Department of Biotechnology

School of Engineering and Technology

Nagaland University, (Hqrs: Lumami), Meriema, Kohima

(Central University established by an Act of Parliament No. 35 of 1989)

M.Sc Biotechnology Syllabus (2 Year Program)

Latest Revision: 2025

[Approved by 41st Academic Council (AC:41:11:2) held on 11th November 2025]

Curriculum

First Semester								
Sl. No	**Subject Code**	**Subject Name**	**Contact Hour Per Week**				**Credit**	**Category**
			L	**T**	**P**	**Total**		
Theory Courses								
1	**BTM101**	**Biochemistry**	3	-	-	3	3	DSC
2	**BTM102**	**Immunology**	3	-	-	3	3	DSC
3	**BTM103**	**Bioinformatics**	3	-	-	3	3	DSC
4	**BTM104**	**Microbiology**	3	-	-	3	3	DSC
5	**BTM105**	**Research Methodology and Scientific Communication Skills**	2	-	-	2	2	SEC
6	**BTM106**	**Basics of Mathematics and Statistics**	2	-	-	2	2	GE
7	**BTM107**	**Basics of Chemistry and Physics**	2	-	-	2	2	GE
		Total for theory courses				18	18	
Practical Courses								
1	**BTM111**	**Biochemistry and Analytical Techniques Lab**	-	-	4	4	2	DSC
2	**BTM112**	**Microbiology Lab**	-	-	4	4	2	DSC
3	**BTM113**	**Immunology Lab**	-	-	4	4	2	DSC
		Total for Practical courses				12	6	
		Total for First Semester				30	24	
Second Semester								
Theory Courses								
1	**BTM201**	**Genetic Engineering**	3	-	-	3	3	DSC
2	**BTM202**	**Cell and Molecular Biology**	3	-	-	3	3	DSC
3	**BTM203**	**Plant and Animal Biotechnology**	3	-	-	3	3	DSC
4	**BTM204**	**Genomics and Proteomics**	3	-	-	3	3	DSC
5	**BTM205**	**Elective -I**	2	-	-	2	2	DSE
6	**BTM206**	**Genetics**	2	-	-	2	2	DSC
7	**BTM207**	**Elective II**	2	-	-	2	2	DSE
		Total for theory courses				18	18	
Practical Courses								
1	**BTM211**	**Molecular Biology and Genetic Engineering Lab**	-	-	4	4	2	DSC
2	**BTM212**	**Plant and Animal Biotechnology Lab**	-	-	4	4	2	DSC
		Total for Practical courses				8	4	
		Total for Second Semester				26	22	
Third Semester								
Theory Courses								
1	**BTM301**	**Bioprocess Engineering and Technology**	3	-	-	3	3	DSC
2	**BTM302**	**Emerging Technologies**	3	-	-	3	3	DSC
3	**BTM303**	**Elective III**	2	-	-	2	2	DSE
4	**BTM304**	**Bio entrepreneurship**	2	-	-	2	2	SEC
5	**BTM305**	**Intellectual Property Rights, Biosafety and Bioethics**	3	-	-	3	3	SEC
6	**BTM307**	**Elective IV**	2	-	-	2	2	DSE
		Total for theory courses				15	15	
Practical Courses								
1	**BTM311**	**Bioprocess Engineering and Technology Lab**	-	-	4	4	2	DSC
2	**BTM312**	**Bioinformatics Lab**	-	-	4	4	2	DSC

		Total for Practical courses				8	4	
		Total for the third semester				23	19	
Fourth Semester								
Practical Courses								
1	**BTM411**	**Dissertation**	-	-	40	40	20	
		Total for Practical courses				40	20	
		Total for Fourth Semester				40	20	
		Total for M.Sc Biotechnology				119	85	

Elective Courses:

Semester	Elective	Proposed
2nd	Elective I	Computational & Data-Driven Biotechnology
		Computational Biology
		Internet of Things
		Big Data Analytics
		Artificial Intelligence
	Elective II	Biomedical & Therapeutic Biotechnology
		Drug Discovery and Development
		Molecular Diagnostics
		Rational Drug Discovery
		Vaccines
3rd	Elective III	Molecular & Genetic Engineering
		Genome Editing
		Gene Expression & Transgenetics
		Protein Engineering
		Biosimilars Technology
	Elective IV	Applied & Emerging Technologies
		Biological Imaging
		Environmental Biotechnology
		Nanobiotechnology
		Biomaterials

Scheme of Examination:

a) C1 Examination:20 Marks (As per University Norms)

b) C2 Examination- Internal Assessment: 20 Marks (As per University Norms)

*To appear in the End Semester Examination, the student must appear in all the Mid Semester Examinations.

End-of-Semester Examination for courses is of 60 Marks.

Semester-1

BTM-101: Biochemistry (Credit 3)

Course Objectives:

The objectives of this course are to build upon undergraduate-level knowledge of biochemical principles, with a specific emphasis on different metabolic pathways. The course shall make the students aware of various disease pathologies within the context of each topic.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Gain fundamental knowledge in biochemistry
- Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.

Unit I: Chemical Basis of Life — 7 lectures

Miller-Urey experiment and abiotic formation of biomolecules; composition of living matter; properties and role of water; pH and buffering in biological systems; ionization, hydrophobicity, and emergent properties; biomolecular hierarchy, macromolecules, and molecular assemblies.

Unit II: Protein structure — 4 lectures

Amino acid properties; peptide bonds and protein structure determination; Ramachandran plot and protein evolution; model proteins (myoglobin, hemoglobin, ribonuclease, chymotrypsin); protein purification and characterization; principles of folding (Anfinsen's dogma, Levinthal paradox, free energy landscape, molten globule state, chaperones); protein degradation and folding disorders; basics of molecular dynamics.

Unit III: Enzyme Kinetics and Catalysis — 5 lectures

Principles of enzyme catalysis; Michaelis-Menten kinetics; regulation by activation, inhibition, covalent modification; catalytic antibodies; catalytic strategies (proteases, carbonic anhydrases, restriction enzymes, nucleoside monophosphate kinase); regulation strategies with hemoglobin; isozymes, zymogens, and covalent regulation.

Unit IV: Carbohydrates, Lipids, and Glycobiology — 2 lectures

Monosaccharides, disaccharides, and polysaccharides (glycogen, amylose, cellulose); glycoproteins and glycolipids; lipids and lipoproteins (storage, membrane, signaling lipids); basics of glycolysis, citric acid cycle, pentose phosphate pathway, gluconeogenesis, glycogen metabolism.

Unit V: Structure and Functions of Nucleic Acids — 3 lectures

Nucleosides, nucleotides, DNA and RNA structure; historical development of DNA double helix; differences between RNA and DNA; DNA as the genetic material

Unit VI: Bioenergetics 4 lectures

Principles of bioenergetics and free energy; oxidation of carbon fuels; coupled reactions; oxidative phosphorylation, and photosynthesis; regulation of central metabolism; F1-F0 ATP synthase, mitochondrial shuttles, and chloroplast proton gradients; Calvin cycle; fatty acid metabolism, amino acid catabolism, nucleotide biosynthesis, sterol and cholesterol metabolism (mevalonate pathway); metabolic integration and regulation; vitamins and cofactors in metabolism; TOR, autophagy, starvation responses, insulin signaling.

Recommended Text and reference Books:

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.doi:10.1038/nature02261.
5. Richards, F. M. (1991). *The Protein Folding Problem*. Scientific American, 264(1), 54-63.doi:10.1038/scientificamerican0191-54.

BTM-102:: Immunology (Credit 3)

Course 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 the immune system and the mechanisms by which our body elicits immune response. This will be imperative for students as it will help them to predict about nature of the immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Evaluate usefulness of immunology in different pharmaceutical companies;
- Identify proper research lab working in area of their own interests;
- 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 system7 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; Organs of immune system, primary and secondary lymphoid organs. antigens: immunogens, haptens; Major Histocompatibility Complex: MHC genes, MHC and immune responsiveness and disease susceptibility

Unit II: Immune Response Generated by B- and T-lymphocytes 11 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; 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; Hapten-carrier system

Unit III: Antigen-Antibody Interactions 8 lectures

Precipitation, agglutination and complement mediated immune reactions; 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: Vaccinology 2 lectures

Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology

Unit V: Clinical Immunology 7 lectures

Immunity to infection: bacteria, viral, fungal and parasitic infections; Tolerance, hypersensitivity; autoimmunity; types of autoimmune diseases, Transplantation: immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immune senescence, immune exhaustion in chronic viral infection, NK cells in chronic viral infection and malignancy.

Unit VI: Immunogenetics 5 lectures

Major histocompatibility complex genes and their role in autoimmune and infectious diseases, HLA typing, human major histocompatibility complex (MHC), Complement genes of the human major histocompatibility complex: implication for linkage disequilibrium and disease associations, genetic studies of rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis

Recommended Text and reference Books:

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. 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.

BTM-103:: Bioinformatics (Credit 3)

Course 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.

Students Learning Outcomes:

On completion of this course, students 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 analyses and interpret results of their study.

Unit I: Bioinformatics Basics — 7 lectures

Bioinformatics basics: Computers in biology and medicine; Introduction to Unix and Linux systems and basic commands; Database concepts; Protein and nucleic acid databases; Structural databases; Biological XML DTD's; pattern matching algorithm basics; databases and search tools: biological background for sequence analysis; Identification of protein sequence from DNA sequence; searching of databases similar sequence; NCBI; publicly available tools; resources at EBI; resources on web; database mining tools.

Unit II: DNA Sequence Analysis — 8 lectures

DNA sequence analysis: gene bank sequence database; submitting DNA sequences to databases and database searching; sequence alignment; pair wise alignment techniques; motif discovery and gene prediction; local structural variants of DNA, their relevance in molecular level processes, and their identification; assembly of data from genome sequencing.

Unit III: Multiple Sequence Analysis — 7 lectures

Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTALW and CLUSTALX for multiple sequence alignment; submitting DNA protein sequence to databases: where and how to submit, SEQUIN, genome centre's; submitting aligned sets of sequences, updating submitted sequences, methods of phylogenetic analysis.

Unit IV: Protein Modelling — 8 lectures

Protein modelling: introduction; force field methods; energy, buried and exposed residues; side chains and neighbors; fixed regions; hydrogen bonds; mapping properties onto surfaces; fitting monomers; RMS fit of conformers; assigning secondary structures; sequence alignment-methods, evaluation, scoring; protein completion: backbone construction and side chain addition; small peptide methodology; software accessibility; building peptides; protein displays; substructure manipulations, annealing.

Unit V: Protein Structure Prediction and Virtual Library 9 lectures

Protein structure prediction: protein folding and model generation; secondary structure prediction; analyzing secondary structures; protein loop searching; loop generating methods; homology modelling: potential applications, description, methodology, homologous sequence identification; align structures, align model sequence; construction of variable and conserved regions; threading techniques; topology fingerprint approach for prediction; evaluation of alternate models; structure prediction on a mystery sequence; structure aided sequence techniques of structure prediction; structural profiles, alignment algorithms, mutation tables, prediction, validation, sequence based methods of structure prediction, prediction using inverse folding, fold prediction; significance analysis, scoring techniques, sequence-sequence scoring; protein function prediction; elements of in silico drug design; Virtual library: Searching Pub Med, current content, science citation index and current awareness services, electronic journals, grants and funding information.

Recommended Text and reference Books:

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.

BTM-104:: Microbiology (Credit 3)

Course Objectives:

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

Students Learning Outcomes:

On completion of this course, students should be able to:

- Identify major categories of microorganisms and analyze their classification, diversity, and ubiquity
- Identify and demonstrate structural, physiological, and genetic similarities and differences of major categories of microorganisms
- Identify and demonstrate how to control microbial growth
- Demonstrate and evaluate interactions between microbes, hosts and the environment.

Unit I: Microbial Characteristics — 8 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 — 9 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 archaea, Thermoplasm; eukarya: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes.

Unit III: Control of Microorganisms — 5 lectures

Sterilization, disinfection, and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, and biological control of microorganisms.

Unit IV: Virology — 8 lectures

Virus and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles – viroids and prions.

Unit V: Host-Microbes Interactions — 9 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; prebiotics and probiotics.

Recommended Text and reference Books:

1. Pelczar, M. J., Reid, R. D., & Chan, E. C. (2001). *Microbiology* (5th ed.). New York: McGraw-Hill.
2. Willey, J. M., Sherwood, L., Woolverton, C. J., Prescott, L. M., & Willey, J. M. (2011). *Prescott's Microbiology*. New York: McGraw-Hill.
3. Matthai, W., Berg, C. Y., & Black, J. G. (2005). *Microbiology, Principles and Explorations*. Boston, MA: John Wiley & Sons.

BTM-105:: Research Methodology & Scientific Communication (Credit 2)

Course Objectives:

The objectives of this course are to give background on history of science, emphasizing methodologies used to do research, use framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics.

Students Learning Outcomes:

On completion of this course, 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.

Unit I: Foundations of Science and Research Methodologies — 4 lectures

History and philosophy of science; empirical science and the scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist versus holistic biology.

Unit II: Research Preparation and Ethics — 3 lectures

Choosing a mentor, lab, and research problem; maintaining a lab notebook; introduction to research ethics and integrity; plagiarism and plagiarism-detection tools; scientific misconduct and responsible research practices.

Unit III: Process of Scientific Communication — 6 lectures

Principles of effective communication; setting goals and outcomes; barriers and strategies to overcome them; non-verbal communication, body language, cultural sensitivity, and listening skills; creating value in professional and scientific conversations.

Unit IV: Scientific Writing and Publication — 8 lectures

Types of technical and scientific documents; structure of scientific papers including title, abstract, introduction, methods, results, discussion, and references; drafting effective titles and abstracts; writing style and coherence; plagiarism and referencing; publication process, peer review, open access, ethical issues; writing review articles, reports, and project proposals.

Unit V: Oral and Visual Scientific Communication — 5 lectures

Designing and delivering scientific presentations; use of visual aids (PowerPoint, posters, infographics); scientific poster preparation and presentation; defending during Q&A; participation in group discussions and academic debates.

Unit VI: Digital Literacy and Research Tools — 4 lectures

Information searching and web browsing skills; use of search engines, databases, and hidden web; effective email communication; reference managers (Mendeley, EndNote, Zotero); emerging tools for research collaboration and networking.

Recommended Text and reference Books:

1. Valiela, I. (2001). Doing Science: Design, Analysis, and Communication of Scientific Research. Oxford: Oxford University Press.
2. On Being a Scientist: a Guide to Responsible Conduct in Research. (2009).
3. Washington, D.C.: National Academies Press. Gopen, G. D., & Smith, J. A.
4. The Science of Scientific Writing. American Scientist, 78 (Nov-Dec 1990), 550-558. Mohan, K., & Singh, N. P. (2010).
5. Speaking English Effectively. Delhi: Macmillan India. Movie: Naturally Obsessed, The Making of a Scientist.

BTM-106:: Basics of Mathematics and Statistics (Credit 2)

Course Objectives:

The objective of this course is to give conceptual exposure of essential contents of mathematics and statistics to students.

Students Learning Outcomes:

Students should be able to

- Gain broad understanding in mathematics and statistics;
- Recognize importance and value of mathematical and statistical thinking, training, and approach to problem solving, on a diverse variety of disciplines

Unit I: Algebra — 6 lectures

Linear equations, functions: slopes-intercepts, forms of two-variable linear equations; constructing linear models in biological systems; quadratic equations (solving, graphing, features of, interpreting quadratic models etc.), introduction to polynomials, graphs of binomials and polynomials; Symmetry of polynomial functions, basics of trigonometric functions, Pythagorean theory, graphing and constructing sinusoidal functions, imaginary numbers, complex numbers, adding-subtracting-multiplying complex numbers, basics of vectors, introduction to matrices.

Unit II: Calculus — 4 Lecture

Differential calculus (limits, derivatives), integral calculus (integrals, sequences and series etc.).

Unit III: Mathematical Models in Biology — 4 Lecture

Population dynamics; oscillations, circadian rhythms, developmental patterns, symmetry in biological systems, fractal geometries, size-limits & scaling in biology, modeling chemical reaction networks and metabolic networks.

Unit IV: Statistics — 5 Lecture

Probability: counting, conditional probability, discrete and continuous random variables; Error propagation; Populations and samples, expectation, parametric tests of statistical significance, nonparametric hypothesis tests, linear regression, correlation & causality, analysis of variance, factorial experiment design.

Recommended Text and reference Books:

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.

BTM-107:: Basics of Chemistry and Physics (Credit 2)

Course Objectives:

The objectives of this course are to cover all essentials required to appreciate physico-chemical principles underlying biological processes.

Students Learning Outcomes:

Students should be able to have a firm foundation in fundamentals and application of current chemical and physical scientific theories.

Unit I: Basic Physics for Biologists 12 lectures (10 Hours Teaching + 2 Hour Tutorials)

Physical quantities and their dynamics: definitions and dimensions; vectors & scalars, displacement, velocity, acceleration, kinematic formulas, angular momentum, torque etc. force, power, work, energy (kinetic & potential/electric charge separation, electromagnetic spectrum, photons etc.); springs & Hookes laws; elastic and inelastic collisions; Newton's law of motions (centripetal and centrifugal forces etc.); simple harmonic motions, mechanical waves, Doppler effect, wave interference, amplitude, period, frequency & wavelength; diffusion, dissipation, random walks, and directed motions in biological systems; low Reynolds number - world of Biology, buoyant forces, Bernoulli's equation, viscosity, turbulence, surface tension, adhesion; laws of thermodynamics: Maxwell Boltzmann distribution, conduction, convection and radiation, internal energy, entropy, temperature and free energy, Maxwell's demon (entropic forces at work in biology, chemical assemblies, self-assembled systems, role of ATP); Coulomb's law, conductors and insulators, electric potential energy of charges, nerve impulses, voltage gated channels, ionic conductance; Ohms law (basic electrical quantities: current, voltage & power), electrolyte conductivity, capacitors and capacitance, dielectrics; various machines in biology i.e. enzymes, allostery and molecular motors (molecules to cells and organisms).

Unit II: Basic Chemistry for Biologists 12 lectures (10 Hours Teaching + 2 Hour Tutorials)

Basic constituents of matter - elements, atoms, isotopes, atomic weights, atomic numbers, basics of mass spectrometry, molecules, Avogadro number, molarity, gas constant, molecular weights, structural and molecular formulae, ions and polyatomicions; chemical reactions, reaction stoichiometry, rates of reaction, rate constants, order of reactions, Arrhenious equation, Maxwell Boltzmann distributions, rate-determining steps, catalysis, free-energy, entropy and enthalpy changes during reactions; kinetic versus thermodynamic controls of a reaction, reaction equilibrium (equilibrium constant); light and matter interactions (optical spectroscopy, fluorescence, bioluminescence, paramagnetism and diamagnetism, photoelectron spectroscopy; chemical bonds (ionic, covalent, Van der Walls forces); electronegativity, polarity; VSEPR theory and molecular geometry, dipole moment, orbital hybridizations; states of matter - vapor pressure, phase diagrams, surface tension, boiling and melting points, solubility, capillary action, suspensions, colloids and solutions; acids, bases and pH - Arrhenious theory, pH, ionic product of water, weak acids and bases, conjugate acid-base pairs,

buffers and buffering action etc; chemical thermodynamics - internal energy, heat and temperature, enthalpy (bond enthalpy and reaction enthalpy), entropy, Gibbs free energy of ATP driven reactions, spontaneity versus driven reactions in biology; redox reactions and electrochemistry - oxidation-reduction reactions, standard cell potentials, Nernst equation, resting membrane potentials, electron transport chains (ETC) in biology, coupling of oxidative phosphorylations to ETC; theories of ATP production and dissipation across biological membranes; bond rotations and molecular conformations - Newman projections, conformational analysis of alkanes, alkenes and alkynes; functional groups, optically asymmetric carbon centers, amino acids, proteins, rotational freedoms in polypeptide backbone (Ramachandran plot).

Recommended Text and reference Books:

1. Baaquie, B. E. (2000). Laws of Physics: a Primer. Singapore: National University of Singapore.
2. Matthews, C. P., & Shearer, J. S. (1897). Problems and Questions in Physics. New York: Macmillan Company.
3. Halliday, D., Resnick, R., & Walker, J. (1993). Fundamentals of Physics. New York: Wiley.
4. Ebbing, D. D., & Wrighton, M. S. (1990). General Chemistry. Boston: Houghton Mifflin.
5. Averill, B., & Eldredge, P. (2007). Chemistry: Principles, Patterns, and Applications. San Francisco: Benjamin Cummings.
6. Mahan, B. H. (1965). University Chemistry. Reading, MA: Addison-Wesley Pub.
7. Cantor, C. R., & Schimmel, P. R. (2004). Biophysical Chemistry. San Francisco: W.H. Freeman.

BTM-111:: Biochemistry & Analytical Techniques Lab (Credit 2)

Course 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.

Students Learning Outcomes:

On completion of this course, students should be able to:

- To elaborate concepts of biochemistry with easy to run experiments;
- To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in biochemistry.

Syllabus

1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer- Lambert's Law.
4. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.
5. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution's choice).
    a. Preparation of cell-free lysates
    b. Ammonium Sulfate precipitation
    c. Ion-exchange Chromatography
    d. Gel Filtration
    e. Affinity Chromatography
    f. Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
    g. Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification)
    h. Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
    i. Enzyme Kinetic Parameters: Km, Vmax and Kcat.
6. Experimental verification that absorption at OD_{260} is more for denatured DNA as compared to native double stranded DNA. Reversal of the same following DNA renaturation. Kinetics of DNA renaturation as a function of DNA size.
7. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools. (Optional Experiments)
8. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy).
9. Determination of mass of small molecules and fragmentation patterns by Mass Spectrometry.

BTM-112:: Microbiology Lab (Credit 2)

Course Objectives:

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

Students Learning Outcomes:

On completion of this course, 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

Syllabus

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

Recommended Text and reference Books:

1. Cappuccino, J. G., & Welsh, C. (2016). *Microbiology: a Laboratory Manual*. Benjamin-Cummings Publishing Company.
2. Collins, C. H., Lyne, P. M., Grange, J. M., & Falkinham III, J. (2004). *Collins and Lyne's Microbiological Methods* (8th ed.). Arnolds.
3. Tille, P. M., & Forbes, B. A. *Bailey & Scott's Diagnostic Microbiology.*

BTM-113:: Immunology (Credit 2)

Course 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.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Evaluate usefulness of immunology in different pharmaceutical companies
- Identify proper research lab working in area of their own interests
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in setting of infection (viral or bacterial) by looking at cytokine profile.

Syllabus

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

Semester-2

BTM-201 :: Genetic Engineering (Credit 3)

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.

Students 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 practicals 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 of Genetic Engineering — 6 lectures

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

Unit II: Different Types of Vectors — 7 lectures

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

Unit III: PCR and Variants of PCR — 7 lectures

Principles of PCR: primer design; fidelity of thermo stable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.

Unit IV: Gene Manipulation and Protein-DNA Interaction 7 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 Silencing and Genome Editing Technologies 13 lectures

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; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.

Recommended Text and reference Books:

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

BTM-202 :: Cell and Molecular Biology (Credit 3)

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.

Students 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 — 6 lectures

Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes.

Unit II: Chromatin Structure and Dynamics — 12 lectures

Chromatin organization - histone and DNA interactome: structure and assembly of eukaryotic and prokaryotic DNA polymerases, DNA-replication, repair and recombination; chromatin control: gene transcription and silencing by chromatin-Writers,-Readers and –Erasers; Transcriptional control: Enzymes, enhancers, repressor, promoters, and transcription factors; trancriptional initiation, elongation and termination; post-transcriptional modification, breakdown of selective and specific mRNAs through interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; Genetic codes and their characteristics, 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 III: Cellular Trafficking — 3 lectures

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 IV: Cellular Processes — 8 lectures

Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and trans-membrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.

Unit V: Cellular Signalling — 3 lectures

Introduction to cell signalling, Components of a signalling pathway, Secondary messengers, Signaling pathways and receptor systems (GPCRs, RTKs, intracellular messengers such as

cAMP, DAG, IP_3, Ca^{2+}), MAP kinase cascades, Ras signaling, and nuclear receptor pathways, Misregulation of signaling in diseases like cancer

Unit VI: Genome Instability and Cell Transformation 8 lectures

Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.

Recommended Text and reference Books:

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.

BTM-203:: Plant and Animal Biotechnology (Credit 3)

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.

Students 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 Tissue Culture — 10 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; 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 — 10 lectures

Genetic engineering: Agrobacterium-plant interaction; virulence; Ti and Ri plasmids; opines and their significance; T-DNA transfer; disarmed Ti plasmid; Genetic transformation - Agrobacterium-mediated gene delivery; cointegrate and binary vectors and their utility; direct gene transfer - PEG-mediated, electroporation, particle bombardment and alternative methods; screenable and selectable markers; characterization of transgenics; chloroplast transformation; marker-free methodologies; advanced methodologies - cisgenesis, intragenesis and genome editing; molecular pharming - concept of plants as bio factories, production of industrial enzymes and pharmaceutically important compounds.

Unit III: Animal Reproductive Biotechnology and Vaccinology — 8 lectures

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

Vaccinology: history of development of vaccines, introduction to the concept of vaccines, conventional methods of animal vaccine production, recombinant approaches to vaccine production, modern vaccines.

Unit IV: Plant and Animal Genomics 4 lectures

Overview of genomics – definition, complexity and classification; need for genomics level analysis; methods of analyzing genome at various levels – DNA, RNA, protein, metabolites and phenotype; genome projects and bioinformatics resources for genome research – databases; overview of forward and reverse genetics for assigning function for genes.

Unit V: Molecular Mapping and Marker-Assisted Selection 8 lectures

Molecular markers - hybridization and PCR based markers RFLP, RAPD, STS, SSR, AFLP, SNP markers; DNA fingerprinting-principles and applications; introduction to mapping of genes/QTLs; marker-assisted selection - strategies for Introducing genes of biotic and abiotic stress resistance in plants: genetic basis for disease resistance in animals; molecular diagnostics of pathogens in plants and animals; detection of meat adulteration using DNA based methods.

Recommended Text and reference Books:

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

BTM-204:: Genomics and Proteomics (Credit 3)

Course Objectives:

The objectives of this course are to provide introductory knowledge concerning genomics, proteomics and their applications.

Students 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 — 4 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 — 3 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- 16Sr RNA 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, iso electric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, proteome databases.

Unit VI: Proteomics — 8 lectures

Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in genome, gene function- forward and reverse genetics, gene ethics; protein protein and protein-DNA interactions; protein chips and functional proteomics; clinical and biomedical applications of proteomics; introduction to metabolomics, lipidomics, metagenomics and systems biology.

Recommended Text and reference Books:

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.

BTM-206:: Genetics (Credit 2)

Course 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.

Students Learning Outcomes:

On successful completion of this course, students will be able :

- Describe fundamental molecular principles of genetics;
- Understand relationship between
- phenotype and genotype in human genetic traits;
- Describe the basics of genetic mapping;
- Understand how gene expression is regulated

Unit I: Genetics of Bacterial and Bacteriophages — 7 lectures

Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; 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

Non-Mendelian and Mendelian ratios, Meiotic crosses, tetrad analyses, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, transposon mutagenesis, synthetic lethality, genetic epistasis

Unit III: *Drosophila* Genetics as a Model of Higher Eukaryotes — 7 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. Cancer genetics (hereditary, familial, oncogenes)

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, Fisher's theorem, Hardy- Weinberg equilibrium, linkage disequilibrium; in-breeding depression & mating systems; population bottlenecks, migrations;

Unit V: Quantitative genetics of complex traits (QTLs) and Plant Genetics — 4 lectures

Complex traits, Laws of segregation in plant crosses, inbreeding, selfing, heterosis, gene pyramiding

Recommended Text and reference Books:

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.

BTM-211:: Molecular Biology and Genetic Engineering Lab (Credit 2)

Course Objectives:

The objectives of this course are to provide students with experimental knowledge of molecular biology and genetic engineering.

Students 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.

Syllabus

1. Concept of lac-operon: a) Lactose induction of B-galactosidase. b) Glucose Repression. c) Diauxic growth curve of *E.coli*
2. UV mutagenesis to isolate amino acid auxotroph
3. Phage titre with epsilon phage/M13
4. Genetic Transfer-Conjugation, gene
5. Plasmid DNA isolation and DNA quantitation
6. Restriction Enzyme digestion of plasmid DNA
7. Agarose gel electrophoresis
8. Polymerase Chain Reaction and analysis by agarose gel electrophoresis 9. Vector and Insert Ligation
9. Preparation of competent cells
10. Transformation of *E.coli* with standard plasmids, Calculation of transformation efficiency
11. Confirmation of the insert by Colony PCR and Restriction mapping
12. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in *E.coli,* SDS-PAGE analysis
13. Purification of His-Tagged protein on Ni-NTA columns a) Random Primer labeling b) Southern hybridization.

Recommended Text and reference Books:

1. Green, M. R., & Sambrook, J. (2012). Molecular Cloning: a Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.

BTM-213:: Plant and Animal Biotechnology Lab (Credit 2)

Course Objectives:

The objectives of this course are to provide hands-on training in basic experiments of plant and animal biotechnology.

Students Learning Outcomes:

On completion of course, students should be able to gain basic skills in plant and animal biotechnology.

Syllabus: Plant Biotechnology

1. Prepare culture media with various supplements for plant tissue culture.
2. Prepare explants of *Valleriana wallichii* for inoculation under aseptic conditions.
3. Attempt *in vitro* andro and gynogenesis in plants *(Datura stramonium)*.
4. Isolate plant protoplast by enzymatic and mechanical methods and attempt fusion by PEG (available material).
5. Culture *Agrobacterium tumefaciens* and attempt transformation of any dicot species.
6. Generate an RAPD and ISSR profile of *Eremurus persicus* and *Valleriana wallichii*.
7. Prepare karyotypes and study the morphology of somatic chromosomes of *Allium cepa, A. sativum, A. tuberosum* and compare them on the basis of karyotypes.
8. Pollen mother cell meiosis and recombination index of select species (One achiasmate, and the other chiasmate) and correlate with generation of variation.
9. Undertake plant genomic DNA isolation by CTAB method and its quantitation by visual as well as spectrophotometeric methods.
10. 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.
11. Study genetic fingerprinting profiles of plants and calculate polymorphic information content.

Syllabus: Animal Biotechnology

1. Count cells of an animal tissue and check their viability.
2. Prepare culture media with various supplements for plant and animal tissue culture.
3. Prepare single cell suspension from spleen and thymus.
4. Monitor and measure doubling time of animal cells.
5. Chromosome preparations from cultured animal cells.
6. Isolate DNA from animal tissue by SDS method.
7. Attempt animal cell fusion using PEG.

Semester-2 (Elective-I)

BTM-205:: Computational Biology (Credit 2)

Course Objectives:

The objective of this course is to provide students with theory and practical experience of essentials to aid for genomic, proteomic and metabolomics courses and drug design program.

Students Learning Outcomes:

On completion of this course, the students are expected to:

- Develop an understanding of the basic theory of these computational tools.
- Develop required database extraction, integration, coding for computational tools and methods necessary for all Omics.
- Create hypothesis for investigating specific contemporary biological questions, provide help to experiment with or develop appropriate tools.
- Critically analyze and interpret results of their study with respect to whole systems.

Unit I: Introduction to Computational Biology Basics and Biological Databases 4 lectures

Computers in biology and medicine; Overview of biological databases, nucleic acid & protein databases, primary, secondary, functional, composite, structural classification database, Sequence formats & storage, Access databases, Extract and create sub databases, limitations of existing databases.

Unit II: Pairwise and Multiple Sequence Alignments 5 lectures

Local alignment, Global alignment, Scoring matrices – PAM, BLOSUM, Gaps and penalties, Dot plots. Dynamic programming approach: Needleman and Wunsch Algorithm, Smith and Waterman Algorithm. Hidden Markov Model: Viterbi Algorithm. Heuristic approach: BLAST, FASTA. Building Profiles, Profile-based functional identification.

Unit III: Genome Analysis 6 lectures

Polymorphisms in DNA sequence, Introduction to Next Generation Sequencing technologies, Whole Genome Assembly and challenges, Sequencing and analysis of large genomes, Gene prediction, Functional annotation, Comparative genomics, Probabilistic functional gene networks, Human genome project, Genomics and crop improvement. Study available GWAS, ENCODE, HUGO projects; Extract and build sub-databases; Visualization tools including Artemis and Vista for genome comparison; Functional genomics case studies.

Unit IV: Structure Visualization 3 lectures

Retrieving and drawing structures, Macromolecule viewing platforms, Structure validation and correction, Structure optimization, Analysis of ligand-protein interactions; Tools such as PyMol or VMD.

Unit V: Molecular Modelling 6 lectures

Significance and need, Force field methods, Energy, Buried and exposed residues, Side chains and neighbours, Fixed regions, Hydrogen bonds, Mapping properties onto surfaces, RMS fit of

conformers and protein chains, Assigning secondary structures, Sequence alignment: methods, evaluation, scoring. Protein curation: Backbone construction and side chain addition. Different types of protein chain modelling: ab initio, homology, hybrid, loop. Template recognition and alignments, Modelling parameters and considerations, Model analysis and validation, Model optimization, Substructure manipulations, Annealing, Protein folding and model generation, Loop generating methods, Loop analysis. Analysis of active sites using different methods in studying protein–protein interactions.

Unit VI: Structure-Based Drug Development 6 lectures

Molecular docking: Types and principles, Semi-flexible docking, Flexible docking. Ligand and protein preparation, Macromolecule and ligand optimization, Ligand conformations, Clustering, Analysis of docking results and validation with known information. Extra-precision docking platforms, Use of small-molecule libraries, Natural compound libraries for virtual high-throughput screenings.

Unit VI: Ligand-based Drug Development 6 lectures

Quantitative structure-activity relationships; Introduction to chemical descriptors like 2D, 3D, and Group-based; Radar plots and contribution plots, and Activity predictions. Pharmacophore modeling, Pharmacophore-based screenings of compound library, Analysis, and experimental validation.

Recommended Text and Reference Books:

1. Mount, D. W. (2001). *Bioinformatics: Sequence and Genome Analysis*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
2. Bourne, P. E., & Gu, J. (2009). *Structural Bioinformatics*. Hoboken, NJ: Wiley-Liss.
3. Lesk, A. M. (2004). *Introduction to Protein Science: Architecture, Function, and Genomics*. Oxford: Oxford University Press.
4. Campbell, M., & Heyer, L. J. (2006). *Discovering Genomics, Proteomics and Bioinformatics*. Pearson Education.
5. Oprea, T. (2005). *Chemoinformatics in Drug Discovery*, Volume 23. Wiley Online Library.
6. Gasteiger, J., & Engel, T. (2003). *Chemoinformatics: A Textbook*. Wiley Online Library.

Semester-2 (Elective-I)

BTM-205 :: Artificial Intelligence (Credit 2)

Course Objectives:

The objective of this course is to provide students with a comprehensive understanding of the fundamental concepts, methodologies, and applications of Artificial Intelligence, including search strategies, probabilistic reasoning, decision-making processes, and reinforcement learning, to enable them to design and implement intelligent systems.

Students Learning Outcomes:

On completion of this course, students will be able to apply search and heuristic methods for problem-solving; use probabilistic models and Bayesian networks for reasoning under uncertainty; formulate and solve decision-making problems using Markov decision processes; implement reinforcement learning methods such as Q-learning and temporal difference learning; and critically analyze AI techniques to develop effective, real-world intelligent solutions.

Unit I: Introduction

Concept of AI, history, current status, scope, agents, environments, problem formulations, review of tree and graph structures, state space representation, search graph and search tree

Unit II: Search Algorithms

Random search, search with closed and open list, depth and breadth first search, heuristic search, best first search, A* algorithm, game search

Unit III: Probabilistic Reasoning

Probability, conditional probability, Bayes rule, Bayesian networks – representation, construction and inference, temporal model, hidden Markov model

Unit IV: Markov Decision Process

MDP formulation, utility theory, utility functions, value iteration, policy iteration and partially observable MDPs

Unit V: Reinforcement Learning

Passive reinforcement learning, direct utility estimation, adaptive dynamic programming, temporal difference learning, active reinforcement learning – Q learning.

Recommended Text and reference Books:

1. Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3rd Edition, Prentice Hall.
2. Elaine Rich and Kevin Knight, *Artificial Intelligence*, Tata McGraw Hill.
3. Trivedi, M.C., *A Classical Approach to Artificial Intelligence*, Khanna Publishing House, Delhi.
4. Saroj Kaushik, *Artificial Intelligence*, Cengage Learning India, 2011.
5. David Poole and Alan Mackworth, *Artificial Intelligence: Foundations for Computational Agents*, Cambridge University Press, 2010.

Websites

1. https://nptel.ac.in/courses/106105077
2. https://nptel.ac.in/courses/106106126
3. https://aima.cs.berkeley.edu
4. https://ai.berkeley.edu/project_overview.html (for Practicals)

Semester-2 (Elective-I)

BTM-205:: Internet of Things (IoT) (Credit 2)

Course Objectives:

The objective of this course is to introduce students to the architecture, design principles, technologies, hardware, software, applications, and security aspects of the Internet of Things (IoT), enabling them to develop and analyze IoT solutions for real-world scenarios.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Understand IoT architecture, design principles, networking, and communication fundamentals.
- Demonstrate knowledge of IoT hardware, software components, and programming APIs for device integration and communication protocols.
- Develop IoT applications and analyze case studies across domains such as healthcare, agriculture, transportation, and home automation.

Unit I: Introduction to IoT

Architectural overview, design principles and needed capabilities, IoT applications, sensing, actuation, basics of networking, M2M and IoT technology fundamentals, devices and gateways, data management, business processes in IoT, Everything as a Service (XaaS), role of cloud in IoT, security aspects in IoT.

Unit II: Elements of IoT

Hardware components: computing (Arduino, Raspberry Pi), communication, sensing, actuation, I/O interfaces; software components: programming APIs (using Python/Node.js/Arduino) for communication protocols – MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP.

Unit III: IoT Application Development

Solution framework for IoT applications, implementation of device integration, data acquisition and integration, device data storage – unstructured data storage on cloud/local server, authentication and authorization of devices.

Unit IV: IoT Case Studies

Case studies and mini projects based on industrial automation, transportation, agriculture, healthcare, and home automation.

Recommended Text and reference Books:

1. Vijay Madisetti, Arshdeep Bahga, *Internet of Things: A Hands-on Approach*, University Press.
2. Jeeva Jose, *Internet of Things*, Khanna Publishing House, New Delhi, 2018.
3. S.R.N. Reddy, Rachit Thukral, Manasi Mishra, *Introduction to Internet of Things: A Practical Approach*, ETI Labs.
4. Pethuru Raj, Anupama C. Raman, *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC Press.
5. Adrian McEwen, *Designing the Internet of Things*, Wiley.
6. Raj Kamal, *Internet of Things: Architecture and Design*, McGraw Hill.
7. Cuno Pfister, *Getting Started with the Internet of Things*, O'Reilly Media.

Semester-2 (Elective-II)

BTM-207:: Drug Discovery and Development (Credit 2)

Course Objectives:

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

Students Learning Outcomes:

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

Unit I: Target Identification and Molecular Modelling 7 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 the identification of lead compounds. Rational drug design, based on understanding the three-dimensional structures and physicochemical properties of drugs and receptors. Modelling drug/receptor interactions with emphasis on molecular mechanisms, molecular dynamics simulations, and homology modelling. Conformational sampling, macromolecular folding, structural bioinformatics, receptor-based and ligand-based design and docking methods, in silico screening of libraries, semi-empirical and ab initio methods, QSAR methods, molecular diversity, design of combinatorial libraries of drug-like molecules, macromolecular and chemical databases.

Unit II: Lead Optimization 5 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 (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 5 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; Scope of GLP, SOP for conduct of clinical and non-clinical testing, 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 Trial 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 Affair 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 setup, Animal ethical issues and compliance.

Recommended Text and reference Books:

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

Semester-2 (Elective-II)

BTM-207:: Molecular Diagnosis (Credit 2)

Course 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- or post-natal analysis of genetic diseases and identification of individuals predisposed to disease ranging from common cold to cancer.

Students 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 — 4 lectures

DNA, RNA, Protein: An overview; chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs.

Unit II: Molecular Markers — 5 lectures

Random Amplification of Polymorphic DNA (RAPD), Genomic library and cDNA library DNA, polymorphism as genetic markers, Restriction Fragment Length Polymorphism (RFLP), Amplified Fragment Length Polymorphism (AFLP), DNA fingerprinting

Unit III: Diagnostic Metabolomics — 2 lectures

Metabolite profiles for biomarker detection the body fluids/tissues in various metabolic disorders by making 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: 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.

Unit VI: Quality Assurance and Control — 1 lectures

Quality oversight; regulations and approved testing.

Recommended Text and reference Books:

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. 20
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.

Semester-2 (Elective-II)

BTM-207:: Rational Drug Delivery (Credit 2)

Course Objectives:

The objective of this course is to introduce students to molecular modeling and computational techniques applied in modern drug discovery. The course emphasizes computer-aided drug design, molecular mechanics, quantum mechanics, docking, molecular dynamics, pharmacophore modeling, and QSAR.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Explain the principles and workflow of drug discovery using bioinformatics and computational tools.
- Apply molecular mechanics and quantum mechanics concepts in drug design.
- Derive pharmacophore models and apply QSAR methodologies in drug discovery.
- Critically assess ADMET properties and design drug-like compounds.

Unit I: Molecular Modelling in Drug Discovery

Drug discovery process; role of bioinformatics in drug design; methods of computer-aided drug design; ligand design methods; drug design approaches; target identification and validation; lead optimization and validation; structure- and ligand-based drug design; modeling of target-small molecule interactions; molecular simulations; protein modeling.

Unit II: Quantum Mechanics and Molecular Mechanics

Features of molecular mechanics force fields; bond structure and bending angles; electrostatic, van der Waals, and non-bonded interactions; hydrogen bonding in molecular mechanics; derivatives of molecular mechanics energy function; applications of energy minimization.

Unit III: Molecular Dynamics Simulation Methods

Molecular dynamics using simple models; molecular dynamics with continuous potentials and at constant temperature and pressure; time-dependent properties; solvent effects in molecular dynamics; conformational changes from molecular dynamics simulation and applications.

Unit IV: Molecular Docking and Lead Optimization

Molecular docking; types of molecular docking, docking algorithms and programs; structure-based methods to identify lead compounds; de novo ligand design; applications of 3D database searching and virtual screening; strategies for target identification and validation, lead identification, optimization and validation; combinatorial chemistry and library design; drug likeness and compound filtering; ADMET property prediction; computer-based tools for drug design.

Unit V: Pharmacophore and QSAR

Pharmacophore derivation, 3D pharmacophore prediction and applications in drug discovery; QSARs and QSPRs; QSAR methodology; descriptors used in QSAR (electronic, topology, quantum chemical-based descriptors); use of genetic algorithms, neural networks, and principal component analysis in QSAR equations.

Recommended Text and reference Books:

1. Fred E. Cohen, Walter Hamilton Moos, *Computational Methods in Drug Design*. ESCOM Science, 1993.
2. Alan Hinchliffe, *Molecular Modelling for Beginners*. John Wiley & Sons, 2008. ISBN: 978-0470513149.
3. Arup Ghose, Vellarkad Viswanadhan, *Combinatorial Library Design and Evaluation: Principles, Software, Tools, Applications in Drug Discovery*. CRC Press, 2001. ISBN: 0-8247-0487-8.
4. Jan H. Jensen, *Molecular Modeling Basics*. CRC Press, 2010. ISBN: 9781420075267.
5. Hugo Kubinyi, Gerd Folkers, Yvonne C. Martin, *3D QSAR in Drug Design: Recent Advances*. Springer Science & Business Media. ISBN: 0-306-46858-1.
6. K. I. Ramachandran, Gopakumar Deepa, Krishnan Namboori, *Computational Chemistry and Molecular Modeling*. Springer, ISBN: 978-3540773023.

Semester-2 (Elective-II)
BTM-207:: Vaccines (Credit 2)

Course Objectives:

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

Students Learning Outcomes:

By the end of this course, students should be able to:

- Understand fundamental concepts of the human immune system and basic immunology.
- Differentiate and understand immune responses in relation to infection and vaccination.
- Understand requirements and designing of different types of vaccines.
- Recognize the importance of conventional and emerging vaccine technologies.

Unit I: Introduction to Vaccines and Immunology — 3 lectures

History of vaccines, milestones from Jenner to mRNA vaccines, immunological principles of vaccination, innate and adaptive immunity, mechanism of immune memory, herd immunity, global impact of vaccination on public health.

Unit II: Types of Vaccines — 4 lectures

Live attenuated, inactivated, subunit, toxoid vaccines, recombinant vaccines including DNA, RNA and viral vector-based vaccines, synthetic and peptide-based vaccines, adjuvants types and mechanisms, combination vaccines and multivalent vaccines.

Unit III: Vaccine Development and Production — 5 lectures

Discovery to clinical trials, preclinical and regulatory approval, reverse vaccinology, structural vaccinology, computational approaches, bioprocessing and production including cell culture, fermentation, purification, formulation and stability, WHO and national guidelines, safety and quality assurance.

Unit IV: Vaccines Against Infectious Diseases — 4 lectures

Vaccines against viral diseases including polio, influenza, COVID-19, HIV prospects; vaccines against bacterial diseases including tuberculosis, diphtheria, cholera.

Unit V: Emerging Vaccines and Challenges — 4 lectures

Emerging vaccines including cancer vaccines, therapeutic vaccines, microbiome-based vaccines; challenges including antigenic variation, cold chain logistics, vaccine hesitancy.

Unit VI: Future Perspectives and Case Studies **4 lectures**

Nanotechnology and vaccine delivery systems, personalized vaccines in cancer and precision medicine, case studies of COVID-19, HPV and malaria vaccines, ethical, social and economic aspects of vaccination.

Recommended Text and reference Books:

1. Janeway, C. A., Travers, P., Walport, M., & Shlomchik, M. J. (2005). *Immunobiology: The Immune System in Health and Disease*. Garland Science.
2. Kindt, T. J., Osborne, B. A., Goldsby, R. A., & Kuby, J. (2013). *Kuby Immunology*. W.H. Freeman.
3. Kaufmann, S. H. (2004). *Novel Vaccination Strategies*. 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*.

Semester-3

BTM-301:: Bioprocess Engineering and Technology

(Credit 3)

Course Objectives:

The objectives of this course are to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

Students Learning Outcomes:

On completion of this course, students should 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 analyze any bioprocess from a market point of view

Unit I: Introduction — 4 lectures

Fermentation process, chronological development of fermentation industry, Parts of fermentation process, scope of fermentation Technology.

Unit II: Basic Principles of Biochemical Engineering — 12 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 III: Stoichiometry and Models of Microbial Growth — 8 lectures

Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.

Unit IV: Bioreactor Design and Analysis — 12 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 V: Downstream Processing — 3 lectures

Important industrial bioprocesses e.g. ethanol production

Recommended Text and reference Books:

1. Shuler, M. L., & Kargi, F. (2002). Bioprocess Engineering: Basic Concepts. Upper Saddle River, NJ: Prentice Hall.
2. Stanbury, P. F., & Whitaker, A. (2010). Principles of Fermentation Technology. Oxford: Pergamon Press.
3. Blanch, H. W., & Clark, D. S. (1997). Biochemical Engineering. New York: M. Dekker.
4. Bailey, J. E., & Ollis, D. F. (1986). Biochemical Engineering Fundamentals. New York: McGraw-Hill. 24
5. El-Mansi, M., & Bryce, C. F. (2007). Fermentation Microbiology and Biotechnology. Boca Raton: CRC/Taylor & Francis.

BTM-302:: Emerging Technologies (Credit 3)

Course 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.

Students 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, Dark field; 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 Photo activated Localization Microscopy (PALM).

Unit II: Mass Spectroscopy 12 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: System 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 — 3 lectures

X-ray diffraction methods, solution & solid-state NMR, cryo-electron microscopy, small angle X-ray scattering, Atomic force microscopy.

Unit V: CRISPR-CAS Technology — 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 of antibody against native proteins, nanobody as a tool for protein structure-function studies, use of nanobodies for molecular imaging, catabolic antibodies using nanobodies.

Recommended Text and reference Books:

1. Campbell, I. D. (2012). Biophysical Techniques. Oxford: Oxford University Press.
2. Serdyuk, I. N., Zaccai, N. R., & Zaccai, G. (2007). Methods in Molecular Biophysics: Structure, Dynamics, Function. Cambridge: Cambridge University Press.
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. Annual Review of Biochemistry, 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). The Heroes of CRISPR. Cell, 164(1-2), 18-28. doi:10.1016/j. cell.2015.12.041.
7. Ledford, H. (2016). The Unsung Heroes of CRISPR. Nature, 535(7612), 342-344. doi:10.1038/535342a.
8. Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J. A., & Charpentier, E. (2012). A Programmable Dual-RNA-Guided DNA Endonuclease in Adaptive Bacterial Immunity.
9. 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).
10. 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). Nanobody Stabilization of G Protein-Coupled Receptor Conformational States. Current Opinion in Structural Biology, 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. 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.
15. Chakravarty, R., Goel, S., & Cai, W. (2014). Nanobody: The “Magic Bullet” for Molecular Imaging? Theranostics, 4(4), 386-398. doi:10.7150/thno.8006

BTM-304:: Bio-Enterpreneurship (Credit – 2)

Course 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. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects.

Students Learning Outcomes:

Students should be able to gain entrepreneurial skills, understand the various operations involved

Unit I: Innovation and Entrepreneurship in Bio-Business 8 lectures

Introduction and scope in Bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.

Unit II: Bio-markets - Business Strategy and Marketing 8 lectures

Negotiating the road from lab to the market (strategies and processes of negotiation with financiers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

Unit III: Finance and Accounting 8 lectures

Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology.

Technology – assessment, development & up-gradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

Unit IV: Technology Management 8 lectures

in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centre's and various agencies. T he knowledge pertaining to management should also help students to be able to build up a strong network within the industry.

Recommended Text and reference Books:

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. 29
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. Desai, V. (2009).
5. The Dynamics of Entrepreneurial Development and Management. New Delhi: Himalaya Pub. House.volutionary Genetics. Oxford: Oxford University Press.

BTM-305:: Intellectual Property Rights, Biosafety, & Bioethics (Credit – 3)

Course Objectives:

The objectives of this course are

- To provide basic knowledge on intellectual property rights and their implications in biological research and product development
- To become familiar with India's IPR Policy
- To learn bio-safety and risk assessment of products derived from biotechnology and regulation of such products
- 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.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
- 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;
- Gain knowledge of bio-safety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research

Unit I: Introduction to IPR — 5 lectures

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

Unit II: Patenting — 5 lectures

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: Bio-Safety **5 lectures**

Bio-safety and Bio-security - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; bio-safety levels; GRAS organisms, bio-safety levels of specific microorganisms; recommended bio-safety 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 **5 lectures**

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 – bio-safety levels and category of rDNA experiments; field trails – bio-safety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

Unit V: Bioethics **5 lectures**

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 – bio-piracy.

Recommended Text and reference Books:

1. Ganguli, P. (2001). Intellectual Property Rights: Unleashing the Knowledge Economy. New Delhi: Tata McGraw-Hill Pub.
2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
3. Complete Reference to Intellectual Property Rights Laws. (2007). Snow White Publication Oct.
4. Kuhse, H. (2010). Bioethics: an Anthology. Malden, MA: Blackwell.
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/

BTM-311:: Bioprocess Engineering & Technology Lab (Credit 2)

Course Objectives:

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

Students Learning Outcomes:

Students should be able to

- Investigate, design and conduct experiments, analyze and interpret data, and apply the laboratory skills to solve complex bioprocess engineering problems;
- Apply skills and knowledge gained will be useful in solving problems typical of bio industries and research.

Syllabus:

1. Basic Microbiology techniques
   a) Scale up from frozen vial to agar plate to shake flask culture.
   b) Instrumentation: Microplate reader, spectrophotometer, microscope. c) Isolation of microorganisms from soil samples.
2. Experimental set-up
   a) Assembly of the bioreactor and sterilization.
   b) Growth kinetics.
   c) Substrate and product inhibitions.
   d) Measurement of residual substrates.
3. Data Analysis
   a) Introduction to Metabolic Flux Analysis (MFA).
4. Fermentation
   a) Batch.
   b) Fed-batch.
   c) Continuous.

Recommended Text and reference Books:

1. Shuler, M. L., & Kargi, F. (2002). Bioprocess Engineering: Basic Concepts. Upper Saddle River, NJ: Prentice Hall. 2. Stanbury, P. F., & Whitaker, A. (2010). Principles of Fermentation Technology. Oxford: Pergamon Press.
2. Blanch, H. W., & Clark, D. S. (1997). Biochemical Engineering. New York: M. Dekker.
3. Bailey, J. E., & Ollis, D. F. (1986). Biochemical Engineering Fundamentals. New York: McGraw-Hill.
4. 5. El-Mansi, M., & Bryce, C. F. (2007). Fermentation Microbiology and Biotechnology. Boca Raton: CRC/Taylor & Francis.

BTM-312:: Bioinformatics Lab (Credit 2)

Course Objectives:

The aim of this course is to provide practical training in bioinformatic methods, including accessing major public sequence databases and using different computational tools to find, analyze, and interpret protein and nucleic acid sequences with various software packages.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Describe the contents and properties of major 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, apply the principle of dynamic programming, and execute pairwise sequence alignment.
- Predict secondary and tertiary structures of protein sequences.

Syllabus:

1. Using NCBI and UniProt web resources.
2. Introduction and use of various genome databases.
3. Sequence information resources: NCBI, EMBL, GenBank, Entrez, SwissProt/TrEMBL, UniProt.
4. Similarity searches using BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
6. Phylogenetic analysis of protein and nucleotide sequences.
7. Gene prediction methods: GRAIL, Genscan, Glimmer.
8. RNA structure prediction tools.
9. Primer designing and restriction site prediction tools.
10. Protein structure prediction databases: PDB, SCOP, CATH.
11. Construction and study of protein structures using DeepView/PyMOL.
12. Homology modelling of proteins.
13. Tools for mutation analysis and energy minimization of protein structures.
14. miRNA prediction, designing, and target prediction tools.

Semester-3 (Elective-III)

BTM-303:: Genome Editing (Credit 2)

Course Objectives:

The objective of this course is to provide students with comprehensive knowledge of traditional and modern genome editing technologies. It will cover the principles, tools, and applications of gene editing, with emphasis on CRISPR/Cas9 and related systems, along with discussions on ethical, safety, and risk considerations.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Explain traditional gene editing methods such as homologous recombination, RNAi, Cre-LoxP, and Flp-FRT systems.
- Describe engineered enzyme systems including ZFNs, TALENs, meganucleases, and CRISPR/Cas9.
- Design single-guide RNAs (sgRNAs) and explain the principle of Multiplex Automated Genomic Engineering (MAGE).
- Apply gene editing techniques for targeted mutation, gene therapy, chromosomal rearrangements, endogenous gene labeling, and transgenesis in animals and plants.
- Evaluate applications of genome editing in biofuel production and bioremediation.
- Analyze ethical, safety, and risk aspects associated with targeted gene editing.

Syllabus:

1. Overview of traditional methods: homologous recombination for gene knockout, RNAi system, Cre-LoxP and Flp-FRT systems.
2. Engineered enzyme systems: Zinc Finger Nucleases (ZFNs), Transcription Activator-Like Effector Nucleases (TALENs), meganucleases.
3. CRISPR/Cas9 system: principle, components, and mechanism.
4. Design and optimization of sgRNA.
5. Multiplex Automated Genomic Engineering (MAGE).
6. Applications:
    a. Targeted gene mutation.
    b. Gene therapy.
    c. Chromosome rearrangements.
    d. Functional studies with stem cells.
    e. Transgenic animals and GM plants.
    f. Endogenous gene labeling and targeted transgene addition.
    g. Applications in biofuel production and bioremediation.
7. Ethics, biosafety, and risk assessment in gene editing.

Recommended Text and reference Books:

1. Luo, Yonglun (Ed.), *CRISPR Gene Editing, Methods and Protocols*.
2. Krishnarao Appasani (Ed.), *Genome Editing and Engineering, From TALENs, ZFNs and CRISPRs to Molecular Surgery*.
3. Donald P. Weeks, Bing Yang (Eds.), *Progress in Molecular Biology and Translational Science, Vol 149 – Genome Editing in Plants*. Academic Press.
4. Tsang, Stephen H. (Ed.), *Precision Medicine, CRISPR, and Genome Engineering: Moving from Association to Biology and Therapeutics*. Springer.

Semester-3 (Elective-III)

BTM-303:: Gene Expression and Transgenetics (Credit 2)

Course Objectives:

The objective of this course is to provide students with knowledge and practical insights into gene expression systems and the development and use of transgenic animals. The course emphasizes expression vectors, host systems for recombinant protein production, purification strategies, regulatory requirements, and applications of transgenic technologies in research and industry.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Describe different expression vectors, promoters, and tags for recombinant protein production.
- Compare protein overexpression systems across prokaryotic, eukaryotic, plant, and cell-free models.
- Apply methods for purification of tagged and tag-free proteins.
- Explain GMP and GLP requirements for protein expression and purification.
- Understand creation methods, applications, and ethical considerations of transgenic animals.
- Evaluate the use of transgenic animals in biotechnology, research, aquaculture, and medicine.

Syllabus:

Overview of recombinant protein expression vectors and promoters; vectors with tags (His, GST, MBP, GFP); cleavable and non-cleavable tags; vectors for tag-free protein expression; overexpression of integral membrane proteins; overexpression in prokaryotic systems such as E. coli, B. subtilis, Corynebacterium, Pseudomonas fluorescens; eukaryotic hosts including yeasts (S. cerevisiae, Pichia pastoris), insect cell lines (Sf21, Sf9, BTI-TN-5B1-4), mammalian cell lines (Chinese Hamster Ovary, Human Embryonic Kidney), and plant single-cell systems; chloroplast transformation and protein expression in chloroplasts; cell-free protein expression using extracts from E. coli, rabbit, wheat germ, and insect systems; purification of tagged and tag-free proteins; GMP and GLP requirements. Use of transgenic animals: history, safety, and ethical considerations; methods for creation of transgenic animals including DNA microinjection, embryonic stem cell-mediated gene transfer, retrovirus-mediated gene transfer; applications of transgenic animals in medical research, toxicology, mammalian developmental genetics, molecular biology, pharmaceutical industry, biotechnology, aquaculture, and xenografting; humanized animal models.

Recommended Text and reference Books:

1. Joseph M. Fernandez, James P. Hoeffler, *Gene Expression Systems: Using Nature for the Art of Expression*.
2. Gary H. Perdew, Jack P. Vanden Heuvel, Jeffrey M. Peters, *Regulation of Gene Expression*. Springer.
3. Simon Baumberg (Ed.), *Prokaryotic Gene Expression*. Oxford Press.
4. Carl Pinkert, *Transgenic Animal Technology: A Laboratory Handbook*, 3rd Edition. Elsevier.
5. Shah Krunal V., *Ethical Use of Transgenic Animals*. Lambert.
6. E. F. Wagner, F. Theuring (Eds.), *Transgenic Animals as Model Systems for Human Diseases*. Springer.

Semester-3 (Elective-III)

BTM-303:: Protein Engineering (Credit – 2)

Course Objectives:

The aim of this course is to introduce methods and strategies commonly used in protein engineering.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Analyse structure and construction of proteins by computer-based methods.
- Describe structure and classification of proteins.
- Analyse purity and stability of proteins and explain best storage methods.
- Explain how proteins can be used for different industrial and academic purposes such as structure determination, organic synthesis, and drug design.

Unit I: Introduction to Protein Engineering — 5 lectures

Protein engineering – definition, applications; Features or characteristics of proteins that can be engineered (definition and methods of study) – affinity and specificity; Spectroscopic properties; Stability to changes in parameters such as pH, temperature, and amino acid sequence; Aggregation propensities; Protein engineering with unnatural amino acids and its applications.

Unit II: Stability of Protein Structure — 5 lectures

Methods of measuring stability of a protein; Spectroscopic methods to study physicochemical properties of proteins: far-UV and near-UV CD, Fluorescence, UV absorbance, ORD; Hydrodynamic properties – viscosity, hydrogen-deuterium exchange; Introduction to NMR spectroscopy – emphasis on measurable parameters and their interpretation.

Unit III: Applications — 5 lectures

Forces stabilizing proteins – Van der Waals, electrostatic, hydrogen bonding, weakly polar interactions, hydrophobic effects; Entropy–enthalpy compensation; Experimental methods of protein engineering – directed evolution (gene site saturation mutagenesis), module shuffling, guided protein recombination; Optimization and high-throughput screening methodologies such as GigaMetrix, high-throughput microplate screens; Applications – bacteriorhodopsin-based devices, engineering antibody affinity by yeast surface display; Applications to vaccines, peptidomimetics, and drug discovery.

Unit IV: Computational Approaches — 5 lectures

Computational approaches to protein engineering – sequence and 3D structure analysis, data mining, Ramachandran map; Mechanisms of protein stabilization in psychrophiles, thermophiles, and mesophiles; Protein design; Directed evolution for protein engineering and its potential.

Unit V: Case Studies — 1 lectures

Case Studies

Recommended Text and reference Books:

1. T. E. Creighton (Ed.) (1997). *Protein Structure: A Practical Approach* (2nd Edition). Oxford University Press.
2. Cleland & Craik (2006). *Protein Engineering, Principles and Practice*, Vol. 7. Springer Netherlands.
3. Mueller & Arndt. *Protein Engineering Protocols* (1st Edition). Humana Press.
4. Robertson D. E., Noel J. P. (Eds.) (2004). *Protein Engineering Methods in Enzymology*, Vol. 388. Elsevier Academic Press.
5. J. Kyte (2006). *Structure in Protein Chemistry* (2nd Edition). Garland Publishers.

Semester-3 (Elective-III)

BTM-303:: Biosimilars Technology (Credit – 2)

Course Objectives:

The objective of this course is to provide students with comprehensive knowledge of biosimilar technologies, their development, characterization, regulatory requirements, and applications in the pharmaceutical industry. The course will introduce bioequivalence studies, challenges in biosimilar development, & industrial case studies.

Students Learning Outcomes:

On completion of this course, students should be able to:

- Define biologics, biosimilars, and super biologics, and differentiate them from chemical generics.
- Explain developmental, regulatory, and market challenges in biosimilar development.
- Describe different types of biosimilar drugs, including peptides, proteins, antibodies, vaccines, nucleic acids, and cell-based therapies.
- Apply various physicochemical and spectroscopic methods for biosimilar characterization.

Unit I: Introduction to Biopharma

Generics in Biopharma; definition of biologics, biosimilars, and super biologics; differences between chemical generics and biosimilars; developmental and regulatory challenges in biosimilar development; prerequisites for biosimilar development; market potential of biosimilars.

Unit II: Types of Biosimilar Drugs

Peptides, proteins, antibodies, enzymes, vaccines; nucleic acid–based therapies (DNA, RNA, etc.); cell-based therapies (including stem cells).

Unit III: Characterization Methods

Aggregation, precipitation, floccule strength, precipitate aging & kinetics; adsorption of proteins & peptides on surfaces; effect of temperature on protein structure; hydration & thermal stability of proteins; solid powders, suspensions in non-aqueous solvents, reversed micelles, aqueous polyols; analytical and spectrophotometric characterization of proteins; protein sequencing and structure determination.

Unit IV: Bioequivalence Studies

Immunogenicity & allergenicity of biosimilars; factors affecting immunogenicity: structural, post-translational modifications, formulations, impurities, manufacturing methods; types of bioequivalence: average, population, individual; experimental designs & statistical considerations: non-replicated designs (General Linear Model), replicated crossover designs; introduction to “Orange Book” and “Purple Book.”

Unit V: Case Studies

Indian companies: Biocon, Intas, Dr. Reddy's, Reliance, Bharat Biotech, Lupin, Cipla, Shanta, etc.; example biosimilars: erythropoietin, growth hormone, granulocyte-stimulating factors, interferons, streptokinase, monoclonal antibodies.

Recommended Text and reference Books:

1. Laszlo Endrenyi, Paul Declerck, Shein-Chung Chow, *Biosimilar Drug Development*, Drugs and Pharmaceutical Sciences, Vol 216, CRC Press.
2. Cheng Liu, K. John Morrow Jr., *Biosimilars of Monoclonal Antibodies: A Practical Guide to Manufacturing, Preclinical and Clinical Development*, Wiley, 2016.
3. https://www.drugs.com/medical-answers/many-biosimilars-approvedunited-states-3463281/

Semester-3 (Elective-IV)

BTM-307:: Biological Imaging (Credit 2)

Course Objectives:

The objectives of this course are to provide complete overview of state-of-the-art live-cell imaging techniques using microscopes currently available in the literature. Live-cell imaging techniques allow real-time examination of almost every aspect of cellular function under normal and experimental conditions. With live-cell imaging experiments, main challenges are to keep cells alive and healthy over a period of time. The growing number of live-cell imaging techniques means one can obtain greater amounts of information without stressing out cells.

Students Learning Outcomes:

On completion of this course, students will:

- Gain a complete overview of the super-resolution field, from fundamentals to state-of-the-art methods and applications in biomedical research.
- Learn the comparative advantages and disadvantages of each technique, covering all key techniques in biomedical science.
- Acquire knowledge of new tools to increase resolution in sub-nanometer-scale images of living cells and tissues.
- Understand how enhanced imaging provides new information about molecules, pathways, and dynamics.

Unit I: Widefield Fluorescent Microscopy — 3 lectures

Introduction to live-cell imaging using widefield fluorescence microscopy. Principles of image acquisition with CCD cameras and epi-fluorescence illumination sources (mercury lamp, xenon lamp, LEDs). Role of interference filters for excitation and emission specificity. Applications in imaging adherent cells, organelles, and thin tissue sections (<5 μm). Advantages of short excitation exposure and collection of full aperture emission light. Combination with contrast techniques such as phase contrast and differential interference contrast (DIC) for morphological and viability studies in live cells.

Unit II: Confocal Laser Scanning Microscopy (CLSM) — 3 lectures

Principles of optical sectioning and elimination of out-of-focus light. Use of pinholes and photomultiplier detectors to improve resolution. Scanning of a single laser spot across specimens to generate high-contrast images. Mechanism of fluorescence detection through pinhole filtering. Applications in imaging thick specimens and obtaining serial optical sections.

Unit III: Spinning Disc Confocal Microscopy (SDCM) — 2 lectures

Use of the Nipkow disc with thousands of pinholes in spiral patterns for parallelized confocal imaging. Simultaneous illumination of multiple specimen points for real-time imaging (≥30 fps). Role of CCD cameras in capturing dynamic cellular processes. Applications in high-speed imaging of live-cell dynamics.

Unit IV: Light Sheet Fluorescence Microscopy (LSFM or SPIM) 2 lectures

Principles of selective plane illumination for gentle live imaging of embryos, tissues, and spheroids. High temporal resolution and 3D imaging capabilities. Applications in developmental biology and long-term cell tracking. Introduction to lattice light-sheet microscopy for super-resolved live-cell imaging.

Unit V: Super Resolved Fluorescence Microscopy 8 lectures

Super-Resolution in a Standard Microscope: From Fast Fluorescence Imaging to Molecular Diffusion Laws in Live Cells; Photoswitching Fluorophores in SuperResolution Fluorescence Microscopy; Image Analysis for Single-Molecule Localization Microscopy; Deconvolution of Nanoscopic Images; Super-Resolution Fluorescence Microscopy of the Nanoscale Organization in cells; Correlative Live-Cell and SuperResolution Microscopy and Its Biological Applications; SAX Microscopy and Its Application to Imaging of 3D-Cultured Cells; Quantitative Super-Resolution Microscopy for Cancer Biology and Medicine.

Unit VI: Re-Scan Confocal Microscopy 4 lectures

Structured Illumination Microscopy; Correlative Nanoscopy: AFM Super-Resolution (STED/STORM); Stochastic Optical Fluctuation Imaging.

Recommended Text and reference Books:

1. Rajagopal Vadivambal, Digvir S. Jayas. (2015). *Bio-Imaging: Principles, Techniques, and Applications*. ISBN 9781466593671 - CAT# K20618.
2. Alberto Diaspro, Marc A. M. J. van Zandvoort. (2016). *Super-Resolution Imaging in Biomedicine*. ISBN 9781482244342 - CAT# K23483.
3. Taatjes, Douglas, Roth, Jürgen (Eds.). (2012). *Cell Imaging Techniques: Methods and Protocols*. ISBN 978-1-62703-056-4.

Semester-3 (Elective-IV)

BTM-307:: Environmental Biotechnology (Credit 2)

Course Objectives:

This course aims to introduce fundamentals of Environmental Biotechnology. The course will introduce major groups of microorganisms, 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.

Students Learning Outcomes:

On completion of this course, students will be able to understand the 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; strain improvement; Biodiversity and its conservation; Role of microorganisms in geochemical cycles; Microbial energy metabolism, microbial growth kinetics and elementary chemostat theory, relevant microbiological processes, microbial ecology.

Unit II: Bioremediation — 6 lectures

Bioremediation: Fundamentals, methods and strategies of application (biostimulation, bioaugmentation) – examples. Bioremediation of metals (Cr, As, Se, Hg), radionuclides (U, Te), organic pollutants (PAHs, PCBs, pesticides, TNT, etc.), technological aspects of bioremediation (*in situ, ex situ*).

Unit III: Role of Microorganisms in Bioremediation — 6 lectures

Application of bacteria and fungi in bioremediation: White rot fungi vs specialized degrading bacteria – examples, uses, and advantages vs disadvantages. Phytoremediation: Fundamentals and description of major methods of application (phytoaccumulation, phytovolatilization, rhizofiltration, phytostabilization).

Unit IV: Biotechnology and Agriculture — 11 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 and microorganisms (nitrogen-fixing symbiosis, mycorrhiza fungi symbiosis). Plant growth-promoting rhizobacteria (PGPR) – uses, practical aspects, and problems in application.

Unit V: Biofules — 11 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 Text and reference Books:

1. G. M. Evans and J. C. Furlong (2003). *Environmental Biotechnology: Theory and Applications*. Wiley Publishers.
2. B. Ritmann and P. L. McCarty (2000). *Environmental Biotechnology: Principle & Applications*. 2nd Ed., McGraw Hill Science.
3. Scragg, A. (2005). *Environmental Biotechnology*. Pearson Education Limited.
4. J. S. Devinny, M. A. Deshusses and T. S. Webster (1998). *Biofiltration for Air Pollution Control*. CRC Press.

Semester-3 (Elective-IV)

BTM-307:: Nanobiotechnology (Credit 2)

Course Objectives:

The course aims at providing a general and broad introduction to the multi-disciplinary field of nanotechnology. It will familiarize students with the combination of the top-down approach of microelectronics and micromechanics with the bottom-up approach of chemistry/biochemistry, a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve our everyday life.

Students Learning Outcomes:

On successful completion of this course, students should be able to describe the basic science behind the properties of materials at the nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.

Unit I: Introduction to Nanobiotechnology — 5 lectures

Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular nanostructures; Nanopores; Biomolecular motors; Bio-inspired nanostructures; Synthesis and characterization of different nanomaterials.

Unit II: Nano-films — 5 lectures

Thin films; Colloidal nanostructures; Self-assembly; Nanovesicles; Nanospheres; Nanocapsules and their characterization.

Unit III: Nanoparticles — 5 lectures

Nanoparticles for drug delivery – concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

Unit IV: Application of Nanoparticles — 5 lectures

Nanoparticles for diagnostics and imaging (theranostics); Concepts of smart stimuli-responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.

Unit V: Nanomaterials — 5 lectures

Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

Unit VI: Nanotoxicity — 5 lectures

Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

Recommended Text and reference Books:

1. Gero Decher, Joseph B. Schlenoff (2003). *Multilayer Thin Films: Sequential Assembly of Nanocomposite Materials*. Wiley-VCH Verlag GmbH & Co. KGaA.
2. David S. Goodsell (2004). *Bionanotechnology: Lessons from Nature*. Wiley-Liss.
3. Neelina H. Malsch (2005). *Biomedical Nanotechnology*. CRC Press.
4. Greg T. Hermanson (2013). *Bioconjugate Techniques* (3rd Edition). Elsevier.

Semester-3 (Elective-IV)

BTM-307:: Biomaterials (Credit – 2)

Course Objectives:

The objective of this course is to provide students with fundamental knowledge of materials, their structures, properties, processing methods, and applications in biomedical engineering, enabling them to analyze, design, and select appropriate biomaterials for medical use.

Students Learning Outcomes:

On completion of this course, students should be able to:

1. Understand the classification, structure, and properties of metals, ceramics, polymers, and composites used in biomedical applications.
2. Explain the processes of melting, solidification, nucleation, phase diagrams, and surface modifications.
3. Demonstrate knowledge of biomaterials processing and advanced fabrication techniques.
4. Apply the principles of material selection and biomimetic synthesis for medical applications.

Syllabus

Introduction to Materials: General structure and properties; classification of common materials and applications; chemical bonding; crystalline and amorphous states; melting, solidification, nucleation, and phase diagrams; metals and alloys in medical applications including stainless steel, cobalt-based alloys, titanium-based alloys (including shape memory alloys); ceramics and glasses – bio-ceramics, types and classification, calcinations, annealing, sintering, nearly inert ceramics, bio-reactive glasses and glass ceramics, calcium phosphate ceramics; introduction to polymers – definition, classification, polymerization, rubber, plastics, fibers, and resins with structure–property relationship; biodegradable polymers and natural polymers; composites, pyrolytic carbon, carbon nanotubes; bulk properties, surface properties, and modification of surface properties; basic principles of engineering manufacturing, methods and applications of common manufacturing processes such as milling, grinding, finishing, rolling, forging; concept of biomimetic synthesis; preparation of fiber and wire; fabrication of porous materials; direct molding technique; advanced fabrication techniques.

Recommended Text and reference Books:

1. *Biomaterials Science - An Introduction to Materials in Medicine*, Buddy Ratner, Allan Hoffman, Frederick Schoen, Jack Lemons, ISBN: 9780080470368, Academic Press, 2004.
2. *Biomaterials: An Introduction*, J. Bo. Park.
3. *Materials Science and Engineering*, Callister.
4. *Materials for Medical Engineering*, Euromat 99, Vol. 2.

Semester-4

BTM-411:: Dissertation (Credit 20)

Course Objectives:

The objectives of this course are to prepare 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 them in the art of analysis and thesis writing.

Students Learning Outcomes:

By the end of this course, students should be able to:

- Select and defend a research topic, and effectively plan, execute, evaluate, and discuss their experiments.
- Demonstrate in-depth knowledge of the chosen area of research.
- Critically and systematically integrate knowledge to identify issues within the framework of a specific thesis.
- Design and plan research effectively.
- Create, analyse, and critically evaluate technical solutions.
- Conduct research independently.
- Perform analytical techniques and experimental methods.
- Demonstrate project management skills.
- Develop report writing skills.
- Enhance problem-solving abilities.
- Strengthen communication and interpersonal skills.

Syllabus: Planning & Performing Experiments

Based on the project proposal submitted in the earlier semester, students should be able to plan and engage in an independent and sustained critical investigation of a chosen research topic relevant to biological sciences and society. They should systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply suitable techniques, and draw appropriate conclusions.

Senior researchers will mentor students to ensure they can work independently, understand the aim of each experiment, and anticipate possible outcomes.

Syllabus: Thesis Writing

At the end of their project, students are required to write a thesis detailing the aim, methodology, results, discussion, and future work related to their project. Students may aim to publish their research findings in peer-reviewed journals. If their findings have application-oriented outcomes, they may also pursue patent applications.

The End