Department of Biotechnology
Savitribai Phule Pune University
M.Sc. Biotechnology (2 Year Course)
Syllabus According to NEP-2020 (2024-2025)

Semester I							
	Code	Theory	Credits		Code	Practical	Credits
Core	BT CT 401	Biochemistry	4		BT CP 407	Laboratory I: Biochemistry and Analytical Techniques	2
	BT CT 402	Cell and Molecular Biology	4		BT CP 408	Laboratory II: Microbiology	2
	BT CT 403	Microbiology	2				
	BT CT 404	Research Methodology	4				
Elective	BT ET 405	Model systems in Biology	2		BT EP 409	Seminar	2
	BT ET 406	Developmental Biology	2		BT EP 410	Review writing/Tutorials	2
Semester II							
	Code	Theory	Credits		Code	Practical	Credits
Core	BT CT 411	Genetics	2		BT CP 418	Laboratory III: Molecular Biology and Genetic Engineering	2
	BT CT 412	Immunology	2		BT CP 419	Laboratory IV: Immunology	2
	BT CT 413	Plant and Animal Biotechnology	2				
	BT CT 414	Genetic Engineering	4				
	BT CT 415	On Job Training	4				
Elective	BT ET 416	Emerging Technologies	2		BT EP 420	Laboratory V: Plant Biotechnology	2
	BT ET 417	Bioentrepreneurship and Start-up Management	2		BT EP 421	Laboratory V: Animal Biotechnology	2

Semester III							
	Code	Theory	Credits		Code	Theory/Practical	Credits
Core	BT CT 501	Bioprocess Engineering and Technology	4		BT CP 508	Laboratory VI: Bioprocess Engineering and Technology	2
	BT CT 502	Molecular Diagnostics	2		BT CP 509	Laboratory VII: Bioinformatics	2
	BT CT 503	Bioinformatics	2				
	BT CT 504	Genomics and Proteomics	2				
	BT CT 505	Research Project	4				
Elective	BT ET 506	Drug Discovery and Development	2		BT EP 510	Critical Analysis of Classical Paper	2
	BT ET 507	Vaccines	2		BT EP 511	Project proposal preparation and presentation	2
Semester IV							
	Code	Theory	Credits		Code	Theory/Practical	Credits
Core	BT CT 512	Theoretical Foundations of Research Project	4		BT CP 518	Laboratory VIII: Advanced Laboratory Techniques	4
	BT CT 513	Experimental design and Innovations in Research Project	2				
	BT CT 514	Intellectual Property Rights, Biosafety and Bioethics	2				
	BT CT 515	Research Project	6				
Elective	BT ET 516	Environmental Biotechnology	2		BT EP 519	Advanced Topics in Biotechnology	2
	BT ET 517	Stem Cell Technology	2		BT EP 520	Seminar	2

CT: Core Theory; ET: Elective Theory; CP: Core Practical; EP: Elective Practical

Semester I

BT CT 401: Biochemistry (Core Theory - 4 Credits)

Objectives*: The course on Biochemistry revolves around all the three domains of biochemistry including structural, functional and applied aspects. The course will build upon the undergraduate level knowledge of biochemical principles with specific emphasis on structure/function relationships in biochemistry, which will also include the implications of the biochemical pathways in disease biology. The course shall make the students aware of various disease pathologies within the context of each topic. Moreover, the last topic on Clinical biochemistry will provide focused importance of biochemical reactions in the field of clinical diagnosis and therapeutics.*

Learning outcomes*: On completion of this course, students should be able to gain fundamental knowledge in biochemistry; understand the structural and functional basis of various pathological conditions from the perspective of biochemical reactions.*

Unit I: Chemical basis of life (6L)
Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water: properties of water, essential role of water for life on earth; buffer and maintenance of blood pH; pH optima of gastric juice and different enzymes (pepsin, trypsin and alkaline phosphatase); emergent properties of biomolecules, biomolecular hierarchy, macromolecules, molecular assemblies.

Unit II: Protein structure (6L)
Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.

Unit III: Enzyme catalysis (6L)
General principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.

Unit IV: Glycobiology (4L)
Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; Lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.

Unit V: Structure and functions of DNA & RNA and lipids (6L)
Self-assembly of lipids, micelle, bio-membrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena. Nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material, Nucleotide biosynthesis.

Unit VI: Bioenergetics (10L)
Basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Oxidative phosphorylation; importance of electron transfer in oxidative phosphorylation; F1-F0 ATP Synthase; shuttles across mitochondria; regulation of oxidative phosphorylation; Photosynthesis – chloroplasts and two photosystems; proton gradient across thylakoid membrane.
Reciprocal regulations and non-carbohydrate sources of glucose; Citric acid cycle, entry to citric acid cycle, citric acid cycle as a source of biosynthetic precursors.

Unit VII: Role of vitamins & cofactors in metabolism (10L)
Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; elucidation of metabolic pathways; logic and integration of central metabolism; entry/ exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; Biochemistry of metabolic disorders and hormonal imbalance (diabetes, obesity, etc.).
Target of rapamycin (TOR) & Autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling. Protein turnover and amino acid catabolism; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway.

Unit VIII: Clinical Biochemistry (12L)
Clinical significance of specific biochemical markers of cardiovascular (troponin, NT-proBNP, BNP, D-Dimer), liver (ALT, AST, C-reactive protein), kidney (Creatinine, BUN, KIM-1) gastric (Gastrin, H. pylori IgG/IgA, CA19-9) and pancreatic (Amylase, Pancreatic Elastase, C-peptide) and Diabetes mellitus (Insulin, FPG, OGTT, HbA1c, HOMA-IR).
Biochemical Parameters in Clinical Diagnosis: Testing of Blood for Liver, Renal, Lipid and Electrolytes, Clinical endocrine markers: TFTs, insulin, cortisol. Serum lipids and lipoprotein profile as biochemical markers of selected human diseases.

Recommended Textbooks and References:

1. Stryer, L. (2015). Biochemistry. (8th ed.) New York: Freeman.
2. Lehninger, A. L. (2012). Principles of Biochemistry (6th ed.). New York, NY: Worth.
3. Voet, D., & Voet, J. G. (2016). Biochemistry (5th ed.). Hoboken, NJ: J. Wiley & Sons.
4. Dobson, C. M. (2003). Protein Folding and Misfolding. Nature, 426(6968), 884-890.
5. Richards, F. M. (1991). The Protein Folding Problem. Scientific American, 264(1), 54-63.
6. Michael T. Madigan, Kelly S. Bender, Daniel H. Buckley, W. Matthew Sattley and David A. Stahl. (2018).

7. Hans-Walter Heldt, Birgit Piechulla (2016) Plant Biochemistry. Fourth Edition. (ISBN 978-0128102145)
8. Textbook of Biochemistry. Thomas M. Devlin. 7th Edition. John Wiley and Sons; ISBN 978-0-470-28173-4

BT CT 402: Cell and Molecular Biology (Core Theory - 4 Credits)

Course Objectives: *The objectives of this course are to sensitize the students to the fact that as we go down the scale of magnitude from cells to organelles to molecules, the understanding of various biological processes becomes deeper and inclusive.*

Learning Outcomes: *Student should be equipped to understand three fundamental aspects in biological phenomenon: a) what to seek? b) how to seek? c) why to seek?*

Unit I: Dynamic organization of cell (12 lectures)
Cell: structural and functional organization (basic information about cell organelles functions and cytoskeleton). Bio-membranes: structure-function relationship.
Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.

Unit II: Cellular processes and signaling (12 lectures)
Cell signaling: cell surface, hormone, receptors and signal transduction and second messengers. Cell cycle and its regulation; cell-ECM and cell-cell interactions; cell motility and migration; cell death: different modes of cell death and their regulation (apoptosis, necrosis, necroptosis, autophagy, senescence etc.).

Unit III: Chromatin structure and dynamics (24 lectures)

DNA Replication and DNA Repair: DNA polymerases, mechanisms of DNA replication in prokaryotes and eukaryotes DNA replication models, Mutagens and DNA damage, DNA repair and recombination.
Transcription regulation in Prokaryotes & Eukaryotes: Chromatin control: gene transcription and silencing by chromatin-Writers, -Readers and –Erasers; Transcriptional control: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, structures of promoters and enhancers, transcription factors as activators and repressors, Transcriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small noncoding RNAs (miRNAs and siRNAs).
Translation regulation in Prokaryotes & Eukaryotes: Protein translation machinery, ribosomes composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co and post-translational modifications, mitochondrial genetic code translation product cleavage, modification and activation.

Unit IV: Genome instability and cell transformation (12 lectures)
Types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; tumor cell vs. normal cell; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; epigenetic changes in tumorigenesis; cell growth and death pathways; cell cycle and genome maintenance; EMT and Metastasis; cancer models: cultured cells and animal models e.g. transgenic mice and PDX, etc.

Recommended Textbooks and References:

1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2008).
2. Molecular Biology of the Cell (5th Ed.). New York: Garland Science.
3. Lodish, H. F. (2016). Molecular Cell Biology (8th Ed.). New York: W.H. Freeman.
4. Krebs, J. E., Lewin, B., Kilpatrick, S. T., & Goldstein, E. S. (2014). Lewin's Genes XI. Burlington, MA: Jones & Bartlett Learning.
5. Cooper, G. M., & Hausman, R. E. (2013). The Cell: a Molecular Approach (6th Ed.). Washington: ASM; Sunderland.
6. Hardin, J., Bertoni, G., Kleinsmith, L. J., & Becker, W. M. (2012). Becker's World of the Cell. Boston (8th Ed.). Benjamin Cummings.
7. Watson, J. D. (2008). Molecular Biology of the Gene (5th ed.). Menlo Park, CA: Benjamin/Cummings.

BT CT 403: Microbiology (Core Theory - 2 Credits)

Objectives: *The objectives of this course are to introduce field of microbiology with special emphasis on microbial diversity, morphology, physiology and nutrition; methods for control of microbes and host- microbe interactions.*

Student Learning Outcomes: *Students should be able to 1) Identify major categories of microorganisms and analyze their classification, diversity, and ubiquity; 2) Identify and demonstrate structural, physiological, genetic similarities and differences of major categories of microorganisms; 3) Identify and demonstrate how to control microbial growth; 4) Demonstrate and evaluate interactions between microbes, hosts and environment.*

Unit I: Microbial characteristics (6 lectures)
Introduction to microbiology and microbes, history & scope of microbiology, morphology, structure, growth and nutrition of bacteria, bacterial growth curve, bacterial culture methods; bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation; antimicrobial resistance.

Unit II: Microbial diversity (6 lectures)
Microbial taxonomy and evolution of diversity, classification of microorganisms, criteria for classification; classification of bacteria; Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria, Mycobacteria and Mycoplasma. Archaea: Halophiles, Methanogens, Hyperthermophilic archae, Thermoplasm; eukarya: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes.

Unit III: Control of microorganisms (6 lectures)
Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms Sterilizing Gases; Evaluation of Antimicrobial Agent Effectiveness

Unit IV: Host-microbes interaction (6 lectures)
Host-pathogen interaction, ecological impact of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbes and nutrient cycles; microbial communication system; bacterial quorum sensing; microbial fuel cells

Uni V: Virology (6 lectures)
Viruses – characteristics and structure Replication of viruses; Classification of viruses; Viruses and their system/hosts; Bacteriophages; sub viral particles (viroids and prions), virus detection and cultivation methods; overview of the application of viruses in biotechnology.

Recommended Textbooks and References:

1. Willey JM, Sherwood LM, Woolverton CJ. Prescott's Microbiology. 8th Edition, New York. The McGraw Hill Companies. International Edition. pp. 2011:873-84.
2. Madigan MT, Martinko JM, Dunlap PV, Clark DP. Brock biology of microorganisms 12th edn. Int. Microbiol. 2008; 11:65-73.
3. Black JG, Black LJ. Microbiology: principles and explorations. John Wiley & Sons; 2018 Jan 4.

BT CT 404: Research Methodology (Core Theory - 4 Credits)

Course objectives: *The course aims to give background on history of science, emphasizing methodologies employed in research, using framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics. Further, the course is designed for the students to learn basic biostatistical principles and how these principles are employed to decipher the significance of findings. The course also includes the use of various ways of data presentation to educate them about the importance of articulating data in appropriate formats of presentation.*

Learning outcomes: *Students should be able to understand history and methodologies of scientific research, applying these to recent published papers; understand and practice scientific reading, writing and presentations; appreciate scientific ethics through case studies. Students will learn to analyze and present the data in different formats by using some computational skills.*

Unit I: Research Methodology (4 lectures)
History of science and science methodologies: Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.

Unit II: Preparation for Research (4 lectures)
Choosing a mentor, lab and research question; maintaining a lab notebook.

Unit III: Research Designs: (4L)
Types of Research Designs and Stages Selection and Formulation of Research Problem, Objective(s) and Hypothesis Developing Research Plan – Exploration, Description, Diagnosis, Experimentation, Determining Experimental and Sample Design.

Unit IV: Computing skills for scientific research (6 lectures)
Web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

Unit V: Scientific Communication (10L)
Technical writing skills, types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers.
Peer review process and problems, recent developments such as open access and non-blind review; characteristics of effective technical communication; scientific presentations.
Presentation skills - formal presentation skills; preparing and presenting using overhead projector, PowerPoint; defending interrogation; Scientific poster preparation & presentation; participating in group discussions.

Unit VI: Research Ethics (8L)
Various National and International Committees/Institutional Review Boards – Roles and Importance, Intellectual Property rights – Commercialization, Royalty Reproduction of Published Material.
Ethics in publications: Citation and Acknowledgement, Plagiarism. Ethical issues in data acquisition, processing, presentation and publication. scientific misconducts; Data management, theft and preventive practices. COPE and its role in publication ethics management.
Ethical norms and guidelines in animal and human research, role of government and international organizations.

Unit VII: Data Collection (6L)
Sources of Data – Primary and Secondary, Types of Data, – Categorical, discrete, Methods of Data Collection: Survey, Interviews (in-depth or Key Informant interviews), Focus Group Discussion (FGD), Observation, Records or Experimental Observations, Challenges in data collection: ethics and governance, integrity and reproducibility, underrepresentation and over-representation, sociocultural aspects.

Unit VIII: Data Processing and Presentation (6 lectures)
Qualitative Approaches Including Grounded Theory, Ethnography, Narrative Inquiry, Phenomenology and Case-Study.
Statistical Graphics – Histograms, Frequency Polygon, Ogive, Dot plots, Stem plots, Bar Graphs, Pareto Charts, Pie Charts, Scatterplots, Boxplots; Using offline and online tools for data analysis and presentations.

Unit IX: Biostatistics (12 lectures)
Probability: counting, conditional probability, types of variables, dependent and independent, discrete and continuous random variables, Error propagation; Populations and samples, Sampling and its methods, random sampling, non-probability sampling, expectation, measures of central tendency, Distribution, normal and skewed distribution, variation and its measures, Standard error, Kurtosis, Student t test, F-test, paired and unpaired test, confidence interval, single-tailed, double-tailed, Wilcoxon Rank sum test, Z-distribution, Correlation and linear regression, Pearson's correlation, r value, correlation & causality, analysis of variance (ANOVA), parametric tests of statistical significance, nonparametric hypothesis tests, factorial experiment design, practical approaches in biomedical data analysis.

Recommended Textbooks and References:

1) Stroud, K. A., & Booth, D. J. (2009). Foundation Mathematics. New York, NY: Palgrave Macmillan.
2) Aitken, M., Broadhursts, B., & Haldky, S. (2009) Mathematics for Biological Scientists. Garland Science.
3) Billingsley, P. (1986). Probability and Measure. New York: Wiley.
4) Rosner, B. (2000). Fundamentals of Biostatistics. Boston, MA: Duxbury Press.
5) Daniel, W. W. (1987). Biostatistics, a Foundation for Analysis in the Health Sciences. New York: Wiley.
6) Valiela, I. (2001). Doing Science: Design, Analysis, and Communication of Scientific Research. Oxford: Oxford University Press.
7) On Being a Scientist: a Guide to Responsible Conduct in Research. (2009). Washington, D.C.: National Academies Press.
8) Gopen, G. D., & Smith, J. A. The Science of Scientific Writing. American Scientist, 78 (Nov-Dec 1990), 550-558.
9) Mohan, K., & Singh, N. P. (2010). Speaking English Effectively. Delhi: Macmillan India.

BT ET 405: Model Systems in Biology (Elective Theory - 2 Credits)

Course objectives*: Understanding the physiological uniqueness and diversities among large range of animals is worthy of pursuit in quest of understanding biology and applying it to solve the appropriate problems. The broader goal of the course is also to sensitize the students towards the selection of appropriate model systems in research to make meaningful contributions to develop new theories and to advocate the educated citizenry of the future.*

Learning outcomes*: The students will gain the principles and philosophical perspectives on use of different model systems in biology; receive the in-depth ideas in some of the candidate model systems; and develop the clear understanding on appropriate use of biological models for in vivo and in vitro experimental purposes.*

Unit I: Introduction to biological model systems (2L)
Prokaryotic or microbial model systems, vertebrate and invertebrate animal models, specificity and robustness of models, Krogh's Principle and Hans Kreb's Ideas into the model systems.

Unit II: Historical perspectives (3L)
Beginnings of use of models in biology research; Medicine research; pet research; intriguing theories into fruit flies use; emergence of the supermodel of drosophila; Laboratory mice and rats as standard mammalian model system; Nonhuman Primates.

Unit III: Important aspects in selection of model systems (5L)
Perspectives on model systems in biomedical research, Abstract models and material models, Model fidelity, Dealing with Biological complexity. Translatability, replicability, biological variations.

Unit IV: Experimental model systems and pragmatic approaches of its use (14L)
Philosophy for popular models in biology, Understanding the model systems from biomedical research perspective, Importance and uniqueness of different models, Importance of life cycles, Significance and challenges in the use of specific models in research, Comparative research and its uses in Biology; Model systems for non-genetic and genetic studies;
Examples: Invertebrates-*D. melanogaster*, *C. elegans*; Vertebrates- Zebrafish, mice and primates; *In Vitro* model systems-Hela cells, HEK cells, cell lines, concept of triple negative cancer cells; Microbial cells-*E. coli* and *Yeast*.

Unit V: Unique model systems (6L)
Unique Models: Squid, Sea Urchin, naked mole rat; Disease mouse models: SCID, db/db, ob/ob, Agouti mouse, APP Transgenic mouse, etc.
Examples of model systems from disease standpoint: Infectious diseases, cardiovascular problems, obesity, diabetes, cancer, neurodegenerative disorders (PD, Alzheimer's, etc.).

Recommended Textbooks and References:

1. Model systems in biology: history, philosophy, and practical concerns / Georg Striedter. Cambridge, Massachusetts: The MIT Press, [2022] ISBN 9780262046947.
2. Animal models in medicine and biology. Editors: Eva Tvrdá, Sarat Chandra Yenisetti; IntechOpen ISBN: 1838800115.
3. Animal Models in Research: Principles and Practice. Editors: Harikrishnan Vijayakumar Sreelatha, Satish Patel, Perumal Nagarajan, Springer Singapore ISBN: 978-981-97-0047-9 Springer Singapore.

BT ET 406: Development Biology (Elective Theory - 2 Credits)

Objectives: *The objectives of this course are to familiarize the students with concepts of developmental biology, gene regulation and its applications in biotechnology.*

Learning Outcomes: *Student will understand the intricacies of developmental Biology process and importance of gene regulation during development.*

Unit 1: Introduction to Developmental Biology (4 lectures)
Overview of developmental processes, Historical perspectives in developmental biology, Key experiments in developmental biology, Significance of developmental biology in biotechnology and medicine, notable case studies in developmental biology.

Unit 2: Gametogenesis, Fertilization, and Early Embryonic Development (8 lectures)
Gametogenesis: spermatogenesis and oogenesis, Molecular mechanisms of fertilization; Early embryonic development: cleavage patterns, Blastula formation and establishment of body axes, Developmental milestones in embryogenesis.

Unit 3: Genetic Regulation of Development (6 lectures)
Overview of transcription factors, signaling pathways and epigenetic mechanisms in development processes, Techniques for studying gene expression during developmental processes, Practical applications and Emerging trends in developmental genetics.

Unit 4: Developmental Genetics and Model Organisms (6 lectures)
Introduction to model organisms, Genetic screens and mutagenesis techniques, Comparative developmental biology, Applications in biotechnology, Gene therapy and developmental genetics, Ethical considerations in developmental genetics.

Unit 5: Developmental Plasticity and Environmental Factors (6 lectures)
Effects of environmental cues on development, Developmental plasticity and phenotypic variation, Epigenetic inheritance and transgenerational effects, Mechanisms of environmental influence on development.

Recommended Textbooks and References:

1. Principles of Development" by Lewis Wolpert et al. Oxford University Press, 2015
2. Developmental Biology" by Scott F. Gilbert, Sinauer Associates, Inc. 2020 (12th Edition)
2. Essential Developmental Biology" by Jonathan M. W. Slack, Wiley-Blackwell, 2012 (3rd Edition).
3. Developmental Biology" by Michael J. F. Barresi and Scott F. Gilbert, Sinauer Associates, Inc. 2018 (9th Edition).
4. Molecular Biology of the Cell" by Bruce Alberts et al. Garland Science, 2014 (6th Edition).
5. Epigenetics" by C. David Allis et al., Cold Spring Harbor Laboratory Press, 2015

BT CP 407: Laboratory I - Biochemistry and Analytical Techniques
(Core Practical - 2 Credits)

Objectives: *The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach students the utility of set of experimental methods in biochemistry in a problem-oriented manner.*

Learning Outcomes: *On completion of this course, students should be able to: 1) To elaborate concepts of biochemistry with easy to run experiments; 2) To familiarize with basic laboratory*

instruments and understand the principle of measurements using those instruments with experiments in biochemistry.

1. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
2. To determine an unknown protein concentration by Bradford / BCA Method.
3. To estimate the concentrations of reducing sugars by the DNSA method.
4. To separate the mixture of amino acids by Thin Layer Chromatography.
5. To prepare cell-free protein lysates to isolate enzyme of interest.
6. To perform ammonium sulfate precipitation for partial purification of enzyme of interest from crude extract.
7. To determine units and specific activity of enzyme of interest.
8. To determine the enzyme kinetics parameters (Km and Vmax).
9. To purify the enzyme/proteins by chromatographic method-Ion-exchange Chromatography.
10. To purify the enzyme/proteins by chromatographic method - Gel Filtration.
11. To prepare a chart for computing protein concentration, amount of total protein specific activity of the enzyme preparation at each stage of purification (ammonium sulphate precipitation, IEC, SEC).
12. To perform electrophoretic separation of proteins by SDS-PAGE Gel Electrophoresis.

BT CP 408: Laboratory II - Microbiology (Core Practical - 2 Credits)

Objectives: *The objective of this laboratory course is to provide practical skills on basic microbiological techniques.*

Learning Outcomes: *Students should be able to Isolate, characterize and identify common bacterial organisms; determine bacterial load of different samples; perform antimicrobial sensitivity tests; preserve bacterial cultures.*

1. Sterilization, disinfection and safety in microbiological laboratory
2. Preparation of media for cultivation of bacteria
3. Isolation of bacteria in pure culture by streak plate method
4. Preparation of bacterial smear and Gram's staining
5. Antimicrobial sensitivity test and demonstration of drug resistance
6. Maintenance of stock cultures: slants, stabs and glycerol stock cultures
7. Isolation and identification of bacteria from soil and water samples
8. Study of colony and growth characteristics of some common bacteria: *Bacillus, E. coli, Staphylococcus, Streptococcus,* etc.
9. Enumeration of bacteria: standard plate count
10. Determination of phenol coefficient of antimicrobial agents.
11. Determination of Minimum Inhibitory Concentration (MIC)

BT EP 409: Seminar (Elective Practical - 2 Credits)

Objectives: *The objectives of this course are to familiarize students with recent literature in a specific field to inculcate the research interest, update the knowledge and train the students to read and review the scientific literature. Students will be fascinated to the new frontier areas in particular field of biology and biotechnology, which will instill the inquisitiveness and motivation to pursue career in research and development.*

Learning Outcomes: *Students should be able to read and understand the research article. Moreover, students will read the relevant literature in concurrence with the research paper they have selected for Seminar presentation. This will enrich their knowledge as well as they will secure the recent developments in the field.*

Assessments: Students will choose a recently published (during last 2 years) research article of their choice from a reputed research journal and will present the findings and their views about the article. Students will present their seminar on research article in their own class. External and internal subject experts will be available for the evaluation of the presentation by the student.

BT EP 410 Review Writing/ Tutorials (Elective Practical- 2 Credits)

Course Objectives: *As a student progresses into training in science on a bench, it is pertinent for them to read the scientific literature and grasp the concepts. In this regard, it is advisable to train the students during the Masters' program to read the literature, formulate the wisdom, and effectively communicate the same with others. One of the ways is to encourage the students to read the literature on a topic of their interest and write a small, concise review. Similarly, the students may also be offered tutorials to enhance understanding in focused areas. The practice of engaging with faculty for review writing or taking tutorials on current topics of research is expected to foster their knowledge and at the same time, it will inculcate the habit of scientific reading and writing.*

Learning Outcomes: *Students will be able to learn and demonstrate the following abilities*

- *Searching relevant literature from different sources.*
- *Formulate appropriate scientific questions.*
- *Articulate the framework of the topic in a concise manner.*
- *Develop wisdom through scientific reading of the literature.*
- *Critical thinking and scientific writing.*

Assessment Criteria: Every individual student will write a review or report on a tutorial (10-15 pages) on the topic of their interest and submit for evaluation within a stipulated time. The review/Report written by students on focused topic a will be evaluated by an internal faculty member (25 marks) and a scientist/faculty member from outside the Department (25 marks). Accordingly, the scores will be provided as marks for internal and external assessments.

BT EP 410: Critical Analysis of Classical Papers (Elective Practical - 2 Credits)

Course Objectives: *The objectives of this course are to familiarize students with classic literature to make them appreciate how ground-breaking discoveries were made without, necessarily, use of high-end technologies.*

Learning Outcomes: *Students should be able to train in the exercise of hypothesis building and methods of addressing the hypothesis with readily available technology.*

Assessments: *Students will choose one classical paper from the list given below which will be updated from time to time. Students will present the findings and their critical views about the research article in their own class in front of faculty members. External and internal subject experts will be available for the evaluation of the presentation by the student.*

Unit I: Molecular Biology

1. Studies on the chemical nature of the substance inducing transformation of Pneumococcal types: Induction of transformation by a desoxyribonucleic acid fraction isolated from Pneumococcus type III. Avery OT, Macleod CM, McCarty M.; J Exp Med. 1944 Feb 1;79(2):137-58.
   Note: This paper demonstrates that DNA is the transforming Principle originally described by Fredrick Griffith.
2. Independent functions of viral protein and nucleic acid in growth of bacteriophage. Hershey AD and Chase M.; J Gen Physiol. 1952 May;36(1):39-56.
   Note: This paper demonstrates that DNA, and not protein, component of phages enters bacterial cells.
3. Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid. Watson JD and Crick FH; Nature. 1953 Apr 25;171(4356):737-8
   Note: In this one-page paper Watson and Crick first described the structure of DNA double helix Study help - Watson_Crick_Nature_1953_annotated
4. Transposable mating type genes in Saccharomyces cerevisiae. James Hicks, Jeffrey N. Strathern & Amar J.S. Klar; Nature 282, 478-483,1979
   Note: This paper provided evidence for ‘cassette hypothesis’ of yeast mating type switches i.e. interconversion of mating types in yeast (S. cerevisiae) occurs by DNA rearrangement.
5. Messelson & Stahl experiment demonstrating semi-conservative replication of DNA. Meselson M and Stahl FW.; Proc Natl Acad Sci U S A. 1958 Jul 15;44(7):671-82
   Note: The experiment demonstrating semi-conservative mode of DNA replication is referred to as "the most beautiful experiment in biology"
6. In vivo alteration of telomere sequences and senescence caused by mutated Tetrahymena telomerase. RNAs Guo-Liang Yu, John D. Bradley, Laura D. Attardi & Elizabeth H. Blackburn; Nature 344, 126-132, 1990
   Note: This paper demonstrates that the telomerase contains the template for telomere synthesis

Unit II: Cell Biology

1. A protein-conducting channel in the endoplasmic reticulum. Simon SM AND Blobel G.; Cell. 1991 May 3;65(3):371-80

Note: This paper demonstrates the existence of a protein conducting channel Study help - A brief history of Signal Hypothesis

2. Identification of 23 complementation groups required for post-translational events in the yeast secretory pathway. Novick P, Field C, Schekman R.; Cell. 1980 Aug;21(1):205-15
   Note: In this groundbreaking paper Randy Schekman's group used a mutagenesis screen for fast sedimenting yeast mutants to identify genes involved in cell secretion
3. A yeast mutant defective at an early stage in import of secretory protein precursors into the endoplasmic reticulum. Deshaies RJ and Schekman R.; J Cell Biol. 1987 Aug;105(2):633-45
   Note: Using another yeast mutation screen Schekman lab identifies Sec61, a component of ER protein Conducting Channel (PCC). Suggested reference paper - A biochemical assay for identification of PCC.
4. Reconstitution of the Transport of Protein between Successive Compartments of the Golgi. Balch WE, Dunphy WG, Braell WA, Rothman JE.; Cell. 1984 Dec;39(2 Pt 1):405-16
   Note: This paper describes setting up of an in vitro reconstituted system for transport between golgi stacks which eventually paved the way for identification of most of the molecular players involved in these steps including NSF, SNAP etc.
5. A complete immunoglobulin gene is created by somatic recombination. Brack C, Hirama M, Lenhard-Schuller R, Tonegawa S.; Cell. 1978 Sep;15(1):1-14
   Note: This study demonstrates DNA level molecular details of somatic rearrangement of immunoglobulin gene sequences leading to the generation of functionally competent antibody generating gene following recombination.
6. A novel multigene family may encode odorant receptors: a molecular basis for odor recognition. Buck L and Axel R; Cell. 1991 Apr 5;65(1):175-87
   Note: This paper suggests that different chemical odorants associate with different cell-specific expression of a transmembrane receptor in Drosophila olfactory epithelium where a large family of odorat receptors is expressed.
7. Kinesin walks hand-over-hand. Yildiz A, Tomishige M, Vale RD, Selvin PR.; Science. 2004 Jan 30;303(5658):676-8
   Note: This paper shows that kinesin motor works as a two-headed dimeric motor walking hand-over-hand rather than like an inchworm on microtubule tract using the energy of ATP hydrolysis.

Unit III: Developmental Biology/ Genetics

1. Mutations affecting segment number and polarity in Drosophila. Christiane Nusslein-Volhard and Eric Weischaus; Nature 287, 795-801, 1980
   Note: This single mutagenesis screen identified majority of the developmentally important genes not only in flies but in other metazoans as well.
2. Information for the dorsal--ventral pattern of the Drosophila embryo is stored as maternal mRNA. Anderson KV and Nüsslein-Volhard C; Nature. 1984 Sep 20-26;311(5983):223-7
   Note: This landmark paper demonstrated that early dorsal-ventral pattern information is stored as maternal mRNA in flies and devised the method of identifying genes encoding such genes
3. Hedgehog signalling in the mouse requires intraflagellar transport proteins. Huangfu D, Liu A, Rakeman AS, Murcia NS, Niswander L, Anderson KV.; Nature. 2003 Nov 6;426(6962):83-7
   Note: One of the architects of original fly mutagenesis screens conducted a mouse mutagenes screen which identified a gene Kif3a as a major component of hedgehog signaling pathway.

Eventually this discovery revolutionizes our understanding of mechanisms of action of signaling pathways by demonstrating central role of cillia in it.
Suggested Reference paper - Design and execution of a embryonic lethal mutation screen in mouse.

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Semester II

BT CT 411: Genetics (Core Theory - 2 credits)

Objectives: *The objectives of this course are to take students through basics of genetics and classical genetics covering prokaryotic/ phage genetics to yeast and higher eukaryotic domains. On covering all classical concepts of Mendelian genetics across these life-forms, students will be exposed to concepts of population genetics, quantitative genetics encompassing complex traits, clinical genetics and genetics of evolution.*

Learning Outcomes: *On successful completion of this course, student will be able to: 1) Describe fundamental molecular principles of genetics; 2) Understand relationship between phenotype and genotype in human genetic traits; 3) Describe the basics of genetic mapping; 4) Understand how gene expression is regulated.*

Unit I: Genetics of bacteria and bacteriophages (10 lectures)
Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of gene.

Unit II: Yeast genetics (6 lectures)
Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, complementation groups, transposon mutagenesis, synthetic lethality, genetic epistasis.

Unit III: Drosophila genetics as a model of higher eukaryotes (4 lectures)
Monohybrid & dihybrid crosses, back-crosses, test-crosses, analyses of autosomal and sex linkages, screening of mutations based on phenotypes and mapping the same, hypomorphy, genetic mosaics, genetic epistasis in context of developmental mechanism.

Unit IV: Population genetics and genetics of evolution (4 lectures)
Introduction to the elements of population genetics: genetic variation, genetic drift, neutral evolution; mutation selection, balancing selection, Fishers theorem, Hardy- Weinberg equilibrium, linkage disequilibrium; in-breeding depression & mating systems; population bottlenecks, migrations, Bayesian statistics; adaptive landscape, spatial variation & genetic fitness.

Unit V: Quantitative genetics of complex traits (QTLs) (2 lectures)

Complex traits, mapping QTLs, yeast genomics to understand biology of QTLs.

Unit VI: Plant genetics (2 lectures)
Laws of segregation in plant crosses, inbreeding, selfing, heterosis, maintenance of genetic purity, gene pyramiding

Recommended Textbooks and References:

1. Hartl, D. L., & Jones, E. W. (1998). Genetics: Principles and Analysis. Sudbury, MA: Jones and Bartlett.
2. Pierce, B. A. (2005). Genetics: a Conceptual Approach. New York: W.H. Freeman.
3. Tamarin, R. H., & Leavitt, R. W. (1991). Principles of Genetics. Dubuque, IA: Wm. C. Brown.
4. Smith, J. M. (1998). Evolutionary Genetics. Oxford: Oxford University Press.

BT CT 412: Immunology (Core Theory - 2 credits):

Objectives: *The objectives of this course are to learn about structural features of components of immune system as well as their function. The major emphasis of this course will be on development of immune system and mechanisms by which our body elicits immune response. This will be imperative for students as it will help them to predict about nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.*

Learning Outcomes: *On completion of this course, students should be able to:1) Evaluate usefulness of immunology in different pharmaceutical companies; 2) Identify proper research lab working in area of their own interests; 3) Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in the setting of infection (viral or bacterial).*

Unit I: Immunology: fundamental concepts and overview of the immune system (5 lectures)
Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens: immunogens, haptens; Major Histocompatibility Complex: MHC genes, MHC and immune responsiveness and disease susceptibility, Organs of immune system, primary and secondary lymphoid organs.

Unit II: Immune responses generated by B and T lymphocytes (8 lectures)
Immunoglobulins - basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self & non-self-discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines: properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation, Hapten-carrier system.

Unit III: Antigen-antibody interactions (6 lectures)
Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques: RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence microscopy, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosensor assays for assessing ligand –receptor interaction; CMI techniques: lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs.

Unit IV: Clinical immunology (8 lectures)
Immunity to infection : bacteria, viral, fungal and parasitic infections (with examples from each group); hypersensitivity: Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; treatment of autoimmune diseases; transplantation: immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology: tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency: primary immunodeficiencies, acquired or secondary immunodeficiencies, autoimmune disorder, anaphylactic shock, immunesenescence, immune exhaustion in chronic viral infection, immune tolerance, NK cells in chronic viral infection and malignancy.

Unit V: Immunogenetics (3 lectures)
Implication for linkage disequilibrium and disease associations, genetic studies of rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis, genetics of human immunoglobulin, immunogenetics of spontaneous control of HIV, KIR complex.

Recommended Textbooks and References:

1. Kindt, T. J., Goldsby, R. A., Osborne, B. A., & Kuby, J. (2006). Kuby Immunology. New York: W.H. Freeman.
2. Brostoff, J., Seaddin, J. K., Male, D., & Roitt, I. M. (2002). Clinical Immunology.
2. London: Gower Medical Pub.
3. Murphy, K., Travers, P., Walport, M., & Janeway, C. (2012). Janeway's Immunobiology. New York: Garland Science.
4. Paul, W. E. (2012). Fundamental Immunology. New York: Raven Press.
5. Goding, J. W. (1996). Monoclonal Antibodies: Principles and Practice: Production and Application of Monoclonal Antibodies in Cell Biology, Biochemistry, and Immunology. London: Academic Press.
6. Parham, P. (2005). The Immune System. New York: Garland Science.

BT CT 413: Plant and Animal Biotechnology (Core Theory - 2 credits)

Course Objectives: *The objectives of this course are to introduce students to the principles, practices and application of animal biotechnology, plant tissue culture, plant and animal genomics, genetic transformation and molecular breeding of plants and animals.*

Learning Outcomes: *Students should be able to gain fundamental knowledge in animal and plant biotechnology and their applications.*

Unit I: Plant tissue culture and animal cell culture (13 lectures)

Plant tissue culture: historical perspective; totipotency; organogenesis; Somatic embryogenesis; establishment of cultures – callus culture, cell suspension culture, media preparation – nutrients and plant hormones; sterilization techniques; applications of tissue culture - micropropagation; somaclonal variation; androgenesis and its applications in genetics and plant breeding; germplasm conservation and cryopreservation; synthetic seed production; protoplast culture and somatic hybridization - protoplast isolation; culture and usage; somatic hybridization - methods and applications; cybrids and somatic cell genetics; plant cell cultures for secondary metabolite production.

Animal cell culture: brief history of animal cell culture; cell culture media and reagents; culture of mammalian cells, tissues and organs; primary culture, secondary culture, continuous cell lines, suspension cultures; Maintenance of sterility and use of antibiotics, Mycoplasma, viral and other contaminants, Characteristics of cells in culture. Cell cloning and cell synchronization. Contact inhibition, anchorage (in) dependence, cell-cell communication etc, Cell senescence. Cell and tissue response to tropic factors, Growth studies: Cell proliferation, mitosis in growing cells. Organ culture: Methods, behaviour of organ explant, and utility of organ culture. Organ transplants. Freeze storing of cells and transport of cultures, Application of animal cell culture for virus isolation and in vitro testing of drugs, testing of toxicity of environmental pollutants in cell culture, application of cell culture technology in production of human and animal viral vaccines and pharmaceutical proteins.

Unit II: Plant genetic manipulation (6 lectures)

Genetic engineering: *Agrobacterium*-plant interaction; virulence; Ti and Ri plasmids; opines and their significance; T-DNA transfer; *Agrobacterium*-mediated gene delivery; direct gene transfer - PEG-mediated, electroporation, particle bombardment and alternative methods; chloroplast transformation; advanced methodologies - cisgenesis, intragenesis and genome editing; production of industrial enzymes and pharmaceutically important compounds.

Unit III: Animal reproductive biotechnology (6 lectures)

Animal reproductive biotechnology: structure of sperms and ovum; cryopreservation of sperms and ova of livestock; artificial insemination; superovulation, embryo recovery and in vitro fertilization; culture of embryos; cryopreservation of embryos; embryo transfer technology; transgenic manipulation of animal embryos; animal cloning - basic concept, cloning for conservation of endangered species.

Unit IV: Applications of Transgenic Plants and Animals (5 lectures)

Applications of transformed plants (Disease/Pest/Herbicide tolerance, Improvement of crop quality, Abiotic stress tolerance). Pharmaceutical products: Human protein replacement, Human therapeutics, and vaccines.

Recommended Textbooks and References:

1. Chawla, H. S. (2000). Introduction to Plant Biotechnology. Enfield, NH: Science.
2. Razdan, M. K. (2003). Introduction to Plant Tissue Culture. Enfield, NH: Science.
2. Slater, A., Scott, N. W., & Fowler, M. R. (2008). Plant Biotechnology: an Introduction to Genetic Engineering. Oxford: Oxford University Press.

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

BT CT 414: Genetic Engineering (Core Theory - 4 credits)

Course Objectives: *The objectives of this course are to teach students with various approaches to conducting genetic engineering and their applications in biological research as well as in biotechnology industries. Genetic engineering is a technology that has been developed based on our fundamental understanding of the principles of molecular biology and this is reflected in the contents of this course.*

Learning Outcomes: *Given the impact of genetic engineering in modern society, the students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practical in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.*

Unit I: Introduction and tools for genetic engineering (8 Lectures)

Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, cohesive and blunt end ligation; linkers; adaptors; T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; labelling of DNA: nick translation, radioactive and non-radioactive probes, hybridization techniques: northern, southern, western, south-western, far-western and colony hybridization.

Unit II: Different types of vectors (7 Lectures)

Plasmids; PUC19 and Bluescript vectors, pET-based vectors; Bacteriophages; M13 mp vectors; Phagemids; Cosmids; Lambda vectors; Baculovirus vector system; Insertion and Replacement vectors; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression vectors; Protein purification: His-tag; GST-tag; Inclusion bodies: methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; plant based vectors, yeast vectors, shuttle vectors.

Unit III: Different types of PCR techniques (7 Lectures)
Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection.

Unit IV: Gene manipulation and protein-DNA interaction (8 Lectures)
Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit V: Gene Editing (8L)
Transgenic animals in complex disease modelling. Zinc finger nuclease, TALEN and CRISPR-Cas9 methods of gene editing. Application of Gene editing in understanding lineage development. Application of gene editing in gene repair and disease modelling.

Unit VI: Gene silencing and genome editing technologies (16L)
Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; introduction to methods of genetic manipulation in different model systems *e.g.* fruit flies (*Drosophila*), worms (*C. elegans*), frogs (*Xenopus*), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model.

Unit VII: Diagnostics and therapeutics of Genetic diseases (6L)
Diagnosis of various Genetic diseases (eg. Cystic fibrosis, Sickle Cell Anemia and Huntington disease) and designing of gene therapy.

Recommended Textbooks and References:

1. Old, R. W., Primrose, S. B., & Twyman, R. M. (2001). Principles of Gene Manipulation: an Introduction to Genetic Engineering. Oxford: Blackwell Scientific Publications.
2. Green, M. R., & Sambrook, J. (2012). Molecular Cloning: a Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
3. Brown, T. A. (2006). Genomes (3rd ed.). New York: Garland Science Pub.
4. Selected papers from scientific journals, particularly Nature & Science.
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

BT CT 415: On Job Training (Core Theory/Practical – 4 credits)

Course Objectives: *On Job Training (OJT) provide opportunities for enhancing research capabilities and career development. These are structured and supervised short-term task-oriented placements or projects for defined duration. OJT should be arranged to benefit both the*

research-intern and the research internship providing organization. Following are the intended objectives of engaging students in research internship program:

a) *To provide an opportunity to the students to carry out research in a real work environment with faculty guidance over a specific period.*
b) *To create conditions conducive for students to exercise a quest for knowledge and its discovery and applicability for solving research/ complex/ real-life problems.*
c) *To provide the opportunities to the students to learn, understand and sharpen the research acumen, as well as the communication/ technical/managerial skills required for conducting research.*
d) *To give students an exposure to the societal challenges through rural /social internships and getting them trained for social innovations.*
e) *To familiarize students with research methods, analytical tools and techniques along with their appropriate usage.*
f) *To train students to writing research proposals, scientific reports, presentations, and/or manuscripts for publication.*
g) *To promote academic, professional developments.*
h) *To facilitate researchers in HEIs/ research organizations/ industrial R&D labs/ other Nationally reputed institutions/organizations etc. to look for innovative solutions through research interns.*
i) *To identify collaborating HEIs/research organizations/industrial research centres etc. for supporting research internship programme.*

Learning Outcomes: *Students should be able to demonstrate the following abilities*

- *Prepare students for a career after graduation by exploring your options.*
- *Achieve integration between theory and practice.*
- *Assess student's interests and abilities.*
- *Develop an appreciation for work and its role in the economy.*
- *Gain the skills and attitudes necessary for success at work.*
- *Prepare for job interviews by developing communication and interpersonal skills.*
- *Establish a record of work experience.*
- *Develop employment contacts that can lead directly to a full-time position after graduation.*

Structure of the Course: Students are expected to join OJT placements. The Department and the University provides support and guidance to the students to secure OJT positions in reputable organizations. OJT must be conducted outside the home Institution to offer real-world work platforms to the students. OJT covers any subject within the syllabus, allowing students to align their experience with their academic interests. Students are allowed to undergo OJT not less than 120 hours. Students are instructed to maintain activity log-books and attendance during OJT. At the end of the OJT, students are instructed to submit the OJT completion certificates and a concise report including the skills learned during OJT.

Assessments: At the end of the Semester, the students will be evaluated at two levels.

a) Internal Evaluation: The internal evaluation of students will be tested on their OJT performance by a series of questions. Mentors, instructors, and supervisors will be asked to evaluate performance based on University-set performance parameters. As part of the OJT process, students will be asked to submit a report containing their OJT completion

certificate, attendance report, and activity logbook to both, the workplace where OJT took place and to the Department.

b) External Evaluation: Students will prepare the presentation based on their work and experience during the OJT. The OJT presentation will be evaluated by the faculty and scientists. In the OJT presentation, students will have to explain the various tasks and objectives performed, the skills-sets they have developed during OJT, etc. They shall be able to discuss the expected outcomes of their OJT training.

Recommended Textbooks and references:

1. Guidelines for Internship/Research Internship for Under Graduate Students (https://www.ugc.gov.in/pdfnews/0063650_Draft-Guidelines-for-Internship-and-Research-Internship-for-Under-Graduate-Students.pdf)
2. Draft Guidelines for Research Internship with Faculty and Researchers at Higher Education Institutions/Research Institutions (https://www.ugc.gov.in/pdfnews/1887287_Rsearch-Internship-Guidelines-120522.pdf)

BT ET 416: Emerging Technologies (Elective Theory - 2 credits)

Objectives: *This course is broad-based in nature encompassing several new technologies that current experimental researchers are employing to probe complex system biology questions in life-sciences. The objectives of this course are to teach basics of the new principles to students so as to appreciate current-day research tool-kit better.*

Learning Outcomes: *Students should be to learn history, theoretical basis and basic understanding of latest technologies in area of biotechnology. They should also be able to learn about various applications of these technologies. The students may also learn one application in depth through an assignment and/or seminar.*

Unit I: Optical microscopy methods (8 lectures)

Basic Microscopy: Light Microscopy: lenses and microscopes, resolution: Rayleigh's Approach, Darkfield; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy: What is fluorescence, what makes a molecule fluorescent, fluorescence microscope; optical arrangement, light source; filter sets: excitation filter, dichroic mirror, and barrier, optical layout for image capture; CCD cameras; back illumination, binning; recording color; three CCD elements with dichroic beam splitters, boosting the signal. Advanced Microscopy: Confocal microscope: scanning optical microscope, confocal principle, resolution and point spread function, light source: gas lasers & solid-state, primary beam splitter; beam scanning, pinhole and signal channel configurations, detectors; pixels and voxels; contrast, spatial sampling: temporal sampling: signal-to-noise ratio, multichannel images. nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence, advantages of two-photon excitation, tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, three-dimensional reconstruction; advanced fluorescence techniques: FLIM, FRET, and FCS, Fluorescence Lifetime, Fluorescence Resonant Energy Transfer (FRET), Fluorescence Correlation Spectroscopy (FCS), Evanescent Wave Microscopy; Near-Field and Evanescent Waves, Total

Internal Reflection Microscopy; Near-Field Microscopy; Beyond the Diffraction Limit: Stimulated Emission Depletion (STED), Super-Resolution Summary, Super-Resolution Imaging with Stochastic Optical Reconstruction Microscopy (STORM) and Photoactivated Localization Microscopy (PALM).

Unit II: Mass spectroscopy (4 lectures)
Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.

Unit III: Systems biology (3 lectures)
High throughput screens in cellular systems, target identification, validation of experimental methods to generate the omics data, bioinformatics analyses, mathematical modeling and designing testable predictions.

Unit IV: Structural biology (5 lectures)
X-ray diffraction methods, solution & solid-state NMR, cryo-electron microscopy, small angle X-ray scattering, Atomic force microscopy.

Unit V: CRISPR-CAS (6 lectures)
History of its discovery, elucidation of the mechanism including introduction to all the molecular players, development of applications for in vivo genome engineering for genetic studies, promise of the technology as a next generation therapeutic method.

Unit VI: Nanobodies (4 lectures)
Introduction to nanobodies, combining nanobody with phage-display method for development to antibody against native proteins, nanobody as a tool for protein structure-function studies, use of nanobodies for molecular imaging, catabolic antibodies using nanobodies.

Recommended Textbooks and References:

1. Campbell,I.D.(2012). Biophysical Techniques.Oxford:OxfordUniversityPress.
2. Serdyuk, I. N., Zaccai, N. R., & Zaccai, G. (2007). Methods in Molecular Biophysics: Structure,Dynamics,Function.Cambridge:CambridgeUniversityPress.
3. Phillips, R., Kondev,J., & Theriot,J.(2009). Physical Biology of the Cell. New York: Garland Science.
4. Nelson,P.C.,Radosavljević,M.,&Bromberg, S.(2004). Biological Physics: Energy, Information, Life. New York:W.H. Freeman.
5. Huang,B., Bates, M., & Zhuang,X. (2009). Super-Resolution Fluorescence Microscopy.AnnualReviewofBiochemistry,78(1), 993-1016.doi:10.1146/annurev. biochem.77.061906.092014.
6. Mohanraju,P.,Makarova,K.S.,Zetsche,B.,Zhang,F.,Koonin,E.V.,&Oost,J.V. (2016). Diverse Evolutionary Roots and Mechanistic Variations of the CRISPR-Cas Systems.Science,353(6299).doi:10.1126/science.aad5147.
7. Lander,E.(2016).TheHeroesofCRISPR.Cell,164(1-2),18-28.doi:10.1016/j. cell.2015.12.041.

8. Ledford, H. (2016). The Unsung Heroes of CRISPR. Nature, 535(7612), 342-344. doi:10.1038/535342a.
9. Jinek,M., Chylinski,K., Fonfara,I., Hauer,M.,Doudna,J.A.,&Charpentier,E. (2012). A ProgrammableDual-RNA-GuidedDNAEndonuclease inAdaptive Bacterial Immunity. Science, 337(6096), 816-821. doi:10.1126/science.1225829.
10. Hamers-Casterman,C.,Atarhouch,T.,Muyldermans,S.,Robinson,G.,Hammers, C., Songa, E. B., Hammers, R. (1993). Naturally Occurring Antibodies Devoid of Light Chains. Nature, 363(6428), 446-448. doi:10.1038/363446a0.
11. Sidhu, S. S., & Koide, S. (2007). Phage Display for Engineering and Analyzing Protein Interaction Interfaces. Current Opinion in Structural Biology, 17(4), 481-487. doi:10.1016/j.sbi.2007.08.007.
12. Steyaert,J.,&Kobilka,B.K.(2011).NanobodyStabilizationofGProtein-Coupled Receptor Conformational States.CurrentOpinionin StructuralBiology, 21(4), 567-572. doi:10.1016/j.sbi.2011.06.011.
13. Vincke, C., & Muyldermans, S. (2012). Introduction to Heavy Chain Antibodies and Derived Nanobodies. Single Domain Antibodies, 15-26. doi:10.1007/978-1-61779- 968-6_2.
14. Verheesen, P., & Laeremans, T.(2012). Selection by Phage Display of Single Domain Antibodies Specific to Antigens in their Native Conformation. Single Domain Antibodies, 81-104. doi:10.1007/978-1-61779-968-6_6.
15. Li,J.,Xia,L.,Su,Y.,Liu,H.,Xia,X.,Lu,Q.Reheman,K.(2012).Molecular Imprint of Enzyme Active Site by Camel Nanobodies. Journal of Biological Chemistry J.Biol. Chem., 287(17), 13713-13721. doi:10.1074/jbc.m111.336370.
16. Sohier,J.,Laurent,C.,Chevigné,A.,Pardon,E.,Srinivasan,V.,Wernery,U.Galleni, M.(2013).Allosteric Inhibition of VIM Metallo-β-Lactamases by a Camelid Nanobody. Biochemical Journal, 450(3), 477-486. doi:10.1042/bj20121305.
17. Chakravarty, R., Goel, S., & Cai, W. (2014). Nanobody: The “Magic Bullet” for Molecular Imaging? Theranostics, 4(4), 386-398. doi:10.7150/thno.8006.

BT ET 417: Bioentrepreneurship and Start-up Management (Elective Theory - 2 credits)

Objectives: *Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bioentrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.*

Learning Outcomes: *Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.*

Unit I: Bioentrepreneurship (5 lectures)

Introduction to bio-business, from the Indian context, SWOT analysis of bio-business. Ownership, Concept of Entrepreneur (Features, Types, Functions), Development of Entrepreneurship (Characteristics, Evolution); Stages in entrepreneurial process; Role of entrepreneurs in Economic Development; Entrepreneurship in India; Entrepreneurship - its barriers. Small scale industries: Definition; Characteristics; Need and rationale; Objectives; Scope; Market Feasibility Study; Technical Feasibility Study; Financial Feasibility Study & Social Feasibility Study. Global bio business and industry future trends.

Unit II: Entrepreneurial Strategies and Competencies (5 lectures)

Business Models and Strategy: Entry Wedges, Resource-Based Strategies, Information Rules Strategies, Strategy and Industry Environments, Crafting and Evaluating Strategy, Entrepreneurship competencies: qualities of a successful entrepreneur, Entrepreneurial traits, developing competencies; Tools of assessment; Institutional Framework, Role of SSI Sector in the Economy; Failure, Causes and Preventive Measures, Turnaround Strategies.

Unit III: Start-up Environment and Business Plan (5 lectures)

Schematic of the New Venture's Environment; Processes of Business Environment Analysis (Political, Governmental, Stakeholder, Technological, Macroeconomic, Socio-demographic); Competitive and Competitor Analysis; Elements of Business plan; Feasibility study; Critiquing the plan; Formalities and procedures in registration of a business; Regulatory norms and legal aspects; Format and presentation of report; Marketing strategies.

Unit IV: Managing New Venture and Financing (5 lectures)

Preparing for the new venture launch; New venture expansion strategies; Venture Capital and Angel Investment; Importance and Benefits; Sources of Investment; Role of Central Government and State Government in promoting Entrepreneurship; Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make in India), strategic dimensions of patenting & commercialization strategies; Export Oriented Units; Fiscal and Tax concessions.

Unit V: Start-up Survival and Growth (3 lectures)

Stages of growth in a new venture; Growing with the market; Growing within the industry; Venture life patterns; Reasons for new venture failures; Scaling Ventures – preparing for change; Leadership succession. Support for growth and sustainability of the venture.

Unit VI: Planning for Harvest and Exit (2 lectures)

Dealing with Failure: Bankruptcy, Exit Strategies- Selling the business, cashing out but staying in, being acquired; Going Public (IPO); Liquidation.

Unit VII: Entrepreneurship Opportunity in Industrial Biotechnology (5 lecture)

Business opportunity, Essential requirement, marketing strategies, schemes, challenges and scope-with case study- Pollution monitoring and Bioremediation for Industrial pollutants, Pesticides, Herbicides etc. Integrated compost production- microbe enriched compost. Bio pesticide/insecticide production. Fermented products-probiotic and prebiotics. Stem cell

production, stem cell bank, contract research. Production of monoclonal/polyclonal antibodies, Single cell protein and secondary metabolite production. Contact research in microbial genomics.

Recommended Textbooks and References:

1. Adams, D. J., & Sparrow, J. C. (2008). Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences. Bloxham: Scion.
2. Shimasaki, C. D. (2014). Biotechnology Entrepreneurship: Starting, Managing, and Leading Biotech Companies. Amsterdam: Elsevier. Academic Press is an imprint of Elsevier.
3. Onetti, A., & Zucchella, A. Business Modeling for Life Science and Biotech Companies: Creating Value and Competitive Advantage with the Milestone Bridge. Routledge.
4. Jordan, J. F. (2014). Innovation, Commercialization, and Start-Ups in Life Sciences. London: CRC Press.
2. Desai, V. (2009). The Dynamics of Entrepreneurial Development and Management. New Delhi: Himalaya Pub. House.
3. Kathleen R Allen, Launching New Ventures, An Entrepreneurial Approach,
4. CengageLearning, 2016.
5. Anjan Raichaudhuri, Managing New Ventures Concepts and Cases, Prentice Hall
6. International, 2010.
7. S. R. Bhowmik & M. Bhowmik, Entrepreneurship, New Age International, 2007.
8. Steven Fisher, Ja-nae' Duane, The Startup Equation -A Visual Guidebook for Building
9. Your Startup, Indian Edition, Mc Graw Hill Education India Pvt. Ltd, 2016.
10. Donald F Kuratko, Jeffrey S. Hornsby, New Venture Management: The Entrepreneur's
11. Road Map, 2e, Routledge, 2017.
12. Vijay Sathe, Corporate Entrepreneurship, 1e, Cambridge, 2009

BT CP 418: Laboratory III - Molecular Biology and Genetic Engineering
(Core Practical - 2 credits)

Objectives: *The objective of this course is to provide students with experimental knowledge of molecular biology and genetic engineering.*

Learning Outcomes: *Students should 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.*

1. Plasmid DNA isolation, DNA quantitation and agarose gel electrophoresis.
2. Genomic DNA isolation, DNA quantitation and agarose gel electrophoresis.
3. Total RNA isolation, cDNA preparation and quantitative real time PCR.
4. Preparation of competent cells and calculation of transformation efficiency.
5. Polymerase Chain Reaction and analysis by agarose gel electrophoresis.
6. Restriction enzyme digestion and analysis by agarose gel electrophoresis.
7. Vector and Insert ligation and screening of clones.
8. Purification of His-Tagged protein by Ni-NTA column chromatography.

9. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in *E. coli*, SDS-PAGE analysis.
10. Chromatin Immunoprecipitation.

BT CP 419: Laboratory IV - Immunology (Core Practical - 2 credits)

Objectives: *The objectives of this laboratory course are to develop an understanding about practical aspects of components of immune system as well as their function. Basic as well as advanced methods will be taught to detect different antigen and antibody interactions, isolation of different lymphocyte cells etc. and how they can be used in respective research work.*

Student Learning Outcomes: *Students should be able to: 1) Evaluate usefulness of immunology in different pharmaceutical companies; 2) Identify proper research lab working in area of their own interests.*

1. Selection of animals, preparation of antigens, immunization and methods of blood collection, serum separation and storage.
2. Antibody titre by ELISA method.
3. Double diffusion and Radial Immunodiffusion.
4. Immuno-electrophoresis and rocket immunoelectrophoresis
5. Complement fixation test.
6. Isolation and purification of IgG from serum or IgY from chicken egg.
7. SDS-PAGE, Immunoblotting
8. Dot blot assays.
9. Blood smear identification of leucocytes by Giemsa stain.
10. Separation of leucocytes by dextran method.
11. Demonstration of Phagocytosis of latex beads and their cryopreservation.
12. Separation of mononuclear cells by Ficoll-Hypaque and their cryopreservation.
13. Histology and Immuno-fluorescence microscopy.
14. Demonstration of FACS.

BT EP 420: Laboratory V: Plant Biotechnology (Elective Practical - 2 Credits)

Objectives: *The objectives of this course are to provide hands-on training in basic experiments of plant biotechnology.*

Learning Outcomes: *On completion of course, students should be able to gain basic skills in plant biotechnology.*

1. Prepare culture media with various supplements for plant tissue culture.
2. Prepare explants of Tomato and carrot for inoculation under aseptic conditions.
3. Attempt *in vitro* andro and gynogenesis in plants (*Datura stramonium*).
4. Culture Agrobacterium tumefaciens and attempt transformation of any dicot species.
5. Isolate plant protoplast by enzymatic and mechanical methods and attempt fusion by PEG (available material).

6. Undertake plant genomic DNA isolation by CTAB method and its quantitation by visual as well as spectrophotometric methods.
7. Perform PCR amplification of 'n' number of genotypes of a species for studying the genetic variation among the individuals of a species using random primers.
8. Prepare karyotypes and study the morphology of somatic chromosomes of *Allium cepa, A. sativum, A. tuberosum* and compare them on the basis of karyotypes.
9. Study genetic fingerprinting profiles of plants and calculate polymorphic information content.
10. Pollen mother cell meiosis and recombination index of select species (one achiasmate, and the other chiasmate) and correlate with generation of variation.

BT EP 421: Laboratory V: Animal Biotechnology (Elective Practical - 2 Credits)

Objectives: *The objectives of this course are to provide hands-on training in basic experiments of animal biotechnology.*

Learning Outcomes: *On completion of course, students should be able to gain basic skills in animal biotechnology.*

1. Preparatory techniques: Washing of glassware, dry and steam sterilisation. Maintenance of aseptic conditions, Sterilisation techniques, Media preparation: Filter sterilisation, Sterility tests, and media storage. Serum inactivation.
2. Prepare single cell suspension from spleen and thymus. Counting the cells and checking the viability.
3. Growth studies. Cell count, mitotic index.
4. Chromosome preparations from cultured animal cells.
5. *In vitro* assay of drugs, predictive test for anticancer drugs (Cell migration assays).
6. Staining and screening of cells /sera for mycoplasma.
7. Cell cloning by single cell dilution method,
8. Freeze storing and revival.
9. Clonogenic assay, Cell-cell interaction: Co-culture of normal and mutant cells
10. Transfection of animal cells with GFP/RFP/YFP.
11. Differential Cell staining

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Semester III

BT CT 501: Bioprocess Engineering and Technology (Core Theory - 4 Credits)

Objectives: *Understand the microbial Fundamentals and apply the bioprocess engineering (stoichiometric)principles to it to develop the microbial growth models facilitating the way for optimization of various bioprocesses. Educate the students to design the bioreactors along with analysis and modify for optimal product for various bioreactor system. Analyse and evaluate financial factors like cost analysis of equipment, media, and downstream processing making the bioprocess as one of the best sustainable option. Impart the practical skills to the students in the*

separation and purification of bioproducts, understanding the role of various techniques in downstream processing. Involve the students in understanding the importance of enzyme and microbial systems in food processing, pharmaceutics and other industrial applications and preservation of the fermented product. Educate the students about quality control measures and the regulatory landscape of governing biotechnological products, including compliance with national and international standards.

Learning Outcomes: *Upon successful completion of this course, students will be able to: Appreciate relevance of microorganisms from industrial context. Carry out stoichiometric calculations and specify models of their growth. Give an account of design and operations of various fermenters. Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products. Calculate yield and production rates in a biological production process, and also interpret data. Calculate the need for oxygen and oxygen transfer. Critically analyse any bioprocess from market point of view. Give an account of important microbial/enzymatic industrial processes in food and fuel industry. Analyse and apply quality control measures in bioprocessing and understand the regulatory frameworks affecting biotechnological products, including compliance with Good Manufacturing Practices (GMP)*

Unit I: Basic principles of biochemical engineering (9 lectures)
Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.

Unit II: Stoichiometry and models of microbial growth (6 lectures)
Elemental balance equations; metabolic coupling – ATP and NAD^+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.

Unit III: Bioreactor design and analysis (8 lectures)
Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformation; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.

Unit IV: Fermentation Economics (8 lectures)
Isolation of microorganisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling; effluent treatment and disposal.

Unit V: Downstream processing and product recovery (7 lectures)
Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.

Unit VI: Applications of enzyme technology in food processing (5 lectures)
Enzyme function and reactions in process techniques; enzymatic bioconversions e.g., starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. baking by amylases, deoxygenation and desugaring by glucoses oxidase, beer mashing and chill proofing; cheese making by proteases.

Unit VII: Pharmaceutical applications of microbial technology (7 lectures)
Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria – production and applications in food preservation; biofuels and biorefinery.

Unit VIII: Quality Control and Regulatory Aspects of Biotechnology Products (10 lectures)
Quality Control in Fermentation Processes: Raw material selection and testing; In-process monitoring and control; Analytical methods for product characterization; Quality control considerations during downstream processing. National Regulatory Frameworks: Overview of Indian regulatory agencies and their roles; Compliance requirements for biotechnological products; International Regulatory Landscape: Harmonization efforts and global regulatory trends for biotech products; regional regulatory requirements; Strategies for resolving international regulatory challenges. Documentation and Regulatory Compliance: Good Manufacturing Practices (GMP) in biotechnological product manufacturing; Regulatory documentation and record-keeping. Audits and inspections: Preparation and response Case Studies and Practical Applications; Ethical considerations and societal impacts of biotechnological products.

Recommended Textbooks and References:

1. Shuler, M. L., Kargi, F. (2002). Bioprocess Engineering: Basic Concepts. Upper Saddle River, NJ: Prentice Hall.
2. Stanbury, P. F., Whitaker, A. (2010). Principles of Fermentation Technology. Oxford: Pergamon Press.
3. Blanch, H. W., Clark, D. S. (1997). Biochemical Engineering. New York: M. Dekker.
4. Bailey, J. E., Ollis, D. F. (1986). Biochemical Engineering Fundamentals. New York: McGraw-Hill.
5. El-Mansi, M., Bryce, C. F. (2007). Fermentation Microbiology and Biotechnology. Boca Raton: CRC/Taylor Francis.
6. Stanbury, P. F., Whitaker, A. (2010). Principles of Fermentation Technology. Oxford: Pergamon Press.
7. Quality by Design for Biopharmaceuticals: Principles and Case Studies; by Anurag S. Rathore and Rohin Mhatre
8. Regulatory Affairs for Biomaterials and Medical Devices; by Stephen F. Amato and Ajit Sadana
9. Regulatory Affairs in Biopharmaceuticals; by Gary Walsh
10. Biotechnology and Biopharmaceuticals: Transforming Proteins and Genes into Drugs; by Rodney J. Y. Ho and Milo Gibaldi

11. Good Manufacturing Practices for Pharmaceuticals: A Plan for Total Quality Control; by Sidney H. Willig, James R. Stoker, and James P. M. O' Connor
12. Bioseparations Science and Engineering; by Harrison, Todd, Rudge and Petrides, Oxford University Press 2015 (2nd ed.)
13. Bioprocess engineering: an introductory engineering and life science approach; by Kim Gail Clarke, Woodhead Publishing, 2013
14. Bioprocess engineering principles, by Pauline M. Doran, 2nd edition, Academic Press, 2013.

BT CT 502: Molecular Diagnostics (Core Theory - 2 Credits)

Objectives: *The objectives of this course are to sensitize students about recent advances in molecular biology and various facets of molecular medicine which has potential to profoundly alter many aspects of modern medicine including pre-natal or post-natal analysis of genetic diseases and identification of individuals predisposed to disease ranging from common cold to cancer.*

Learning Outcomes: *Students should be able to understand various facets of molecular procedures and basics of genomics, proteomics and metabolomics that could be employed in early diagnosis and prognosis of human diseases.*

Unit I: Genome biology in health and disease (5 lectures)
DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs.

Unit II: Genome: resolution, detection & analysis (5 lectures)
PCR: ARMS; Multiplex; ISH; ISA; DHPLC; DGGE; CSCE; SSCP; Nucleic acid sequencing: new generations of automated sequencers; Microarray chips; EST; SAGE; microarray data normalization & analysis; Diagnostic proteomics: SELDI-TOF-MS.

Unit III: Diagnostic metabolomics (2 lectures)
Metabolite profile for biomarker detection of the body fluids/tissues in various metabolic disorders by using LCMS & NMR technological platforms.

Unit IV: Detection and identity of microbial diseases (4 lectures)
Direct detection and identification of pathogenic-organisms that are slow growing or currently lacking a system of in vitro cultivation as well as genotypic markers of microbial resistance to specific antibiotics.

Unit V: Detection of inherited diseases (4 lectures)
Exemplified by two inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: Fragile X Syndrome: Paradigm of new mutational mechanism of unstable triplet repeats. Von-Hippel Lindau disease: recent acquisition in growing number of familial cancer syndromes.

Unit VI: Radiation in diagnostics (5 lectures)
X-Rays in diagnostics; CT-scan, MRI and radioisotopes in disease and diagnostics; Sonography and diagnosis.

Unit VII: Molecular oncology (5 lectures)
Detection of recognized genetic aberrations in clinical samples from cancer patients; types of cancer-causing alterations revealed by next-generation sequencing of clinical isolates; predictive biomarkers for personalized onco-therapy of human diseases such as chronic myeloid leukemia, colon, breast, lung cancer and melanoma as well as matching targeted therapies with patients and preventing toxicity of standard systemic therapies

Recommended Textbooks and References:

1. Campbell, A. M., & Heyer, L. J. (2006). Discovering Genomics, Proteomics, and Bioinformatics. San Francisco: Benjamin Cummings.
2. Brooker, R. J. (2009). Genetics: Analysis & Principles. New York, NY: McGraw-Hill.
3. Glick, B. R., Pasternak, J. J., & Patten, C. L. (2010). Molecular Biotechnology: Principles and Applications of Recombinant DNA. Washington, DC: ASM Press.
4. Coleman, W. B., & Tsongalis, G. J. (2010). Molecular Diagnostics: for the Clinical Laboratorian. Totowa, NJ: Humana Press.

BT CT 503: Bioinformatics (Core Theory - 2 Credits)

Objectives: *The objectives of this course are to provide theory and practical experience of the use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.*

Learning Outcomes: *Student should be able to develop an understanding of basic theory of these computational tools; gain working knowledge of these computational tools and methods; appreciate their relevance for investigating specific contemporary biological questions; critically analyse and interpret results of their study.*

Unit I: Bioinformatics basics (2 lectures)
Fundamentals of Bioinformatics: Integration of Computers in Biology and Medicine; Key Bioinformatics Resources (NCBI, EBI); Databases for Proteins and Nucleic Acids; Repositories for Structural Data.

Unit II: Pairwise sequence Alignment (6 lectures)
Molecular Evolution Mechanisms: Foundations of Sequence Analysis; Pairwise Sequence Alignment Concepts (Optimal Alignment, Global Alignment, and Local Alignment).
Methods for Pairwise Sequence Alignments: Dot Matrix Analysis, Interpretation of Dot Plots, merits and demerits of Dot Plot Method. Basics of Scoring Matrices in Pairwise Sequence Alignments: Defining Scoring Matrices, Log Odd Values (significance, and Derivation).
Scoring Matrices Design: The Role of Genetic Code and Physical Similarity between Amino Acid Residues. Examples of Scoring matrices: PAM and BLOSUM Scoring Matrices.

Dynamic Programming Algorithms in Sequence Alignment: Needleman-Wunsch Algorithm, Nussinov-Jacobson Algorithm.
Database Searching Programs: BLAST/FASTA.

Unit III: Multiple sequence alignment (MSA) and its application (6 lectures)
MSA Fundamentals: Progressive Strategies for MSA, Clustal: Algorithm, Factors Affecting the Quality of MSA, Practical Considerations. Limitations of Clustal: the Single Parameter Problem and Local Minimum Problem. DNA OR Protein sequences in Evolutionary Analysis.
Applications of Multiple Sequence Alignment: Basic Terms in Phylogeny (Taxa, Types of Nodes, Lineages, Clades, Rooted and Unrooted Trees) Outgroups in phylogeny: Basic Concept, Significance Applications, and Implementation. Homology, Orthologs, and Paralogs. Methods for Tree Reconstruction: Character-Based (Parsimony and Maximum Likelihood) and Distance-Based (NJ, UPGMA). Choice of Method selection. Tree Reliability. Tree Construction Package: Phylip/MEGA.

Unit IV: Protein modelling and Protein structure prediction (8 lectures)
Introduction to Protein Structures, Protein Data Bank (PDB), and PDB Flat File Format. Basics of Protein Structure Visualization: Major Non-Covalent Interactions for Protein Stability (Hydrogen Bonds, Hydrophobic Forces, van der Waals Interactions, Pi-Stacking, and Salt Bridges). Mapping Properties onto Protein Surfaces, Fitting Monomers, Concepts and application of RMSD. Concepts in Structure Predictions: The logic of Structure Predictions, Secondary Structure Prediction, Fold Recognition, Homology Modeling, Ab Initio Structure Prediction.

Unit V: Molecular Docking and molecular dynamics simulations (8 lectures)
Structure-Based Drug Design Introduction:
Modelling Protein-Ligand Interactions. Pose Prediction and Affinity Prediction.
Rigid Body Docking: Concept, Relevant Software, and Limitations.
Flexible Ligand Docking:
a. Systematic Methods (Conformational Search, Fragmentation, and Database Methods). Types of Systematic Methods 1. Conformational Search Methodology, Advantages, and Disadvantages. 2. The Fragmentation Method, Place and Join Algorithm and Incremental Construction Algorithm. 3. Database method.
b. Random/ Stochastic Methods: Monte Carlo Method, Genetic Algorithm, and Tabu Search.
Concepts in affinity prediction: Challenge in Affinity Prediction, Scoring Functions, Force Field-Based, Empirical, and Knowledge-Based.
Introduction to Molecular Simulation Methods:
Need for Studying Molecular Dynamics (MD) Simulations, Concept, Types. All-Atom and Coarse-Grain MD Simulations. Conventional and Steered MD Simulations. Hamiltonian Equations in MD Simulations: Derivation, Practical Drawbacks of Hamiltonian Equations, Taylor Expansion in MD Simulations. Derivation of the Velocity Verlet Algorithm.
Initial Conditions and Maxwell-Boltzmann Distribution: Initial Velocities assignment. Maxwell-Boltzmann Theory in Velocity Assignment.
Force Fields: The Concepts and Examples of Force Fields, Detailed Explanation of Terms within the CHARMM Force Field.

Recommended Textbooks and References:

1. Lesk, A. M. (2002). Introduction to Bioinformatics. Oxford: Oxford University Press.
2. Mount, D. W. (2001). Bioinformatics: Sequence and Genome Analysis. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
3. Baxevanis, A. D., & Ouellette, B. F. (2001). Bioinformatics: a Practical Guide to the Analysis of Genes and Proteins. New York: Wiley-Interscience.
4. Pevsner, J. (2015). Bioinformatics and Functional Genomics. Hoboken, NJ.: Wiley-Blackwell.
5. Bourne, P. E., & Gu, J. (2009). Structural Bioinformatics. Hoboken, NJ: Wiley-Liss.
6. Lesk, A. M. (2004). Introduction to Protein Science: Architecture, Function, and Genomics. Oxford: Oxford University Press.

BT CT 504: Genomics and Proteomics (Core Theory- 2 Credits)

Objectives: *The objectives of this course is to provide introductory knowledge concerning genomics, proteomics and their applications.*

Learning Outcomes: *Students should be able to acquire knowledge and understanding of fundamentals of genomics and proteomics, transcriptomics and metabolomics and their applications in various applied areas of biology.*

Unit I: Basics of genomics and proteomics (3 lectures)
Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.

Unit II: Genome mapping (5 lectures)
Genetic and physical maps; markers for genetic mapping; methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, in situ hybridization, comparative gene mapping.

Unit III: Genome sequencing projects (4 lectures)
Human Genome Project, genome sequencing projects for microbes, plants and animals, accessing and retrieving genome project information from the web.

Unit IV: Comparative genomics (5 lectures)
Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence.

Unit V: Proteomics (5 lectures)
Aims, strategies and challenges in proteomics; proteomics technologies: 2D-PAGE, isoelectric focusing, mass spectrometry, MALDI-TOF, proteome databases.

Unit VI: Functional genomics and proteomics (8 lectures)

Transcriptome analysis for identification and functional annotation of gene; protein chips and functional proteomics; introduction to metabolomics, lipidomics, metagenomics.

Recommended Textbooks and References:

1. Primrose, S. B., Twyman, R. M., Primrose, S. B., & Primrose, S. B. (2006). Principles of Gene Manipulation and Genomics. Malden, MA: Blackwell Pub.
2. Liebler, D. C. (2002). Introduction to Proteomics: Tools for the New Biology. Totowa, NJ: Humana Press.
3. Campbell, A. M., & Heyer, L. J. (2003). Discovering Genomics, Proteomics, and Bioinformatics. San Francisco: Benjamin Cummings.

BT CT 505: Research Project (Core Theory/Practical - 4 Credits)

Objectives: *The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.*

Learning Outcomes: *Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:*

- *In-depth knowledge of the chosen area of research.*
- *Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.*
- *Competence in research design and planning.*
- *Capability to create, analyze and critically evaluate different technical solutions.*
- *Ability to conduct research independently.*
- *Ability to perform analytical techniques/experimental methods.*
- *Project management skills.*
- *Report writing skills.*
- *Problem solving skills.*
- *Communication and interpersonal skills.*

Planning and performing experiments: *Based on the project proposal, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.*

Thesis writing: *At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim*

to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Assessments: *At the end of the Semester, the students will submit the hard copy and soft copy of the thesis/report as per guidelines to the dissertation coordinator within the stipulated time. The dissertation thesis will be evaluated by individual student's supervisor (50% of total marks) and one examiner from the Department as external examiner (50% marks). There will be no presentation for semester-III dissertation.*

BT ET 506: Drug Discovery and Development (Elective Theory - 2 Credits)

Objectives: *This course will give a broad overview of research and development carried out in industrial setup towards drug discovery.*

Learning Outcomes: *On completion of this course, students should be able to understand basics of R&D in drug discovery and should be able to apply knowledge gained in respective fields of pharmaceutical industry.*

Unit I: Target identification and molecular modeling (6 lectures)
Identification of target or drug leads associated with a particular disease by a number of different techniques including combinations of molecular modeling, combinatorial libraries and high-throughput screening (HTS); Conceptualizing the automation of the HTS process and the importance of bioinformatics and data processing in identification of lead compounds; Rational drug design, based on understanding the three-dimensional structures and physicochemical properties of drugs and receptors; Modeling drug/receptor interactions with the emphasis on molecular mechanisms, molecular dynamics simulations and homology modeling; Conformational sampling, macromolecular folding, structural bioinformatics, receptor-based and ligand-based design and docking methods, in-silico screening of libraries, semi-empirical and ab-initio methods, QSAR methods, molecular diversity, design of combinatorial libraries of drug-like molecules, macromolecular and chemical databases.

Unit II: Lead optimization (6 lectures)
Identification of relevant groups on a molecule that interact with a receptor and are responsible for biological activity; Understanding structure activity relationship; Structure modification to increase potency and therapeutic index; Concept of quantitative drug design using Quantitative structure–activity relationship models (QSAR models) based on the fact that the biological properties of a compound are a function of its physicochemical parameters such as solubility, lipophilicity, electronic effects, ionization, stereochemistry, etc.; Bioanalytical assay development in support of in vitro and in vivo studies (LC/MS/MS, GC/MS and ELISA).

Unit III: Preclinical development (6 lectures)
Principles of drug absorption, drug metabolism and distribution - intestinal absorption, metabolic stability, drug-drug interactions, plasma protein binding assays, metabolite profile studies, Principles of toxicology, Experimental design for preclinical and clinical PK/PD/TK studies, Selection of animal model; Regulatory guidelines for preclinical PK/PD/TK studies; control on

animal house, report preparation and documentation Integration of non-clinical and preclinical data to aid design of clinical studies.

Unit IV: Drug manufacturing (4 lectures)
Requirements of GMP implementation, Documentation of GMP practices, CoA, Regulatory certification of GMP, Quality control and Quality assurance, concept and philosophy of TQM, ICH and ISO 9000; ICH guidelines for Manufacturing, Understanding Impurity Qualification Data, Stability Studies.

Unit V: Clinical Trials Design (4 lectures)
Objectives of Phase I, II, III and IV clinical studies, Clinical study design, enrollment, sites and documentation, Clinical safety studies: Adverse events and adverse drug reactions, Clinical PK, pharmacology, drug-drug interaction studies, Statistical analysis and documentation.

Unit VI: Fundamentals of regulatory affairs and bioethics (4 lectures)
Global Regulatory Affairs and different steps involved, Regulatory Objectives, Regulatory Agencies; FDA guidelines on IND and NDA submissions, Studies required for IND and NDA submissions for oncology, HIV, cardiovascular indications, On-label vs. off-label drug use GCP and Requirements of GCP Compliance, Ethical issues and Compliance to current ethical guidelines, Ethical Committees and their set up, Animal Ethical issues and compliance.

Recommended Textbooks and References:

1. Krogsgaard-Larsen et al. Textbook of Drug Design and Discovery. 4th Edition. CRC Press.
2. Kuhse, H. (2010). Bioethics: An Anthology. Malden, MA: Blackwell.
3. Nally, J. D. (2006) GMP for Pharmaceuticals. 6th edition. CRC Press
4. Brody, T. (2016) Clinical Trials: Study Design, Endpoints and Biomarkers, Drug Safety, and FDA and ICH Guidelines. Academic Press.

BT ET 507: Vaccines (Elective Theory - 2 Credits)

Course Objectives: *This course will provide students with an overview of current developments in different areas of vaccines.*

Student Learning Outcomes: *By the end of this course, students should be able to:*
- *Understand fundamental concepts of human immune system and basic immunology;*
- *Differentiate and understand immune responses in relation to infection and vaccination;*
- *Understand requirement and designing of different types of vaccines;*
- *Understand importance of conventional and new emerging vaccine technologies.*

Unit I: Basics in Infectious Immunology (4 Lectures)
Protective immune response in bacterial; viral and parasitic infections; Primary and Secondary immune responses during infection;

Unit II: Evaluation and ethics (6 lectures)

Clinical endpoints for vaccine evaluation, Vaccines and public health, legal and ethical considerations, Sex differences and vaccines, Vaccines and Public perception, Maternal/Neonatal Immunization, Reverse Vaccinology.

Unit III: Vaccine types & design (6 lectures)
History of vaccines, Conventional vaccines; Bacterial vaccines; Viral Vaccines; Vaccines based on routes of administration: parenteral, oral, mucosal; Live attenuated and inactivated vaccine; Subunit Vaccines and Toxoids; Peptide Vaccine.

Unit IV: Adjuvants in vaccination (8 lectures)
Vaccination and immune response; Adjuvants in Vaccination; Modulation of immune responses: Induction of Th1 and Th2 responses by using appropriate adjuvants and antigen delivery systems - Microbial adjuvants, Liposomal and Microparticles as delivery systems; Chemokines and cytokines; Role of soluble mediators in vaccination; Oral immunization and Mucosal Immunity.

Unit V: Vaccine technologies (6 lectures)
New Vaccine Technologies; Rationally designed Vaccines; DNA Vaccination; Mucosal vaccination; New approaches for vaccine delivery; Engineering virus vectors for vaccination; Vaccines for targeted delivery (Vaccine Delivery systems); Disease specific vaccine design: Tuberculosis Vaccine; Malaria Vaccine; HIV/AIDS vaccine; COVID vaccines, New emerging diseases and vaccine needs (Ebola, Zika).

Recommended Textbooks and References:

1. Janeway, C. A., Travers, P., Walport, M., & Shlomchik, M. J. (2005). Immuno Biology: the Immune System in Health and Disease. USA: Garland Science Pub.
2. Kindt, T. J., Osborne, B. A., Goldsby, R. A., & Kuby, J. (2013). Kuby Immunology. New York: W.H. Freeman.
3. Kaufmann, S. H. (2004). Novel Vaccination Strategies. Weinheim: Wiley-VCH.
4. Journal Articles (relevant issues) from: Annual Review of Immunology, Annual Review of Microbiology, Current Opinion in Immunology, Nature Immunology, Expert review of vaccines.

BT CP 508: Laboratory VI - Bioprocess Engineering and Technology (Core Practical - 2 Credits)

Objectives: *The objectives of this laboratory course are to provide hands-on training to students in upstream and downstream unit operations.*

Learning Outcomes: *Students should be able to:1) Investigate, design and conduct experiments, analyse and interpret data, and apply the laboratory skills to solve complex bioprocess engineering problems; 2) Apply skills and knowledge gained will be useful in solving problems typical of bio industries and research.*

1. Scale up from frozen culture vial of industrial important microorganism to agar plate to shake flask culture.
2. Isolation of microorganisms having a character of industrial importance from soil samples.
3. Study of growth kinetics of industrial important microorganisms.
4. Stoichiometric calculations of various bioprocesses.
5. Media optimization using Plackett Burman (PB) design
6. Determination of mixing time and Reynold's number for an agitator.
7. Determination of cell density of industrial yeast cell suspension.
8. Determination of kill curve for industrial yeast.
9. Determination of volumetric oxygen transfer coefficient of bioprocess.

BT CP 509: Laboratory VII: Bioinformatics (Core Practical - 2 Credits)

Course Objectives: *The aim of this course is to provide practical training in bioinformatic methods including accessing major public sequence databases, use of different computational tools to find sequences, analysis of protein and nucleic acid sequences by various software packages.*

Student Learning Outcomes: *On completion of this course, students should be able to:*
• Describe contents and properties of most important bioinformatics databases;
• Perform text- and sequence-based searches and analyze and discuss results in light of molecular biological knowledge;
• Explain major steps in pairwise and multiple sequence alignment, explain principle and execute pairwise sequence alignment by dynamic programming;
• Predict secondary and tertiary structures of protein sequences.

1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
3. Sequence information resource: Using EMBL, Genbank, Entrez, Swissprot/TrEMBL.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
6. Phylogenetic analysis of protein and nucleotide sequences.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
12. Homology modelling of proteins.
13. Use of tools for mutation and analysis of the energy minimization of protein structures.
14. Use of miRNA prediction, designing and target prediction tools.

BT EP 510: Review Writing/Tutorials (Elective Practical - 2 Credits)

Course Objectives: *As a student progresses into training in science on a bench, it is pertinent for them to read the scientific literature and grasp the concepts. In this regard, it is advisable to train the students during the Masters' program to read the literature, formulate the wisdom, and effectively communicate the same with others. One of the ways is to encourage the students to read the literature on a topic of their interest and write a small, concise review. Similarly, the students may also be offered tutorials to enhance understanding in focused areas. The practice of engaging with faculty for review writing or taking tutorials on current topics of research is expected to foster their knowledge and at the same time, it will inculcate the habit of scientific reading and writing.*

Learning Outcomes: *Students will be able to learn and demonstrate the following abilities*

- *Searching relevant literature from different sources.*
- *Formulate appropriate scientific questions.*
- *Articulate the framework of the topic in a concise manner.*
- *Develop wisdom through scientific reading of the literature.*
- *Critical thinking and scientific writing.*

Assessment Criteria*: Every individual student will write a review or report on a tutorial (10-15 pages) on the topic of their interest and submit for evaluation within a stipulated time. The review/Report written by students on focused topic a will be evaluated by an internal faculty member (25 marks) and a scientist/faculty member from outside the Department (25 marks). Accordingly, the scores will be provided as marks for internal and external assessments.*

Structure of the course: Every individual student will write a review or report on a tutorial (10-15 pages) on the topic of their interest and submit for evaluation within a stipulated time.

Recommended Textbooks and References:

1. Paraminder Dhillon. (2022) How to write a good scientific review article. The FEBS Journal 289:3592–3602.
2. How to read a scientific paper (biology): http://www.biochem.arizona.edu/classes/bioc568/papers.htm
3. Manisha Bahl. (2023) A Step-by-Step Guide to Writing a Scientific Review. Journal of Breast Imaging 5: 480–485. https://doi.org/10.1093/jbi/wbad028

BT EP 511: Project proposal preparation and presentation (Elective Practical - 2 Credits)

Course Objectives: *The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.*

Learning Outcomes: *Students should be able to demonstrate the following abilities*

- *Formulate a scientific question;*
- *Present scientific approach to solve the problem;*
- *Interpret, discuss and communicate scientific results in written form;*
- *Gain experience in writing a scientific proposal;*

- *Learn how to present and explain their research findings to the audience effectively.*

Structure of the Course: *Students should first select a lab wherein they would like to pursue their dissertation. Students will be advised to prepare their proposal under the guidance of their supervisors. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest and help them to select a topic for their project proposal preparation and presentation. The topic of the research should be other than their dissertation topic. Students should engage in developing the project proposal in a systematic and concise manner with critical review of literature. Student should be able to provide relevant information sources and appropriately apply qualitative and/or quantitative experimental designs in their proposals.*

Assessment Criteria*: At the end of the Semester, the students will be evaluated at two levels.*

1. *Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students will write the proposal by constructing a logical outline for the project including analysis steps, expected outcomes and prepare a complete research proposal in a designed format of project submission. The proposal will be evaluated by the internal faculty members as internal assessment of 25 marks.*
2. *Project proposal presentation: Students will prepare the presentation of the project and their presentation will be evaluated by the faculty and scientists. Students will be able to defend their proposal for funding on various grounds including objectives and outcomes. They should also be able to discuss the expected outcomes of their work. The presentation will be evaluated by external faculty members, which will be considered as external assessment of 25 marks.*

Recommended Textbooks and References:

1. Sudheesh K, Duggappa DR, Nethra SS. How to write a research proposal? Indian J Anaesth. 2016 Sep;60(9):631-634. doi: 10.4103/0019-5049.190617. PMID: 27729688; PMCID: PMC5037942.
2. Safiah Sidek , Massila Kamalrudin , Mustafa Mat Deris (2019) Writing A Research Proposal (UTeM Press). ISBN 9789672145790.
3. Write a Winning Research Proposal: How to Generate Grant Ideas and Secure Funding Using Research Project. Author: Martins Zaumanis. Peer Recognized Publishing House, UK. ISBN-10: 3907363191; ISBN-13:978-3907363195.

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Semester IV

BT CT 512: Theoretical Foundations of Research Project
(Core Theory - 4 Credits)

Course Objectives: *This course aims to equip students with the fundamental theoretical knowledge and practical skills needed to design and conduct rigorous research projects. Emphasis will be placed on understanding research methodologies, designing experiments, and analyzing data.*

Course Overview: *Overview of Theoretical Frameworks; Conducting a Comprehensive Literature Review; Formulating Research Questions and Hypotheses; Research Design Principles - Sampling Techniques and Strategies; Introduction to Research Methodologies; Quantitative*

Methods: Data Collection and Statistical Analysis; Qualitative Methods: Data Collection Techniques; Coding and Thematic Analysis; Integrating Quantitative and Qualitative Data; Ethical Considerations in Research, Institutional Review Board (IRB) Processes, Interpreting Data and Drawing Conclusions, Writing Research Reports and Papers to reputed peer-reviewed Journals, Designing and Conducting Pilot Studies, Assessing Reliability and Validity; Finalizing Research Proposals; Peer Review and Feedback Sessions

Assessments: Literature review, research proposal, data analysis project, and final exam.

Recommended Textbooks and References:
Selected chapters from research methodology textbooks, journal articles, and supplementary materials provided throughout the course.

BT CT 513: Experimental Design and Innovations in Research Project (2 Credits)

Course Objectives: *This course focuses on fostering innovation within research projects, emphasizing creative problem-solving, identifying research opportunities, and developing ground-breaking methodologies. Students will learn to design and implement innovative research projects that push the boundaries of current knowledge.*

Course Overview: *Introduction to Innovation in Research; Understanding Innovation Ecosystems; Identifying Research Gaps and Opportunities; Techniques for Creative Thinking and Brainstorming; Conducting State-of-the-Art Reviews; Case Studies of Innovative Research; Developing Innovative Research Questions; Formulating Hypotheses for Novel Research; Methodological Approaches for Innovation; Design Thinking in Research; Leveraging Technology and Tools for Innovative Research; Introduction to Emerging Technologies; Prototyping and Experimentation; Pilot Testing Innovative Ideas; Assessing Impact and Scalability; Finalizing and Presenting Research Proposals; Peer Review and Feedback Sessions*

Assessments: Innovation case study, project proposal, prototype development, and final presentation.

Recommended Textbooks and References:
Selected readings from innovation management and research methodology texts, relevant journal articles, and case studies. Additional resources and tools will be provided throughout the course.

BT CT 514: Intellectual Property Rights, Biosafety and Bioethics (Core Theory – 2 credits)

Objectives: *The objectives of this course are:1) To provide basic knowledge on intellectual property rights and their implications in biological research and product development; 2) To become familiar with India's IPR Policy; 3) To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products; 4) To become familiar with ethical issues in biological research. This course will focus on consequences of biomedical research technologies such as cloning of whole organisms, genetic modifications, DNA testing.*

Learning Outcomes: *On completion of this course, students should be able to: 1) Understand the rationale for and against IPR and especially patents; 2) Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations; 3) Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents; 4) Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations; 5) Understand ethical aspects related to biological, biomedical, health care and biotechnology research.*

Unit I: Introduction to intellectual property (5L)

Types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of 'prior art': invention in context of "prior art"; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

Unit II: Patenting (6L)

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

Unit III: Biosafety and Biosecurity (6L)

Introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

Unit IV: National and international regulations (6L)

International regulations: Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations: EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

Unit V: Bioethics (7L)

Introduction, ethical conflicts in biological sciences - interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research – cloning and stem cell research, Human and animal experimentation, animal rights/welfare, Agricultural biotechnology - Genetically engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – biopiracy.

Recommended Textbooks and References:

1. Ganguli, P. (2001). Intellectual Property Rights: Unleashing the Knowledge Economy.
2. New Delhi: Tata McGraw-Hill Pub.
3. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of
4. Commerce, GoI
5. Complete Reference to Intellectual Property Rights Laws. (2007).
6. Snow White Publication Oct.
1. Kuhse, H. (2010). Bioethics: an Anthology. Malden, MA: Blackwell.
2. Office of the Controller General of Patents, Design & Trademarks; Department of
7. Industrial Policy & Promotion; Ministry of Commerce & Industry; Government
8. of India. http://www.ipindia.nic.in/
1. Karen F. Greif and Jon F. Merz, Current Controversies in the Biological Sciences
9. -Case Studies of Policy Challenges from New Technologies, MIT Press
1. World Trade Organisation. http://www.wto.org
2. World Intellectual Property Organisation. http://www.wipo.int
3. International Union for the Protection of New Varieties of Plants. http://www.upov.int
4. National Portal of India. http://www.archive.india.gov.in
5. National Biodiversity Authority. http://www.nbaindia.org
6. Recombinant DNA Safety Guidelines, 1990 Department of Biotechnology, Ministry
10. of Science and Technology, Govt. of India. Retrieved from http://www.envfor.nic.in/
11. divisions/csurv/geac/annex-5.pdf
1. Wolt, J. D., Keese, P., Raybould, A., Fitzpatrick, J. W., Burachik, M., Gray, A., Wu,
12. F. (2009). Problem Formulation in the Environmental Risk Assessment for Genetically
13. Modified Plants. Transgenic Research, 19(3), 425-436. doi:10.1007/s11248-009-9321-9
14. Craig, W., Tepfer, M., Degrassi, G., & Ripandelli, D. (2008). An Overview of General
15. Features of Risk Assessments of Genetically Modified Crops. Euphytica,
16. 164(3), 853-880. doi:10.1007/s10681-007-9643-8
17. Guidelines for Safety Assessment of Foods Derived from Genetically Engineered
18. Plants. 2008.
19. Guidelines and Standard Operating Procedures for Confined Field Trials of

20. Regulated Genetically Engineered Plants. 2008. Retrieved from
21. http://www.igmoris.nic.in/guidelines1.asp
22. Alonso, G. M. (2013). Safety Assessment of Food and Feed Derived from GM
23. Crops: Using Problem Formulation to Ensure "Fit for Purpose" Risk Assessments.
24. Retrieved from http://biosafety.icgeb.org/inhousepublicationscollectionbiosafetyreviews.

BT CT 515: Research Project (Core Theory/Practical - 6 Credits)

Course Objectives:
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes:
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- *In-depth knowledge of the chosen area of research.*
- *Capability to critically and systematically integrate knowledge to identify issues that must be addressed within the framework of specific thesis.*
- *Competence in research design and planning.*
- *Capability to create, analyse and critically evaluate different technical solutions.*
- *Ability to conduct research independently.*
- *Ability to perform analytical techniques/experimental methods.*
- *Project management skills.*
- *Report writing skills.*
- *Problem solving skills.*
- *Communication and interpersonal skills.*

Assessments: *At the end of the Semester, the students will submit the hard copy and soft copy of the dissertation thesis as per guidelines to the dissertation coordinator within the stipulated time. The Thesis will be evaluated at two levels.*

Thesis Evaluation: The dissertation thesis will be evaluated by individual student's supervisor (50% of total marks) and external examiner outside the Department as per preference of the dissertation supervisor.

Thesis Presentation: Two external examiners will evaluate the thesis presentation by individual dissertation student at the Department. One examiner will be from the Department excluding the student's supervisor and another will be from outside the Department.

BT ET 516: Environmental Biotechnology (Elective Theory - 2 Credits)

Objectives: *This course aims to introduce fundamentals of Environmental Biotechnology. The course will introduce major groups of micro-organisms tools in biotechnology and their most important environmental applications. The environmental applications of biotechnology will be presented in detail and will be supported by examples from the national and international literature.*

Learning Outcomes: *On completion of course, students will be able to understand use of basic microbiological, molecular and analytical methods, which are extensively used in environmental biotechnology.*

Unit I: Introduction to environment (6 lectures)
Introduction to environment; pollution and its control; pollution indicators; waste management: domestic, industrial, solid and hazardous wastes; Biodiversity and its conservation; Role of microorganisms in biogeochemical cycles

UNIT II: Biotechnological intervention for restoration of environment (14 L)
Microbial treatment of wastewater (sewage & industrial effluent) - aerobic and anaerobic methods, Solid waste, Sources & management of solid waste – landfill, combustion, incineration and composting, Bioremediation Concept, types of Bioremediation - in situ and ex situ bioremediation, Microbial bioremediation of heavy metals (biotransformation, biosorption & bioaccumulation; Examples Cr,/As/ Se/ Hg) and Xenobiotic compounds (biotransformation & biodegradation: Examples PAHs/ PCBs,/Pesticides/ TNT etc), Phytoremediation concept, types and its applications, Microbial bioleaching,

Unit III: Biotechnology and agriculture (6 lectures)
Bioinsecticides: *Bacillus thuringiensis*, Baculoviruses, uses, genetic modifications and aspects of safety in their use; Biofungicides: Description of mode of actions and mechanisms (e.g. Trichoderma, Pseudomonas fluorescens); Biofertilizers: Symbiotic systems between plants – microorganisms (nitrogen fixing symbiosis, mycorrhiza fungi symbiosis), Plant growth promoting rhizobacteria (PGPR) – uses, practical aspects and problems in application.

Unit IV: Biofuels (6 lectures)
Environmental Biotechnology and biofuels: biogas; bioethanol; biodiesel; biohydrogen; Description of the industrial processes involved, microorganisms and biotechnological interventions for optimization of production; Microbiologically enhanced oil recovery (MEOR); Bioleaching of metals; Production of bioplastics; Production of biosurfactants: bioemulsifiers; Paper production: use of xylanases and white rot fungi.

Recommended Textbooks and References:

1. Environmental Biotechnology, Edited by Hans-Joachim Jördening and Josef Winter
2. Environmental Bioremediation Technologies, Shree N. Singh and Rudra D. Tripathi ((Eds.)
3. Environmental Microbiology: Fundamentals and Applications, Jean-Claude Bertrand • Pierre Caumette Philippe Lebaron • Robert Matheron Philippe Normand • Te´ lesphore Sime-Ngando Editors.

BT ET 517: Stem Cell Technology (Elective Theory - 2 Credits)

Course Objectives: *The objectives of this course are to familiarize the students with different types of stem cells and their use in regenerative medicine and ethics.*

Student learning outcomes: *Students will be able to understand the proliferation and differentiation of stem cells and their applications in Biotechnology.*

Unit I: Basics of Stem Cell Biology (6 lectures)
Origin of stem cells. Characteristics of stem cells. Formation of Totipotent, Pluripotent, and multipotent stem cells. Stem cell types - embryonic stem cells, adult stem cells, cancer stem cells and induced pluripotent stem cells. Similarities and differences between different types of stem cells. Regeneration in vertebrates and invertebrates.

Unit II: Adult Stem cells and iPSCs (6 lectures)
Properties, sources and lab tests of adult stem cells. Different types of adult stem cells including neural stem cells, hematopoietic stem cells, germinal stem cells. Steven's experiment proving that teratoma origins lead to ES cells. Dedifferentiation, trans-differentiation, reprogramming of iPSCs, and methods of producing iPSCs. Stem cells and aging. Molecular mechanisms in cloning (e.g. Dolly).

Unit III: Regenerative Medicine (8 lectures)
Stem cell preparation and therapeutic uses, tissue engineering, cell therapy, gene therapy, bioartificial organs, cell-based immunotherapy, and cell progenitor types and the basics of tissue engineering. Cell Processing and Manufacture, Preclinical Studies, Clinical Research, Stem Cell-based Medical Innovation and Clinical Application

Unit IV: Stem Cell Ethics (10 lectures)
Global regulatory and ethical issues in commercialization of stem cell-based therapy. Ethical concerns associated with Laboratory-based Human Embryonic Stem Cell Research. Ethics involved in Review Processes, Procurement of Biomaterials, Derivation. Issues regarding banking of stem cells from different human sources (umbilical cord, dental pulp etc.).
Concerns related to distribution of Human Pluripotent Stem Cell Lines and Mechanisms for Enforcement and their Clinical Translation.

Recommended Textbooks and References:

1. Scudellari, Megan "A decade of iPS cells" Nature, 534: 310-312
2. Reardon, Sara "Leukaemia success heralds waves of gene-editing therapies" Nature, 527: 146-147.
3. Hall, Stephen "The first tinkering with human heredity may happen in the infertility clinic" Scientific American, Dec 2016.
4. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2008). Molecular Biology of the Cell (5th Ed.). New York: Garland Science.
5. Lodish, H. F. (2016). Molecular Cell Biology (8th Ed.). New York: W.H. Freeman.

6. Regalado, Antonio “Engineering the perfect baby” MIT Technology Review, March 5, 2015
7. Knoblich, Juergen “Building a brain in the lab” Scientific American, Jan 2017.
8. Bredenoord, AL, Clevers, H, Knoblich J (2017) “Human tissues in a dish: The research and ethical implications of organoid technology” Science 355.

BT CP 518: Laboratory VIII-Advanced Laboratory Techniques (Core Practical - 4 Credits)

Objectives: *To introduce students to statistical methods for optimizing media formulations. To familiarize students with microfiltration methods for effectively separating cells from broth in bioprocesses, ensuring product purity and process efficiency. To equip students with the knowledge of advanced analytical techniques such as HPLC, FPLC, GC, and GC-MS for measuring product and substrate concentrations to facilitate process monitoring and control. Also to introduce students to the assays commonly employed in research laboratories at academic as well as industrial setups.*

Learning Outcomes: *Students will able to compare and differentiate the various common types of fermentation processes, identifying their advantages and applications in different biotechnological contexts. Design and implement media optimization experiments using various statistical method, analyzing results to improve microbial growth and product yield. Demonstrate proficiency in using microfiltration to separate cells from fermentation broth, evaluating the effectiveness of different membrane technologies. Use analytical techniques such as HPLC, FPLC, GC, and GC-MS to quantify products and substrates in bioprocesses, interpreting results for process optimization and quality control. Students will able to perform advance assay and could be able to easily employ in their future research.*

Unit I:

1. Assembly of bioreactor and sterilization: Batch fermentation/Fed-batch fermentation/Continuous fermentation.
2. Extraction of intracellular/extracellular fermentation product from broth (antibiotics/proteins) by liquid-liquid extraction techniques.
3. Bioseparations, measurement of amount of metabolites (substrate/product) by various chromatographic techniques like HPLC/FPLC/GC/GC-MS etc.

Unit II:

1. Luciferase reporter assay.
2. Construction of 3d spheroids
3. Quantification of microbial biofilms by using crystal violet and MTT
4. Determining the biofilm structural organization via scanning electron microscopy.
5. Estimation of drug combination effects in cancer: Antagonistic, Additive or Synergistic.
6. DNA methylation analysis (Methylated DNA Immunoprecipitation-RT-PCR)

BT EP 519: Advanced topics in Biotechnology (Elective Theory - 2 Credits)

Objectives: *The objective of this course is to understand the latest techniques used in the field of molecular Biology and Biotechnology.*

Learning outcomes: *The students will be able to gather the information and the application of the selected technique in the field of biotechnology.*

Assessment: *The course will be conducted in the form of student presentations on latest technologies with case studies. Some of the following areas includes*

1. Powerful tools for genome-scale engineering Crisper CAS9, Zinc finger nuclease technology
    a. Clustered regularly interspaced short palindromic repeats (CRISPR)-Cas9, CRISPRa; CRISPRi
    b. Multiplex automated genome engineering (MAGE),
    c. Promoter engineering,
    d. CRISPR-based regulations,
    e. Synthetic small regulatory RNA (sRNA)-based knockdown
2. ChiP Sequencing and Ribosome fingerprinting
3. High C analysis - genome-wide Chromatin Conformation Capture
4. Lentiviral libraries
5. Functional genomics and phenomics
6. Genome wide expression profiling
7. Epigenomic mapping- Tools for study of epigenetic modifications
    a. DNA methylation
    b. Chromatin
    c. RNA
    d. microRNA regulatory activities
    e. Non-coding RNA
8. Gene drive
9. GE techniques as applicable in species conservation
10. Inclusion of any other recent advanced tool and technique developed in the field of genetic engineering.
11. Synthetic Biology
12. Systems Biology

BT EP 520: Seminar (Elective Practical - 2 Credits)

Objective: *The objectives of this course are to familiarize students with recent literature in a specific field to inculcate the research interest, update the knowledge and train the students to read and review the scientific literature. Students will be fascinated to the new frontier areas in particular field of biology and biotechnology, which will instill the inquisitiveness and motivation to pursue career in research and development.*

Learning Outcomes: *Students should be able to read and understand the research article. Moreover, students will read the relevant literature in concurrence with the research paper they*

have selected for Seminar presentation. This will enrich their knowledge as well as they will secure the recent developments in the field.

Assessments: *Students will choose a recently published (during last 2 years) research article of their choice from a reputed research journal and will present the findings and their views about the article. Students will present their seminar on research article in their own class. External and internal subject experts will be available for the evaluation of the presentation by the student.*

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