5

*NUES: Comprehensive evaluation of the students by the concerned coordinator of NCC / NSS / Cultural Clubs / Technical Society / Technical Clubs, out of 100.These activities shall start from the 1st semester and the evaluation shall be completed by the end of the 6th semester.

Paper Code: BT-201	Paper name: Microbiology	L	T	P	C
Paper id:	(3rd Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To understand microbial structure, growth, nutrition, metabolism and fermentation
2. To understand microbial classification and identification and their diversity
3. To understand the role of microbes in health, environment and industrial applications

Course Outcomes: After successful completion of this course, the students should be able to gain:

1. Knowledge and use of microbial structure, growth, metabolism and fermentation
2. Knowledge and use of classification and identification of various groups of microbes
3. Knowledge and use of the role of microbes in health, environment and industry

1. **Microbes in Human Life:** Introduction of microorganisms, Brief history and scope of microbiology, Microbes & human welfare, Microbes & disease. **(2)**

2. **Functional Anatomy of Prokaryotic Cells:** Size, shape and arrangement of bacterial cells, Structure of the cell and cell wall, Preparation and staining of specimens for microscopy. **(2)**

3. **Microbial Growth:** Nutritional requirements and nutritional categories, nutrients uptake by microbial cells, Culture media, Isolation of pure cultures, Cultivation and preservation of cultures, Microbial growth Kinetics. **(4)**

4. **Control of Microbial Growth:** Physical and chemical methods of microbial control, Action of microbial control agents and evaluation of effectiveness of antimicrobial agents. **(4)**

5. **Microbial Physiology and Metabolism:** Metabolic diversity and pathways of energy use, unique pathways of microbial fermentation and photosynthesis. **(4)**

6. **Microbial Taxonomy:** Classification of microorganism, Methods of classification and identification of microorganisms, Assessing Microbial phylogeny, Bacterial diversity- archaebacteria, eubacteria, fungi, algae, protozoa and helminthes. **(4)**

7. **A Survey of the Microbial World:** General characteristics of representative microorganisms of each group
   Archaebacteria - *halophiles, thermophiles and methanogens*
   Eubacteria: Gram -ve (Proteobacteria- *Chlamydia, Spirochaetes),* Nonproteobacteria *(E. coli, Psuedomonas, Rhizobium,),* Gram +ve bacteria *(Bacillus, Staphylococcus, Mycoplasma, Streptomyces),* Fungi (Yeast and Rhizopus), lichens
   Viruses (Viral structures, Cultivation and identification and viral multiplication). **(8)**

8. **Microbial Interactions with Humans:** Principles of disease and epidemiology, Microbial diseases and their control, Mechanism of microbial pathogenicity, history, spectrum and action of antibiotics and other antimicrobial drugs, Superbugs and opportunistic infections, Biosecurity, Microbiome.**(6)**

9. **Applied and Industrial Microbiology:** Industrial fermentation, Primary and Secondary metabolites, Role of microorganisms in the production of probiotics, industrial chemicals and pharmaceuticals, biofilms, Microbes as alternative energy sources, bioremediation, and as industrial products. **(6)**

Text / Reference Books:

1. Microbiology: An Introduction by Tortora, Funke and Case. 13th Edition, 2019.
2. Prescott, Harley and Klein's Microbiology by Willey J, Kathleen Sandman K and Wood D, ISE 2019.
3. Brock Biology of Microorganisms by Madigan MT, and Martinko JM, Bender KS,. 14th edition. Prentice Hall International Inc, 2014

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	2	3	1	1	2	3	2	2	3	1	3
CO2	2	2	3	2	2	2	3	2	2	3	1	3
CO3	3	3	3	2	2	3	3	2	2	3	2	3

Paper Code: BA-203	Paper name: Biochemistry	L	T	P	C
Paper id:	(3rd Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To provide an advanced understanding of the core principles and topics of biochemistry, their experimental basis and enable students to acquire a specialised knowledge & understanding of structure and functions of biomolecules like; Proteins, Carbohydrates and Lipids.
2. To provide understanding of characterisation, separation and clinical significance of biomolecules like:; Proteins, Carbohydrates and Lipids.
3. To provide understanding of metabolic pathways and their regulation with respect to biomolecules like: Proteins, Carbohydrates and Lipids.
4. To provide hands on approach and learnings of different laboratory techniques in the biochemical laboratory.

Course Outcomes: at the end of the course students will be able to:

1. Understand the structural and functional relationships of biological molecules that form the basis of living organisms.
2. Understand how biomolecules are isolated and characterised through various analytical techniques that are used in contemporary biochemistry laboratories.
3. Gain understanding on fundamental biochemical principles of metabolism of biomolecules (Proteins, Carbohydrates, Lipids). They will learn the biochemical reactions in metabolic pathways and understand their interrelations. Students would also gather a firm understanding and relevance of stringent regulations of metabolic pathways.
4. Have better practical understanding of methods/techniques covered in theory course.

1. **Amino acids:** Classification, Structure, Function, Methods of Characterization, Separation Techniques based on their structure and properties, Clinical Significance. **(3)**

2. **Proteins:** Classification, Primary, Secondary, Tertiary and Quaternary structure, Function, Methods of separation & characterisation and Modification of proteins. **(3)**

3. **Carbohydrates:** Mono, oligo and Polysaccharide, Classification, Structure, Function, Separation and Characterization Techniques, Clinical significance. **(6)**

4. **Lipids:** Classification, Structure, Function, Separation and Characterization Techniques, Clinical Significance. **(6)**

5. **Catabolic pathways and their Regulations:** Carbohydrates, Proteins and Lipids; Glycolysis, Protein catabolism, Fatty acid degradation and their regulations. **(5)**

6. **Anabolic pathways and their regulations:** Carbohydrates, Proteins and Lipids; Gluconeogenesis, Translation, Biosynthesis of saturated fatty acids and their regulations. **(5)**

7. **The Tricarboxylic Acid Cycle:** Discovery of the TCA Cycle, Steps in the TCA Cycle, Stereochemical Aspects of TCA Cycle Reactions, ATP Stoichiometry of the TCA Cycle, Thermodynamics of the TCA Cycle, The Amphibolic Nature of the TCA Cycle, The Glyoxylate Cycle, Regulation of TCA Cycle Activity, Anaplerotic Reactions. **(6)**

8. **Electron Transport and Oxidative Phosphorylation:** The Mitochondria Electron - Transport Chain, Oxidative Phosphorylation, Transport of Substrates, Pi, ADP and ATP into and out of Mitochondria, Electron Transport and ATP Synthesis in Bacteria.**(6)**

Text / Reference Books:

1. Lehninger Principles of Biochemistry by Nelson DL and Cox MM. W H Freeman & Co. 2017.
2. Biochemistry by Lubert Stryer. 4th Edition W H Freeman & Co. 1995.
3. An introduction to practical biochemistry by Plummer D. T. 2012.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	3	3	1	1	3	3	3	3	3
CO2	3	2	3	3	3	2	1	3	3	3	3	3
CO3	3	2	3	3	3	1	1	3	3	3	3	3
CO4	3	2	3	3	3	2	2	3	3	3	3	3

Paper Code: BT-205	Paper name: Cell Biology	L	T	P	C
Paper id:	(3rd Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To understand the structure and purpose of basic components of prokaryotic and eukaryotic cells, especially macromolecules, membranes, and organelles and the cytoskeleton.
2. To understand the process of cellular signaling, transport and trafficking with emphasis on the sub-cellular bio-molecules participating in these processes.
3. To know in detail the cell cycle, cellular replication process and cellular aberrations during oncogenic conditions.

Course Outcomes:

After successful completion of this course, the students should be able to understand:

1. The basic components of prokaryotic and eukaryotic cells
2. How molecules are transported across cell.
3. How cells perceive and transmit signal.
4. How cell undergo division and its regulation.

1. **The Cell:** Discovery of Cells and the Development of Cell Biology, Prokaryotic cell, Eukaryotic cells, Cellular compartmentalization, Organellar architecture. **(3)**

2. **The Nucleus:** Chromosomal DNA and its Packaging, The Global Structure of Chromosome. **(4)**

3. **Cytoskeleton:** The Nature of the Cytoskeleton, Intermediate Filaments, Microtubules, Cilia and Centrioles, Actin Filaments, Actin-binding Proteins, Muscle. **(4)**

4. **Cell Junctions, Cell Adhesion, and the Extracellular Matrix :** Cell Junctions, Cell-Cell Adhesion, The Extracellular Matrix of Animals, Extracellular Matrix Receptors on Animal Cells- the Integrins, The Plant Cell Wall. **(4)**

5. **Membrane Structure, Transport of Molecules and Membrane Excitability:** The Lipid Bilayer, Membrane Proteins, Principles of Membrane Transport, Carrier Proteins and Active Membrane Transport, Ion channels and Electrical Properties of Membrane. **(5)**

6. **Protein Sorting and Vesicular Trafficking in the Cell:** The Compartmentalization of Higher Cells, The Transport of Molecules into and out of the Nucleus, The Transport of Proteins into Mitochondria and Chloroplasts, Peroxisomes, The endoplasmic reticulum., Transport from the ER through the Golgi Apparatus, Transport from the Trans Golgi Network to Lysosomes, Transport from the Plasma Membrane via Endosome: Endocytosis, The Molecular Mechanisms of Vesicular Transport and the Maintenance of Compartmental Diversity. **(6)**

7. **Cell Signaling:** General Principles of Cell Signaling, Signaling via G-Protein-linked Cell-Surface Receptors, Signaling via Enzyme-linked Cell-Surface Receptors, Kinase Receptors, Structural Features of Trans-membrane Receptors, Hormone Receptor Interaction, Two-component signaling, Second messengers. **(6)**

8. **Cell Cycle and Division:** The General Strategy of the cell Cycle, The Mechanics of Cell Division, The Early Embryonic Cell Cycle, Cell- Cycle control in Yeasts and Multicellular Animal. **(4)**
9. **Cancer:** Cancer as a Microevolutionary Process, Tumor cells, Proto-oncogenes and viral oncogenes, Tumor suppressor genes. **(4)**

Text / Reference books:

1. Molecular Biology of Cell by Bruce Alberts, et al., Garland Science. 2017.
2. The World of the Cell, by Becker, Kleinsmith, and Hardin, 6th edition, Pearson Education. 2006.
3. The Cell: A Molecular Approach. Fourth Edition. By Cooper GM and Hausman RE. ASM Press and Sunderland (Massachusetts): Sinauer Associates. 2007
4. Molecular Cell Biology by Lodish H et al., Ninth Edition, Macmillan Learning. 2021
5. Cell and Molecular Biology by Karp. 9th Edition, John Wiley & Sons. 2019.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	2	2	3	1	3	2	1	1	2	2
CO2	2	3	2	2	3	1	3	2	1	1	2	2
CO3	2	3	2	2	3	1	3	2	1	1	2	3
CO4	3	3	3	3	3	1	3	2	1	1	2	2

Paper code: BT-209	Paper name: Genetics	L	T	P	C
Paper id:	(3rd Semester; Professional Core)	3	1	0	4

Course Objectives:

Introduction of the subject of genetics, its branches, and applications.

1. To understand the principles of genetics including Mendelian and modern concepts of heredity.
2. To learn the different chromosomal and numerical variations, and underlying factors including mutations.
3. To know in detail the fine structure of genes and genome.

Course Outcomes:

After successful completion of this course, the students should be able to understand:

1. The historical and modern concepts of heredity
2. The role of genetic mechanisms contributing towards variation and evolution.
3. How genetic concepts affect broad societal issues including health and disease, food and natural resources, environmental sustainability, etc.
4. How to solve genetics problems related with this course.

1. **Introduction to Genetics:** Brief history of genetics, genes and environment, epigenetics, genetics and society, forward and reverse genetics; scope and significance of genetics. **(2)**

2. **Mendelian Analysis:** Mendel's laws of inheritance, extentensions to Mendelism, interaction of genes, quantitative inheritance. **(6)**

3. **Chromosome Theory of Inheritance:** Chromosomal basis of inheritance, chromosomes theory of inheritance, sex determination, sex linkage, dosage compensation **(4)**

4. **Linkage:** Discovery of linkage, basic eukaryotic chromosome mapping, three point testcross, interference and coincidence, complete linkage, linkage maps, Chi-square test. **(6)**

5. **Mutations:** Morphological and biochemical mutations, mutagens, detection of mutations, one gene-one enzyme hypothesis, colinearity, mutations rates and frequencies, mutation breeding. **(6)**
6. **Fine Structure of Gene:** The modern concept of gene, promoter, terminator, fine structure of rll locus in T4 phage, split genes, overlapping genes. **(2)**

7. **The Extranuclear Genome:** Maternal inheritance, concept of extranuclear genome in higher plants and *Chlamydomonas,* overview of mitochondrial and chloroplast genomes. **(4)**

8. **Structural and Numerical Changes in Chromosomes:** Detection and inheritance of deficiencies, duplications, inversions, translocations, aneuploidy, haploidy and polyploidy. **(6)**

9. **Population Genetics:** Darwin's evolution, variation and its modulation, effect of sexual reproduction on variation, sources of variation. Hardy-Weinberg equilibrium. **(2)**

10. **The Dynamic Genome:** Discovery of transposable elements in maize, transposable elements in prokaryotes and eukaryotes. **(2)**

Text/ Reference Books:

1. Introduction to Genetic Analysis by Griffiths A, Doebley J, Peichel C and Wasserman D, Macmillan Learning.Com, 12th Edition, 2020.
2. Genetics by Gupta PK, Rastogi Publications, Meerut, 5th Edition, 2019.
3. Concepts of Genetics, Klug WS, Cummings M, Spencer CA, Palladino MA and Killian D, Pearson 12th Edition, 2019.
4. Principles of Genetics by Snustad P and Simmons MJ, Wiley, 7th Edition 2015.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	2	3	1	3	3	2	3	2	3	1	3
CO2	1	3	2	2	3	3	2	3	1	3	1	3
CO3	2	3	3	3	3	2	2	3	2	3	1	3
CO4	3	3	3	3	3	2	2	3	2	3	1	3

Paper Code: CT-211	Paper name: Introduction to Material and Energy Balance	L	T	P	C
Paper id:	(3rd Semester; Professional Core)	3	1	0	4

Course Objective

1. To impart basic knowledge of engineering calculations.
2. To impart knowledge of the material balance.
3. To impart knowledge of the energy balance.

Course Outcomes:

1. Ability to understand engineering calculations.
2. Ability to analyze and solve stoichiometry problems.
3. Ability to assess energy balances in different biochemical and bioprocess systems.

1. **Introduction to engineering calculation:** Physical variables, dimensions and Units, measurements convention, standard conditions and ideal gases, physical and chemical property data. **(4)**

2. **Stoichiometry:** Fundamentals, examples: Stoichiometry of amino acid synthesis, Incomplete reaction and yields. **(4)**

3. **Material balances (MB):** Thermodynamic preliminaries, System and process, state and equilibrium, procedure for MB calculations. **(4)**

4. **Examples for basic MB:** Continuous Filtration, Batching mixing, MB with Recycle, By-pass and Purge Streams. **(4)**

5. **Stoichiometry of growth and product formation:** Growth stoichiometry and elemental balance, Electron balances, Biomass yield, product stoichiometry, Theoretical Oxygen demand. **(8)**

6. **Energy balances (EB):** Basic energy concepts such as units, intensive and extensive properties, General energy balance equations, Enthalpy calculation procedures. **(4)**

7. **Enthalpy:** Enthalpy change in non-reactive processes, steam tables, procedure for EB calculations, Enthalpy change due to reaction. **(4)**

8. **Example of basics EB:** Continuous water heater, cooling in down stream. **(4)**

9. **Heat of Reaction:** Heat of reaction for processes with biomass production, Energy balance equation for cell culture. **(4)**

Text/Reference books:

1 Basic Principles and Calculations in Chemical Engineering by Himmelblau DM, Riggs JB, Eighth Edition, PHI, 2012.
2. Bioprocess Engineering- Basic concepts by Schuler ML & Kargi F, Hall E 1992.
3. Bioprocess Engineering Principles by Pauline M. Doran, Academic Press 1995.

Course Outcome(CO) to Programme Outcome(PO) Mapping (scale 1: low, 2: Medium, 3:High)												
CO/PO	P001	P002	P003	P004	P005	P006	P007	P008	P009	P010	P011	P012
CO1	3	2	2	1	1	2	2	1	1	1	2	1
CO2	3	2	1	1	1	2	2	1	1	1	2	1
CO3	3	2	1	1	1	2	2	1	1	1	2	1

SEMESTER IV

Group	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-202	Immunology and Immunotechnology	3	1	4
PC	BT-204	Molecular Biology	3	1	4
PC	BT-206	Enzyme Technology	3	1	4
PC	BT-208	Techniques in Biotechnology	3	1	4
PC	CT-212	Fundamentals of Heat and Mass Transfer	3	1	4
Practical/Viva Voce					
PC	BT-254	Molecular Biology – Lab	0	3	1.5
PC	BT-256	Enzyme Technology – Lab	0	3	1.5
PC	BT-258	Immunology and Immunotechnology – Lab	0	3	1.5
PC	BT-260	Techniques in Biotechnology- Lab	0	3	1.5
Total			**15**	**17**	**26**

Paper Code: BT-202	Paper name: Immunology and Immunotechnology	L	T	P	C
Paper id:	(4th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To study the basic mechanisms that regulate immune responses and maintain tolerance.
2. To learn the molecular basis of complex cellular processes involved in inflammation and immunity, the states of health and disease.
3. To understand basic mechanisms and therapeutic implications including biosafety issues in Immunology.

Course Outcomes: After successful completion of this course, the students should be able to:

1. Understand the basic concepts of immunological process at a cellular and molecular level, define central immunological principles and concepts, compare and contrast the key mechanisms and cellular players of innate and adaptive immunity and interplay between them.
2. Use the knowledge of different immunology tools and techniques to design strategies and conduct quantitative and qualitative experiments to evaluate the presence of antigen and antibodies.
3. Apply the concepts of immunology and immuno-technology to analyze and solve problems in basic and applied biotechnology/life sciences research.

1. **Introduction to Immunology:** Historical perspective, Properties of immune response, Innate and acquired immunity. **(4)**

2. **Cells & Tissues of Immune System:** Lymphocytes, Classes of lymphocytes, Antigen presenting cells, NK Cells, Mast Cells, Dendritic Cell, Organs of the Immune System. Bone marrow, Thymus, Lymph node, Spleen, CALT, MALT. **(4)**

3. **Molecular Immunology:** Molecular structure of antibody, Classification, lsotypes, lmmunoglobulin Super family, Synthesis assembly and expression of immunoglobulin molecules, Function and diversity, Generation of antibody diversity. **(4)**

4. **Antigens:** Nature of antigens, Different characteristics of antigens, Mitogens, Hapten, lmmunogen, Adjuvants. **(4)**

5. **MHC:** Discovery of MHC complex, Role of MHC, Structure of MHC molecule, Binding of peptides to MHC molecules, MHC restriction. **(4)**

6. **Effecter Mechanism of Immune Response:** Cytokines, T- cell receptors, B-cell receptor, Cell mediated cytotoxic responses, complement system, Antigen processing and presentation. **(4)**

7. **Immunological Techniques:** Antigen-antibody reactions, Immunodiffusion, lmmunoelectrophoresis, ELISA, RIA, lmmunoflourescence, Flow cytometry. **(4)**

8. **Immune system in health and disease:** Introduction to mechanisms underlying- Autoimmunity, Hypersensitivity, Tumor immunity, Tissue and organ transplant. **(5)**

9. **Production of Antibodies:** Production of polyclonal and monoclonal antibodies, and their applications, chimeric and humanized monoclonal antibodies. **(4)**

10. **Vaccines:** Active and passive immunization, Live and attenuated Vaccines, Subunit, Conjugate and DNA vaccines, Biosafety issues in immunology. **(3)**

Text/ Reference books:

1. Kuby Immunology By Owen, Punt, & Stranford, 7th, Seventh Edition, Macmillan press, 2018.
2. The Elements of Immunology by Khan FH, Pearson Education, 2009.
3. Essentials of Immunology: Ivan Riot- Blakswell Scientific Publications, Oxford, Thirteenth Edition, 2017.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	3	2	2	3	2	1	1	1	1	3
CO2	3	3	3	3	3	2	1	2	2	2	2	3
CO3	3	3	3	3	3	2	2	2	2	2	1	3

Paper Code: BT-204	Paper name: Molecular Biology	L	T	P	C
Paper id:	(4th Semester; Professional Core)	3	1	0	4

Course Objectives: This course focuses on structure and function of biologically important molecules that allow genes to be expressed and maintained from generation to generation. Emphasis will be laid on the structure and properties of Nucleic acids (DNA and RNA) and the molecular events that govern cell functions such as DNA replication, Gene expression and its regulation, DNA mutations and their repair.

Course Outcomes:
After completion of this course, students should be able to:

1. Understand basic structure and properties of nucleic acids.
2. Understand mechanism of gene expression and its regulation including epigenetic regulatory mechanisms.
3. Appreciate concept of genomic mutations and how they are manifested at phenotype level.
4. Understand significance of biomolecules in understanding molecular evolution and phylogeny.

1. **Basic Concepts of Genome and its Organisation**: Structure and properties of nucleic acids: Watson and Crick model of DNA structure, A, B & Z forms of DNA, denaturation and renaturation of DNA, melting temperature (Tm), hyperchromic effect; Nuclear genome and its organisation; Introduction to flow of genetic information: central dogma of molecular biology; Model organisms for studying molecular biology; Brief introduction to chloroplast and mitochondrial genomes. **(7)**

2. **Replication of DNA**: Features of nuclear DNA replication, Proof of semiconservative nature of DNA replication and its mechanism, Features of bidirectional DNA replication. **(3)**

3. **Gene Expression**: From DNA to RNA: Structure and function of gene promoters and terminators. Transcription initiation, elongation and termination, RNA polymerases; RNA processing and splicing. **(4)**

4. **RNA Structure.** Types of RNA (coding and non-coding): Function and properties. **(3)**

5. **From RNA to Proteins**: Components of protein synthesis machinery: messenger RNA and transfer RNA structure and function; Concept of genetic code; Mechanism of protein synthesis in prokaryotes and eukaryotes: initiation, elongation and termination of RNA chains. **(5)**

6. **Principles of Gene Expression**: Regulation of transcription, promoters, enhancer elements; RNA splicing; Post-transcriptional and Post-translational regulation; Concept of operons and regulation of gene expression in prokaryotes and eukaryotes. **(4)**

7. **Epigenetic Mechanisms of Gene Regulation**: Epigenetic modifications, Concept of histone code, Introduction to DNA/Protein methyltransferases and their activities. **(4)**

8. **Molecular Basis of Mutations:** Types of DNA damage, mutagens; Overview of different mechanisms of DNA repair, homologous recombination; Effect of mutations on information content of a gene (examples of human genetic diseases and plant phenotypes). **(6)**

9. **Molecular Phylogeny:** Concept of Phylogenetic stress. Importance of DNA/protein sequences in tree construction and its interpretation. **(4)**

Text / Reference Books:

1. Molecular Biology: Principles of Genome Function, Craig N et al., Oxford University Press, Third edition 2021.
2. Molecular Biology: Structure and Dynamics of Genomes and Proteomes Zlatanova J and vanHolde KE, Garland Science, Taylor and Francis Group. 2016.
3. Lewin's Essential Genes, Krebs J et al., Fourth Edition 2021.
4. Genomes 4, Brown TA, Fourth Edition Garland Science, 2018.
5. Molecular Biology of the Cell (Sixth Edition), Alberts B et al. Garland Science, Taylor and Francis Group, 2015.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	1	2	1	1	2	1	2	3	3	2	3
CO2	3	2	2	1	1	2	2	3	3	3	2	3
CO3	1	2	2	1	1	3	3	2	3	3	2	2
CO4	2	2	2	2	1	2	3	2	3	3	2	2

Paper Code: BT-206	Paper name: Enzyme Technology	L	T	P	C
Paper id:	(4th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To provide a deeper insight into the fundamentals of enzyme structure and function and kinetics of soluble and immobilized enzymes.
2. The students will acquire in depth knowledge to maintain enzymes, design enzymatic reactions, perform immobilization and isolate value added products from the substrates.
3. To effectively learn the current applications and future potential of enzymes and the enzymatic process.

Course Outcomes: After successful completion of this course, the students should be able to understand:

1. The classification and basic structure of enzymes.
2. The mechanism and kinetics of enzymes.
3. The production of enzymes and their applications in industry.

1. **Introduction to Enzymes:** What are enzymes, Brief history of enzymes, Nomenclature and classification of enzymes, Properties of enzymes, Structure of enzymes, Active site of enzymes, Factors influencing enzyme activity, Enzyme assays. **(6)**

2. **Specificity and Mechanism of Enzymes Action**: Types of specificity, The Koshland "induced fit" hypothesis, Strain or transition – state stabilization hypothesis. Mechanism of catalysis, Mechanism of reaction catalyzed by enzyme without cofactors, Metal-activated enzymes and metalloenzymes, Coenzymes in enzyme catalyzed reactions. **(6)**

3. **Enzyme Kinetics**: Kinetics of enzyme-catalyzed reaction, Methods for investigating the kinetics of enzyme-catalyzed reactions, Interpretation of Km, Vmax, Turnover number and Kcat, Specific activity of enzymes, Enzyme units, Inhibition of enzyme activity, Regulation of enzyme activity. **(5)**

4. **Immobilization of Enzymes**: Concept, Methods of immobilization, Kinetics of immobilized enzymes, Effects of immobilization on enzymes, Use of immobilized enzymes, Bioreactors using immobilized enzymes. **(4)**

5. **Industrial Applications of Enzymes**: Industrial enzymes: Market of industrial enzymes, Traditional (non-recombinant) sources of industrial enzymes, The impact of genetic engineering on enzyme production, Engineered enzymes, Extremophiles: hyperthermophiles, Enzymes from hyperthermophiles, Enzymes from additional extremophiles, Enzymes in organic solvent. **(4)**

6. **Proteases and Carbohydrases:** Proteolytic enzymes: Carbohydrases, Lignocellulose degrading enzymes, Pectin and Pectic enzymes. **(6)**

7. **Other Industrial Enzymes:** Lipases, Penicillin acylase, Amino acylase and Amino acid production, Cyclodextrins and cyclodextrin glycosyltransferase, Enzymes in animal nutrition, Enzymes in molecular biology. Clinical applications of enzymes. **(5)**
8. **Enzyme Engineering**: Prediction of enzyme structure, Design and construction of novel enzymes. **(4)**

Text / Reference Books:

1. Enzymes: Biochemistry, Biotechnology and Clinical Chemistry by Palmer T and Bonner PL: Woodhead publishing limited, 2007.
2. Fundamentals of Enzymology by Price NC and Stevens L: Oxford/Panima Pub Corp, 3rd Edition, 2009.
3. Enzymes in Industry: Production and Applications by Aehle W, WILEY-VCH Verlag GmbH & Co. KGaA., 3rd edition 2007.
4. Introduction to Proteins Structure by Branden and Tooze, Garland Publishing Group,1999.
5. Proteins: *Biochemistry and Biotechnology* by Walsh G: John Wiley & Sons, Ltd, 2014.
6. Lehninger Principles of Biochemistry: by Nelson DL, Cox MM, Macmillan, 6th edition, 2021.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO 8	PO 9	PO1 0	PO1 1	PO1 2
CO1	2	3	1	3	3	1	2	1	3	3	3	3
CO2	3	3	3	3	3	2	2	2	3	3	3	3
CO3	3	2	3	2	3	3	3	3	3	2	3	3

Paper Code: BT-208	Paper name: Techniques in Biotechnology	L	T	P	C
Paper id:	(4th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To understand the basic techniques employed in biotechnology research and analysis as well as data handling which are the prerequisites for a variety of courses defined in this syllabus in later semesters.
2. To study the principles and application of the modern techniques popularly employed in biotechnology.
3. To develop the understanding of various tools and techniques and where they may be employed in biotechnology analysis.

Course Outcomes:

After successful completion of this course, the students should be able to understand:

1. The theory behind various techniques used in biotechnology.
2. The utility of various biotechnology tools in biological research.
3. The basic concepts of analytical techniques and integrate its relevance to study biological processes at cellular and whole genome level.

1. **pH:** Concept of pH, Henderson Hasselbach equation, composition and preparation of some commonly used buffers, pH meters.**(2)**
2. **Colorimetry and Spectroscopy:** Basic principles, nature of electromagnetic radiation, Beer-Lambert laws, colorimetric methods & instruments, principles of spectroscopy, types of spectra-absorbance, emission, fluorescence and action spectra, single and double beam spectrophotometers, densitometers, flame photometer, fluorimeters. **(4)**
3. **Cell separation:** Flow cytometry, magnetic beads, elutriator. **(2)**
4. **Microscopy**: Basic principles, instrumentation, light and phase contrast, interference, polarization, inverted fluorescence, confocal & electron microscopes & their applications, Introduction to microtome. **(4)**
5. **Centrifugation:** Principle, types of centrifuges, rotors, differential and gradient ultracentrifugation-preparative & analytical. **(4)**
6. **Chromatography:** Principles, methodology and applications of chromatography using paper, thin layer, column (gel filtration, ion exchange, affinity), GC, HPCL, FPCL. **(5)**
7. **Electrophoresis**: Principles and types of electrophoresis and their applications for proteins, nucleic acids, including gradient gel and pulse-filed gel electrophoresis; gel matrices: polyacrylamide, agarose, etc. critical parameters for optimum separation and resolution, two dimensional electrophoresis (IEF). **(5)**
8. **Radioisotope Methods and Tracer Techniques in Biology:** Basic principles of radioactivity, properties & handling of radioisotopes in biology & medicine, radiation units, Geiger Muller & scintillation counters, autoradiography, radionuclide imaging, CT scan. **(4)**

9. **Immunochemical Techniques:** Production of antibodies, Immunoprecipitation, Immunoassays, Immunohistory and Immunocytochemistry **(4)**
10. **Biophysical Techniques:** X-ray crystallography, Nuclear Magnetic Resonance (NMR) spectra, Magnetic Resonance Imaging (MRI), lasers in biology and medicine, Mass spectrometry. **(6)**

Text / Reference Books:

1. Introductory Practical Biochemistry by Sawhney SK & Singh R; *Narosa Publishing House*, 2000.
2. Principles and Techniques of Biochemistry and Molecular Biology by Wilson K & Walker J, 6th Edition, Cambridge Press, 2008.
3. Practical Techniques in Molecular Biotechnology by Bal Ram Singh, Raj Kumar: Cambridge University Press, 2021
4. Advanced Methods in Molecular Biology and Biotechnology by Khalid Z. Masoodi, Sameena Maqbool Lone, Rovidha Saba Rasool; Elsevier Science, 2020.
5. Quantitative Bioimaging: An Introduction to Biology, Instrumentation, Experiments, and Data Analysis for Scientists and Engineers by Raimund J. Ober, E. Sally Ward, Jerry Chao; CRC Press, 2020

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2
CO1	2	3	2	3	3	2	2	2	1	1	2	3
CO2	2	3	3	3	3	3	2	3	1	1	2	3
CO3	3	3	2	3	3	3	2	3	1	1	2	3
CO4	3	3	3	3	3	3	2	3	1	1	2	3

Paper Code: CT-211	Paper name: Fundamentals of Heat and Mass Transfer	L	T	P	C
Paper id:	(4th Semester; Professional Core)	3	1	0	4

Course Objectives:

The objective of the subject is to make student familiar with the fundamental concepts of Heat and mass transfer.

Course Outcomes:

Students will understand

1. Principles of heat transfer and solve heat transfer problems using different heat transfer laws.
2. Concept of different convective heat transfer and heat exchangers.
3. Concept of molecular diffusion in gas, liquid and solids, and determination of diffusion coefficient.
4. Determination of mass transfer coefficient and mass transfer rate.
5. Determination of NTU and HTU.

1. **Heat transfer:** Modes of heat transfer. **(2)**

2. **Heat transfer by conduction:** Fourier's law, Three-dimensional conduction equation, Thermal conductivity, Steady-state conduction, unsteady-state conduction. **(5)**

3. **Heat transfer by convection:** Coefficient of heat transfer, Natural convection, Forced convection, Jackets and coils of agitated vessels, Nonnewtonian Fluids, Liquid Metals. **(5)**

4. **Heat transfer with change of phase condensation:** Condensation, Boiling (vaporization) of liquids. **(3)**

5. **Heat transfer by radiation:** General references, Nomenclature for radiative transfer, Nature of thermal radiation. Radiative exchange between surfaces and solids, Emissivities of combustion products, Radiative exchange between gases or suspended matter and a boundary, combustion chamber heat transfer. **(5)**

6. **Fundamentals of mass transfer**: Introduction, Fick's First Law, Continuity and Flux Expressions, Diffusivity Estimation-Gases, Diffusivity Estimation-Liquids, Diffusion of Fluids in Porous Solids. **(8)**

7. **Interphase Mass Transfer:** Mass-Transfer Principles: Dilute Systems, Concentrated Systems, HTU (Height Equivalent to One Transfer Unit), NTU (Number of Transfer Units), Definitions of Mass-Transfer Coefficients k<, and kl, Simplified Mass-Transfer Theories. **(6)**

8. **Mass-Transfer Correlations**: Effects of Total Pressure on k_G, and k_L, Effects of Temperature on k_G, and k_L, Effective Interfacial Mass-Transfer Area a, Volumetric Mass-Transfer Coefficients Kc.a and Kla. Example of Mass Transfer in Biological Reactor. **(6)**

Text/ Reference Books:

1. Heat Transfer, Holman JP, McGraw, Hill, New York, 10th Ed, 2010.
2. Unit Operations of Chemical Engineering, McCabe WL, Smith JC and Harriott P. McGrawHill International edition, Singapore, 7th Ed., 2005.
3. Mass-Transfer Operation, Treybal RE, McGraw Hill, 3rd Edition, 1981
4. Chemical Engineering design, Coulson and Richardson's Butterworth-Heinemann, volume 6, 4th edition, 2005.
5. Fundamentals of Momentum, Heat Transfer and Mass transfer, Welty JR, Wicks CE, Wilsons RE, Rorrer G, John Wiley & Sons Inc., 5th Edition, USA, 2008.
6. Fundamentals of Heat and Mass Transfer, Dewitt et al., John Willey & Sons. 7th edition, 2011.
7. Heat Transfer. By Alan J. Chapman. The Macmillan Company, New York. 1960. Published online by Cambridge University Press: 2006.

Course Outcome(CO) to Program Outcome(PO) Mapping (scale 1: low, 2: Medium, 3:High)												
CO/PO	P001	P002	P003	P004	P005	P006	P007	P008	P009	P010	P011	P012
CO1	1	2	3	3	2	1	2	1	3	1	1	2
CO2	3	3	3	3	2	1	2	1	3	1	1	3
CO3	3	3	3	3	2	1	2	1	3	1	1	3
CO4	3	3	3	3	2	1	2	1	3	1	1	3
CO5	3	3	3	3	2	1	2	1	3	1	1	3

SEMESTER V

Code	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-305	Animal Biotechnology	3	1	4
PC	BT-307	Recombinant DNA Technology	3	1	4
PC	BT-311	Plant Biotechnology	3	1	4
PC	BT-313	Unit Operations and Plant Design for Biomanufacturing	3	1	4
*PCE-1/***EAE-1	BT-315	*Professional Core elective-1/***Elective in Emerging Areas-1	3	1	4
**OAE-1	BT-317	**USBT Open area elective-1 or Elective from other schools	3	1	4
Mandatory course	USMS112	Entrepreneurial Mindset	2		2
Practical/Viva Voce					
PC	BT-353	Unit Operations and Plant Design for Biomanufacturing - Lab	0	3	1.5
PC	BT-355	Animal tissue Culture – Lab	0	3	1.5
PC	BT-357	Recombinant DNA Technology- Lab	0	3	1.5
PC	BT-361	Plant Biotechnology – Lab	0	3	1.5
Total			**18**	**18**	**32**

***PCE: Professional Core Elective-1 (Select any one)**

		L	T/P	Credits
PCE-1	Stem Cell Technology	3	1	4
PCE-1	Environmental Sustainability	3	1	4
PCE-1	Pharmacogenomics	3	1	4

****OAE: Open Area Electives-1 Offered by USBT (Select any one)**

		L	T/P	Credits
OAE-1	Biomaterials	3	1	4
OAE-1	Precision Medicine and wellness	3	1	4
OAE-1	Regenerative Medicine	3	1	4
	MOOCs (Only Govt. approved platforms like SWAYAM, NPTEL, e-PG Pathshala, etc.)			4

***** EAE: Emerging Area Elective-1 offered by USBT (Select any one)**

EAE1-BT	Nanobiotechnology	**L**	**T/P**	**Credits**
EAE1-BT	Rational Drug discovery	3	1	4
EAE1-BT	Artificial Intelligence in Healthcare	3	1	4

Paper Code: BT-305	Paper name: Animal Biotechnology	L	T	P	C
Paper id:	(5th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. The students will learn the ability to correlate between different biological samples and show the importance of different media in animal tissue culture.
2. The students should be able to develop the knowledge and understanding to know how to use different sources of tissues and develop the ability to handle different sources for tissue culture.
3. To understand the application of animal biotechnology in pharmaceutical biotechnology.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Understand the basic concepts of animal tissue culture and cell growth properties, describe advantages and limitations of animal tissue culture technique
2. Use the knowledge of different animal tissue culture techniques to design strategies and design and interpret various cell-based assays
3. Apply the concepts of animal biotechnology to analyze and solve problems in basic and applied biotechnology/life sciences research. Understand, examine and discuss the ethical, legal and social issues related to Animal Biotechnology.

1. **Introduction to Animal Tissue Culture:** Background, Advantages, Limitations, Application, Culture Environment, Cell Adhesion, Cell Proliferation, Differentiation. **(4)**

2. **Design, Layout and Equipment:** Planning, Construction, Layout, Essential Equipments, Aseptic Technique, Objectives, Elements, Sterile Handling, BioSafety, Risk Assessment, General Safety, Fire, Radiation, Biohazards. **(5)**

3. **Media:** Physicochemical Properties, Balanced Salt Solutions, Complete Media, Serum, Serum-Free Media, Disadvantages of Serum, Advantages of Serum-Free media. **(5)**

4. **Primary** Culture: Isolation of Tissue, Steps involved in primary cell culture, Cell Lines, Nomenclature, Subculture and Propagation, Immortalization of cell lines, Cell line designations, Routine maintenance, Introduction to cell culture reactors and scale-up (in suspension and in monolayer). **(5)**

5. **Characterization & Quantitation of Cell Line:** Need for characterization, Morphology, Chromosome Analysis, DNA Content, RNA and Protein, Enzyme Activity, Antigenic Markers, Transformation, Immortalization, Aberrant Growth Control, Tumorigenicity, Cell counting, DNA content, Protein, Rates of Synthesis, Cell Proliferation, Plating Efficiency, Labeling Index, Generation Time. **(5)**

6. **Contamination:** Source of contamination, Type of microbial contamination, Monitoring, Eradication of Contamination, Cross-Contamination. **(3)**

7. **Cryopreservation:** Need of Cryopreservation, Preservation, Cell banks, Transporting cells. **(2)**

8. **Cytotoxicity:** Introduction, In vitro limitations, Nature of assay, Viability assay, Survival assay, Microtitration assay, Transformation assay. **(3)**

9. **Transgenic Animals:** Methodology, Embryonic Stem Cell method, Microinjection method, Retroviral vector method, Applications of transgenic animals. **(4)**

10. **Applied Aspects of Animal Biotechnology:** Cloning and selection, In Vitro Fertilization and Embryo Transfer- Steps involved in IVF, Fertilization by means of micro insemination, PZD, ICSI, SUZI, MESA; Introduction to gene therapy: ex vivo versus in vivo gene therapy. Application of animal cell culture technology in drug testing, production of human and animal viral vaccines and pharmaceutical proteins. Bioethical concerns in animal biotechnology. **(4)**

Text/ Reference Books:

1. Animal Cell Culture: A Practical Approach by Freshney RI, Eigth edition, Wiley- Blackwell publication, 2021.
2. Principles of Gene Manipulation and Genomics by Primrose SB and Twymanr, Seventh Edition, Wiley- Blackwell publication, 2006.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	2	2	3	1	2	1	1	1	3
CO2	3	3	3	3	3	2	2	3	3	2	1	3
CO3	3	3	3	3	3	2	2	3	2	2	2	3

Paper Code: BT-307	Paper name: Recombinant DNA Technology	L	T	P	C
Paper id:	(5th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To introduce various tools used in rDNA technology.
2. To provide an understanding of the different techniques employed to identify, isolate, manipulate, analyze and express nucleic acids.
3. To train students in designing research methodologies using rDNA tools and techniques.
4. To learn about different applications of rDNA technology, as well as the ethical, legal and social concerns related to rDNA technology.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Use the knowledge of different rDNA tools and techniques to design strategies and conduct experiments to isolate, manipulate, analyze and express nucleic acids.
2. Apply the concepts of rDNA technology to analyze and solve problems in basic and applied biotechnology/life sciences research.
3. Understand, examine and discuss the ethical, legal and social issues related to rDNA technology.

1. **Enzymes used in RDT:** Restriction Endonucleases, DNA Ligase, Alkaline Phosphatase, Polynucleotide Kinase, DNA and RNA Polymerases, Exonucleases, Reverse Transcriptase, Introduction to Genome Editing. **(5)**

2. **Vectors:** Characteristics of vectors, Different kinds of vectors- Plasmids, Bacteriophage based vectors, Phagemids, Cosmids, Artificial chromosomes, Plant and Animal Virus based vectors, Shuttle vectors, Expression vectors. **(5)**

3. **Gene transfer and Selection:** Methods of introduction of foreign DNA, Bacterial and eukaryotic hosts, Selection and Screening strategies. **(4)**

4. **Labeling and Detection of Nucleic acids:** Concept of a probe, DNA and RNA probes, Methods for labeling of probe, Radioactive labeling, Non-radioactive labeling, Direct and Indirect labeling. **(4)**

5. **Analysis and Expression of cloned genes:** Restriction enzyme analysis, RFLP, Southern hybridization, Northern hybridization, Western blotting, South-Western blotting, In-situ hybridization, Concept of Reporter genes, Factors affecting heterologous protein expression, Fusion proteins. **(5)**

6. **Gene libraries** - cDNA synthesis, Construction of genomic and cDNA libraries, Linkers, Adaptors, Homopolymer tailing, Amplification of gene libraries, Screening of libraries by colony and plaque hybridization, immunological screening. **(4)**

7. **Polymerase Chain Reaction (PCR):** Basic principles of PCR and use of different heat stable enzymes, Designing of primers, Variations in PCR, Applications of PCR. **(4)**

8. **Nucleic Acid Sequencing:** Sanger's dideoxy chain termination method, Introduction to Next Generation Sequencing platforms. **(4)**

9. **Modifying Genes:** Types of mutations, Chemical mutagens, Random mutagenesis, Site-directed mutagenesis: methodology, *In-vivo* versus in vitro Mutagenesis, Applications. **(3)**

10. Ethical, Legal and Social Issues in Recombinant DNA Technology. **(2)**

Text / Reference Books:

1. Gene Cloning and DNA Analysis: An Introduction by Brown TA, Wiley-Blackwell, 8th Edition, 2020.
2. Genetic Engineering: Emerging Concepts and Technologies by Faraday P, Syrawood Publishing House, 2018.
3. Molecular Biotechnology: Principles and Applications of Recombinant DNA by Glick BR and Patten CL, American Society for Microbiology Press, 5th Edition, 2017.
4. Molecular Cloning: A Laboratory Manual by Green MR and Sambrook J, Cold Spring Harbor Laboratory Press, 4th Edition, 2014.
5. From Genes to Genomes: Concepts & Applications of DNA Technology by Dale JW & Schartz MV, Wiley-Blackwell, 2011.
6. Principles of Gene Manipulation and Genomics by Primrose and Twyman, 2006.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	2	1	2	1	1	3	2	3	3
CO2	3	3	3	3	1	2	2	1	3	3	3	3
CO3	1	1	1	1	1	3	3	3	3	3	1	2

Paper Code: BT-311	Paper name: Plant Biotechnology	L	T	P	C
Paper id:	(5th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To study various components of plant tissue culture media and optimize media for achieving desired objectives in vitro.
2. To expose students to various techniques for plant improvement and multiplication.
3. To know the types of potential plant products, their applications and harvesting through cell cultures.

Course Outcomes:

After successful completion of this course, the students should be able to understand:

1. The basics of various plant cell, tissue and organ culture based in vivo and in vitro techniques and the design of plant tissue culture laboratory.
2. The concept and potential of cellular totipotency and utilizing it for various applications.
3. The application of numerous techniques for plants and their product improvement and their advantages and limitations as well.

1. **Introduction:** History of plant tissue culture, evolution of plant improvement methods, green revolution to genetic engineering approaches, comparison of conventional and advanced biotechnological methods. **(4)**

2. **Basics of Plant Tissue Culture:** Design of a plant tissue culture laboratory and additional facilities: Composition of commonly used culture media, selection criterion for different types of media and medium preparation, role of plant growth regulators and other adjuvants, diversity of disinfecting agents and sterilization protocols. **(4)**

3. **Concept of Cellular Totipotency and Development of Regeneration Protocols:** direct and indirect organogenesis, choice of explants, induction of Somatic embryos, artificial/synthetic seed technology, cryopreservation, clonal propagation, pathogen free plant production, implications in plant germplasm conservation. **(4)**

4. **Potential of Variability Induced *in vitro:*** Somaclonal & gametoclonal variations, sources and reasons for their occurrence, their inheritance and detection in subsequent generations, screening and selection of desirable variations, application potential. **(4)**

5. **Cell and Protoplast Suspension Culture:** Isolation of single cells/protoplasts, culture of single cells, suspension cultures-batch and continuous, plant cell bioreactors and their basic design, techniques of somatic hybridization and cybridization, examples and use of somatic hybrids and cybrids in plant improvement efforts. **(4)**

6. **Haploid Production:** Androgenesis, factor affecting androgenesis, ontogeny of androgenic haploids, plant regeneration from pollen embryos, gynogenesis, haploid production through distant hybridization to raise homozygous diploids, applications and limitations. **(4)**

7. **Triploid Production:** Endosperm culture, callusing/organogenesis, histology and cytology of cells, role as nurse tissue, potential applications such as seedless fruits and role in breeding programs. **(4)**

8. **Zygotic Embryo Culture:** Culture requirements at various stages of development, role of the suspensor in embryo culture, microsurgical experiments, morphogenic potential of the embryo callus, techniques of embryo rescue, in vitro pollination and fertilization efforts

and their applications. **(4)**

9. **Transgenic Plant Production:** Need for their production, Nuclear genome transformation, organelle genome transformation, essential steps involved, examples of popular transgenic plants, ethical, commercial and marketing aspects of transgenic technology and its limitations. **(4)**

10. **Plants as Biofactories:** Sustainable and renewable nature of source plants/explants, production of chemicals, pigments, flavonoids, perfumes, insecticides, anticancer agents and other useful compounds at industrial scale, strategies used to optimize their production and commercialization aspects. **(4)**

Text/References books:

1. Plant Tissue Culture: Theory and Practice by Bhojwani SS. 5th Revised Edition, Elsevier. 2005.
2. Experiments in plant tissue culture by Dodds, JH & Roberts, LW. Cambridge University press, Cambridge. 1995.
3. Agrobiotechnology and Plant Tissue Culture by Bhojwani SS. Oxford University Press. 2003.
4. Plant Biotechnology: the genetic manipulation of plants by Slater, S, Scott, NW & Fowler, MR, second edition, Oxford. 2008.
5. Plant biotechnology: Principles and applications by Abdin MZ, Kiran U, Kamaluddin and Ai A. Springer, 2017.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	3	2	3	2	2	2	2	2	2	1
CO2	2	2	3	2	2	2	2	2	2	2	2	1
CO3	3	3	3	2	3	3	3	3	3	2	3	2

Paper Code: BT-313	Paper name: Unit Operations and Plant Design for Biomanufacturing	L	T	P	C
Paper id:	(5^{th} Semester; Professional Core)	3	1	0	4

Course Objectives:

1. To study material and energy transfer and its application in bioprocesses.
2. To expose students to aspects of bioprocess design and development.
3. To elaborately develop and understanding of plant design and layout in general as well as for specific bioprocesses.

Course Outcomes:

After successful completion of this course, the students should be able to understand:

1. The properties of fluids and the applications of fluid mechanics.
2. The various applications of mass and heat transfer in bioprocess.
3. The basics plant design and development specific to bioprocess engineering

1. **Definitions and Principles:** Unit operations, Unit Systems, Dimension Analysis, Introduction to engineering calculations. **(3)**

2. **Introduction to Fluid Mechanics and applications**: Fluid Statics and Its applications, Fluid Flow Phenomena, Basic Equations of Fluid Flow, Flow of Incompressible Fluids, Flow past Immersed Objects, Transportation and Metering of Fluids, Agitation and Mixing of Liquids. **(5)**

3. **Heat Transfer and Its Applications:** Heat Transfer by Conduction, Principles of Heat Flow in Fluids, Heat Transfer to Fluids, Design equation for Heat Transfer and its application, Heat-Exchange Equipment, Evaporation. **(5)**

4. **Mass Transfer and Its Applications:** Principles of Diffusion and Mass Transfer between Phases, Gas Absorption, Humidification Operations, Distillation, Leaching and Extraction, Drying of Solids, Fixed-Bed Separations, Membrane Separation Processes, Crystallization. **(6)**

5. **Operations Involving Particulate Solids:** Properties and Handling of Particulate Solids, Mechanical Separations: Screening, Filtration, Crossflow filtration, Gravity & centrifugal sedimentation process. **(6)**

6. **Introduction to Plant Design:** General Overall Design Considerations, Practical Considerations in Design, Engineering Ethics in Design. **(3)**

7. **Design Considerations:** Health and Safety Hazards, Loss Prevention, Environmental Protection, Plant Location, Plant Layout, Plant Operation and Control, Patent Considerations. **(4)**

8. **Process Design Development:** Development of Design Database, Process Creation, Process Design, Process Flow Diagrams, Piping and Instrumentation Diagrams, Vessel and Piping Layout Isometrics, Equipment Design and Specifications, The Preliminary Design - A Specific Example. **(4)**

9. **Flow sheet Synthesis and Development:** General procedure, process information, Input/output structure, Functions Diagram, Operation diagrams, process flowsheet, Software use in flowsheet generation. **(4)**

Text/References books:

1. Unit Operations of Chemical Engineering by McCabe W, Julian Smith J, Harriott P, 2014.
2. Plant Design and Economics for Chemical Engineer by Peters MS, 2003.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	2	2	2	1	1	1	2	3
CO2	3	3	3	3	2	2	2	1	1	1	2	3
CO3	3	3	3	3	3	3	3	2	3	3	3	3

Paper Code: BT-309	Paper name: Stem Cell Technology	L	T	P	C
Paper id:	(5th Semester; Professional Elective)	3	1	0	4

Course Objective(s):

1. To understand the Stem Cells (SCs) and their role in regenerative biology.
2. To know about research on animal models for tissue regeneration.
3. To communicate the application of SCs based techniques.
4. To be aware about the ethical issues related to SCs research.

Course Outcomes:

After successful completion of this course, the students should be able:

1. To understand the basics of Stem Cells.
2. To learn isolation, characterization of Stem Cells.
3. To learn the application-based role of Stem Cells in biotechnology.
4. To learn stem cell based ethical concern.

1. **Introduction to stem cells**: Introduction to stem cells, History and Principles, Properties, Types of stem cells (SCs), History and Fundamentals of Stem Cell Technology (SCT); Applications and Implications. **(5)**

2. **Stem Cell Biology:** SCs Types and properties; Derived from extraembryonic membrane amniotic fluid, germ cell, hematopoietic organs, peripheral blood and bone marrow transplantation, bone marrow and cord blood collection, cryopreservation. **(6)**

3. **Stem Cell Treatment Methodology:** Isolation, Culture and trans-differentiation of Embryonic SCs and adult SCs; cellular reprogamming, induced pluripotent stem cells (iPSCs) and their therapeutic potential. Hormonal role in differentiation. **(6)**

4. **Stem Cell Techniques**: Cell sorting: Immunomagnetic, microfluidic and FACS; GFP tagging. **(6)**

5. **Translational Technological Advances:** Stem Cell Therapy, Drug Development, Disease Modelling, Tissue Regeneration; Molecular pathways of pluripotency. **(6)**

6. **Stem Cell Niche:** Bone marrow, neural tissue, gut epithelium, epidermis. **(3)**

7. **Stem Cells in plants:** Founder zone, shoot meristem of higher plants. **(3)**

8. **Clinical Applications:** Diabetes, cancer, heart disease, muscoskeletal dystrophy, skin burns; Current Research; Stem cell regulations, Ethical concerns. **(5)**

***Text/ References Books*:**

1. Essentials of Stem Cell Biology by Lanza R., fourth edition, 201 Academic Press.
2. Stem cells by Gian Paolo Bagnara, 2020.
3. Hematopoietic Stem Cell Transplantation by Treleaven J, first edition 2019.
4. Stem cells in clinic and research by Gholamrezanezhad A, Intech, 2019.
5. The Science of Stem cells, by Slack JMW, 2018.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	1	2	2	1	2	1	3	2	2	3	2
CO2	3	1	2	1	1	2	1	3	2	2	3	2
CO3	3	1	3	2	1	2	2	3	2	3	3	3
CO4	1	1	3	1	1	3	2	3	2	2	2	2

Paper Code: PCE-	Paper name: Environmental Sustainability	L	T	P	C
Paper id:	(5th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

1. Learn about the economic, social, and environmental aspects of sustainability and some frameworks for defining and measuring progress toward a sustainable society.
2. Explore the major impacts that humans have on the environment.
3. Be introduced to: life cycle assessment (LCA) and geographic information systems (GIS).
4. Participate in field trips to explore projects related to sustainability.

Course Outcomes

After taking the course, students should be able to:

1. Explore complex challenges and analyze multi-dimensional problems
2. Extrapolate from one conceptual context to others
3. Synthesize alternative solutions to multi-dimensional challenges
4. Effectively communicate complex ideas

1. **Introduction to sustainability**: need and concept of sustainability, Models and Frameworks for Sustainability, Sustainable development
2. **Environmental issues:** climate change, resource depletion, food-energy-water nexus, eutrophication, acidification, human/ecosystem toxicity, smog, ozone depletion
3. **Sustainable development:** Sustainable Process and product development, Intro to Lifecycle Assessment (LCA), Industrial Ecology
4. **Challenges:** Social, environmental and economic sustainability concepts, Sustainable development goals, challenges for sustainable development.
5. **Protocols:** Multi-lateral environmental agreements and protocols, Clean Development mechanism (CDM), National and international Environmental legislations
6. **Pollution management:** Pollution mitigation through technology interventions, Waste water, Air and solid waste management systems, EMS ISO 14001 and other international standards
7. **Geographical information Systems and remote sensing**: QGIS, ArcGIS and other open-source software, National platforms like bharatmaps, mapservice, National remote sensing Centre (NRSC)
8. **Green chemistry & engineering**: sustainable urbanization, industrialization and poverty reduction, Social and technological changes and challenges, Industrial processes, Industrial symbiosis

Text/Reference Books:

1. Environmental Studies by Sharma SC & Poonia MP, Khanna Publishing House, New Delhi. 2017.
2. Understanding Chemistry by Rao CNR, Universities Press (India) Pvt. Ltd., 2011.
3. Waste Water Treatment for Pollution Control and Reuse by Arceivala, Asolekar S, Shyam, Mc-Graw Hill Education India Pvt. Ltd., New York, 2007.
4. Environmental Engineering Science by Nazaroff, William, Cohen, Lisa Willy, New York, 2000.
5. Fundamentals of renewable energy processes by Vieira A, Da Rosa, Academic Press Oxford, UK; 2013.
6. Waste Water Engineering by Metcalf & Eddy, Mc-Graw Hill, New York, 2013.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	1	2	2	3	2	3	2	2
CO2	2	2	2	2	1	2	2	3	2	3	2	2
CO3	2	3	2	3	2	2	2	1	2	2	2	1

Paper Code: PCE-	Paper name: Pharmacogenomics	L	T	P	C
Paper id:	(5th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

1. Give students an understanding of the principles of human genetics and genomics as they apply to improving the problems in drug therapy optimization and patient care, thus providing basic understanding of discipline of pharmacogenomics.
2. Give students an understanding of the genetic basis of variability in drug response can contribute to drug efficacy and toxicity, adverse drug reactions and drug-drug interaction. As such, pharmacists need a thorough understanding of the genetic component of patient variability to deliver effective individualized pharmaceutical care.
3. Enable students to better understand and manage the new genomics based diagnostic tools as they become available as well as make best treatment choices.

Course Outcomes

After successful completion of this course, the students should be able to understand:

1. Explain the basic principles of human genetics and heredity.
2. Understand the impact of Pharmacogenomics in different therapeutic areas.
3. Recognize the societal and ethical implications of genetic testing and the resultant individualization of drug therapy.
4. Identify key sources and reliable databases with pharmacogenomics knowledge base.

1. **Introduction:** Introduction to pharmaceutical biotechnology and pharmacogenomics, Pharmacological and pharmacogenomics approaches to improve drug delivery clinical outcomes. **(4)**

2. **Molecular Pharmacology:** Genetic polymorphism of CYP isoenzymes and drug transporters as well as their regulators (e. g., PXR or RXRα), Advancements in molecular pharmacology, informatics, nanotechnology and genomics for the new drug development era. **(4)**
3. **New pharmacological classes:** New pharmacological classes of drugs (antibodies, antisense RNAs, siRNAs, aptamers), Personalized medicine and drug prescription, Pharmacology and pharmacogenomics of cardiovascular system. **(4)**

4. **Clinical pharmacogenomics:** Clinical pharmacogenomics and drug interactions; Adverse drug reactions (ADR: intrinsic and extrinsic); Toxicogenomics, Toxicotranscriptomics, Toxicoproteomics, Toxicometabonomics; Practical utility of various pharmacogenomics resources in the clinical setting. **(4)**
5. **Biotherapeutics:** Protein drugs and the development of biotherapeutics, Pharmaceutical biotechnology of monoclonal antibodies (mAbs); Pharmacodynamics and pharmacokinetics of mAbs; Pharmacogenomics of mAbs. **(4)**

6. **Cancer therapeutics:** Development of new innovative molecularly-targeted cancer therapeutics; Cancer pharmacogenomics and biotherapeutics. **(4)**

7. **Applications:** Drugs related to the pharmacogenomics application in clinical practice: Pharmacodynamics- and pharmacogenomics-guided warfarin dosing in individual patients. **(4)**

8. **Pharmacological assessment:** Pharmacological assessment of tamoxifen-paroxetine interaction and pharmacogenomics of tamoxifen in oncology; Thiopurine drugs and pharmacogenomics of TPMT enzyme in guiding dosage schemes. **(4)**

9. **Pharmacogenomics:** Pharmacogenomics of antidepressant and psychotropic drugs; Pharmacogenomics of Cetuximab and Panituximab. Recombinant Coagulation Factors and Thrombolytic Agents, Recombinant Human Deoxyribonuclease I, Hematopoietic Growth Factors. **(4)**

10. **Applications:** Focus on Erythropoiesis-Stimulating Agents, Interferons and Interleukins, Vaccines, Gene Therapy, Stem Cell Technology. **(4)**

Text/Reference Books:

1. Pharmaceutical Biotechnology: Concepts and Applications by Walsh G, John Wiley & Sons: West Sussex. 2007.
2. Pharmaceutical Biotechnology: Fundamentals and Applications by Daan JA, Crommelin, Robert D. Sindelar, Bernd Meibohm Informa Healthcare: New York. 2008.
3. Pharmacogenomics: The Search for Individualized Therapies. Licinio J and Wong M-L, Wiley-Blackwell 2009.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	1	2	2	1	3	1	2	2	2	2	2
CO2	2	1	2	1	2	3	1	2	2	2	2	2
CO3	1	1	2	1	1	3	1	3	2	2	2	1
CO4	1	1	2	1	1	3	2	2	2	2	2	2

Paper Code: USMS112	Paper name: Entrepreneurial Mindset	L	T	P	C
Paper id:	(5th Semester; Mandatory course)	2	0	0	2

Course Objectives

1. To provide a fundamental for basic entrepreneurial skills and to acquaint them with the world of entrepreneurship and inspire them to set up and manage their businesses.
2. To acquaint students with the process of creativity and innovation.
3. To expose students to various aspects of entrepreneurship and business.
4. To expose students to case studies on successful entrepreneurs

Course Outcomes

Upon completion of the course, the student will be able to demonstrate knowledge of the following topics:

1. Form a strong foundations for basic entrepreneurial skills
2. Understand creativity and innovation for opportunity recognition
3. Learn about opportunity analysis and writing of business plans
4. Students will be inspired by examples of successful entrepreneurs.

1. **Introduction:** The Entrepreneur, Theories of Entrepreneurship; Characteristics of successful entrepreneurs, myths of entrepreneurship; **(5)**
2. Entrepreneurial mindset-creativity (steps to generate creative ideas, developing creativity) and innovation (types of innovation) **(5)**
3. **Promotion of Venture and Writing a business plan:** Opportunity Analysis; External Environment Analysis Economic, social and Technological Analysis. Business plan- What is business plan, parts of a business plan. Writing a Business plan. **(5)**
4. **Entrepreneurship Support: Entrepreneurial Development Programmes (EDP):** EDP Role of Government in Organizing EDPs. **(5)**
5. Institutions supporting small business enterprises: central level, state level, other agencies, industry associations. **(5)**
6. **Practicals:**
   Presenting a business plan
   Project on Start up India any other Government policy on entrepreneurship **(5)**
7. Discussion on why Start up fails, role of MSME etc.
   Discussion on role of entrepreneur in economic growth
   Discussion on Technology park **(5)**
8. Case study discussion on successful Indian entrepreneurs. **(5)**

Text/Reference Books:

1. Entrepreneurship Development and Small Business Entreprise by Charantimath, Pears Education 8th Ed., 2014.
2. Entrepreneurship: A Small Business Approach by Bamford CE, McGraw Hill Education, 1st Ed, 2015.
3. Entrepreneurship by Asrich et al. McGraw Hill Education, 2013.
4. Entrepreneurship Development: An analysis Study by Balaraju, Theduri, Akansha Publishing House, 2012.
5. A Guide to Entrepreneurship by David, Otis, Jaico Bookss Pubishing House, Delhi, 2014.
6. Entrepreneurship Management by Kaulgud, Aruna, Vikas Publishing House, Delhi, 2012.
7. Entrepreneurship Development by Chhabra, TN, Sun India, 2014.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	1	2	2	1	1	1	2	2	2	2	3
CO2	2	1	2	1	2	1	1	2	2	2	3	3
CO3	1	1	2	1	1	1	1	3	2	2	2	3
CO4	1	1	2	1	1	1	2	2	2	2	3	2

Paper Code: BT-303	Paper name: Biomaterials	L	T	P	C
Paper id:	(5th Semester; Open Area Elective)	3	1	0	4

Course Objectives:

1. To introduce the various types of biomaterials available.
2. To communicate the application of biomaterials.
3. Understanding the impact of characterization studies on the type of biomaterial studied.

Course Outcomes:

After successful completion of this course, the students should be able to understand:

1. Appreciate utilities of biomaterials for medical applications.
2. Understanding about the biomaterial characterization.
3. To understand the role of biomaterials w.r.t. the cell-type.

1. **Introduction to biomaterials:** Origin and History, Types: Origin based (natural and synthetic) and property based (Biofilm, metal, polymer blends, hydrogel, ceramics). **(4)**

2. **Classification**: Introduction to polymers; General structure: Core and surface morphology and their modification; Properties of the functional biomaterials (surface, physico-chemical and mechanical), Structure to function relationship. Cell-biomaterial interaction: sensitization, biocompatibility and toxicological screening. **(6)**

3. **Synthesis techniques**: Concept of biomimetic synthesis, Annealing, Sintering, Direct molding technique, calcination, different advanced fabrication technique, chemical bonding, melting-nucleation-solidification. **(6)**

4. **Engineering manufacturing procedures:** Basic principle, preparation of wire and fiber, manufacturing porous materials. Application and limitation of common manufacturing processes. **(4)**

5. **Characterization studies (Analytical Instruments):** Surface and bulk microstructural evaluation: SEM, AFM; Crystalline behavior evaluation: NMR, TEM-SAED; Shelf-life of the product via DSC; Qualitative and qualitative analysis: FTIR and XRD. **(8)**

6. **Medical applications**: Metals and alloys; Ceramic, inert-ceramic and bio-ceramic; Rubber, plastic, fibers and resins. Biodegradable polymers, composites, pyrolytic carbon, carbon nanotubes. **(6)**

7. **Qualifying cell behavior via statistical analysis**: Fisher test, regression methods. **(2)**

8. **Current research**: Biomaterial for organ replacement (cardiovascular, ocular, wound dressing), Biosensors and diagnostic devices. **(4)**

Text/Reference Books:

1. Biomaterials: An Introduction, by Park J, Lakes RS. Third Edition, 2017.

2. Biomaterials Science: An introduction to materials in Medicine by Ratner BD and Lemons JE, 2020.
3. Bioengineering Fundamentals by Saterbak A, Second Edition, 2017.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	2	1	3	3	3	2	2	2	2
CO2	3	3	3	2	1	3	3	2	2	2	3	2
CO3	3	2	2	1	1	3	1	2	2	2	2	2

Paper Code: PCE-	Paper name: Precision Medicine and Wellness	L	T	P	C
Paper id:	(5th Semester; Professional Core Elective)	3	1	0	3

Course Objectives

1. Use of modern omics techniques and systems biology in providing personalized medicine and preventive health care.
2. Understand how the diversity of life evolves over time by processes (leading to) of genetic change, particularly the role of genetic and genomic variation throughout the genome in health and disease.
3. Describe recent advances in disease risk prediction, molecular diagnosis and progression of diseases, and targeted therapies for individuals.
4. Critically evaluate primary and secondary precision medicine research
5. Utilize modern human genomic and transcriptomic methods to analyze health and disease data in dry and wet lab settings.

Course Outcomes

After successful completion of this course, the students should be able to understand:

1. Precision medicare and preventive care system using modern omics tools.
2. Recent advances in disease risk prediction, molecular diagnosis and progression of diseases and targeted therapies for individuals.

1. **Introduction:** Use of genomics, transcriptomics, proteomics and metabolomics in understanding disease condition. Microbiome, Nutritional genomics/ nutrigenomics, nutrigenetics and nutritional epigenomics. **(5)**

2. **Genome:** Whole Genome Sequencing, Pharmacogenome, Biomarker identification and validation of a disease state. **(5)**

3. **Overview:** Precision Medicine, the Human Genome, and Human Genomic Variation, Human Genome project. Cancer genome project. **(5)**

4. **Epigenome:** DNA Methylation, Histone Modifications, Chromatin Remodeling Factors, Different types of genetic and non-genetic variations. **(5)**

5. **Genetic screening and diagnosis**: prenatal carrier testing and newborn screening for Mendelian diseases, Pharmacogenomic testing for drug selection, dosing and predicting adverse effects of commonly prescribed drugs, Tumor profiling, Patient data and clinical decisions. **(5)**

6. **Developing Evidence**: For PM & Designing PM Clinical Trials, Implementation Science & Costs of PM, Risk assessment through omics approach. **(5)**

7. **Ethical, legal, and social implications:** Health privacy and policy laws for precision medicine. Educating the Public and Providers. **(5)**

8. **Ayurveda system of Prakriti and Agni**: Population health and public health interventions. AYUSH recommendations wrt precision medicine and wellness, National Medical council and Indian Pharmacopeia wrt precision medicine. **(5)**

Text/Reference Books:

1. The New Genetics, NIH Publication, Bethesda, MD: U.S. Department of Health and Human Services. 2010.
2. Genomic and Precision Medicine by Ginsburg G and Willard H, Third edition, 2016.
3. The Language of Life: DNA and the Revolution in Personalized Medicine, Francis S. Collins, 2011.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	3	3	2	2	3	2	2	3	3
CO2	3	2	3	3	2	2	2	2	2	3	2	2

Paper Code: PCE-	Paper name: Regenerative Medicine	L	T	P	C
Paper id:	(5th Semester; Open Area Elective)	3	1	0	4

Course Objectives

1. To apply prior scientific knowledge to understand regenerative medicine concepts.
2. To evaluate potential ethical concerns surrounding advances in regenerative medicine.
3. To develop skills to enhance sustainability of bioartificial organs

Course Outcomes

After successful completion of this course, the students should be able to understand:

1. Understand the concept of regenerative medicine as a bio-skill.
2. To strengthen critical thinking skills through analysis of scientific literature.
3. Demonstrate skills, processes, and resources needed to make a successful transition from medical to biotechnology.

1. **Introduction and overview:** Role and relation w.r.t tissue engineered product and biomaterials. Augment, repair, replace and regenerate genes, cells, tissue, organs and metabolic processes. **(4)**
2. **Molecular and cellular basis of organ development:** Cloning of somatic cells by nuclear transfer, nuclear transplantation, mechanism of embryonic development. **(5)**
3. **Molecular basis of disease:** Role of eight growth factor in *in vitro* stem cell differentiation. Niche biology and its role in stem cells fate determination. Organoids and its application. Stem cells transplantation and its application. **(4)**
4. **Cell reprogramming and reconditioning**: Tissue regeneration, Isolation of pluripotent cells from mouse embryo (landmark research), Adult fibroblasts into pluripotent cells. **(5)**
5. **Translational Research and Personalised Medicine**: Chondrodysplasia and colon cancer, effect of mutation on cartilage derived morphogenetic protein 1. **(4)**
6. **Gene Therapy:** Hematopoietic stem cells, induced pluripotent stem cells (iPSCs) and viral vector-mediated. **(3)**
7. **Bioartificial Organs**: Therapeutic uses of Stem cells, Tissue regeneration driven by growth hormone. Mesenchymal Stem Cells in osteoarthritis, Bone marrow cells in Myocardial infarction, Bioartificial heart, bioartificial kidney. **(5)**
8. **Organ Transplantation**: Bone marrow stem cell transplantation in myeloproliferative disorders, Human IPSCs in neuro-morphological diseases. **(4)**
9. Ethical, legal and social concerns in regenerative medicine. **(2)**
10. **Experimental models:** Meta-analysis of non-malignant diseases: Autoimmune, cardiac or vascular disease, blood-derived stem cells preclinical and clinical studies. **(4)**

Text/Reference Books:

1. Translational Regenerative Medicine by Atala A, Allickson J, 2014.
2. Cell Biology and Translational Medicine, Volume 13 by Turksen K, 2021.
3. Dictionary of Stem Cells, Regenerative Medicine and translational

Medicine by Dye FJ, 2017.

4. Stem Cell Engineering: Principles and Applications by Artmann, Minger and Hescheler, Springer, 2011.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	1	1	2	3	2	2	2	3	3
CO2	3	2	2	1	1	3	2	3	2	2	3	3
CO3	3	2	2	2	1	3	2	2	2	2	3	3

Paper Code: EAE	Paper name: Nanobiotechnology	L	T	P	C
Paper id:	(5th Semester; Emerging Area Elective)	3	1	0	4

Course Objectives:

1. To enumerate the role of nanoscience in biotechnology
2. To know the spectrum of applications at nano-scale
3. To understand the techniques for nanoscale applications.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Learn nano-scale synthesis techniques.
2. Learn application-based synthesis techniques in nanobiotechnology.
3. Learn the role of nanobiotechnology in healthcare.

1. **Overview:** History and overview of Nanobiotechnology; Applications and Implications; Current Research; Top-down and bottom-up approaches. **(4)**
2. **Nanostructures**: Properties, Synthesis techniques and applications of Carbon nanotubes, metal nanoparticles, zinc oxide nanoparticles and nanochemicals. **(6)**
3. **Microfabrication and nanofabrication**: Processes, Drug delivery and Gene delivery tools in nanobiotechnology, nanobiosensors-different classes and recognition elements.**(6)**
4. **Nanodevices:** Quantum Dots Technology and its application, Tumor Targeting, nanoimaging agents, nanodiagnostic devices. **(5)**
5. **Nanoparticles monitoring**: Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM). **(4)**
6. **Biological nanoparticles**: Microbial, plant cell (green synthesis) and animal cell based, Cytotoxicity. **(5)**
7. **Applications**: Food technology and environmental science. **(4)**
8. **Application in healthcare**: Biomedical nano-polymers, Application in health and disease pharmaceuticals, cardiovascular, ophthalmology and orthopedics. **(6)**

Text/References books:

1. Nanotechnology in Biology and medicine: Methods, Devices and applications by Vo-Dinh T, CRC Press, 2019.

2. Nanobiotechnology-II Concepts and applications by Mirkin CA and Niemeyer CM, Wiley VCH, 2007

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	1	2	2	2	2	2	3	2	3
CO2	3	2	3	1	1	2	2	2	2	3	2	3
CO3	3	2	3	1	1	3	2	3	3	3	3	3

Paper Code: EAE	Paper name: Rational Drug Discovery	L	T	P	C
Paper id:	(5th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

1. This course is aimed at imparting knowledge and skill to understand the drug discovery process.
2. Rational methods to identify and design 117 molecules for new medications greatly shortening the discovery phase of drug development by computational methods

Course Outcomes

After the completion of this course students are expected to:

1. Understand various methods of rational drug design such as modelling of protein and target-small molecule interactions.
2. Molecular docking, lead optimization.
3. Combinatorial chemistry and library design.
4. Virtual screening, Toxicity (ADMET) property analysis, Pharmacophore and QSAR.

1. **Molecular Modelling in Drug Discovery**: Drug discovery process, Role of Bioinformatics in drug design, Methods of computer aided drug design, ligand design methods, drug design approaches, Target identification and validation, lead optimization and validation, Structure and ligand-based drug design, modelling of target-small molecule interactions, Molecular simulations.**(5)**
2. **Protein Modelling:** Knowledge-based free modelling, comparative modelling, Threading and fold-recognition, Composite structure modeling approach, Structure refinement and validation. Introduction to various online and stand-alone computer programs to model protein structure. **(5)**
3. **Quantum Mechanics and Molecular Mechanics:** Features of molecular mechanics force fields; Bond structure and bending angles – electrostatic, van der Waals and non – bonded interactions, hydrogen bonding in molecular mechanics; Derivatives of molecular mechanics energy function; Application of energy minimization. **(5)**
4. **Molecular Dynamics Simulation Methods:** Molecular Dynamics using simple models; Molecular Dynamics with continuous potentials and at constant temperature and pressure; Time – dependent properties; Solvent effects in Molecular Dynamics; Conformational changes from Molecular Dynamics simulation and application. **(5)**
5. **Molecular Docking and Lead Optimization**: Molecular Docking; Types of Molecular Docking, docking algorithms and programs, Structure-based methods to identify lead compounds; de novo ligand design. **(5)**
6. **Applications of 3D Databases Searching and Virtual Screening:** Strategy for target identification and Validation, lead identification, optimization and validation. Combinatorial chemistry and library design, virtual screening, drug likeness and compound filtering, Absorption, distribution, metabolism, excretion and toxicity (ADMET) property prediction, computer based tools for drug design. **(5)**
7. **Pharmacophore and QSAR:** Pharmacophore derivation, 3D pharmacophore prediction and application in drug discovery; QSARs and QSPRs, QSAR Methodology, Various Descriptors used in QSARs: Electronic; Topology; Quantum Chemical based Descriptors. **(5)**
8. Use of Genetic Algorithms, Neural Networks and Principal Components Analysis in the

QSAR equations. **(5)**

Text/Reference Books:

1. Computational methods in drug design by Cohen FE, Hamilton W, Moos Publisher: ESCOM Science, 1993.
2. Molecular Modelling for Beginners by Hinchliffe A, Publisher: John Wiley & Sons Inc, 2008.
3. Combinatorial Library Design and Evaluation: Principles, Software, Tools, Applications in Drug Discovery by Ghose A, Viswanadhan V, Publisher: CRC Press, 2001.
4. Molecular Modeling Basics by Jensen JH, Publisher: CRC Press, 2010.
5. 3D QSAR in Drug Design: Recent Advances by Kubinyi H, Folkers G, Martin YC, Publisher: Springer Science & Business Media. 1998.
6. Computational Chemistry and Molecular Modeling by Ramachandran KI, Deepa G, Namboori K, Publisher: Springer – Verlag Berlin Heidelberg. 2008.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	3	1	2	1	2	3	2	2
CO2	3	3	2	3	3	1	2	2	2	3	2	2
CO3	3	3	2	3	3	1	2	1	2	3	2	1

Paper Code: PCE-	Paper name: Artificial Intelligence in Healthcare	L	T	P	C
Paper id:	(5th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

1. To equip student to identify, understand, and interpret methods and evidence from artificial intelligence and other relevant literature.
2. To train students to effectively communicate and disseminate knowledge in any science or engineering domain in the context of computing, systems, and/or biomedical applications.

Course Outcomes

After successful completion of this course, the students should be able to understand:

1. Understand models of human and artificial intelligence, specifically computational models of intelligence.
2. Comprehend a collection of machine learning models (identified and covered in the course), and their applications in medicine and healthcare.
3. Identify and apply appropriate intelligent system models and computational tools to specific problems in biomedicine and healthcare.
4. Analyze the performance of specific models as applied to biomedical problems, and justify their use and limitations.

1. **Introduction to Human and Artificial Intelligence**: Terminologies, computational models of intelligence; conceptual frameworks from cognitive and educational psychology, neuroscience, information theory, and linguistics; philosophical foundations of AI. **(5)**
2. **Review of relevant mathematical and statistical concepts:** Logarithmic loss, cross entropy optimizing cost functions; linear and logistic regression. **(5)**
3. **Forms of Learning:** supervised, semi-supervised, unsupervised, active, and transfer learning, Supervised Learning: (a) Decision trees, non-parametric methods for learning, support vector machines, (b) Bio-inspired Learning (from perceptron to deep learning): neural basis of computing, classical neural networks, deep neural networks, deep belief networks, recurrent neural networks, and convolutional neural networks. **(5)**
4. **Unsupervised Learning:** Basic and advanced clustering techniques, dimensionality reduction (feature selection and feature extraction), Knowledge Representation and Reasoning: Prepositional logic, first-order logic, ontological engineering, probabilistic reasoning **(5)**
5. **Time-series analysis**: Temporal models (probabilistic reasoning over time), Emerging paradigms and concepts in artificial social and emotional intelligence, Unique characteristics and challenges in medicine and healthcare; History and status quo of intelligent and expert systems in medicine. **(5)**
6. Risk stratification, patient outcome prediction, disease progression modelling, Clinical decision-making and intelligent systems to support evidence-based medicine, Phenotype and clinical/bio-marker discovery, Relevance to personalized medicine. **(5)**
7. **Analysis of tissue morphology and other medical imaging applications**: Tools and Technologies for implementing AI methods, Model evaluation and performance metrics, cross-validation, model interpretability. **(5)**
8. **Ethics of AI:** Bias, fairness, accountability, and transparency in machine learning; Ethical, Legal, and Social Issues of AI in medicine and healthcare. **(5)**

Text/Reference Books:

1. Artificial Intelligence: A Modern Approach by Russell S and Norvig P. (3rd ed.). Prentice Hall Press, Upper Saddle River, NJ, USA. 2009.
2. Programming Collective Intelligence by Segaran T. (First ed.). O'Reilly Media, 2007.
3. Machine Learning in Medicine - a Complete Overview by Cleophas TJ, and Zwinderman AH. Springer. 2015.
4. Practical Machine Learning by Gollapudi S, Packt Publishing Ltd. 2016.
5. Machine Learning in Action by Harrington P. Manning Publications Co., USA. 2012.
6. Selected seminal and contemporary readings from peer-reviewed literature such as Proceedings of Machine Learning in Healthcare, Artificial Intelligence in Medicine, IEEE Transactions on Biomedical and Health Informatics, and other relevant venues.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	3	1	2	1	3	1	1	2
CO2	3	2	2	3	2	1	2	1	3	1	1	3
CO3	3	3	2	3	3	1	2	1	2	1	1	2
CO4	3	2	3	3	3	1	2	1	3	2	1	2

SEMESTER VI

Group	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-314	Bioinformatics	3	1	4
PC	BT-316	Intellectual Property Rights, Biosafety and Bioethics in Biotechnology	3	1	4
PC	BT-318	Downstream Processing	3	1	4
PC	BT-322	Bioprocess Engineering	3	1	4
PCE-2*/ EAE-2***	BT-312	Professional Core Elective-2	3	1	4
OAE-2**	BT-320	**Open area elective offered by USBT-1 or Elective from other schools	3	1	4
Practical/Viva Voce					
PC	BT-352	Bioinformatics – Lab	0	3	1.5
PC	BT-360	Bioprocess Engineering – Lab	0	3	1.5
PCE	BT-354	Food and Nutrition Technology -Lab	0	3	1.5
Total			**18**	**15**	**28.5**

***PCE: Professional Core Elective-2 (any one)**

		L	T/P	Credits
PCE-2	Statistical Methods in Biology and Experimental Design	3	1	4
PCE-2	Food and Nutrition Technology	0	3	1.5
PCE-3	Food and Nutrition Technology- Lab			
PCE-4	Entrepreneurship and case studies			

****Open Area Elective-2 (any one)**

		L	T/P	Credits
OAE2-BT	Plant Secondary Metabolites and Their Applications	3	1	4
OAE	Waste Management and Upcycling			
OAE	Artificial Intelligence for Designing Therapeutics			
	MOOCs (Only Govt. approved platforms like SWAYAM, NPTEL, e-PG Pathshala, etc.)			4

Paper Code: BT-314	Paper name: Bioinformatics	L	T	P	C
Paper id: 013314	(6th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. This course is beneficial for students to understand the principles of analyzing biological data, building models and testing hypotheses using computer science algorithms.
2. This course is a survey of algorithms and tools in biological sequence analysis, genome-wide disease association, and precision medicine.
3. It will also introduce information technology practices in the field of biotechnology.
4. The course will provide a basic overview of various information repositories widely used in biological sciences; and tools for searching or querying those databases.
5. This course will build foundation of sequence alignment techniques and to find evolutionary connections. It will help students to analyze mRNA expression data and gene annotations.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Perform Computational analyses of biological sequences, genome-wide studies and relate the results to core principles of biology.
2. Use Computational methods to help execute a biological research plan.
3. Browse or retrieve gene, protein sequences and related information from biological databases.
4. Understand Align sequences using dot matrices, dynamic programming and heuristic approach; understand the notion of similarity, identity and gaps in the context of sequence alignment and deduce evolutionary relationships among sequences.

1. **General introduction**: Bioinformatics, Computational biology, in silico analysis, Biocomputing, bioinformatics and its applications. **(5)**
2. **Significance of bioinformatics analysis**: Scientific acceptance and validation of bioinformatics data interpretation. Biological databases and tools: Nucleotide sequence databases, Protein sequence, NCBI, EBI, DDBJ, Sequence file formats, Collection of sequences, Sequence annotation, Sequence description. **(5)**
3. **Structural and functional databases:** PDB, MMDB, KEGG, Uniprot, Structure file formats, Visualizing structural information, Structure viewer tools, Patent database, in silico tools for rDNA technology. **(5)**
4. **Database searching**: BLAST and its types, Entrez, Ensembl-Biomart. Evolutionary basis of sequence alignment, Optimal alignment methods, Substitution Scores and gap penalties, Statistical significance of alignments, database similarity searching, **(5)**
5. **Pairwise sequence alignment:** Dynamic programming, Scoring Matrices, Distance matrices, Gaps. Multiple sequence alignment: Progressive alignment methods, Dynamic and heuristic methods, Scoring Matrices, Distance matrices, Gaps, Low complexity regions, Repetitive elements, Relevance to inferences about evolution, **(5)**
6. **Introduction to molecular phylogeny:** Phylogenetic analysis: Introduction, Types of Phylogenetic Trees, Methods (UPGMA, NJ, MP,ML, etc.) and Applications. Bootstrap. Plotting and visualization of trees, interpretation of molecular phylogeny data. **(5)**
7. **DNA barcoding:** methods, tools and databases, CBOL recommendations, BOLD. **(5)**
8. **Computational genomics**: Genomic variations and its associations: Linking genes, variations and diseases; Introduction to biomarkers and personalized medicine. Network biology and human diseases: Genome-wide association studies (GWAS), Genome editing

tools and applications to human diseases, Cancer genomics – TCGA, GREF, Immuno-informatics. **(5)**

Text/Reference Books:

1. Bioinformatics and Functional Genomics by Pevsner J. 2nd Edition. 2015.
2. A Primer of Genome Science by Gibson G and Muse SV. Third Edition. 2009
3. Essential Bioinformatics by Xiong J, Cambridge University Press; 1st edition 2006.
4. Bioinformatics: methods and applications by Rastogi SC, PHI learning; 4th edition, 2013.
5. The Dictionary of Genomics, Transcriptomics and Proteomics by Kahl G, Willey VCH, 2015.
6. Web-resources and suggested reviews/ research papers.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	3	1	2	1	3	1	1	3
CO2	3	3	2	3	3	1	2	1	3	1	1	3
CO3	3	3	2	3	3	1	2	1	3	1	1	3
CO4	3	3	3	3	3	1	2	1	3	2	1	2

Paper Code: BT-316	Paper name: Intellectual Property Rights, Biosafety and Bioethics in Biotechnology	L	T	P	C
Paper id:	(6^{th} Semester; Professional Core)	3	1	0	4

Course Objectives:

1. Knowledge of the various societal, governance and regulatory issues for safe and acceptable biotechnology.
2. Knowledge of the principles and practices of safety and ethics in biotechnology research and industry
3. Knowledge of the global and national aspects of intellectual property rights in biotechnology, bioeconomy

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Understand and apply safe practices of biotechnology in compliance with the regulations
2. Understand and apply ethical professional practices in biotechnology and beyond
3. Understand and apply the laws of intellectual property rights in biotechnology and beyond.

1. Biotechnology and Society, perceptions of the consumers, government, industry and civil society. **(3)**
2. Biotechnology and globalization, role of international economic and regulatory regimes.**(4)**
3. **Bioethics:** Codes of ethics in history, UN Declaration on bioethics and human rights, implications. **(4)**
4. **Research and regulatory ethics:** Responsible Conduct of Research, misconduct, Falsification, fabrication, plagiarism, conflict of interest, regulatory misconduct, implications for public trust in biotechnology. **(4)**
5. Biosafety: Concepts, biosafety in the laboratory, institution and outside, regulatory regime through institutional, state and national biosafety bodies, biosafety in rDNA work, hospitals, fields etc. **(4)**
6. **International biosafety dimensions**: Cartagena Protocol, biological warfare and bioterrorism. **(3)**
7. Food safety and environmental safety evaluation of genetically modified microbes, crops, animals. **(6)**
8. Intellectual Property Rights (patent, copyright, design, geographical indication, plant variety, trade secret, their scope and duration of protection, their international harmonisation and transition from national to WTO regime, PCT, TRIPS+, FTAs, current domestic and global scenario. **(3)**
9. **Patents in biotechnology**: Patentable subject matter, procedure of patenting, products and processes, novelty, non-obviousness, utility, enablement, disclosure. **(6)**
10. **IPR in agriculture**: Plant variety Protection, Plant Patents and Utility patents. **(2)**
11. Strategic aspects of patent filing locally and abroad, patent litigation. **(1)**

Text/Reference Books:

1. Encyclopedia of Bioethics, Fillis, J, 2015.
2. Biotechnology - A comprehensive treatise (Vol. 12). Legal economic and ethical dimensions by Rehm HJ, Reed G VCH, 2010.
3. Biotechnology and Safety Assessment by Thomas JA, Fuch RL (3rd Ed). Academic Press. 2002.
4. Biological safety Principles and practices by Wooley D and Byers K (5th Edition), ASM Press, 2017.
5. The law and strategy of Biotechnological patents by Sibley, Butterworth publications, 1994.
6. Recent reviews/articles and websites such as WIPO.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	3	2	2	3	3	2	2	3	2	3
CO2	2	2	3	2	2	3	3	3	2	3	1	3
CO3	3	3	3	2	2	3	3	3	2	3	3	3

Paper Code: BT-318	Paper name: Downstream Processing	L	T	P	C
Paper id:	(6th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. Understanding the fundamentals of downstream processing for biochemical product recovery.
2. Learn the design and operation of unit processes with centrifugation, chromatography, filtration, and membrane processes
3. Examining traditional unit operations, as well as new concepts and emerging technologies that are likely to benefit biochemical product recovery in the future.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Understand effective strategies of downstream processing based on characteristics of biomolecules.
2. Apply the knowledge of various unit operation techniques in downstream processing of biomolecules.
3. Understand and use the knowledge of DSP of industrial important products and quality control.

1. **Introduction to Bioproducts:** Broad classification of bioproducts, small molecules, macromolecules: proteins, nucleic acids and polysaccharides, particulate products: SCP. **(4)**

2. **Introduction to Bioseparation:** Stages of bioseparations, basic principles of bioengineering analysis, process and product quality, criteria for process development. **(4)**

3. **Analytical methods during Downstream Processing:** Assay attributes, analysis of biological activity, analysis of purity, microbiology assays. **(4)**

4. **Unit operations in Downstream Processing:** Cell analysis and flocculation, filtration, sedimentation, extraction (phase separation), liquid chromatography and adsorption, affinity tag-based purification, precipitation, crystallization, evaporation, drying, formulation, container closure system. **(8)**

5. **Screening and Design Purification Strategies:** Overview, low- and high-resolution protein purification methods, establishment of a design space for biopharmaceutical process. **(4)**

6. **DSP of Proteins and Enzymes:** Overview, initial recovery of proteins, removal of whole cells and cell debris, purification of recombinant proteins, purification of proteins from inclusion bodies and membranes. Case study of lipases. **(4)**

7. **DSP of Biotherapeutics and Quality Control:** Purification of therapeutic proteins, range and medical significance of impurities in protein based therapeutic products, detection of endotoxin, virus, mycoplasma and phage, labeling and packing of finished

products. **(4)**

8. **DSP of Small molecules:** Case study of antibiotics and amino acids. **(4)**

9. **DSP of Macromolecules:** Case study of nucleic acid and polysaccharides. **(4)**

Text/Reference Books:

1. Bioseparations Science and Engineering (2nd edition) by Harrison, Todd, Rudge and Petrides, Oxford university Press, 2015.
2. Bioprocess Engineering: Downstream Processing by Show, Ooi and Ling, CRC Press, 2019.
3. Protein Downstream Processing; Design, Development and Application of High and Low-Resolution Methods in Molecular biology by Labrou, Nikolaos Humana Press. 1st and 2nd editions; 2014 and 2021.
4. Proteins: Biochemistry and Biotechnology by Gary Walsh, Second Edition, Wiley Blackwell, 2014.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	2	1	1	1	1	2	2	3
CO2	3	3	3	3	3	2	2	1	2	3	2	3
CO3	3	2	3	3	3	3	2	3	2	3	3	3

Paper Code: BT-322	Paper name: Bioprocess Engineering	L	T	P	C
Paper id:	(6^{th} Semester; Professional Core)	3	1	0	4

Course Objectives:

1. Understanding the overall process kinetics and scale up in bioprocesses including reactor configurations and design.
2. Learn the process technology behind manufacturing of commercially important bioproducts.
3. To know the safety principles and practices including regulatory and ethical norms in bioprocess engineering.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Understand the basic reaction theory and calculate the kinetic parameters of enzymatic reactions.
2. Calculate and analyze the kinetic parameters for microbial growth.
3. Analyze bioprocess design, operation and select suitable bioreactor.

1. **Stoichiometry Of Microbial Growth and Product Formation**: Introduction, Some Other Definitions, Stoichiometric Calculations, Elemental Balances, Degree of Reduction, Theoretical Predictions of Yield Coefficients. **(4)**

2. **Homogeneous Reaction Engineering:** Basic reaction theory, calculation of reaction rates, general reaction kinetics for biological systems, yields in cell culture, cell growth kinetics, production kinetics, kinetics of cell death. Kinetics of substrate uptake, Determining cell Kinetics Parameters from batch data. **(4)**

3. **Heterogeneous Reaction Engineering**: Concentration gradients and reaction rates in solid catalysts, internal mass transfer and reaction, the Thiele modulus and effectiveness factor, external mass transfer. Liquid-solid Mass transfer effects. **(4)**

4. **Process Initialization:** Types of sterilization, thermal death kinetics of microorganism. Heat sterilization of liquid medium in batch and continuous mode. Air sterilization. Inoculum development. Various types of Fermentation, submerged fermentation, aerobic and anaerobic fermentation. Overview of biosynthetic mechanisms. **(5)**

5. **Reactor Engineering:** Bioreactor configurations, practical considerations for bioreactor construction, monitoring and control of bioreactors, ideal reactor operations, batch operation of a mixed reactor. **(5)**

6. **Bioprocess Scale up:** Scale up with constant parameters like OTR, mixing, shear stress, flow regime, Reactor volume, etc. Scale-up methods by currently used rules-of-thumb viz. constant P/V, kLa, Various approaches to scale-up including regime analysis and scale-down. Analysis of alternate bioreactor configurations including cell-recycle, air-lift and immobilized-cell bioreactors, Problems on scale-up methods. **(5)**

7. **Commercial Products Processing (upstream only):** Bulk organics (ethanol), Biomass (Bakers Yeast), Organic acids (Citric Acid), Amino Acids (L-Lysine), Nucleic acids (plasmid or mRNA), Antibiotics (Penicillin), Extra Cellular Polysaccharides (Pneumococcal Vaccines). **(4)**

8. **Process Technology to non-conventional Biological Systems:** Bioprocess considerations in using animal cell cultures, plant cell cultures, genetically engineered organisms. **(5)**

9. **Bioconversions:** Applications of bioconversion, transformation of steroids and sterols. Transformation of non-steroidal compounds, antibiotics and pesticides. Bioenergy-fuel from biomass, production and economics of biofuels. **(4)**

Text / Reference Books:

1. Bioprocess Engineering - Basic concepts by Schuler ML, Kargi F & DeLisa M, 3rd Edition, Prentice Hall, 2017.
2. Bioprocess Engineering Principles by Doran PM, 2nd Edition Academic Press 2012.
3. Basic Biotechnology by Ratledge C & Kristiansen B, "3rd Edn. Cambridge University Press, 2008.
4. Principles of Fermentation Technology by Stanbury PF, Hall SJ & Whitaker A, Â Elsevier India Pvt Ltd, 2007.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	2	3	1	1	1	3	3	3
CO2	3	3	3	3	2	3	2	2	2	3	3	3
CO3	3	3	3	3	3	3	2	3	3	3	3	3

Paper Code: PCE-1	Paper name: Statistical methods in biology and experimental design	L	T	P	C
Paper id:	(6th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

1. To learn biological data collection, presentation, analysis and interpretation.
2. To know the mathematical tools for data analysis and experimental design.
3. To design biological experiments for statistically significant outcomes

Course Outcomes

After successful completion of this course, the students should be able to understand:

1. To identify the type of statistical situation to which different distributions can be applied.
2. To learn how to formulate and test hypotheses about sample means, variances and proportionsand to draw conclusions based on the results of statistical tests.
3. Understand how regression analysis can be used to develop an equation that estimates how two variables are related and to distinguish between correlation and regression.
4. Understand the principles and theory of designing experiments.

1. **Collection and presentation of data:** Different methods of presentation of data, sampling procedures. **(1)**
2. **Probability Distribution:** Introduction to probability and laws of probability, Random Events, Events-exhaustive, Mutually exclusive and equally likely (with simple exercises), Definition and properties of binomial distribution, Poisson distribution and normal distribution. **(5)**
3. **Statistical hypothesis testing:** Making assumption, Null and alternate hypothesis, error in hypothesis testing, one-tailed and two-tailed testing, decision making. **(5)**
4. **Tests of Significance:** Large sample tests - test for an assumed mean and equality of two population means with known S.D., Z-test; Small sample tests- t-test for an assumed mean and equality of means of two populations when sample observations are independent. **(4)**
5. **Correlation and regression:** Karl Pearson's correlation coefficient (r), partial and multiple correlation, Linear Regression equation and simple regression analysis. **(2)**
6. **Parametric and Non parametric tests:** (Mann-Whitney test); paired and unpaired t-test, chi-square test. **(3)**
7. **Analysis of Variance:** The Analysis of Variance (ANOVA), Interpretation of Results, Determining Sample Size, Single-Factor Experiments, The Random Effects Model, The Regression Approach to the Analysis of Variance, Nonparametric Methods in the Analysis of Variance. **(7)**
8. **Design of Experiments:** Importance of experimental designs, principle of experimental designs, Completely Randomised Design (CRD) Randomized Block Design (RBD), Latin Square Design, Factorial designs. **(8)**
9. **Response Surface Methods (RSM) and Designs:** Design of experiments using RSM, Method of Steepest Ascent, Analysis of a Second-Order Response Surface, Experimental Designs for Fitting Response Surfaces. **(5)**

Text/Reference Books:

1. Methods in Biostatistics for Medical Students and Research Workers by Jaype Brothers, 7th Edition, 2011.
2. Statistical methods in biology by Norman T.J. Bailey, Cambridge University Press 3rd Edition, 1995.
3. Biostatistics by Arora PN and Malhan PK, Himalaya Publishing House, 2nd Edition, 2006.
4. Biostatistical analysis by Zar J, Pearson Education, 4th Edition. 1999.
5. Biostatistics; A foundation for analysis in the Health Sciences by Daniel WW and Cross CL, Wiley, Edition. 2013.
6. Statistics for the Life Sciences by Samuels ML and Witmer JA, 3rd edition. Prentice Hall, 2003.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	2	1	1	1	2	1	2	1
CO2	3	3	2	3	2	1	1	1	2	2	2	2
CO3	3	3	2	2	1	1	1	1	2	1	1	1
CO4	3	3	2	3	1	1	1	1	2	1	1	1

Paper Code: BT-312	Paper name: Food and Nutrition Technology	L	T	P	C
Paper id:	(6th Semester; Professional Core)	3	1	0	4

Course Objectives: The objectives of this course are

1. To acquaint the students with various sources of food and nutrition and ways to utilize them.
2. To introduce them to recent advances in biotechnology in foods to produce new products with desirable characteristics.
3. To impart knowledge about processing of various food items for storage, enhanced flavour and nutritional quality.

Course Outcomes:

After successful completion of this course, the students should be able to understand:

1. Should know how to combine various items in diet for balanced food and nutrition.
2. Should have gained knowledge about recent advances in biotechnology related to food technology.
3. Should be able to propose food related technical advances for societal benefit.

1: Introduction: Introduction to concept of food and nutrition, history and scope of food Biotechnology. **(3)**

2: **Sources and their nutritional value**: Development and prospects of utilizing diversity of plants, animals, microbes and miscellaneous natural resources as food items and understanding their nutrition value. **(4)**

3: **Basic techniques in food processing**: Conventional methods for collection, sorting and storage of various types of edible resources, their processing, introduction to relevant biochemical and metabolic pathways applied in food production. **(5)**

4: Methods in food biotechnology: Role of biotechnology in maximising productivity from different food sources, Modern biotechnological methods and processes in animals, plant and microbial product development; Quality control, Screening products for food-borne contaminants, Bioassays and related methods. **(6)**

5: Biotechnological methods in food processing: Use of advanced biotechnological interventions for the processing of food from various sources, technology for nutritional enhancement/up gradation; biofortification, as prebiotics or probiotics etc. **(6)**

9. **Technology for sustainable food and nutritional availability**: preservation of food for managing surplus/bumper yields and ensuring long term quality food and nutrition availability. **(6)**

7: Food processing industry: Consumer concerns about risks and values, biotechnology & food safety, Ethical issues concerning GM foods; testing for GMOs; current guidelines for the production, release and movement of GMOs to promote consumer acceptance. **(6)**

8. **Future and applications of food biotechnology in India**: Need for customized/specialized, nutritious and processed food items by various sectors (army,

locations in difficult to grow or cook etc), examples of products developed. **(4)**

Text/Reference Books:

1. A laboratory manual of food analysis by Singh, S, I K International Publishing House Pvt. Ltd, 2016.
2. Foods: Facts and Principles by Manay S, Swamy S, 4 th Ed. New Age Publishers. 2004.
3. Food Science by Srilakshmi B, New Age Publishers, 2002.
4. Principles of Food Chemistry by Deman JM, 2 nd Ed. Van Nostrand Reinhold, N, 1990
5. Food Nutrition, Science and Technology by Singh N, Singh, IS Woodhead Publishing India PVT. Limited, 2018.
6. Science of Food by Sherington KB and Gaman P, Routledge M, 2015.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	3	2	3	3	3	2	2	3	3	3
CO2	3	3	3	3	3	3	3	3	2	3	2	3
CO3	3	3	3	2	3	3	3	2	3	2	3	3

Paper Code: PCE-	Paper name: Data Science	L	T	P	C
Paper id:	(6th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

The objective of this course is to impart necessary knowledge of the mathematical foundations needed for data science and develop programming skills required to build data science applications.

Course Outcomes

At the end of this course, the students will be able to:

1. Demonstrate understanding of the mathematical foundations needed for data science.
2. Collect, explore, clean, munge and manipulate data.
3. Implement models such as k-nearest Neighbors, Naive Bayes, linear and logistic regression, decision trees, neural networks and clustering.
4. Build data science applications using Python based toolkits.

1. **Introduction to Data Science**: Concept of Data Science, Traits of Big data, Web Scraping, Analysis vs Reporting. **(5)**
2. **Introduction to Programming Tools for Data Science**: Toolkits using Python: Matplotlib, NumPy, Scikit-learn, NLTK; Visualizing Data: Bar Charts, Line Charts, Scatterplots. **(5)**
3. **Working with data**: Reading Files, Scraping the Web, Using APIs (Example: Using the Twitter APIs), Cleaning and Munging, Manipulating Data, Rescaling, Dimensionality Reduction. **(5)**
4. **Mathematical Foundations**: Linear Algebra: Vectors, Matrices. Statistics: Describing a Single Set of Data, Correlation, Simpson's Paradox, Correlation and Causation. **(5)**
5. **Probability:** Dependence and Independence, Conditional Probability, Bayes's Theorem, Random Variables, Continuous Distributions, The Normal Distribution, The Central Limit Theorem. **(5)**
6. **Hypothesis and Inference:** Statistical Hypothesis Testing, Confidence Intervals, P Hacking, Bayesian Inference. **(5)**
7. **Machine Learning Overview of Machine learning concepts** – Over fitting and train/test splits, Types of Machine learning – Supervised, Unsupervised, Reinforced learning, Introduction to Bayes Theorem, Linear Regression- model assumptions, regularization (lasso, ridge, elastic net), Classification and Regression algorithms- Naïve Bayes, K-Nearest Neighbors, logistic regression, support vector machines (SVM), decision trees, and random forest, Classification Errors, Analysis of Time Series- Linear Systems Analysis, Nonlinear Dynamics, Rule Induction, Neural Networks Learning And Generalization, Overview of Deep Learning. **(5)**
8. Case Studies of Data Science Application Weather forecasting, Stock market prediction, Object recognition, Real Time Sentiment Analysis **(5)**

Text/Reference Books:

1. Data Science from Scratch: First Principles with Python by Joel Grus, O'Reilly Media 144, 2015.
2. Hands-On Machine Learning with Scikit-Learn and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems by Aurélien Géron, 1st Edition,

O'Reilly Media, 2017.
3. Data Science & Analytics: Using Python, R and SPSS Programming by Jain VK, Khanna Publishing House, Delhi. 2019.
4. Big Data and Hadoop by Jain VK, Khanna Publishing House, Delhi. 2017.
5. Introduction to Machine Learning using Python by Jeeva Jose, Khanna Publishing House, Delhi. 2020.
6. Machine Learning by Chopra Rajiv, Khanna Publishing House, Delhi. 2018.
7. Deep Learning by Goodfellow I, Bengio Y and Courville A, MIT Press, 2016.
8. Data Mining Concepts and Techniques by Han J and Pei J, Third Edition, Morgan Kaufmann Publishers. 2012.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	2	1	2	1	3	1	1	3
CO2	2	2	2	2	2	1	2	1	3	1	1	3
CO3	2	2	2	2	2	1	2	1	3	1	1	3
CO4	3	3	3	3	3	1	2	1	3	2	1	2

Paper Code: BT-320	Paper name: Plant secondary Metabolites and their Applications	L	T	P	C
Paper id:	(6^{th} Semester; Open area elective)	3	1	0	4

Course Objectives:

1. To understand the meaning and potential utility of various PSMs.
2. To identify plant sources and ways to harvest PSMs diversity.
3. To expose students to their possible applications and commercialization aspects.

Course Outcomes:

After taking this course, students would be able:

1. To develop understanding for various plants derived metabolites produced for their own specific needs besides their multiple potential uses in different walks of life.
2. To assess the choice of plant sources for specific PSMs with relevant uses and propose ways to produce and use them as well.
3. To appreciate the diversity of PSMs and their subsequent development as molecules/metabolites of choice for various uses at commercial scale.

1. Definition of Plant Secondary Metabolites (PSMs), classification/categories of PSMs. **(4)**

2. Chief sources of selected PSMs, their yields, market valuation and potential. **(4)**

3. Functions of PSMs in plant life (defense, reproduction, etc), different conditions and plant parts wherein expression and accumulation of diverse PSMs occurs in situ. **(5)**

4. Commercial/industrial scale production of important PSMs, a brief introduction to various approaches. **(5)**

5. Industrial applications of PSMs: an account of various plant sources and the specific PSMs with possible uses in food industry (coloring, flavoring, fortification, probiotics, neutraceuticals, etc), furniture industry, agricultural sector (insecticide, pesticide agents), textile industry (dyes), perfumery, cosmetics. **(8)**

6. Pharmaceutical/medicinal applications: introduction to diverse plant sources and PSMs from them with evidence based applications as anticancer, antiviral, antibacterial, antifungal, antimicrobial, antitumor, cholesterol-lowering, immunosuppressant, antiprotozoal, antihelminth, and anti-ageing activities to name a few. **(8)**

7. An overview of relevance of harvesting PSMs and ensuring their sustainable production besides utilizing and conserving available plant biodiversity. **(3)**

8. Biosafety, toxicological and environmental concerns with respect to uses of PSMs for various applications. **(3)**

Text/Reference books:

1. Biotechnological approaches to enhance plant secondary metabolites: Recent trends and future prospects by Shahnawaz M. CRC press, 2022.
2. Plant metabolites and regulation under environmental stress by Ahmed et al. Academic press, 2018.

3. Endophytes and secondary metabolites (Reference series in phytochemistry) by Jha, S (Ed). Springer. 2019.
4. Functions of Plant Secondary Metabolites and Their Exploitation in Biotechnology by Wink, M (Ed). Volume 3 of Annual plant reviews, Sheffield Academic Press, 1999.
5. Secondary metabolites-Sources and Applications by Ramasamy V.K. and Suresh, SSR. IntechOpen, 2018.
6. Plant secondary metabolites (Three volume set) Siddhiqui et al. CRC press, 2017.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	3	3	1	3	3	2	3	3	3	3
CO2	2	3	3	3	3	2	3	2	3	3	2	2
CO3	3	3	3	2	2	3	3	2	2	3	3	3

Paper Code: PC-	Paper name: Waste Management and Upcycling	L	T	P	C
Paper id:	(6th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

1. To introduce fundamental aspects of types of waste and its management.
2. To disseminate knowledge on various waste management technologies.
3. To provide knowledge on how waste can be converted to wealth in a sustainable way.
4. To enable students to think innovative way to develop concepts in waste management

Course Outcomes

After successful completion of this course,

1. The students shall get an adequate knowledge on waste and its sustainable management.
2. Students should get enough knowledge on safety guidelines of waste management.
3. Students in groups shall develop concepts in managing waste of their institutions.
4. Students should get experiential learning with a waste management company in the vicinity.

1. **Waste management:** The definition of waste, and its classification in the context of EU legislation, policy and other drivers for change, including the planning and permitting regime for the delivery of waste management solutions Liquid waste collection, treatment and disposal systems: Segregation and mixing schemes; Pre-treatment and its role in the industrial wastewater management; Overview of wastewater treatment technologies and development of wastewater treatment schemes; Operation and maintenance of effluent treatment plants; and Case study of an industrial wastewater management system. **(7)**
2. **Air Pollution management and treatment:** Overview of industrial emissions; Air pollution control systems and overview of air pollution control technologies. **(3)**
3. Development of schemes for the collection, treatment and discharge industrial emissions. **(5)**
4. **Technologies for Waste treatment technologies**: waste incineration and energy from waste, pyrolysis and gasification, anaerobic digestion, composting and mechanical biological treatment of wastes, managing biomedical waste. **(5)**
5. **Health considerations**: In the context of operation of facilities, handling of materials and impact of outputs on the environment; Advances in waste recycling and recovery technologies to deliver added value products; Landfill engineering and the management of landfill leachate and the mining of old landfills. **(5)**
6. Interface of waste and resource management and civil engineering in the context of sustainable waste management in global cities and developing countries. **(5)**
7. Use of decision support tools including multi-criteria analysis, carbon foot-printing and lifecycle analysis, as appropriate. **(5)**
8. Waster Upcycling, waste reuse, Waste down cycling, waste upcycling a social enterprise, Case study in each area. Innovative technologies for sustainable waste management. **(5)**

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Text/Reference Books:

1. Elements of Solid & Hazardous Waste Management by O.P. Gupta, Khanna Publishing House, New Delhi, 2019.
2. Integrated Solid Waste Management by George Tchobanoglous et.al.,McGraw-Hill Publishers, 1993.
3. Waste Management by Bilitewski B, Hardhe G, Marek K, Weissbach A, and Boeddicker H, Springer, 1994.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	2	2	2	1	2	3	1	2	3	2	1
CO2	1	2	2	1	1	2	3	2	2	3	2	2
CO3	1	2	2	1	1	2	2	1	2	3	2	2
CO4	2	2	3	1	1	2	3	2	2	3	2	2

Paper Code: PCE-	Paper name: Artificial Intelligence for Designing Therapeutics	L	T	P	C
Paper id:	(6th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

1. The course will equip students with a conceptual understanding of AI and its applications through medical case studies using machine learning models.
2. This course will help prepare biotechnology graduates to lead in the era of digital medicine.

Course Outcomes

Students will possess the knowledge required to understand AI in medicine and therapeutics. After completion of the course students will be able to

1. Confidently read literature related to artificial intelligence in medicine.
2. Understand how data-driven decisions are made and assessed.
3. Identify and define different types of artificial intelligence tools and techniques used in medicine.
4. Actively participate in the selection, purchase and deployment of AI based medical software.

1. **Introduction to AI**: Healthcare Paradigm Shift in applications of AI, small data and Inductive Bias. **(5)**
2. **Natural Language processing (NLP)**: Hand-engineering, Similarity, Collaborative Filtering, Latent Dirichlet Allocation, Attention, Transformers, BERT, and GPT. **(5)**
3. **Conversational Language Interface:** Consciousness & Mind, CLI: Conversational Language Interface, Dialogue & Virtual Assistant (Alexa, Google Home, & Oval), and Conversational Language Interface. **(5)**
4. **Case studies on diseases:** Cancer Causes and Diagnosis, Neurodegenerative diseases, Life style diseases, disease treatment and How AI May Help. **(5)**
5. **History of AI in Diagnosis**: and its Promises and Limitations, popular reports on development of AI based therapeutic approaches. **(5)**
6. **AI for Psychiatry**: Consciousness, Intelligence, Rule of Nature, Principles of Similarity and Classification. **(5)**
7. **Data Security:** Data Privacy and Regulations Compliance. **(5)**
8. **AI Ethics and future:** AI Future, Consciousness, Mind, and Ethics **(5)**

Text/Reference Books:

1. Probabilistic Machine Learning by Murphy KP, 2022.
2. Artificial Intelligence in Medicine by Xing L, Giger ML, Min JK, 2020.
3. Artificial Intelligence in Medicine by Lidströmer N, Ashrafian H, 2022.
4. Intelligence-Based Medicine by Chang AC, 2020.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	2	3	3	1	2	1	3	1	1	3
CO2	2	2	2	3	2	1	2	1	3	1	1	2
CO3	2	2	2	2	3	1	2	1	3	1	1	3
CO4	3	2	3	3	3	1	2	1	3	2	1	2

SEMESTER VII

Group	Paper Code	Paper	L	T/P	Credits
Theory Papers					
PC	BT-401	Genome Engineering and Editing	3	1	4
PC	BT-403	Environmental Biotechnology	3	1	4
PCE-3*	BT-405	*Professional Core Elective-3	3	1	4
PCE-4**	BT-407	**Professional Core Elective-3	3	1	4
OAE-3***	BT-409	***Open area elective-3	3	1	4
Practical/Viva Voce					
PC	BT-453	Environmental Biotechnology – Lab	0	3	1.5
PC	BT-455	Genome Engineering and Editing		3	1.5
PCE-3	BT-451	Protein Biotechnology – Lab	0	3	1.5
PCE-4	BT-457	Computational Biology Lab	0	3	1.5
Total			**15**	**17**	**26**

***PCE: Professional Core Elective-3: (Select any one)**

		L	T/P	Credits
PCE-3	Protein Biotechnology	3	1	4
PCE-3	Protein Biotechnology – Lab	0	3	1.5
PCE-3	Good laboratory practices and good manufacturing practices	3		3
****Professional Core Electives-4: (Select any one)**				
PCE-4	Computational Biology	3	1	4
PCE-4	Computational Biology -Lab	0	3	1.5
PCE-4	Green Biotechnology			
PCE-4	Internet of Things in Agriculture			

*****OAE: Open Area Electives-3 (Select any one)**

		L	T/P	Credits
OAE-3	Tissue Engineering	2	1	4
OAE-3	Deep Learning in Biotechnology	3	1	4
OAE-3	Plant Stress Biology	3	1	4
	MOOCs (Only Govt. approved platforms like SWAYAM, NPTEL, e-PG Pathshala, etc.)			4

Paper Code: BT-401	Paper name: Genome engineering and editing	L	T	P	C
Paper id:	(7th Semester; Professional Core)	3	1	0	4

Course Objectives: The objective of this course is to introduce next generation of biotechnologists to emerging techniques in genome engineering and editing and to familiarize them with ethical consideration of genome editing. This course will also impart practical knowledge about how genome edits are achieved.

Course Outcomes:

After completion of this course, students will

1. Become aware of the modern biotechnological techniques for plant and animal improvement.
2. Develop critical thinking ability to design experiments.
3. Become aware of advanced technologies in genome engineering and its application in basic research and translational medicine.

1. **Overview of mechanisms regulating gene expression at different levels**: DNA (chromatin modifications), Transcription (transcription factors, enhancers, and repressors), Post-transcription (mRNA splicing, regulation of mRNA levels), Translation and Post-translation(Protein folding, protein modifications). **(4)**
2. **Cellular DNA repair pathways**: Methods to generate double-stranded DNA breaks, Double-strand break repair pathways in eukaryotes: Non-homologous end joining (NHEJ) and Homology-directed repair (HDR) etc. **(4)**
3. **Genetic engineering techniques**: Site-directed DNA recombination (Cre-Lox, Phi31 integrase); Genome editing: Introduction to gene editing mechanisms; Features of targeted nuclease: zinc finger, transcription activator-like effector (TALE) nucleases and homing endonucleases; Uses and applications of engineered nucleases; Next generation sequencing methods and Molecular imaging.**(8)**
4. Introduction to CRISPER-based bacterial and archeal adaptive immune system, Hallmarks of bacterial CRISPER defence system, Different CRISPER systems and their uses in genome editing; steps involved in generation of a desired CRISPER/Cas9 mutation: Target selection, generation and delivery of CRISPER/Cas9 components (DNA, RNA and RNA:protein complexes); Advantages and disadvantages; Identification of desired mutations. **(8)**
5. How do researchers exploit CRISPER for genome editing? Genetic components required to express heterologous genes in an organism, limitations of reverse genetics techniques. **(4)**
6. **Genome editing for crop genome improvement:** Modification of genes for yield traits, improved produce quality; genome editing for abiotic stress tolerance and biotic stress resistance. Generation of transgene-free genome edited crops. **(4)**
7. Applications of genome editing in human disease, Correcting chromosomal aberrations, Synthetic biology for design of antibiotics, developmental biology, CRISPER-mediated gene expression regulation. Limitations of CRISPER/Cas9 targeting methods, alternatives to Cas9 nucleases and its applications. **(4)**
8. Ethical considerations for CRISPER/Cas9 genome editing in humans, Non-heritable

(somatic) and heritable human genome editing; Genetically modified organisms, The balance of risks and benefits of gene editing. **(4)**

Text / Reference Books:

1. Molecular Biology of the Gene by J.D. Watson et al., Pearson 7th edition, 2017.
2. Genome editing. The new frontier of genome engineering with CRISPR- Cas9 by Doudna JA, Charpentier E Science. 346:1258096. 2014.
3. The CRISPR/Cas9 system and its applications in crop genome editing. Crit Rev Biotechnol. 39(3):321-336. doi: 10.1080/07388551.2018.1554621. 2019.
4. Genome Editing: A Practical Guide to Research and Clinical Applications, 1st Edition - March, 2021.
5. CRISPR-Cas: A Laboratory Manual by Doudna J, Mali P, 2016.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	1	1	2	2	3	3	3	2	2
CO2	3	3	2	3	2	1	2	1	3	2	2	3
CO3	3	2	2	1	1	2	2	3	3	3	2	2

Paper Code: BT-403	Paper name: Environmental Biotechnology	L	T	P	C
Paper id:	(7th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. Understanding the waste management techniques including degradation, remediation, recovery and restoration of natural resources.
2. Learn the process of agricultural waste handling and mitigation and generation of biofuels from wastes.
3. To study the environmental genetics and its application in environmental biotechnology.
4. To understand the environmental laws and policies, safety and environmental ethics applicable in environmental biotechnology.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Explain and use the main design criteria for sewage and wastewater treatment processes.
2. Describe different methods and safety precautions used in treatment of municipal solid waste.
3. Learn about the bioremediation technology to address the present day Environmental problems.
4. Learn the principles and mechanisms of microorganisms enzyme and its applications in environmental pollution control.
5. Understand various laws, safety and ethical issues involved in. environmental biotechnology.

1. **Introduction to environment** biotechnology: Issues and scope of environmental biotechnology, concept of ecology and ecosystem, environmental pollution (Water, soil and air). **(5)**
2. **Sewage and waste water treatment:** Anaerobic and aerobic treatment, conventional and advanced treatment technology, methanogenesis, methanogenic, acetogenic, and fermentative bacteria- technical process and conditions, emerging biotechnological processes in waste - water treatment. **(4)**
3. **Solid waste management:** landfills, composting, earthworm treatment, recycling and processing of organic residues, treatment of hazardous waste, biomedical waste management. **(4)**
4. **Biodegradation of xenobiotic compounds**: Organisms involved in degradation of chlorinated hydrocarbons, substituted simple aromatic compounds, polyaromatic hydrocarbons, pesticides, surfactants and microbial treatment of oil pollution. **(4)**
5. **Bioremediation and biorestoration:** Bioremediation strategies,in situ bioremediation, ex situ bioremediation, phytoremediation, reforestation through micropropagation, development of stress tolerant plants, use of mycorrhizae in reforestation, use of microbes for improving soil fertility, reforestation of soils contaminated with heavy metals. **(4)**

6. **Natural resource recovery:** Extraction of metals from ores; recovery of metals from solutions; microbes in petroleum extraction; microbial desulfurization of coal. **(4)**

7. **Environmental biotechnology in agriculture:** Biofertilizers and microbial inoculants, biopesticide, bioinsecticides, bioherbicides. **(4)**

8. **Biofuel**: Fossil fuels and emission from fossil fuels, green-house gases, remediation from the emission from fossil fuels, biological energy sources, biogas, bioethanol, biohydrogen. **(4)**

9. **Genes in Environment**: Degradative plasmids, genetically engineered microbes and plants in environment. **(4)**

10. **Environmental laws:** Environmental laws and policies, safety and environmental ethics. **(3)**

Text / Reference Books:

1. Environmental biotechnology by Scragg A, Oxford University Press. 2005.
2. Text book of environmental biotechnology by Mohapatra PK, I K International Publishing House Pvt. Ltd, 2009.
3. Environmental Biotechnology: Concepts and Applications by Priv.-Doz, Hans-Joachim Jördening, Josef Winter, Wiley VCH Verlag GmbH & Co. KGaA, 2005.
4. Research articles

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2	2	3	3	1	3	2	2	3
CO2	3	3	2	3	2	3	3	2	3	3	2	3
CO3	3	3	3	3	3	3	3	1	3	3	2	3
CO4	2	2	3	3	3	3	3	1	3	3	2	3
CO5	1	1	1	1	1	3	3	3	2	2	3	3

Paper Code: BT-405	Paper name: Protein Biotechnology	L	T	P	C
Paper id:	(7th Semester; Professional Core)	3	1	0	4

Course Objectives:

1. Understanding the protein source, structure, function and their commercial implications.
2. To study the proteome in understanding the function of an organism based on its constituent proteins.
3. To learn about the immunologically important proteins and their role in diseased conditions.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Understand the basic structure, properties and various sources of proteins.
2. Gain detailed insight into the structure-function relationship of proteins and their use in applied scientific research.
3. Be aware and apply concepts of advanced protein engineering technologies and the use of protein biotechnology in healthcare, food, and other industrial applications.

1. **Protein Structure:** Introduction, overview of protein structure, higher-level structure protein post-translational modification, protein stability and folding. **(4)**

2. **Protein Sources:** Introduction, microorganisms as sources of proteins, proteins from plants, animal tissue as protein source and mammalian expression systems. **(4)**

3. **Proteome Analysis**: Expression, Functional, Structural and Spatial proteomics. **(4)**

4. **Therapeutic Proteins**: Introduction, Blood products, Haemophilla A and B, Anticoagulants, Thrombolytic agents, Additional blood related products, vaccine technology, antiviral vaccines. **(4)**

5. **Therapeutic Antibodies and Enzymes**: Introduction, antisera and immunoglobulin, antibodies for in vivo application, therapeutic enzymes for treatment of cancer, debriding agents, anti-inflammatory and digestive aids, enzyme replacement therapy. **(4)**

6. **Hormones and Growth Factors used Therapeutically**: Introduction, cytokine vs hormones, insulin, glucagon, gonadotrophins, growth hormone. **(4)**

7. **Interferons, Interleukins and Additional Regulatory Factors**: interferons, interleukins, tumour necrosis factors, colony-stimulating factors, cytokine toxicity. **(4)**

8. **Protein Engineering**: case studies of engineering cytokines, antibodies. **(4)**

9. **Proteins used for Analytical Purposes**: Enzymes as diagnostic/analytical reagents, antibodies as analytical reagents. Latex agglutination-based immunoassays. Membrane bound diagnostic systems. **(4)**

10. **Industrial Proteins**: Catalytic industrial proteins; proteolytic enzymes used in detergent and food industry. cellulases and cellulosomes, amylase. Non-catalytic industrial proteins; functional properties of proteins, milk and milk proteins, sweet and taste modifying proteins. **(4)**

Text / Reference Books:

1. Proteins: biochemistry and biotechnology by Gary Walsh, Wiley Blackwell, Second Edition, 2014.
2. Protein Engineering Tools and Applications by Huimin Zhao, 2021.
3. Insights into Cytokine-Receptor interactions from cytokine engineering by Spangler JB, Moraga I, Mendoza JL and Garcia KC. Annual Review of Immunology, 2015.
4. Development of therapeutic antibodies for the treatment of diseases by Lu RM, Hwang YC, et al., 2020.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	2	2	1	2	1	1	1	2	1	3
CO2	3	3	3	2	3	2	2	2	3	3	2	3
CO3	3	3	3	3	3	3	2	3	3	3	2	3

Paper Code: BT-407	Paper name: Computational Biology	L	T	P	C
Paper id: 013407	(7th Semester; Professional Core Elective PCE-4)	3	1	0	4

Course Objectives:

1. This course is aimed at computational approaches using computer science algorithms used popularly in biological data analysis.
2. This course is a survey of algorithms and tools in biological sequence analysis and database parsing. It will also introduce information technology practices in the field of biotechnology.
3. The course will provide a basic overview of popular languages like perl and python widely used in computational biology; and tools for searching or querying biological databases.
4. This course will build foundation of coding for biologists and will help students to parse and analyze data in a more efficient manner.

Course Outcomes:

After successful completion of this course,

1. Students will perform computational analyses of biological sequences, genome-wide studies and relate the results to core principles of biology.
2. Students will use computational methods to execute structural analysis and in silico drug design.
3. Students can browse or retrieve gene, protein sequences and related information from biological databases using Perl / Python.

1. **Structural Biology:** 3-D structure visualization and simulation, Basic concepts in Molecular Modeling: different types of computer representations of molecules. **(5)**

2. Secondary structure elucidation using Peptide bond, phi, psi and chi torsion angles, Ramachandran map, anatomy of proteins – Hierarchical organization of protein structure –like CATH,SCOP, FSSP, Classification and comparison of 3D structures: **(5)**

3. DNA & RNA secondary and tertiary structures, t-RNA tertiary structure. Protein Secondary structure prediction: Algorithms viz. Chou Fasman, GOR methods, Tertiary Structure prediction: Fundamentals of the methods for 3D structure prediction (sequence similarity/identity of target proteins of known structure, **(5)**

4. Homology/comparative Modeling, fold recognition, threading approaches, and ab initio structure prediction methods. Molecular modeling (Homology and Ab initio) and validation (Procheck, verify 3D etc), Docking, Molecular dynamics, Energy calculations, CASP. **(5)**

5. Application in drug design: Chemical databases like NCI /PUBCHEM. Fundamentals of Receptor-ligand interactions. Structure-based drug design: Identification and Analysis of Binding sites and virtual screening. Ligand based drug design: **(5)**

6. Structure Activity Relationship – QSARs & Pharmacophore etc. In silico predictions of drug activity and ADMET. **(5)**

7. Computational Biology using Perl: Sequences and Strings, Motifs and Loops, Mutations and Randomization, The Genetic Code, Restriction Maps and Regular Expressions, Parsing

GenBank, PDB, BLAST. **(5)**

8. Introduction to Python programming: Python basics, Introducing the fundamentals, Simple data types, Collection data types, Functions in Python/ biopython, Biological Sequence handling, Pairwise sequence alignment, Sequence alignment, Calculating an alignment score, Optimising pairwise alignment. **(5)**

9. Quick database searches, Multiple sequence alignment, Multiple alignments, Alignment consensus and profiles, Generating simple multiple alignments in Python, Interfacing multiple-alignment programs. **(5)**

10. Sequence variation and evolution, Similarity measures, Bio-motif in sequence analysis, Bio-Phylo in phylogenetic trees. **(5)**

Text/Reference Books:

1. Bioinformatics: A practical guide to the analysis of genes and proteins by Baxevanis AD and Ouellette BFF, John Wiley and Sons, 2002.
2. Bioinformatics: Sequence and Genome Analysis by Mount DW, Cold Spring Harbor Laboratory Press, 2001.
3. Introduction to Bioinformatics Algorithms by Jones & Peuzner; Ane Books, India, 2004.
4. Beginning Perl for Bioinformatics by James Tisdall Publisher(s): O'Reilly Media, Inc. 2001.
5. Python for Bioinformatics (Second Edition) by Bassi S, Chapman & Hall, CRC Mathematical and Computational Biology Series , 2018.
6. Python Programming for Biology: Bioinformatics and Beyond by Stevens TJ, Cambridge University Press, 2015.
7. Bioinformatics Programming using Python by Mitchell L. Model, O'rielly Publications, 2009.
8. Biopython Tutorial and Cookbook by Jeff Chang et al. 2021.
9. Bioinformatics Programming in Python: A Practical Course for Beginners by Ruediger-Marcus Flaig, WILEY-VCH. 2008.
10. Web-resources and suggested reviews/ research papers.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	1	2	1	3	2	1	2
CO2	3	3	3	3	3	1	2	1	3	2	1	2
CO3	3	3	3	3	3	1	2	1	3	2	1	2

Paper Code: PC-	Paper name: Good Laboratory Practices and Good Manufacturing Practices (GLP/GMP)	L	T	P	C
Paper id:	(7th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

Basic understanding of the regulatory requirement of GMP and GLP.

Course Outcomes

After the successful completion of this course, students should be able to:

1. Understand that the areas that come under the Good Laboratory Practices are: personnel and organizational, testing facilities, equipment, testing and controls, records, reports, and protocol for and conduct of non-clinical labs.
2. Understand that the areas that come under GMP are: facilities and buildings, equipment, production, process control, packaging and labeling, laboratory controls, and returned/salvaged drug products., Importance of GMP and GLP for drug regulation

1. Introduction to Good Manufacturing and Laboratory Practices. **(5)**
2. Requirement of GLP and GMP compliance for regulatory approval. **(5)**
3. Ethics in manufacturing and control, Principles of quality by design (QBD). **(5)**
4. Introduction to the concept of Design of Experiment (DOE) Application of QBD principles in Biotech product development. Case studies: Example of QBD and DOE in Process Development, Example of DOE in analytical development. **(5)**
5. Introduction to ICH guidelines and their usage, National and international regulatory authorities and their function, Pharmaceutical 83 Jurisprudence and Laws related to Product design. **(5)**
6. Drug Development & Approval Process, Regulation of Clinical and Preclinical Studies, **(5)**
7. Good Manufacturing Practices, Formulation Production Management, **(5)**
8. Authorization and marketing of drugs. Computer simulation on process design. **(5)**

Text/Reference Books:

1. cGMP starter guide: Principles in Good Manufacturing Practices for Beginners by Tobin EP, Createspace Independent Publishing Platform, April 2016.
2. Good Manufacturing Practices for Pharmaceuticals: GMP in Practice by Cooper B, Createspace Independent Publishing Platform, July 2017.
3. Pharmaceutical Quality by design: Principles and application by Beg S and Hasnain MS, Academic press, March 2019.
4. Modern Industrial Statistics: with applications in R, MINITAB and JMP by Kenett RS, Zacks S, Amberti D, 2nd Edition, Wiley, January 2014.
5. Design of experiments (DoE) in pharmaceutical development by N Politis S, Colombo P, Colombo G, M Rekkas Drug Dev Ind Pharm. 2017.
6. ICH quality guidelines- An implementation guide by Andrew Teasdale, David Elder, Raymond W. Nims, Dec 2017.
7. Drug regulatory affairs by Singh G, Agarwal G an Gupta V, CBS publication,

2005.
8. New Drug Development: A regulatory overview by Mathieu MP, Nov 2000.
9. ICH guidelines available on the official website

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	3	2	1	3	3	3	2	1	1	2
CO2	2	3	3	2	1	3	3	3	2	2	2	3

Paper Code: PCE-	Paper name: Green Biotechnology	L	T	P	C
Paper id:	(7th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

1. The course content aims to make the student understand how biotechnology can help in monitoring or removing the pollutants
2. Developing an understanding of new trends such as biofuels, renewable energy sources.
3. Development of stress-tolerant plants which can minimize the harmful impact of pollutants thereby making the planet earth a better dwelling place.

Course Outcomes

After successful completion of this course,

1. Students will gain knowledge about how to maintain environment.
2. They will also gain the knowledge to use biotechnology for waste management, bioremediation and green energy.

1. **Biological Waste Treatment:** Biological wastewater treatment: Principles and design aspects of various waste treatment methods with advanced bioreactor configuration. **(5)**
2. **Solid waste management:** landfills, recycling and processing of organic residues, minimal national standards for waste disposal. **(5)**
3. **Biodegradation of Xenobiotic Compounds:** Xenobiotic compounds–Definition, examples and sources. Biodegradation- Introduction, effect of chemical structure on biodegradation, recalcitrance, co metabolism and biotransformation. Factors affecting biodegradation, microbial degradation of hydrocarbons. **(5)**
4. **Biotransformations and Biocatalysts:** Basic organic reaction mechanism- Common prejudices against enzymes, advantages & disadvantages of biocatalysts, isolated enzymes versus whole cell systems, biocatalytic application, catalytic antibodies; stoichiometry. **(5)**
5. **Bioremediation and Biorestoration:** Introduction and types of bioremediation, bioremediation of surface soil and sludge, bioremediation of subsurface material, In situ and Ex-situ technologies, phytoremediation- restoration of coal mines a case study. **(5)**
6. **Biorestoration:** reforestation through micropropagation, use of mycorrhizae in reforestation, use of microbes for improving soil fertility, reforestation of soils contaminated with heavy metals. **(5)**
7. **Eco-Friendly Bioproducts from Renewable Sources**: Fundamentals of composting process: scientific aspects and prospects of biofuel production: bioethanol, biohydrogen and biodiesel; biofertilizers and biopesticides. **(5)**
8. **Biotechnology in Environment Protection:** Current status of biotechnology in environment protection and its future, release of genetically engineered organisms in the environment. **(5)**

Text/Reference Books:

1. Environmental Processes I-III by Winter J, 2nd ed., Wiley Publications, 2008.
2. Introduction to Wastewater Treatment by Ramalho RS, Academic Press. 1984.

3. Elements of Water Pollution Control Engineering by Gupta OP, Khannabooks. 2019.
4. Energy Technology by Gupta OP, Khannabooks, 2018.
5. The Biodiversity of India by Bharucha Erach,, Mapin Publishing Pvt. Ltd. 2002.
6. Environmental Biotechnology by Bhattacharya BC & Banerjee R, Oxford Press, 2007.
7. Environmental Biotech by Krimar P, I.K. International Pvt. Ltd., 2006.
8. Environmental Microbiology & Biotechnology by Singh DP, Dwivedi SK, New Age International Publishers, 2004.
10. Environmental Biotechnology by Rittmann B and McCarty P. 1996.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	1	2	2	1	3	3	2	3	1	1	3
CO2	3	2	3	2	1	3	3	3	3	3	2	2

Paper Code: PCE-	Paper name: Internet of Things in Agriculture	L	T	P	C
Paper id:	(7th Semester; Professional Core Elective)	3	1	0	4

Course Objectives

This course introduces the basic concepts and applications of Internet of Things (IoT) technology in agriculture, and its impacts on farming and agricultural industry. Show-case of typical IoT systems used in farms, on farm equipment and in cloud. Hands on experience on essential IoT components, including hardware (wireless sensors, controllers, computers and network devices) and software.

Course Outcomes

Upon completion of this course, the students should be able to:

1. Understand how IoT technologies can be used in agriculture systems and affect an agriculture business;
2. Understand the concept of IoT systems and its major architecture and components;
3. Know typical IoT agricultural systems, understand the architecture and functionalities;
4. Understand how to collect and analyze data with IoT for precision agriculture systems and strategically store and share data for public access;

1. An overview of IOT in agriculture: potential and challenge: application of IoT in agriculture, Architecture and components of a typical IoT system **(5)**
2. Feeling Things: typical sensors and sensor nodes, used in Ag, such as weather, soil, air and crops **(5)**
3. Tag Things: technology available to tag things, such as RFID, bar code, Acting Things: typical actuators in agricultural, applications **(5)**
4. Work principle of sensors and how they can be part of IoT. Thinking Things: embedded and single chip controllers How to select controllers **(5)**
5. Connectivity and networks: wired and wireless technology, Security, How to setup a server for IoT systems **(5)**
6. Conceptual design: Smart irrigation Group discussion: smart irrigation system **(5)**
7. Sensors and microcontrollers, IoT-based Systems - Performance and Security Considerations in IoT server setup **(5)**
8. IoT in field management, IoT in irrigation management **(5)**

Text/Reference Books:

1. Internet of Things: A Hands on Approach by Madisetti V, Bahga A, University Press, 2014.
2. Internet of Things by Jose J, Khanna Publishing House, New Delhi, 2018.
3. Introduction to Internet of Things: A practical Approach by Reddy SRN, Thukral R and Mishra M, ETI Labs
5. Designing the Internet of Thing by Adrian McEwen, Wiley
6. Internet of Things: Architecture and Design by Raj Kamal, McGraw Hill
7. Getting Started with the Internet of Things by Cuno Pfister, O Reilly Media.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	2	3	3	1	2	1	3	1	1	2
CO2	2	2	2	3	3	2	2	1	3	1	1	3
CO3	2	2	2	3	3	2	2	2	3	1	1	2
CO4	2	3	3	3	3	1	2	1	3	2	1	2

Paper Code: BT-409	Paper name: Tissue Engineering	L	T	P	C
Paper id:	(7th Semester; Open Area Elective)	3	1	0	4

Course Objectives:

1. To learn structural and functional units of Tissue Engineering.
2. To understand the principle and characterization studies of tissue engineering approaches.
3. To learn to develop tools for biomedical application via tissue engineering.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Understand the tissue engineering approach.
2. Understand the utility of the tissue engineered biomedical tools.
3. Apply the concept of tissue engineering in healthcare.

1. **Tissue Engineering**: Cells, scaffold and extracellular matrix (ECM), unit-cell processes underlying tissue engineering. **(4)**
2. **Tissue-matrix interactions**: Cell processes (membrane protein based and matrix protein based) and interface-based healing response. Structure and function of naturally occurring ECMs, role of functional subunits of ECM. Cooperative and non-cooperative interactions. Cell division and cell-death. Coordination of cellular fate processes, malfunctioning of soluble signalling. **(6)**
3. **Cell-surface interactions:** Biomaterial surface and protein adsorption analysis, phenotype changes following adhesion of biomaterials, structural determinant of biologically active materials, methodology of cell-surface interaction. **(6)**
4. **Scaffold**: Structural and functional properties, Biodegradation versus biomineralization, product shelf-life. **(4)**
5. **Tissue and Scaffold Characterization tools**; Scanning Electron Microscopy (SEM); Cellular assays (Adhesion, proliferation and migration): Alamar Blue, Hoechst based, Von Kossa based, Alizarin Red S based; Molecular marker-based Characterisation tools. **(6)**
6. **Bioreactors in Tissue Engineering**: Types of bioreactors, bioreactors for bone, cartilage and cardiovascular Tissue Engineering. Cell-culture and co-culture. **(4)**
7. **Clinical studies:** Response to implants, Epithelialization and endo-thelialization in vascular prostheses, skin and liver tissue engineering; implants for bone and cartilage regeneration, Dental prosthetic implant, biomaterial in heart and other organs (artificial pancreas). **(7)**
8. **Applications and Implications** (iPSCs in Tissue Engineering); Current Research (nanoengineered biomaterials and drug delivery); Challenges in Tissue Engineering. **(3)**

***Text /Reference Books*:**

1. Principles of Tissue Engineering, fifth edition by R. Lanza, R.Langer, J.P. Vacanti and A.Atala, 2020.
2. 3D Printing for Tissue Engineering and Regenerative Medicine, by Murat Guvendiren and Vahid Serpooshan, 2020.
3. Cell and Tissue Engineering, by Bojana Obradovic, 2018.

4. Biomaterials- and Microfluidics-Based Tissue Engineered 3D Models: 1230 (Advances in Experimental Medicine and Biology) by J.Miguel Oliveira, Rui L.Reis, 2021.
5. Organ Tissue Engineering (Reference Series in Biomedical Engineering) by Daniel Eberli, Sang Jin Lee, et al., 2021.
6. iPSCs in Tissue Engineering (Advances in Stem Cell Biology), by Alexander Birbrair, 2021.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	1	1	3	1	3	2	2	2	2
CO2	3	2	2	2	1	2	1	3	3	2	2	2
CO3	2	1	2	1	1	3	1	3	3	2	3	2

Paper Code: BT-411	Paper name: Deep Learning in Biotechnology	L	T	P	C
Paper id: 013411	(7th Semester; Open Area Elective)	3	1	0	4

Course Objectives:

1. This course is beneficial for students to understand the principles of analyzing biological data using R, building models and testing hypotheses using computer science algorithms.
2. This course is a survey of algorithms and tools in biological sequence analysis though R / Bio-conductor, genome-wide disease association, and precision medicine. It will also introduce information technology practices in the field of biotechnology.
3. The course will provide a basic overview of various information repositories widely used in R for analyzing biological sciences; and tools for searching or querying those databases.
4. This course will build foundation of sequence alignment techniques and to find evolutionary connections. It will help students to analyze mRNA expression data and gene annotations.

Course Outcomes:

After successful completion of this course,

1. Students will perform computational analyses of biological data using R programmimg.
2. Students will use computational methods to help execute a biological research plan.
3. Students can browse or retrieve gene, protein sequences and related information from biological databases using R.

1. Intro to supervised ML and neural networks, SGD + backprop + optimization + regularization, Deep Learning, Neural Nets and Deep learning primer, **(5)**
2. Intro to genomics + genetics ,+ biological application domains for deep learning, Basic primer on mol. biology for computational students, **(5)**
3. Next generation genomics: An Integrative Approach, Next generation genomics: An Integrative Approach. **(5)**
4. Deep learning for genomics and intro to CNNs, Deep learning: new computational modelling techniques for genomic, **(5)**
5. Deep learning for computational biology, Deep learning in Biomedicine, Applications of CNNs and Dilated CNNs in regulatory genomics and genetics. **(5)**
6. Predicting the sequence specificities of DNA- and RNA-binding proteins by deep learning, Deep learning at base-resolution reveals motif syntax of the cis-regulatory code, Sequential regulatory activity prediction across chromosomes with convolutional neural networks. **(5)**
7. Recurrent neural networks + Transformers, DanQ: a hybrid convolutional and recurrent deep neural network for quantifying the function of DNA sequences, DeepCpG: accurate prediction of single-cell DNA methylation states using deep learning. **(5)**
8. Methods for interpreting deep learning models and generating mechanistic hypotheses, Methods for interpreting deep learning models and generating mechanistic hypotheses, Learning Important Features Through Propagating Activation Differences. **(5)**
9. Axiomatic Attribution for Deep Networks, The Building Blocks of Interpretability, Differentiable Image Parameterizations, CYCLOPS reveals human transcriptional rhythms in health and disease, Bayesian Inference for a Generative Model of Transcriptome Profiles from Single-cell RNA Sequencing, Manifold learning-based methods for analyzing single-cell RNA-sequencing data. **(6)**
10. Generative models, Feedback GANs, Deep generative models of genetic variation capture the effects of mutations, MoleculeNet. **(4)**

Text Books/References:

1. Deep Learning for Coders with Fastai and PyTorch: AI Applications Without a PhD 1st Edition by Jeremy Howard (Author), Sylvain Gugger, O'Reilly, 2020.
2. Machine Learning with Python Cookbook: Practical Solutions from Preprocessing to Deep Learning Paperback 2018 by Chris Albon , O'Reilly, 2018.
3. High-throughput sequence analysis with R and Bioconductor by Marc Carlson
4. Hands-On Machine Learning with Scikit-Learn, Keras and Tensor Flow: Concepts, Tools and Techniques to Build Intelligent Systems by Aurelien Geron, O'Reilly, 2019.
5. Bioinformatics with R Cookbook by Paurush Praveen Sinha
6. Web-resources and suggested reviews/ research papers.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	1	2	1	3	2	1	3
CO2	3	3	3	3	3	1	2	1	3	2	1	3
CO3	3	3	3	3	3	1	2	1	3	2	1	3

Paper Code: OAE	Paper name: Plant Stress Biology	L	T	P	C
Paper id:	(7th Semester; Open Area Elective)	3	1	0	4

Course Objectives:

1. To gain knowledge about plant responses to abiotic and biotic stress.
2. To understand the mechanisms responsible for stress tolerance.
3. To study various research approaches for crop improvements.
4. To study the factors causing injury during stress.

Course Outcomes:

After successful completion of this course, the students should be able to:

1. Understand the plant responses to various stresses at physiological and biochemical level.
2. Understand the factors involved in causing injury during plant stress.
3. Understand the plant stress tolerance mechanisms at molecular level.
4. Understand genetic engineering approaches for crop improvements.

1. **Plant Stress:** Definitions of stress, classification of plant stress, biotic factors, abiotic factors, different phases induced by stress. **(3)**

2. **Effect of plant stress:** Effect of abiotic stress on growth and development, Environmental stress effect on crop production. **(3)**

3. **Plants stress response**: Response of plant stress at morphological, physiological and biochemical level, acclimation and crop adaptation. **(3)**

4. **Biotic stress:** Plant response to pathogens and herbivores, pathogen derived resistance, genetic engineering for biotic stress resistance. **(3)**

5. **Salinity stress:** Mechanisms of salt stress, Salinity responsive genes and proteins, transporter, antiporter, Genetic engineering of salt-tolerant crops. **(3)**

6. **Drought stress:** Mechanisms of dehydration tolerance, Late-embryogenesis-abundant proteins, drought-responsive genes and proteins, Genetic engineering of drought tolerance plants. **(5)**

7. **High temperature stress**: Mechanisms of high temperature tolerance, Heat shock protein, High temperature responsive genes and proteins Genetic engineering of heat tolerance plants. **(5)**

8. **Low temperature stress:** Mechanisms of low temperature tolerance, Cold responsive genes and proteins, Genetic engineering of cold tolerance plants. **(5)**

9. **Heavy metal stress:** Various heavy metals, toxicity to heavy metals, mechanisms of heavy metal tolerance genes and proteins, transporter, recent advances in engineering of heavy metal tolerant crops. **(5)**

10. **Stress signaling:** Stress perception, receptor, secondary messenger, Abscisic acid and stress signaling, Oxidative stress signals, SOS pathway. **(5)**

Text/ References books:

1. Stress biology by Vidhyasekaran, P. Narosa Publishing House, 2007.
2 Plant Physiology by Taiz and Zeiger, 3rd Edition, Panima Publishing Corporation, New Delhi, 2003.
3. Biochemistry and molecular biology of plants by Buchnan, BB, Gruissem W, and Jones RL., American Society for Plant Physiologists, Rockville, USA. 2000.
4. Plant biotechnology -The genetic manipulations of plants by Slater A, Scott N. and Fowler M., Oxford University press. 346p. 2003.
5. Bacterial Disease Resistance in Plants: Molecular Biology and Biotechnological Applications by Vidhyasekaran, P, Haworth Food & Agricultural Products Press, New York.452p, 2005.
6. Physiology and Molecular Biology of Stress Tolerance in Plants by Madhava Rao KV, Raghavendra AS and Janardhan Reddy K, Springer, Netherlands. 2006.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	3	3	2	1	2	2	2	1	2	3	1
CO2	1	2	3	2	1	2	2	2	1	2	3	2
CO3	1	3	3	2	1	2	3	2	1	2	3	3
CO4	3	3	3	3	1	2	3	2	1	2	3	2

SEMESTER VIII

Group	Paper Code	Paper	L	T/P	Credits
Practical/Viva Voce					
	BT-450	*Project Work			12
	BT-452	**Journal Club/Seminar			2
Total					**14**

%*By default every student shall do a project work under the supervision of USBT faculty. Evaluation shall be conducted of 40 marks (Teachers' continuous evaluation/internal assessment) by the supervisor and 60 marks by an external examiner deputed by examinations division (COE) for a total of 100 marks.
**Evaluation shall be conducted for 40 marks (Teachers' continuous evaluation / internal assessment) by appointed teacher and for 60 marks by a bench comprising of all faculty and an external examiner deputed by examinations division (COE) for a total of 100 marks.

In the absence of any supervisor/faculty Dean of the school can assign responsibility of the supervisor (for purpose of examinations) to any faculty of the school.

Note:

1. The programme of study shall be governed by ordinance 11 of the university.
2. Total credits for B.Tech. in Biotechnology (1-8 semesters): 214
3. Minimum credits required: 200