ST. JOSEPH'S COLLEGE (AUTONOMOUS)

BENGALURU-27

Estd.1882

Recognised as "College of excellence" by UGC
Re-accredited with A^{++} grade and 3.79/4.00 CGPA by NAAC
Awarded DBT star status and DIS FIST grant
By Ministry of Science and Technology, GOI

Department of Biotechnology

Funded by the VGST support grant, Government of Karnataka
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M.Sc. Biotechnology Syllabus

2021-23

M.Sc. BIOTECHNOLOGY, COUSE OVERVIEW

	PAPER CODE AND TITLE	TEACHING HOURS	NO. OF CREDITS	TOTAL MARKS
SEMESTER I				
THEORY				
Paper I	BT7121: Biochemistry and Analytical techniques	60	04	100
Paper II	BT7221: Topics in Cell Biology	60	04	100
Paper III	BT7321: Molecular biology	60	04	100
Paper IV	BT7421: Biostatistics	60	04	100
PRACTICALS				
Paper I	BT7P1: Biochemical and Analytical techniques	88	04	50
Paper II	BT7P2: Cell and Molecular Biology	88	04	50
		TOTAL	**24**	**500**
SEMESTER II				
THEORY				
Paper I	BT8121: Microbiology and Molecular Genetics	60	04	100
Paper II	BT8221: Genetic engineering and Synthetic Biology	60	04	100
Paper III	BT8321: Bioinformatics and Computational biology	60	04	100
Paper IV	BT8421: Research Methodology & Scientific Writing	60	04	100
Paper V-A **(DE)**	BT8521: Stem cell and Next Gen Therapeutics	60	04	100
Paper V-B **(DE)**	BT8621: Nanobiotechnology	60		
PRACTICALS				
Paper I	BT8P1: Microbiology and Molecular Genetics	88	04	50
Paper II	BT8P2: Genetic Engineering and Bioinformatics	88	04	50
		TOTAL	**28**	**600**
SEMESTER III				
THEORY				
Paper I	BT9121: Multiomics and Systems Biology	60	04	100
Paper II	BT9221: Immunology and Medical Biotechnology	60	04	100
Paper III	BT9321: Industrial Biotechnology, Entrepreneurship and Bioethics	60	04	100
Paper IV	BT9421: Plant, Animal and Environmental Biotechnology	60	04	100
Paper V **(OE)**	BT9521: Transgenic organisms and Bioethics	30	02	35
PRACTICALS				
Paper I	BT8P1: Multiomics and Big Data in Life Sciences	88	04	50
Paper II	BT8P2: Applied Biotechnology	88	04	50
		TOTAL	**26**	**600**
SEMESTER IV				
	BTRP: Research Project	360	12	300
	Ignitors/Outreach		04	
		TOTAL	**16**	**300**
	Total No. of Credits:		**94**	

Course Curriculum for M.Sc. Biotechnology, 2021-23

Semester	**I**
Paper Code	**BT7121**
Paper Title	**Biochemistry and Analytical Techniques**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:

This course has been designed to introduce the students to concepts in biochemistry. It further emphasizes on the regulation and applications of biomolecules in health. The component of the Analytical techniques facilitates the student to have a detailed insight into all the biophysical techniques involved in Biological research with application to Industry.

Syllabus: BT7121: Biochemistry and Analytical Techniques (60 hours)

Unit	Content	Teaching Hours
BIOCHEMISTRY		**30 Hrs**
Unit 1: Carbohydrates	Classification of carbohydrates, glycosaminoglycans, proteoglycans, sialic acid, lectins, carbohydrate assays, gluconeogenesis, glycogen metabolism & their regulation; glycans in health and disease, glycomimetics, Applications of glycoconjugates.	3 hrs
Unit 2: Amino Acids and Proteins	Classification of amino acids and titration curves; biologically important peptides; Proteins- levels of organization; Ramachandran's plot; Structure and function of Mb, Hb and collagen. Overview of amino acid biosynthesis & urea cycle. Protein folding- molecular chaperones, thermodynamics of folding and unfolding, models of protein folding, misfolding diseases, protein purification and structure investigation, X-ray crystallography, Ramachandran plot, sequencing, and solid phase Merrifield peptide synthesis.	8 hrs
Unit 3: Lipids and Membrane Transport	Classification of lipids; Fatty acid biosynthesis and oxidation. biologically important lipids: cholesterol, bile salts, eicosanoids- leukotrienes, prostaglandins and thromboxanes. Lipid bilayers, micelles, liposomes, membrane structure and assembly, transport of molecules across membrane-channels and pumps, model membrane systems and their applications.	3 hrs

Unit 4: Nucleic Acids	Structure and properties- Bases, Nucleosides, Nucleotides, Polynucleotides. Nucleic acid metabolism: Biosynthesis of purines and pyrimidines, De novo and Salvage pathways, biodegradation of purines and pyrimidines. (atypical nucleotides)	2 hrs
Unit 5: Enzyme Kinetics, Catalysis and Regulation	Properties of enzymes, classification, Michaelis Menten equation, kinetic parameters, Lineweaver -Burk plot, factors affecting enzyme activity, enzyme inhibition, multisubstrate reactions, enzyme units. Different catalytic strategies, Mechanism of RNase, chymotrypsin, carbonic anhydrase and lysozyme; Regulation of enzymes by- allosteric control, covalent modification, proteolytic cleavage and isoenzymes	8 hrs
Unit 6: Bioenergetics and Regulation Of Metabolic Pathways	Bioenergetics-basic principles; Equilibria and concept of free energy; Coupled processes; Glycolytic pathway; Kreb's cycle; Oxidative phosphorylation; Photosynthesis; Elucidation of metabolic pathways; Logic and integration of central metabolism; entry/ exit of various biomolecules from central pathways; Principles of metabolic regulation; Regulatory steps; Signals and second messengers.	6 hrs
ANALYTICAL TECHNIQUES		**30 hrs**
Unit -1: Basics Of pH	Measurement of pH, Biochemical buffers, Selection of biochemical buffer, oxygen electrode and Concepts of biosensors. Concentration of Biomolecules - Salting out with ammonium sulphate, Flash evaporation, Lyophilization, Dialysis, Osmosis, Diffusion, Hollow fiber membranes, Membrane filtration and their applications.	4 hrs
Unit 2- Chromatography	General principles, definitions and applications of Chromatography. Paper chromatography, Gas-liquid chromatography. Principle of Gel filtration, Partition, Adsorption, Ion-exchange, Gel permeation Affinity chromatography, High-performance liquid chromatography, Reverse-phase chromatography.	4 hrs
Unit 3- Centrifugation	Basic principles; Mathematics & theory (RCF, Sedimentation coefficient); Types of centrifuges - Microcentrifuge, High speed & Ultracentrifuges; Preparative centrifugation; Differential & density gradient centrifugation; Rate-zonal; Applications: Isolation of cells, Subcellular Organelles, Viruses and Macromolecules.	3 hrs

Unit 4- Cell And Membrane Techniques	Cell sorting and Flow cytometry - Principles and Applications, Patch clamp, Freeze fracture technique, Electrophysiological techniques. Enzyme and cell immobilization techniques. Methods of cell disintegration; Enzyme assays and controls; Detergents and membrane proteins.	3 hrs
Unit 5- Spectroscopy	Basics principles of Spectroscopy, Beers-Lambert law; transmittance; extinction co-efficient; light sources; monochromators; types of detectors; working principle and applications of visible, UV-visible, IR, Raman, ORD, CD; Fluorimetry and flame photometry. Fluorescence spectrometer; Mass Spectrophotometry – MALDI, ESI-MS-MS, iTRAQ, SWATH-MS, Basics of NMR Spectroscopy, Plasma Emission spectroscopy, Atomic absorption spectroscopy – ICP-OES, AES. Concept of GC-MS, LC-MS.	7 hrs
Unit 6- Electrophoretic Techniques	Introduction and Principles; types of electrophoresis. Polyacrylamide and Agarose gel electrophoresis; Capillary electrophoresis; 2D Electrophoresis; Gradient electrophoresis; Pulsed field gel electrophoresis.	3 hrs
Unit 7- Microscopy	Principles and applications of Microscopy – Confocal & Fluorescence microscopy, Atomic force microscopy and Electron microscopy – SEM, TEM and Cryo-electron Microscopy.	3 hrs
Unit 8- Radioactivity	Radioactive & stable isotopes; Units of radioactivity; Measurement of radioactivity; Geiger-Muller counter; Solid & Liquid scintillation counters (Basic principle, instrumentation & technique); Autoradiography; Applications of isotopes in biochemistry; Radiotracer techniques; Distribution studies; Metabolic studies; Clinical applications.	3 hrs

REFERENCE TEXTS:

BIOCHEMISTRY

1. V.Voet and J.G.Voet, Biochemistry, 3rd edition, John Wiley, New York, 2004.
2. A.L. Lehninger, Principles of Biochemistry, 4th edition, W.H Freeman and Company, 2004.
3. L. Stryer, Biochemistry, 5th edition, W.H. Freeman and Company, 2002.
4. Reginald H. Garrett, Charles M. Grisham. Biochemistry. Brooks Cole 5th Edition (2012). David Bender, Kathleen M. Botham, Robert Murray. Harpers Illustrated Biochemistry. 29th Edition, McGraw-Hill Medical Publishing (2012).

5. Thomas M. Devlin, Textbook of Biochemistry with Clinical Correlations. 7th Edition, John Wiley & Sons (2010).

ANALYTICAL TECHNIQUES

1. Freifelder D., Physical Biochemistry, Application to Biochemistry and Molecular Biology, 2nd Edition, W.H. Freeman & Company, San Fransisco, 1982.
2. Keith Wilson and John Walker, Principles and Techniques of Practical Biochemistry, 8th Edition, Cambridge University Press, 2018.
3. Modern Experimental Biochemistry. 2000. 3rd ed. by R.F. Boyer. The Benjamin Cummings Publ. Company.
4. Xinkun Wang, X. Next-generation sequencing data analysis. 1st edition, CRC Press, 2016.
5. Magdeldin, S. ed., 2015. Recent Advances in Proteomics Research. Intech Open.
6. Ghosh, P.K., 2015. Introduction to protein mass spectrometry. Academic Press.
7. Lottspeich, F. and Engels, J.W. eds., 2018. Bioanalytics: Analytical Methods and Concepts

PRACTICAL I: BT7P1: Biochemical and Analytical techniques (88 hrs)

ANALYTICAL TECHNIQUES

1. Preparation of buffers in biology and calculation of molarity, normality etc.,
2. Optimising a pH meter and measuring the pH.
3. Absorption spectrum of coloured solution.
4. Column chromatography of plant pigments
5. Paper chromatography of amino acids.
6. Thin Layer Chromatographic technique for separation of compounds
7. HPLC of plant pigments-A
8. HPLC of plant pigments-B
9. Preparation of density gradients
10. Measurement of Cell Size and numbers

BIOCHEMISTRY

1. To prepare an Acetic-NaAcetate Buffer system and validate the Henderson-Hasselbach equation.
2. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer- Lambert's Law.
3. Estimation of amino acid by Ninhydrin method
4. Determination of pI of amino acid by titration method.
5. Estimation of glucose by Hagedorn and Jenson method
6. Estimation of inorganic phosphate by Fiske-Subbarow method

7-9. An Enzyme Purification Theme (such as E. coli Alkaline phosphatase or any enzyme)

(a) Preparation of cell-free lysates
(b) Ammonium Sulfate precipitation
(c) Ion-exchange Chromatography
(d) Affinity Chromatography
(e) Generating a Purification Table
(f) Assessing purity by SDS-PAGE Gel Electrophoresis
(g) Enzyme Kinetic Parameters: Km, Vmax and Kcat.

10. Determination of (a) Iodine number and (b) Acetyl number of a lipid

COURSE OUTCOMES FOR BT7121: BIOCHEMISTRY AND ANALYTICAL TECHNIQUES

After successful completion of the course, students will:

CO1	Gain understanding on various biomolecules and their applications in biotechnology.
CO2	Develop insight into central energy metabolic pathways and their regulation.
CO3	Gain hands on skills in isolation, purification, quantification of biomolecules especially enzymes and estimation of Michaelis Menten constants
CO4	Learn the concepts of pH, buffers & Concentration, Separation, Analytical Analysis biomolecules through concepts of Chromatography, Centrifugation, Spectroscopy, Electrophoresis.
CO5	Understand the concepts, types and applications of Microscopy and advanced methods such as Cryo-electron microscopy. Effects and safety of Radioisotope techniques.
CO6	Through the practical sessions of the paper, the student learns how to perform chromatographic separation of biological compounds, aspects of density gradients and concepts of Micrometry.

Semester	**I**
Paper Code	**BT7221**
Paper Title	**Topics in Cell Biology**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:

This class has been designed to expose students to a broad range of advanced cell biological themes. The topics will be covered in depth, with references to the relevant techniques and disease implications. These will provide the students a firm handle on cell biological principles and the ability to understand and analyse a research problem.

Syllabus for BT7212: Topics in Cell Biology (60 hours)

Unit	Content	Teaching Hours
Topics in Cell Biology		**60 hours**
Unit 1: Cell biology basics	Cellular organisation, compartmentalisation, homeostasis, cells to tissue.	2 hrs
Unit 2: Cell differentiation and development	Embryonic and adult stem cells, asymmetric division and the immortal strand hypothesis, concepts of totipotent, pluripotent and multipotent stem cells, iPSC and the stem cell revolution, organoids and 3D culture.	6 hrs
Unit 3: Cellular signalling	Tyrosine kinase signalling, MAPK pathways, Cyclic nucleotide signalling in health and disease, Wnt signalling in development and cancer, nutritional signals (AMPK and mTOR), Immune signalling.	7 hrs
Unit 4: Endo-lysosomal system	Overview of cargo trafficking and the endocytic system, clathrin-coated pits and receptor-mediated endocytosis, non-canonical modes of endocytosis, autophagy and cell survival, exocytosis, targeting the endocytic system, role of phagocytosis in host-pathogen interaction.	6 hrs
Unit 5: Cell and tissue polarity	Cellular asymmetry, polarity in epithelial and non-epithelial tissues, Apico-basal polarity, Baso-lateral polarity, signalling pathways that regulate polarity, asymmetric division in bacteria.	5 hrs

Unit 6: Cell adhesion and motility	Cell-cell and cell-matrix adhesion, adhesion junctions and tight junctions, extracellular matrix and integrin signalling, cell movement and its regulation, collective cell migration.	6 hrs
Unit 7: Cellular redox mechanisms	Redox homeostasis, reactive oxygen and nitrogen species, cellular responses to oxidative stress, oxidative theory of ageing.	4 hrs
Unit 8: Cell Death	Necrotic cell death, Apoptosis and its regulation, Non-canonical modes of cell death, Senescence and ageing, cell death and disease.	5 hrs
Unit 9: Molecular basis of cancer	Immortalization and transformation, Oncogenes, Tumour suppressor genes, dysregulation of the cell cycle, principles of metastasis, Transformation by RNA and DNA tumour viruses, Apoptosis and cancer, regulation my non-coding RNA, cancer stem cell hypothesis, cancer therapy.	8 hrs
Unit 10: Recent advances in cell biology	Phase-transition and non-membrane bound organelles, Fluorescent proteins and cellular sensors, Novel cell imaging modalities.	4 hrs

REFERENCE TEXT:

Molecular Cell Biology, Eighth Edition, 2016

Harvey Lodish; Arnold Berk; Chris A. Kaiser; Monty Krieger; Anthony Bretscher; Hidde Ploegh; Angelika Amon; Kelsey C. Martin

Additional reading material will be provided in class in the form of presentations, handouts and journal articles.

COURSE OUTCOMES FOR BT7221: Topics in Cell Biology

After successful completion of the course, students will:

CO1	Have an in depth understanding of the inner workings of cells and how they form tissues.
CO2	Be able to read and interpret scientific data and critique published articles.
CO3	Have a feeling for translational research, its impact on human health and its clinical application.
CO4	Be able to work with various cell biological models, using in vitro and in vivo assays, including mammalian cells, yeasts and newer model systems like hydra.
CO5	Be able to collect, analyse and interpret cell biological data.

Semester	**I**
Paper Code	**BT7321**
Paper Title	**Molecular Biology**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:
This paper is designed to give students an in-depth understanding of the core, foundational principles of Molecular Biology, while also allowing them to appreciate the scientific experimentation that led to many of the seminal advances in molecular biology.

Syllabus for BT7321: Molecular Biology (60 hours)

Unit	Content	Teaching Hours
SECTION A: THE BIOCHEMISTRY OF LIFE		**12 hours**
UNIT 1- Chemical Bonds determine Macromolecular Structure	Characteristics of chemical bonds, the concept of free energy, the importance of weak bonds and high-energy bonds in biological systems	4 hrs
UNIT 2- Nucleic acids convey Genetic Information	An overview of classical experiments that led to discovery of DNA structure, the mechanism of DNA replication, and the central dogma	4 hrs
UNIT 3- DNA, Genes and Genomes: Structure and Organisation	DNA structure and topology, Genes and Genomes (viral, prokaryotic, eukaryotic, organellar); Nucleosomes, Chromatin and Chromosomes, Features of Prokaryotic and Eukaryotic genomes, RNA, Protein structures and Protein: nucleotide interactions	4 hrs
SECTION B: MAINTENANCE OF THE GENOME		**18 hrs**
UNIT 4- DNA Replication	DNA Polymerase: Structure and mechanism of catalysis, Other proteins involved in DNA replication and a replication overview, DNA synthesis at the Replication Fork in prokaryotes and eukaryotes, Replication origins and Initiation of DNA replication in prokaryotes and eukaryotes, Replication termination and the end replication problem in eukaryotes, Reverse transcription.	7 hrs

UNIT 5- Mutations and DNA Repair	Causes and types of DNA Damage, types of mutagens, Replication errors and Mismatch repair, DNA Repair by Direct reversal of DNA damage, Excision repair	5 hrs
UNIT 6- Homologous recombination and DNA Transposition	The Holliday model of Homologous recombination, The double strand DNA break repair model, Molecular mechanisms of RecBCD and RuvABC mediated homologous recombination, Mechanisms of DNA transposition, Examples of transposable elements and their regulation	6 hrs
SECTION C: GENE EXPRESSION		**18 hrs**
UNIT 7- Transcription	RNA Polymerase structure and the sigma factor, Prokaryoti and eukaryotic promoters, Transcription in prokaryotes transcription in eukaryotes, Processing of eukaryotic mRNA Error correction.	9 hrs
UNIT 8- Translation	Ribosomes, tRNA and the Genetic Code, Initiation, Elongation and termination of prokaryotic translation, Initiation, Elongation and termination of eukaryotic translation, Post translational processing of proteins	9 hrs
	Ribosomes, tRNA and the Genetic Code, Initiation, Elongation and termination of prokaryotic translation, Initiation, Elongation and termination of eukaryotic translation, Post translational processing of proteins	2 hrs
SECTION D: REGULATION OF GENE EXPRESSION		**12 hrs**
UNIT 9- Prokaryotic Gene Expression Regulation	Principles of Gene expression regulation, Gene regulation at transcription initiation: Constitutive and Regulatory control, Regulation of bacterial mRNA elongation by attenuation, CRISPR	6 hrs
UNIT 10- Eukaryotic Gene Expression Regulation	Transcription factors and combinatorial control of eukaryotic gene regulation, Epigenetic regulation of eukaryotic gene expression, Role of RNAs in eukaryotic gene expression regulation, Gene expression regulation in developmental stages	6 hrs

REFERENCE TEXTS

1. Molecular Biology of the Gene, Watson et al, 7th ed, 2014, Pearson EDUCATION
2. Genomes 4.0, T.A Brown, 2017, Garland Science
3. Lewin's GENES XII, Krebs, Goldstein, Kilpatrick, 2017, Jones and Bartlett
4. Molecular Cell Biology, Harvey Lodish et al, 2016, WH Freeman
5. Molecular biology, Robert F. Weaver (5th ed), 2012, McGraw Hill

COURSE OUTCOMES FOR BT7312: MOLECULAR BIOLOGY

After successful completion of the course, students will:

CO1	Gain an in-depth understanding of the macromolecular structure, function and organisation that form the biochemical basis of life, how genomes are maintained, genes are expressed and regulated, through an investigation of the underlying molecular mechanisms.
CO2	Be able to read, understand and analyse primary scientific literature and appreciate both classical and recent experimentation that has advanced the field of molecular biology.
CO3	Develop analytical and problem solving skills by routine quantitative and qualitative analysis to interpret biological data.
CO4	Be able to apply cross disciplinary concepts to understand biological phenomena.
CO5	Exhibit competence in performing basic experiments involving isolation and analysis of DNA, RNA and Protein and some assays for transcription, translation and regulation.
CO6	Be able to independently work safely and effectively in the laboratory and execute a variety of experiments using the standard methods and techniques in molecular biology, and record, analyse and interpret results.

PRACTICAL II: BT7P2: Cell and Molecular Biology (88 hrs)

1. Overview and plan of work for the labs
2. Isolation of primary cells (WBCs)
3. Cell fractionation: Preparation of nuclear/cytoplasmic fractions
4. Sample preparation and protein estimation
5. SDS PAGE for blotting
6. Western blotting for total ERK, other markers for fractionation.
7. Analysis of apoptosis in WBCs/yeast (laddering/morphology)
8. Wound-healing assay for cell movement
9. Effect of starvation induced autophagy on cell viability
10. Hydra as a model for regeneration and polarity
11. Isolation of genomic DNA from bacteria
12. Estimation of bacterial genomic DNA and estimation and purity check of isolated DNA
13. Isolation of DNA from blood
14. Spec estimation and purity analysis
15. In vitro transcription and translation
16. Use of antibiotics to inhibit transcription and translation in *E. coli*
17. Induction of protein expression, solubility of proteins
18. SDS PAGE and coomassie staining
19. RNAi
20. Data Analysis and reporting/Revision/Repeat of failed experiments

Semester	**I**
Paper Code	**BT7421**
Paper Title	**Biostatistics**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:
This course is designed to introduce students to the basics of biostatistical analyses and R programming. It provides students a platform into deriving, consolidating, presenting and analysing data using various statistical procedures and tests. The course also introduces principles of hypothesis testing and design of biological experiments.

Syllabus for BT7421: Biostatistics

Unit	Content	Teaching Hours
BIOSTATISTICS		
UNIT 1: Descriptive Statistics	Frequency Distribution, Characteristics of a Frequency Distribution, Measures of central tendency: mean, median, mode; Expectation; Measures of spread: range, percentile, standard deviation, kurtosis, skewness; Tabular and Graphical Presentation of Data: Histograms, stem-and-leaf plots, box plots. Basics of R programming, Estimation of measures of central tendency and deviation using R, plotting histograms and other plots in R	8 hours
UNIT 2: Probability Theory and Random Variables	Probability Definition, Rules for Calculating Probabilities, Discrete random variables: Bernoulli, Binomial, Poisson, Geometric distributions, Continuous random variables: Normal, Exponential distributions, Standard normal distribution. Calculation of probability & Normal, Binomial and Poisson distributions in R.	10 hours
UNIT 3: Correlation and Regression	Correlation, Karl Pearson correlation, regression analysis, simple linear regression, the least squares method, significance testing of correlation and regression coefficients. R programming for Correlation and Regression analysis.	5 hours
UNIT 4: Inferential statistics and one sample hypothesis testing	Samples and populations: Random, stratified and cluster sampling. Single- and Double-blind experiments. Point and interval estimates, Sampling distributions: t, chi-square, F distributions, Hypothesis testing: null and alternative hypotheses, decision criteria, critical values, type I and type II errors, the meaning of statistical significance, power of a test, One sample hypothesis testing: Normally distributed data: z, t	15 hours

	and chi-square tests. Binomial proportion testing. Programming z, t, F and chi square tests in R.	
UNIT 5: Multi-sample and nonparametric hypothesis testing	Two sample hypothesis testing; Nonparametric methods: signed rank test, rank sum test, Kruskal-Wallis test, Analysis of variance: One-way ANOVA. Curve fitting, Two- way ANOVA. Post ANOVA tests: Tukey's test, Duncan's Test. ANOVA analysis and post hoc analysis in R	12 hours
UNIT 6: Design of Experiments	Designed Experiments, Principles of experimental design, Randomization, Blocking, Replication and Extraneous Variables. Completely Randomized Design, Randomized block design, Latin Square Design, Factorial Design, Split- Block Design. RBD, LSD and FD design analysis in R.	10 hours

REFERENCE TEXTS

1. Wayne W. Daniel, Chad L. Cross,2012, 10th edition, Biostatistics: A Foundation for Analysis in the Health Sciences, Wiley Sciences Publishers
2. Gupta S.P., 2010, 5th Edition, Statistical Methods, Sultan chand & Sons
3. Siegel, S., Johan, N. and Casellan, Jr. 1956. Non-parametric Tests for Behavior Sciences. JohnWiley
4. Learning Statistics: http://freestatistics.altervista.org/en/learning.php. Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html

COURSE OUTCOMES FOR BT7421: BIOSTATISTICS

After successful completion of the course, students will:

CO1	Be able to consolidate, present data in tables, graphs and describe any distribution using the standard population parameters.
CO2	Understand and derive theoretical probability distributions and use them in assigning probabilities to desirable events.
CO3	Gain in-depth understanding of concepts in bivariate analysis such as correlation and regression and linear regression analysis
CO4	Develop insight into hypothesis testing using various testing procedures and be able to draw statistically valid inferences from data.
CO5	Be able to efficiently design and analyze biological experiments.
CO6	Gain expertise in the use of R programming in biostatistical analyses.

Semester	**II**
Paper Code	**BT8121**
Paper Title	**Microbiology and Molecular Genetics**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:
This course introduces microbial diversity and discusses the use of various techniques employed in molecular taxonomy of microbes. It further examines microbial interactions in health as well control and development of resistance. As part of Molecular Genetics, the course introduces concepts in Classical, Quantitative, Human, Bacterial and Viral Genetics. The course also explores epigenetics and use of genetic screens and genome wide association studies to understand the genomes of organisms.

Syllabus for BT8121: Microbiology and Molecular Genetics 60 hours

Unit	Content	Teaching Hours
MICROBIOLOGY		**15 hours**
UNIT 1: Microbial Diversity	General characteristics with emphasis on understanding diversity of: Viruses, Bacteria, Algae, Fungi and Protozoa.	2 hours
UNIT 2: Molecular taxonomy	Criteria for microbial classification-Biochemical methods, serological techniques, phage typing, fatty acid profiles, Flow cytometry, DNA base composition, DNA fingerprinting, rRNA sequence, Nucleic acid hybridization, Chemotaxonomy, signature sequences, and protein sequences.	4 hours
UNIT 3: Microbial interactions in health and diseases	Types of microbial interactions, Normal human microbiota: the metabolic interaction of the gut microbiome. Epidemiology approach to a disease and terminologies involved in the study, approach to descriptive and analytical epidemiology (case studies). Virulent factors in bacteria, epidemiology of *Mycobacterium tuberculosis*	4 hours
UNIT 4: Microbial control and resistance	Introduction to antibiotics and mode of action on bacteria with one example, Introduction to antiviral compounds and their mode of action with any one example, Microbial resistance at molecular level: example: multidrug-resistant *Mycobacterium tuberculosis*.	4 hours

MOLECULAR GENETICS		**45 Hours**
UNIT 1: Classical Genetics	Review of Mendelian laws, concept of dominance, segregation, independent assortment, chromosome theory of inheritance. Allelic and non-allelic interactions, lethal, multiple alleles, test of allelism, complementation; Epistasis. Inheritance; Sex-linked inheritance, Sex determination, Morgan's discovery of sex-linked inheritance of sex-linked genes, extranuclear inheritance, pleiotropy, phenocopy, penetrance and expressivity, linkage, crossing over.	6 Hours
UNIT 2: Genetic Material	Chromosomes and genes; Split genes, pseudogenes, non-coding genes, overlapping genes and gene families. Properties and evolution of genetic material, flow of genetic information, LINES, SINES, Alu family and their applications in genome mapping.	4 Hours
UNIT 3: Mutations	Mutation: types of mutation, mutagens, mechanism of mutation, induction and isolation of mutants and their role in genetic studies, complementation. Model systems for genetic analysis; Bacteriophage, *E. coli, Neurospora crassa*, yeast, *Arabidopsis*, *Drosophila, C. elegans*, Zebra fish, *Homo sapiens* - General outline of life cycle, importance in Genetic analysis. Molecular Mechanisms of Mutation: Forward Genetics and Reverse Genetics Mutation – At DNA level and At protein level, Frame shift mutations: Extragenic suppression and Intragenic suppression Physiological suppression. b) Loss of function mutation, Gain of function mutation, Amorph, Hypomorph and Hypermorph.	6 Hours
UNIT 4: Quantitative Genetics	Multiple factor hypothesis and analysis of polygenes. Genotype-Environment Interaction and models for their measurement, estimation of Heritability Index. Human genetic diversity- Methods of study – Biochemical/molecular genetic markers.	4 Hours
UNIT 5: Human Genetics	Genome organization, Structure of chromosome, Pedigree analysis-Pedigree analysis- Mendelian inheritance and exceptions; Chromosomal analysis (in vitro, in vivo), gene mapping, physical mapping, mapping markers, G/Q banding, FISH, comparative genome hybridization, long range restriction mapping, high resolution mapping STS/EST/MS/SNP/sequencing; Genetic mapping: Linkage analysis (RFLP/MS/SNP), Chromosome mapping based on recombination frequency data Human genome analysis: cloning and sequencing, Generation of 'OMICS' era, significant leads. Chromosomal disorders: Structural and numerical; Autosomal/sex chromosomal/sex reversal; Mechanisms– mitotic/meiotic non-disjunction/chromosomal rearrangements; some examples. Ethical, legal and social	8 Hours

	issues in Human genetics: Prenatal/adult (individual/family/population) screening of mutation/risk factor for genetic diseases	
UNIT 6: Bacterial and Viral Genetics	Genome organization of viruses, and bacteria, Recombination in bacteria. Mechanism of recombination, transposable genetic elements. Transformation and conjugation in bacteria. Linkage map of bacterial chromosomes. Lytic cycle and lysogeny and its regulation. Transduction; specialized, generalized and abortive. Fine structure analysis of T phages; Benzers work, concept of cistrons.	4 Hours
UNIT 7: Population Genetics	Gene pools, allele frequencies, Hardy Weinberg equation, non-random breeding, genetic drift, gene flow, selection, speciation.	3 Hours
UNIT 8: Epigenetics	Role of Heterochromatin and its interactions with histones, antagonistic repressors and activators, global changes on X-chromosomes, effect of condensins, imprinting, inheritance of prions, diseases caused by prions in humans	2 Hours
UNIT 9: Genome-wide association studies (GWAS)	Basic genetic concepts that drive GWAS, including the architecture of common diseases, the structure of common human genetic variations, technologies for capturing genetic information, study designs, and the statistical methods used for data analysis. Future beyond GWAS.	4 Hours
UNIT 10: Genetic screens: Model systems, design and analysis	Use of genetic screens for discovery and characterisation of genes, understanding the biology of complex systems, types of genetic screens, effective design of a genetic screen, interpretation and analysis of screening data, model systems include bacteria, yeast, *C. elegans*, Drosophila, mammalian cells and mice.	4 Hours

REFERENCE TEXTS

Molecular Genetics

1. David Freifelder. (2004). Microbial genetics. 10th edition, Norosa publisher, New Delhi.
2. Lodish, H.D., Baltimore, A., Berk, B.L., Zipursky, P., Mastsydairs and Darnell, J. (2004). Molecular cell biology. Scientific American Books Inc., NY.
3. Gardner/Simmons/Snustad. (2006). Principal of Genetics. 8th Edn. John Wiley & sons.
4. Klug, W.S.,Cummings. (2003). Concepts of genetics, 7th Edn. Pearson Education.
5. Dale, J.W. (1994). Molecular Genetics of bacteria, John Wiley & Sons.
6. Streips and Yasbin. (2001). Modern microbial Genetics. Niley Ltd. 7. John Ringo (2004). Fundamental Genetics. Cambridge University Press
7. Benjamin Lewin, Gene IX, 9th Edition, Jones and Barlett Publishers, 2007.

Microbiology

1. Rowland H. Davis - The Microbial Models of Molecular Biology_ From Genes to Genomes-Oxford University Press, USA .
2. Claire M. Fraser, Timothy Read, Karen E. Nelson - Microbial Genomes (Infectious Disease)-Humana Press.
3. Microbiology by MJ Pelczar Jr, ECS Chan, NR Krieg , Pub: Tata Mcgra-Hill Publishing Co Ltd

COURSE OUTCOMES FOR BT8121: MICROBIOLOGY AND MOLECULAR GENETICS

After successful completion of the course, students will:

CO1	Appreciate diversity among various microorganisms and assess the same using various molecular techniques.
CO2	Understand the effect of various microbial interactions on human health as well as have insight into microbial control development of resistance.
CO3	Be able to understand and apply concepts in Classical, Quantitative, Human Genetics, Bacterial and Viral Genetics.
CO4	Gain insight into the various types of mutations, mutagenic agents and subsequent alterations in inheritance.
CO5	Be able to use model organisms to validate genetic principles governing inheritance as well study of various mutants.
CO6	Apply various techniques to study either entire genomes or specific regions that govern traits of interest.

PRACTICAL BT8P1: Microbiology and Molecular Genetics

Molecular Genetics

1. Induced mutagenesis (random (pcr based, vectors) / site directed (pcr based)
2. Screening of Drosophila P mutants for envt stresses
3. Study of Drosophila mutant types/ mapping using P
4. Drosophila: Mendelian Genetics, Sex linked inheritance
5. Complementation using Drosophila
6. Yeast mutant analysis AD1 and 2
7. Genetic mapping by P1 transduction
8. Genetic mapping by conjugation
9. Measurement of growth rate/ one step growth curve using T even phage

Microbiology

1. Obtaining strains, preparation of media for culturing and maintenance.
2. Preparation and culturing of pure cultures of strains.
3. Antibiotic susceptibility test and evaluation of dosage.
4. Molecular characterization using 16s RNA part a
5. Molecular characterization using 16s RNA part b
6. Molecular characterization using 16s RNA part c
7. Cultivation and isolation of viruses from embryonated eggs.
8. Isolation of bacteriophages from sewage samples
9. Assessment of Genetic diversity using Molecular markers (RAPD/ AFLP)

Semester	**II**
Paper Code	**BT8221**
Paper Title	**Genetic Engineering and Synthetic Biology**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:

This paper enlightens the students about various milestones in aspects of Genetic engineering and Synthetic biology with emphasis on the latest developments and pathway modelling strategies. Many advanced techniques involved in genome editing, cloning, ngs and cell free systems are covered in the paper.

Unit	Content	Teaching Hours
Genetic Engineering and Synthetic Biology		**60 hrs**
Unit -1: Introductory Aspects	Introduction to genetic engineering and recombinant DNA technology, Concept of cloning and its applications. DNA structure – modifications using various enzymatic reactions, hydrolysis and formation of phosphodiester bonds, removal of phosphate groups and its effects.	2 hrs
Unit 2- Modifying DNA for Cloning	DNA cutting and joining-Enzymatic cleavage of DNA. Restriction and modification enzymes, Restriction mapping, DNA ligases, Polynucleotide kinase, Alkaline phosphatases, exonucleases, S1 nucleases, terminal nucleotide transferase, Bal 31 nuclease, Isothermal enzymes such as Bst I DNA polymerases, recombinases, reverse transcriptase, topoisomerase, Klenow fragment, phi29 polymerase.	4 hrs
Unit 3- Sources of Nucleic Acid	Genomic DNA, cDNA, PCR products, chemically synthesised oligonucleotides/genes. Oligos, Concepts of Primer Design, Adapters, linkers, homopolymer tails, modified oligos (labelled oligos), Concepts of degenerate oligos.	3 hrs

Unit 4- Amplification of DNA	Concepts of Polymerase chain reaction - principle, types (RT-PCR, Nested, Multiplex PCR, Long PCR, IC-PCR and Inverse PCR), and applications of PCR. Isothermal methods of DNA amplification - concepts of Loop mediated Isothermal amplification of DNA, Rolling circle amplification of DNA, Recombinase polymerase amplification, Concepts of Real time PCR – SYBR Green assay, Taqman probes, Molecular beacons.	4 hrs
Unit 5- Concepts of Vectors & Cloning	Plasmids – Natural and Artificial plasmids. Advantages and Disadvantages. Vectors used for cloning – Plasmids, Bacteriophage vectors, Phagemids, Cosmids, BACs, YACs, Shuttle vectors, Animal vectors, Ri, Ti plasmids, Binary vectors, Gateway cloning vectors, Viral vectors, VIGS vectors. Design and construction of a customised vector. Construction of an expression vector, strategies for enhanced production of mRNA, dsRNA and Protein. Bacterial, Yeast and Animal expression vectors, Viral vectors for mammalian expression. Heterologous expression systems.	6 hrs
Unit 6- Design of an Expression Vector	Promoter types (Constitutive, tissue specific, stress responsive, development stage specific etc – both prokaryotic and eukaryotic), enhancers, reporter genes, fusion protein tags, marker genes, origin of replication.	3 hrs
Unit 7- Cloning Strategies	PCR cloning, Restriction enzyme - based cloning (blunt ended and sticky ended), Gateway cloning, Gibson assembly and cloning, recombinase cloning (Cre Recombinase based cloning), ligation independent cloning, Seamless cloning strategies, Golden Gate Assembly strategies.	4 hrs
Unit 8- Methods of DNA Transfer	Methodology of DNA transfer – Direct, Indirect methods of gene transfer, Transformation, transfection, Agrobacterium mediated gene transfer (In planta, Floral dip, leaf disc transformation, infiltration etc.,), Freeze thaw technique, Electroporation, Lipofection, Microinjection, Biolistic transfer (Gene gun, Biolistic chamber), Sonication, Ultrasonication, Virus mediated transfer etc.)	4 hrs

Unit 9-Screening of Transformants	ELISA (Enzyme linked immunosorbent Assay) – types, enzyme assays, protein quantification etc., Insertional inactivation – LacZ gene, URA genes etc., Nucleic acid blotting and hybridization - Preparation of DNA and RNA probes, hybridization formats, factors influencing hybridization and applications of hybridization-based tests (NASH). Radiolabelling, Non-radiolabelling methods (Colorimetric, Chemiluminescent, Fluorescent etc.), Southern, Northern, Western, Colony blot hybridization and detection.	7 hrs
Unit 10-Construction of Genomic Libraries	Genomic DNA libraries, Transcriptomic/RNA libraries, Expression libraries (cDNA libraries), Metagenomic libraries, Phage display libraries, Differential expression libraries (SSH libraries).	3 hrs
Unit 11-Sequencing Concepts	DNA Sequencing – Maxim gilbert, Sanger's dideoxy chain termination method of sequencing, Automated Sanger's method, primer walking strategies Protein Sequencing – methods and applications, Next generation sequencing – 454, Illumina, SMRT-PAC Bio, Ion torrent, Oxford Nanopore technologies.	5 hrs
Unit 12-Gene Expression Analysis and Strategies for Regulation of Gene Expression	DNA microarrays and chips, protein microarrays - principles and applications. Transcriptional and Post transcriptional gene silencing. Antisense RNA technology, RNAi technology, microRNA technology for control of gene expression (artificial miRNA production), CRISPR-Cas9 for genome editing and CRISPR – Cas 13 technologies, Transcription factors, Yeast two hybrid systems for assaying protein interactions.	7 hrs
Unit 13-Synthetic Biology	Introduction, Genetic circuits, oscillators and logic gates, synchronized oscillators, biological clocks, communication modules, bacterial photography, mammalian oscillators, pattern formation, genetic elements for new control systems, pathway engineering, biofuels, metabolic engineering, pathway engineering- Artemisinin; de novo design of pathways, engineering in algae, plants, modeling oscillations, networks and cell communication, gene design – BioBricks, gene assembly, gene design – synthetic genomes, new genetic polymers, XNA and CST for selection, orthogonality, refactoring translation, artificial cells – chells, vaccines, chassis, molecular machines, structured devices – DNA, Engineering of Riboswitches, Cell free Biosynthesis – protein expression etc., Structured devices – protein, Ethical, Legal and Social aspects of Synthetic Biology – Biowarfare.	8 hrs

REFERENCE TEXTS

1. Lottspeich, F. and Engels, J.W. eds., 2018. Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology. John Wiley & Sons.
2. Brown, T.A., 2020. Gene cloning and DNA analysis: an introduction. John Wiley & Sons.
3. Primrose, S.B. and Twyman, R., 2013. Principles of gene manipulation and genomics. John Wiley & Sons.
4. Clark, D.P. and Pazdernik, N.J., 2011. Biotechnology: Academic Cell Update Edition. Academic Press.
5. Lu, Y., 2017. Cell-free synthetic biology: Engineering in an open world. Synthetic and systems biotechnology, 2(1), pp.23-27.
6. Zhao, H., 2018. Synthetic Biology–Metabolic Engineering. Springer.
7. Marchisio, M.A., 2018. Introduction to Synthetic Biology: About Modelling, Computation, and Circuit Design. Springer.

COURSE OUTCOMES FOR BT8221: Genetic Engineering and Synthetic Biology

After successful completion of the course, students will:

CO1	Learn sources and purification methods of nucleic acid, modifying them, cloning them into various types of vectors. Application of Amplification techniques in various processes of biological research
CO2	Designing of a customised vector for expression of specific proteins, Advanced cloning techniques, methods of DNA transfer and various types of heterologous expression hosts.
CO3	Learn about the screening and selection methods of positive clones, aspects of sequencing and strategies for controlling the gene expression.
CO4	Get well versed with the concepts of synthetic biology, pathway engineering and synthetic genomes, ethics of using synthetic biology with emphasis on biowarfare.
CO5	Practical sessions will lead the student to have hands-on experience in isolation of nucleic acids, amplification of nucleic acids, modification and cloning of nucleic acids.
CO6	Besides, the students get well versed with the methods of selection, screening of positive clones and concepts of reporter genes.

Semester	**II**
Paper Code	**BT8321**
Paper Title	**Bioinformatics and Computational Biology**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:
This paper covers most of the concepts in bioinformatics and computational biology including emphasis on programming concepts and various tools. Big data analytics, sequence analysis and molecular modelling will empower the learners with an absolute command over the area including research aspects.

Unit	Content	Teaching Hours
Bioinformatics and Computational Biology		**60 hrs**
Unit -1: Introduction to Basics of Computation	Operating systems - CUI, GUI. Basics of Linux operating system - commands. R-programming for Bioinformatics, Biopython - Basics, Object oriented programming.	4 hrs
UNIT 2- Introduction to Bioinformatics	Disciplines – Genomics, Proteomics, Computational Biology, Transcriptomics, Pharmacogenomics, Metabolomics, Phenomics. Concepts. Sequence assembly. Human Genome Project – OMIM database, Bioinformatics databases, Type of databases, Nucleotide sequence databases, Primary nucleotide sequence databases - ENA, Genbank, DDBJ; Secondary nucleotide sequence databases/Specialized genome databases – GOLD, SGD. Literature Databases – PUBMED, MESH.	6 hrs
UNIT 3- Proteins and Databases	Protein structure and function, Protein Primary structure, Amino acid residues, Secondary, Tertiary, Quaternary Structure of Protein, Protein sequence databases- UniprotKB (SwissProt/ TrEMBL), PIR, Sequence motif databases/Secondary Protein sequence databases -Pfam, PROSITE, Interpro. Protein structure databases, Protein Data Bank-SCOP, CATH, KEGG, PubChem, Sequence, structure and function relationship databases, Interactome databases. Methods of Protein Secondary Structure Prediction – GOR, PSIPRED, Neural Networks.	7 hrs

UNIT 4- Sequence alignment and Algorithms	Pairwise Sequence Comparison - Pairwise sequence alignment (global, local), variants: optimal alignment in linear space, semiglobal, affine gap penalties, similarity vs. distance. Pair-wise sequence alignment, Need of Scoring schemes- Penalizing gaps – Linear and Affine gap penalty; Effect of scoring schemes, Identity Scoring Matrix, Scoring matrices for amino acid sequence alignment, PAM Probability matrix, BLOSUM Matrix; Dot-plot visualization; Smith –Waterman algorithm for local alignment, Needleman-Wunsch algorithm, Statistics of Sequence alignment score: E- values, bit scores and sensitivity, specificity; BLAST, Blast variants. Multiple sequence alignment: Clustal Algorithm, MUSCLE, T-COFFEE. Concepts of Sequence analysis. RNA secondary structure prediction – RNA secondary structure, features: stems, loops, bulges, Pseudoknots, Nussinov algorithm, mFold.	9 hrs
UNIT 5- Molecular Phylogenetics	Concept of Phylogenetic tree, Rooted, unrooted, Molecular Clock Hypothesis, Distance based data: Ultrametric trees and UPGMA, Additive trees and Neighbor Joining. Character based data: Maximum Parsimony, and Maximum likelihood method. Methods of tree evaluation: Bootstrapping, Jackknife.	4 hrs
UNIT 6- Big data /NGS Analysis concepts	Introduction to Next Generation Sequencing (NGS) data - Biases and sequencing errors of Illumina technology, FastQ file format, Quality reads assessment (FastQC software), Reads pre-processing. Overview of bioinformatics methods for genome assembly - Overlap-layout-consensus - Debrujin graph - Genome assembly assessment - Sequence alignment of NGS data - Dynamic programming, Heuristic methods, SAM/BAM format, Resequencing and variant calling, Identification of germline variants, Identification of somatic variants Bioinformatics methods for the identification of structural variations (Insertion and Deletion, Translocation, Copy number variation) Variant Calling File (VCF) format and Genomic VCF format, Computational tools for prioritizing candidate genes.	8 hrs
UNIT 7- Transcriptomic analysis and RNA-seq	RNA-seq assembly (TopHat, STAR), Transcripts reconstruction, Gene quantification, Data normalization, Identification of differentially expressed genes, Gene enrichment and gene set analysis. SRA database and GEO databases of NCBI.	6 hrs

UNIT 8- Molecular modelling	Concept of Protein modelling, Ab-initio based protein modelling, Protein homology modelling, Threading concepts. Energy minimization. Basics of Molecular dynamics.	5 hrs
UNIT 9- Ligand-protein interactions	Concept of Docking. Protein-protein docking algorithms and programs, Ligand Protein interaction: docking algorithms and programs.	4 hrs
UNIT 10- Drug Designing	Concepts and mechanism of action of drugs. Pharmacophore based drug design - 2D and 3D structures of chemical compounds, representation of chemical reactions, molecular descriptors. Structure Activity Relationships. Combinatorial library generation. QSAR. Identification of Drug targets, Active site prediction, Targeted drug design (Molecular Shape based), ADMET studies.	5 hrs
UNIT 11- Biological networks	Genomic networks (Gene regulation), Protein-protein interaction networks, Biochemical flux networks, Visualization of networks – Cytoscape, Visualization of Genome - Circos.	2 hrs

REFERENCE TEXTS

1. Baxevanis, A.D., Bader, G.D. and Wishart, D.S. eds., 2020. Bioinformatics. John Wiley & Sons.
2. Xinkun Wang, X. Next-generation sequencing data analysis. 1st edition, CRC Press, 2016.
3. Keith, J.M., Volume I: Data, Sequence Analysis, and Evolution Second Edition.
4. Keith, J.M., Volume II: Structure, Function, and Applications Second Edition.
5. Yao, Y. ed., 2018. Applied Computational Genomics (Vol. 13). Springer.
6. Shaik, N.A., Hakeem, K.R., Banaganapalli, B. and Elango, R., 2019. Essentials of Bioinformatics, Volume I.
7. Larson, R.S. and Oprea, T.I. eds., 2006. Bioinformatics and drug discovery. Totowa, NJ: Humana Press.
8. Mount, David W., and David W. Mount. *Bioinformatics: sequence and genome analysis*. Vol. 1. Cold Spring Harbor, NY: Cold spring harbor laboratory press, 2001.

COURSE OUTCOMES FOR BT8321: Bioinformatics and Computational Biology
After successful completion of the course, students will:

CO1	Learn the basic concepts of Operating systems, able to write codes for sequence analysis in R and Biopython
CO2	Assimilate aspects of Databases, Datamining, Sequence alignment, Sequence analysis, Phylogenetics and would be able to learn the background theory of these aspects which shall help in interpretation of their results
CO3	Learn about methods of NGS sequence assembly, variant analysis, DGE analysis of RNASeq data, visualize the biological networks
CO4	Understand and implement methods of Biomolecular modelling, Docking, Drug Designing
CO5	Through practical sessions would be able to mine data from various databases and be able to generate phylogenetic trees and perform sequence analysis. Would be able to build circular genome plots and pathway interaction maps
CO6	Will be practically able to predict the 3D models of biomolecules, able to design ligand molecules and analyse their ADMET properties.

PRACTICAL II: BT8P2: Genetic Engineering and Bioinformatics (88 hrs)

Genetic engineering

1. Isolation of mRNA from tissues and purity analysis.
2. Synthesis of cDNA from mRNA.
3. PCR primer design and customised vector design.
4. PCR amplification/RT-PCR amplification of gene of interest
5. Isolation of plasmid DNA by Alkaline lysis and Restriction digestion of plasmid DNA
6. Ligation of gene of interest into a vector, prep of competent cells, bacterial transformation
7. Blue-white screening and Colony PCR based screening.
8. Southern blotting transfer and detection.
9. Agroinfiltration of Binary vector with GFP into *N. benthamiana* and Reporter gene assay.

Bioinformatics

1. Information retrieval from Databases – Genbank, Uniprot kb, KEGG, SRA, GEO, Database homology search using BLAST.
2. Sequence analysis using BioEdit package and Phylogenetic analysis using MEGA, Clustal X
3. Evaluation of NGS Sequence quality using FastQC tool, NGS sequence reads, Reads alignment, Annotation using Blast tool.
4. Drawing a heat map, box plot using R.
5. Protein modelling using *Ab intio* servers, Homology modelling tools.
6. Energy Minimisation, Protein structure evaluation using Procheck.
7. QSAR dataset and pharmacophore modelling with molecular modelling tools
8. Prediction of ADMET properties.
9. Rigid body docking, Flexi docking using Autodock and Hex.
10. Cytoscape visualization of gene networks.

Semester	**II**
Paper Code	**BT8421**
Paper Title	**Research Methodology and Scientific Writing**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:
This class introduces students to the basics of how scientific research is performed, and focuses on in-classroom activities that gives students the experience and practice of reading and analysing scientific literature, through to writing a research proposal.

Syllabus for BT8421: Research Methodology and Scientific Writing (60 hours)

Unit	Content	Teaching Hours
SECTION A: RESEARCH METHODOLOGY		**40 hours**
UNIT 1- Fundamentals of Research	Defining scientific research, the philosophy of science, natural science vs social science research, qualitative vs quantitative research, overview of the research process, criteria of good research. *Active learning:* In class discussion about two papers (differing in scientific detail and rigor) on the same topic. Identifying and critiquing elements of research, including the hypothesis and methodology.	6 hrs
UNIT 2- Defining a Research Problem	Identifying a research area of interest, importance of originality and impact, exploratory versus incremental research, why do a literature survey, Systematic Vs Scoping reviews, identifying research gaps, information literacy, how to read a scientific paper, methods and techniques of literature survey, scientific search engines, reference management systems, narrowing and defining the research problem, finding research protocols, establishing a framework for scientific research. *Active learning*: Using Mendeley to sort and tag reference papers relevant to assigned topics, do a systematic review and define specific research questions and objectives.	10 hrs
UNIT 3- Research Design and Sampling Techniques	Overview of research design, hypothesis and overview of hypothesis testing (parametric and non-parametric tests), types of errors and their control, effect of sample size and power analysis.	4 hrs

UNIT 4- Experimentation	Framework of individual experiments, The need for experimental controls: Negative and positive controls, Reagent and Method controls, The need for replicates: Biological Replicates, Technical Replicates, Experimental Repeats, Randomization of samples, Time Courses, and Dose Responses. Repeatability, Reproducibility, Reliability, Specificity and sensitivity of instruments and techniques, *Active learning*: Discussion of papers with adequate and inadequate number of controls and replicates. Hypothesis testing on an artificial dataset.	8 hrs
UNIT 5- Methods of Data Collection, Data Analysis and Documentation	Overview of the types of data, primary and secondary data collection methods, Managing big data, data curation, physical and e-lab notebooks, an overview of statistical tests for data analysis, the choice of the appropriate statistical test, numerical and graphical data, types of graphs. how not to plot graphs, summarization and interpretation. *Active learning*: Analysis of data in selected papers and interpretation of results. A close look at some papers with possibly flawed data interpretation.	6 hrs
UNIT 6- Ethics and Scientific Conduct	Introduction to Ethics, Scientific conduct and misconduct, responsibility and accountability of the researchers, Ethics in human and animal studies, Forms of misconduct: Data fabrication, plagiarism, authorship issues, Image manipulation, duplicate publications, investigation and consequences of scientific misconduct. *Active learning*: Identifying known examples of scientific misconduct and discussion. Case study on image manipulation.	6 hrs
SECTION B: SCIENTIFIC WRITING		**20 hrs**
UNIT 7- Introduction to Science Communication	Types of Scientific communication: Research papers, Research proposals, Posters, Project report; Publishing, H-index, Impact factors in publishing. Elements of effective scientific communication, scientific illustrations *Active learning*: A look at rambling, badly written papers/research proposals vs good ones.	4 hrs

UNIT 8- Writing an effective Review of Literature	Studying the lay of the land in your research area of interest, identifying work relevant to the study, categorizing and concisely describing this work, accurate referencing. *Active learning*: Students will work on writing a review of literature based on work done in Unit 2.	4 hrs
UNIT 9- Writing a Research Proposal	Basic elements of a research proposal, budget considerations, timelines, deliverables and the importance of plan B, funding agencies and research grants. Constructive criticism, how to do peer review, Mind maps, Effective powerpoint presentations. *Active learning*: Students work on writing their research proposals. Specific formats, with word limits for each section will be supplied.	4 hrs
UNIT 10- Presentation of Student Research Proposals	Instructor and Peer Feedback	8 hrs

REFERENCE TEXTS:

1. Research in Medical and Biological Sciences, Petter Laake, Benestad and Olson, 2015, Elsevier
2. Research Methodology, 2nd Ed, CR Kothari, 2004, New Age India Publications
3. Experimental design for Biologists, 2nd Ed, David J. Glass, 2014, CSHL Press

COURSE OUTCOMES FOR BT8421: Research Methodology and Scientific Writing

After successful completion of the course, students will:

CO1	Have a grasp of the fundamentals of scientific research and the basic framework of the scientific process, while also gaining a clear understanding of the ethical dimensions in research.
CO2	Be able to search for, sort, select and critically analyse scientific literature, and prepare a literature review.
CO3	Develop skills in formulating and evaluating research questions, and develop a Research Proposal.
CO4	Be able to formulate a research framework around their research question/s.
CO5	Be able to appreciate and evaluate components of scholarly writing and will demonstrate enhanced writing skills.
CO6	Develop the skills needed for effective science communication and demonstrate augmented presentation skills.

Semester	**II**
Paper Code	**BTDE8521**
Paper Title	**Stem cell and Next Gen Therapeutics**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:
This elective will expose students to state of the art research in stem cells and novel drug modalities. It will cover mechanistic aspects as well as their clinical application using real world scenarios and examples. The syllabus covers crucial aspects of translational research both in basic research as well as pharmaceutical innovations.

Syllabus for
DEPARTMENTAL ELECTIVE-A: BTDE8521
STEM CELL AND NEXT-GEN THERAPEUTICS (60 hours)

Unit	Content	Teaching Hours
Stem cell and next-gen therapeutics		**60 Hrs**
Unit 1: Introduction to stem cells	Overview of the different stages of embryonic development in humans, human embryonic stem cells: classification, derivation and propagation, induced pluripotent stem cells, adult stem cells, mesenchymal stem cells, cord blood stem cells, ethical and public policy considerations.	5 hrs
Unit 2: Basic biology of stem cells	Epigenetics and molecular basis of pluripotency, stem cell niches, mechanisms of stem cell self-renewal, cell cycle regulators in stem cells, epigenetic mechanisms of cellular memory, stem cell differentiation.	6 hrs
Unit 3: Methods in stem cell biology	Isolation and enrichment of stem cells, methods to study epigenetic modifications, generation of uniparental embryonic stem (ES) Cell and induced pluripotent stem cell lines somatic cell nuclear transfer, methods of nuclear reprogramming, gene manipulation techniques used in reprogramming, generation of transgene-free induced pluripotent mouse stem cells by the piggybac transposon.	8 hrs
Unit 4: Stem cell therapy	Stem cell therapeutic strategies for heart diseases, diabetes, neurodegenerative disease, spinal cord injury.	5 hrs

Unit 5: Tissue regeneration and regenerative medicine	Introduction to tissue regeneration, biodegradable polymers and growth actors, 3D bioprinting, artificial organs - bioartificial pancreas, Hepat Assist Liver Support System, red blood cell substitutes, renal replacement devices, artificial womb and breast reconstruction, clinical applications of mesenchymal stem cells for bone tissue regeneration (&/or latest developments in stem cell regenerative biology).	6 hrs
Unit 6: Drug discovery pipeline	Basics of drug discovery and clinical trials, advantages and challenges with traditional small molecules, personalised medicine.	4 hrs
Unit 7: Novel small molecule drugs and targeted therapy	Protein degraders, peptides and cyclopeptides, Antibody-based drugs, bi-specific antibodies, antibody-conjugates.	6 hrs
Unit 8: Nucleic acid-based drugs and gene therapy	RNA-based drugs (siRNA and antisense RNA), use of siRNA in hepatic porphyria, genome engineering and CRISPR, CRISPR-Cas9 gene editing for Sickle cell disease and β-Thalassemia.	8 hrs
Unit 9: Drug delivery	Novel formulations for delivering nucleic acids, nanoparticles, crossing the blood-brain barrier.	6 hrs
Unit 10: Case studies	Stem cell therapy in liver cirrhosis, PROTACS in ovarian cancer, &/or other examples.	6 hrs

COURSE OUTCOMES FOR BTDE8521: STEM CELL AND NEXT-GEN THERAPEUTICS

After successful completion of the course, students will:

CO1	Have an in-depth understanding of next gen stem cell-based and pharmaceutical therapeutics.
CO2	Be able to apply the bench-to-bedside paradigm and translate research findings to clinical interventions.
CO3	Be up to date with the latest research and innovation in the pharma and biotechnology industries.
CO4	Develop an appreciation for interdisciplinary research and its use in drug discovery.
CO5	Have a thorough knowledge of the drug-discovery pipeline and perform case reviews on existing technologies.

Semester	**II**
Paper Code	**BTDE8621**
Paper Title	**Nanobiotechnology**
Number of teaching hours per week	**04**
Total number of teaching hours per semester	**60**
Number of credits	**04**

Objective of the Paper:
This elective paper provides a deep insight into the subject of Nanobiotechnology with emphasis over the aspects of research-oriented applications and some of the aspects of translational research. Concepts related to nanobiotechnology applications in the fields of biology, plant protection, translational medicine, toxicology and environmental research.

Syllabus for BTDE8621 Nanobiotechnology (60 hours)

Unit	Content	Teaching Hours
NANOBIOTECHNOLOGY		60 hrs
Unit -1: Introduction & History	Definitions and concepts of Nanobiotechnology, Historical background and landmarks. Broad areas of Nanobiotechnology, Applications of Nanobiotechnology. Cell-nanostructure interactions	3 hrs
Unit 2- Nanomaterials and Synthesis	Classification, types and characteristics of Nanomaterials used in nanobiotechnological applications – Optical, magnetic, electronic, mechanical and catalytic properties. Nanoparticles, quantum dots, nanotubes and nanowires. Approaches for synthesis of nanomaterials – Physical, Chemical and Biological methods, Techniques used in characterization of nanomaterials - Spectroscopic, morphological and other techniques.	7 hrs
Unit 3- Protein-based Nanostructures, Nanobiomachines & Signalling	Overview, chemistry and structure, Genetics & Secondary cell-wall polymers. Self-assembly in suspension, Recrystallization at solid supports, Formation of regularly arranged Nanoparticles. Cell as Nanobio-machine, link between the signaling pathways & molecular movements as well as neuron function. Concepts in nanobio-machines for information processing and communications	6 hrs

Unit 4- Microbial Nanoparticle Production	Overview and concept of microbial nano-particle production. Methods of microbial nano-particle production. Applications of microbial nano-particles. Magnetosomes, Bacteriorhodopsin and its potential in technical applications – overview, structure, photoelectric applications, photochromic applications and applications in energy. Virus as a nanoparticle – Concepts of Virus like nanoparticles, applications in therapeutics, environmental bioremediation and plant disease control etc., Nanoparticles in microbial bioremediation.	7 hrs
Unit 5- Applications of Nanotechnology In Biology	DNA functionalized Gold nanoparticles, Nanoparticle Based DNA and RNA Detection Assays, Homogeneous DNA Detection, Chip-based (Heterogeneous) DNA Detection Assays, DNA-Nanoparticle Detection of Proteins: Biobarcodes, DNA Nanomechanical, DNA-based Computation, Nanoparticles as Non-Viral Transfection Agents – Chitosan, Liposomes and Solid Lipids, Poly-l-Lysine and Polyethylenimines, Poly(lactide-co-glycolide), Silica, Block Copolymers. Luminescent Quantum Dots for Biological Labeling. Nanoparticle Molecular Labels - Combined Fluorescent and Gold Probes, Gold Cluster-labeled Peptides, Gold Cluster Conjugates of Other Small Molecules, Gold–Lipids: Metallosomes, Larger Covalent Particle Labels, Gold Targeted to His Tags, Enzyme Metallography, Gold Cluster Nanocrystals, Gold Cluster–Oligonucleotide Conjugates, Nanotechnology Application, 3-D Nanostructured Mineralized Biomaterials, Gold-quenched Molecular Beacons, Other Metal Cluster Labels. Protein Targeting - Small Molecule/Nanomaterial - Protein Interactions. Nanomaterial-Cell interactions-Manifestations of Surface Modification (Polyvalency)	9 hrs

Unit 6- Nanobiotechnology of Plant Protection	Nano-biopesticides. Application of Silver, Zinc, Copper, Sulfur and other nanoparticles for control of Plant pathogens, Bioengineered nanomaterials for Plant growth promotion – Fullerene, Single walled Carbon nanotubes and Multiwalled Carbon nanotubes and metal nanoparticles – ZnO, CuO, TiO2, CeO2, Silver, Gold and Iron oxide nanoparticles. Nanostructures in plant protection – nanopesticides, nanoinsecticides, nanofungicides, nanofertilizers. Nanoparticles in post-harvest management. Phytotoxic effects of nanoparticles and biosafety issues. Nanoparticle based diagnostics for plant pathogenic diseases. – Nanobiosensors, Quantum Dots, Nanobarcodes, Nanodiagnostic kits, Nanofabrication Imaging.	8 hrs
Unit 7- Nanobiotechnology In Therapeutics And Diagnosis	Nanoparticles in molecular MRI, Imaging, Surface Modified Nanoparticles, MEMS/NEMS based on Nanomaterials, Peptide/DNA Coupled Nanoparticles, Nanoparticles targeted for drug delivery, Inorganic Nanoparticles For Drug Delivery, Metal/Metal Oxide Nanoparticles (antibacterial/anti fungal/anti viral), Anisotropic and Magnetic Particles (Hyperthermia), Nanorobots and Nanodevices in medicine, Nano dentistry – Imaging, Biomaterials Science, Complement Activation-Related Pseudo allergy Caused by Nanomedicines (CARPA), concepts of Pharmacogenomics and Nanotechnology in Personalized Medicine. Nanotheranostics for diagnosis and therapy of cancer. Nanoscale control of cellular environment for tissue engineering in therapy. Wearable nanobiosensors	9 hrs
Unit 8- Nanobiotechnology For Sustainable Environment	Challenges to sustainability in the environment. Nanotechnology for production of Biofuels (Carbon nanotubes, Chitosan). Nano biocatalysis concepts for bioenergy and biofuels. Nanoparticles in biogas production (methane and biohydrogen). Nanotechnology in Bioreactors and Biorefineries. Nanotechnology in heavy metal bioremediation. Environment and food - detection and mitigation. Nanotoxicology and Nanoinformatics, Geosensing Nanobiosensors, Nanobiosensors in Toxicology, Nanobiosensing for In Vivo applications.	8 hrs

Unit 9- IPR and Regulatory Issues in Nanobiotechnology	Ethical, Legal and Social Issues related to applications of Nanobiotechnology. Nanoparticle induced Cytotoxicity, Genotoxicity, In vivo tests/assays for determining toxicity. TRIPS Agreement, Challenges of patentability, Intellectual property rights – Patenting of Nanobiotech products, Biopiracy, Biosafety levels involved Nanobiotechnology experiments. Regulatory steps involved in approval of Nanobiotechnology products.	5 hrs

REFERNCE TEXTS:

1. Abd-Elsalam, K.A. and Prasad, R. eds., 2018. Nanobiotechnology applications in plant protection. Springer.
2. Mirkin, C.A. and Niemeyer, C.M. eds., 2007. Nanobiotechnology volume I & II: more concepts and applications. John Wiley & Sons.
3. Logothetidis, S. ed., 2012. Nanomedicine and nanobiotechnology. Springer Science & Business Media.
4. Rajesh Singh Tomar, Anurag Jyoti, Shuchi Kaushik. 2020. Nanobiotechnology Concepts and Applications in Health, Agriculture, and Environment. Apple Academic Press.
5. Verma, M.L. ed., 2020. Nanobiotechnology for Sustainable Bioenergy and Biofuel Production. CRC Press.
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COURSE OUTCOMES FOR BTDE8621: Nanobiotechnology

After successful completion of the course, students will:

CO1	Learn what is Nanobiotechnology and the methods of Nanomaterial synthesis and types of Nanomaterials.
CO2	Understand how biological molecules such as proteins and DNA could be organised or integrated with nanostructures or nanoparticles.
CO3	Will learn about the methods of Nanoparticle synthesis, Applications of Nanotechnology in Biology
CO4	Types of nanoparticles used in plant protection and also the concepts of nanotechnology-based diagnosis of plant diseases.
CO5	Assimilate the application of nanotechnology in therapy, diagnosis of human diseases and cancers.
CO6	Will understand how to use products of nanotechnology in environmental pollution control and IPR issues involved in commercialisation of nanobiotechnological products.