DRAFT CURRICULUM

of

M.Sc. BIOTECHNOLOGY

Department of Biotechnology
Ministry of Science & Technology
Government of India

2016

TABLE OF CONTENTS

S. No.	Code	Title	Credits	Page No.
SEMESTER – I				
1	BT401	Biochemistry	3	05
2	BT402	Cell & Molecular Biology	3	07
3	BT403	Genetics	2	09
4	BT404	Microbiology	2	10
5	BT405	Plant & Animal Biotechnology	3	12
6	BT406	Basics of Mathematics & Statistics	2	14
7	BT407	Basics of Chemistry & Physics	2	15
8	BT408	Laboratory I: Biochemistry & Analytical Techniques	4	17
9	BT409	Laboratory II: Microbiology	4	18
TOTAL:			25	

S. No.	Code	Title	Credits	Page No.
SEMESTER – II				
1	BT410	Bioinformatics	3	20
2	BT411	Genetic Engineering	3	21
3	BT412	Genomics & Proteomics	2	23
4	BT413	Immunology	3	25
5	BT414	Molecular Diagnostics	2	27
6	BT415	Research Methodology & Communication Skills	2	29
7	BT416	Elective-1	2	
8	BT417	Laboratory III: Immunology	3	30
9	BT418	Laboratory IV: Molecular Biology and Genetic Engineering	5	31
TOTAL:			25	

S. No.	Code	Title	Credits	Page No.
SEMESTER – III				
1	BT501	Bioprocess Engineering & Technology	3	33
2	BT502	Bioentrepreneurship	2	35
3	BT503	Critical Analysis of Classical Papers	2	37
4	BT504	Emerging Technologies	2	40
5	BT505	Intellectual Property Rights, Biosafety and Bioethics	2	42
6	BT506	Project Proposal	2	45
7	BT507	Project Proposal Presentation	2	46
8	BT508	Research Seminar	1	46
9	BT509	Elective-2	3	
10	BT510	Laboratory V: Bioprocess Engineering & Technology	3	47
TOTAL:			22	

S. No.	Code	Title	Credits	Page No.
SEMESTER – IV				
1	BT511	Dissertation	20	49
TOTAL:			20	

Total Credits	**94**

SEMESTER – I

Biochemistry – *3 credits*

Course Code: BT401

Course Objectives:

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

Student Learning Outcomes:

Students should be able to -

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

Syllabus:

Unit I (7 lectures)
Chemical basis of life*:* Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies;
Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins;
Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamics simulation.

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

Unit III (2 lectures)
Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.

Unit IV (3 lectures)
Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

Unit V (22 lectures)
Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca^{++} signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources of glucose; Citric acid cycle, entry to citric acid cycle, citric acid cycle as a source of biosynthetic precursors; Oxidative phosphorylation; importance of electron transfer in oxidative phosphorylation; F_1-F_0 ATP Synthase; shuttles across mitochondria; regulation of oxidative phosphorylation; Photosynthesis – chloroplasts and two photosystems; proton gradient across thylakoid membrane; Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/ exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation.

Recommended Textbooks and References:

1. Stryer, L. (1988). *Biochemistry*. New York: Freeman.
2. Lehninger, A. L. (1982). *Principles of biochemistry* (4th ed.). New York, NY: Worth.
3. Voet, D., & Voet, J. G. (2004). *Biochemistry* (4th 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.

Cell and Molecular Biology - *3 Credits*

Course Code: BT402

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.

Student 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?

Syllabus:

Unit I (6 lectures)

Dynamic Organization of Cell

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 (12 lectures)

Chromatin Structure and Dynamics

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: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors, trancriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code translation product cleavage, modification and activation.

Unit III (3 lectures)

Cellular Signalling, Transport and Trafficking

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 (8 lectures)

Cellular Processes

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 (3 lectures)

Manipulating and Studying Cells

Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.

Unit VI (8 lectures)

Genome Instability and Cell Transformation

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 Mode of Assessment:

Components	External Examination	Class Tests	Assignments/Seminar/ Project/Quiz
Weightage (%)	60%	20%	20%

Recommended Textbooks and References:

1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2002). *Molecular biology of the cell*. New York: Garland Science.
2. Lodish, H. F. (2000). *Molecular cell biology*. New York: W.H. Freeman.
3. Krebs, J. E., Lewin, B., Kilpatrick, S. T., & Goldstein, E. S. (2014). *Lewin's genes XI*. Burlington, MA: Jones & Bartlett Learning.
4. Cooper, G. M., & Hausman, R. E. (2009). *The cell: A molecular approach*. Washington: ASM ; Sunderland.
5. Hardin, J., Bertoni, G., Kleinsmith, L. J., & Becker, W. M. (2012). *Becker's world of the cell*. Boston: Benjamin Cummings.
6. Watson, J. D. (1987). *Molecular biology of the gene* (7th ed.). Menlo Park, CA: Benjamin/Cummings.

Genetics *- 2 Credits*

Course Code: BT403

Course Objectives:

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

Student Learning Outcomes:

On successful completion of this course, the student will be able to –

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

Syllabus:

Unit I (10 lectures)

Genetics of Bacteria and Bacteriophages

Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of a gene.

Unit II (6 lectures)

Yeast Genetics

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

Unit III (4 lectures)

Drosophila Genetics as a model of higher Eukaryotes

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 the context of developmental mechanisms.

Unit IV (4 lectures)

Population Genetics & Genetics of Evolution

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

Unit V (2 lectures)
Quantitative Genetics of complex traits (QTLs)
Complex traits, mapping QTLs, yeast genomics to understand biology of QTLs.

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

Recommended Mode of Assessment:

Components	External Examination	Internal tests	Take-home assignments	Overall quality of engagement in class
Weightage (%)	50%	30%	10%	10%

Recommended Textbooks and References:

1. Hartl, D. L., & Jones, E. W. (1998). *Genetics: Principles and analysis*. Sudbury, MA: Jones and Bartlett.
2. Pierce, B. A. (2005). *Genetics: A conceptual approach*. New York: W.H. Freeman.
3. Tamarin, R. H., & Leavitt, R. W. (1991). *Principles of genetics*. Dubuque, IA: Wm. C. Brown.
4. Smith, J. M. (1989). *Evolutionary genetics*. Oxford: Oxford University Press.

Microbiology - *2 Credits*

Course Code: BT404

Course Objectives:

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

Student Learning Outcomes:

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

Syllabus:

Unit I (6 lectures)

Microbial Characteristics

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 (9 lectures)

Microbial Diversity

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

Unit III (3 lectures)

Control of Microorganisms

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

Unit IV (5 lectures)

Virology

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 (5 lectures)

Host-Microbes Interaction

Host-pathogen interaction, ecological impacts 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 Mode of Assessment:

Components	Theory Examination	Class Tests	Assignment/Seminar/ Project/Quiz
Weightage (%)	80	10	10

Recommended Textbooks and References:

1. Pelczar, M. J., Reid, R. D., & Chan, E. C. (1977). *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. (1999). *Microbiology, principles and explorations*. Boston, MA: John Wiley & Sons.

Plant & Animal Biotechnology – *3 Credits*

Course Code: BT405

Course Objectives:

The objectives of this course is 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.

Student Learning Outcomes:

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

Syllabus:

Unit I (10 lectures)

Plant Tissue Culture and Animal Cell Culture

Plant tissue culture: historical perspective; totipotency; organogenesis; Somatic embryogenesis; establishment of cultures – callus culture, cell suspension culture, media preparation – nutrients and plant hormones; sterilization techniques; applications of tissue culture - micropropagation; somaclonal variation; androgenesis and its applications in genetics and plant breeding; germplasm conservation and cryopreservation; synthetic seed production; protoplast culture and somatic hybridization - protoplast isolation; culture and usage; somatic hybridization - methods and applications; 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 (10 lectures)

Plant Genetic Manipulation

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

Unit III (8 lectures)

Animal Reproductive Biotechnology and Vaccinology

Animal reproductive biotechnology: structure of sperms and ovum; cryopreservation of sperms and ova of livestock; artificial insemination; super ovulation, embryo recovery and *in vitro* fertilization; culture of embryos; cryopreservation of embryos; embryo transfer technology;

transgenic manipulation of animal embryos; applications of transgenic animal technology; animal cloning - basic concept, cloning for conservation 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 (4 lectures)

Plant and Animal Genomics

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

Unit V (8 lectures)

Molecular Mapping & Marker Assisted Selection

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

Recommended Mode of Assessment:

Components	Theory Examination	Class Tests	Assignment/Seminar/ Project/Quiz
Weightage (%)	80	10	10

Recommended Textbooks and References:

1. Chawla, H. S. (2000). *Introduction to plant biotechnology*. Enfield, NH: Science.
2. Razdan, M. K. (2003). *Introduction to plant tissue culture*. Enfield, NH: Science.
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. (1994). *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. (1997). *New generation vaccines*. New York: M. Dekker.

12. Pörtner, R. (2007). *Animal cell biotechnology: Methods and protocols*. Totowa, NJ: Humana Press.

Basics of Mathematics & Statistics – 2 Credits

Course Code: BT406

Course Objectives:

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

Student Learning Outcomes:

Students should be able to –

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

Syllabus:

Unit I (lectures)

Algebra

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 (lectures)

Calculus

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

Unit III (lectures)

Mathematical models in Biology

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 (lectures)

Statistics

Basic probability, venn diagrams, dependent probability, permutations and combinations, making decisions with probability, correlation & causality, tests of statistical significance, hypothesis testing & null hypothesis, two-way variables, mean/median/mode, variance and

standard deviation, constructing box-plots, expected values with empirical probabilities, binomial distributions, Poisson processes, scatter plots, fitting quadratic and exponential functions to scatter plots, linear regression & correlation; normal distributions, chi-square probability distribution, analyses of variance, Bernoulli distributions and margin of errors, hypothesis testing with one sample, one-tailed and two-tailed tests, T-statistic confidence interval, Anova 1, 2 & 3.

Recommended Mode of Assessment:

Assessment	External Examination	Internal tests /Tutorials	Take-home assignments	Overall quality of engagement in class
Weightage (%)	40%	30%	20%	10%

Recommended Textbooks and References:

1. Stroud, K. A., & Booth, D. J. (2009). *Foundation mathematics*. New York, NY: Palgrave Macmillan.
2. Billingsley, P. (1986). *Probability and measure*. New York: Wiley.
3. Rosner, B. (1986). *Fundamentals of biostatistics*. Boston, MA: Duxbury Press.
4. Daniel, W. W. (1987). *Biostatistics, a foundation for analysis in the health sciences*. New York: Wiley.
5. Pollard, J. H. (1977). *A handbook of numerical and statistical techniques with examples mainly from the life sciences*. Cambridge: Cambridge University Press.

Basics of Physics & Chemistry – *2 Credits*

Course Code: BT407

Course Objectives:

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

Student Learning Outcomes:

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

Syllabus:

Unit I (10 lectures: 10 hours teaching + 5 hours tutorials)

Basic Physics for Biologists

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 (10 lectures: 10 hours teaching + 5 hours tutorials)

Basic Chemistry for Biologists

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 polyatomic ions; 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 Mode of Assessment:

Assessment	External Examination	Internal Tests	Take-home assignments	Overall quality of engagement in class
Weightage (%)	50%	20%	10%	20%

Recommended Textbooks and References:

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.

Laboratory I: Biochemistry and Analytical Techniques – *4 Credits*

Course Code: BT408

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.

Student Learning Outcomes:

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) Generating a Purification Table (protein concentration, amount of total protein)
   g) 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.
   j) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
6. Experimental verification that absorption at OD_{260} is more for denatured DNA as compared to native double stranded DNA.
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.

Laboratory II: Microbiology - *4 credits*

Course Code: BT409

Course Objectives:

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

Student Learning Outcomes:

Students should be able to –
- Ability to isolate, characterize and identify common bacterial organisms.
- Determine bacterial load of different samples.
- Perform antimicrobial sensitivity test.
- Preserve bacterial cultures.

Syllabus *(52 classes)***:**

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 Mode of Assessment:

Components	Practical Examination	Assignment/ Project
Weightage (%)	75	25

Recommended Textbooks and References:

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. (n.d.). *Bailey & Scott's Diagnostic microbiology*.

SEMESTER – II

Bioinformatics – *3 credits*

Course Code: BT410

Course Objectives:

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

Student Learning Outcomes:

Student should be able to –

- Develop an understanding of the basic theory of these computational tools.
- Gain working knowledge of these computational tools and methods.
- Appreciate their relevance for investigating specific contemporary biological questions.
- Critically analyse and interpret the results of their study.

Syllabus:

Unit I (lectures)
Bioinformatics basics: Computers in biology and medicine; Importance of Unix and Linux systems and its 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 the web; database mining tools.

Unit II (lectures)
DNA sequence analysis: gene bank sequence database; submitting DNA sequences to databases and database searching; sequence alignment; pairwise 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 (lectures)
Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTAL W and CLUSTAL X for multiple sequence alignment; submitting DNA protein sequence to databases: where and how to submit, SEQUIN, genome centres; submitting aligned set of sequences, updates and internet resources; methods of phylogenetic analysis.

Unit IV (lectures)
Protein modelling: introduction; force field methods; energy, buried and exposed residues; side chains and neighbours; 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 (lectures)
Protein structure prediction: protein folding and model generation; secondary structure prediction; analyzing secondary structures; protein loop searching; loop generating methods; loop analysis; 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 *insilico* drug design.
Virtual library: Searching Medine, PubMed, current content, science citation index and current awareness services, electronic journals, grants and funding information.

Recommended Mode of Assessment:

Recommended Textbooks and References:

1. Lesk, A. M. (2002). *Introduction to bioinformatics*. Oxford: Oxford University Press.
2. Mount, D. W. (2001). *Bioinformatics: Sequence and genome analysis*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
3. Baxevanis, A. D., & Ouellette, B. F. (2001). *Bioinformatics: A practical guide to the analysis of genes and proteins*. New York: Wiley-Interscience.
4. Pevsner, J. (2015). *Bioinformatics and functional genomics*. Hoboken, NJ.: Wiley-Blackwell.
5. Bourne, P. E., & Gu, J. (2009). *Structural bioinformatics*. Hoboken, NJ: Wiley-Liss.
6. Lesk, A. M. (2004). *Introduction to protein science: Architecture, function, and genomics*. Oxford: Oxford University Press.

Genetic Engineering – *3 credits*

Course Code: BT411

Course Objectives:

The objectives of this course are to teach students with various approaches to conducting genetic engineering that they can apply to their future career 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. This technology has revolutionized the way modern biological

research is done and has impacted mankind with a number of biological products and processes.

Student 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.

Syllabus:

Unit I (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 (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, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.

Unit III (7 lectures)
Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; real time PCR, touchdown PCR, hot start PCR, colony 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 (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; DNaseI footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit V (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; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (drosophila), worms (*C. elegans*), frogs

(xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.

Recommended Mode of Assessment:

Mode of Assessment: Components	External Examination	Class Tests	Assignments
Weightage (%)	50	30	20

Recommended Textbooks and References:

1. Old, R. W., Primrose, S. B., & Twyman, R. M. (2001). *Principles of gene manipulation: An introduction to genetic engineering*. Oxford: Blackwell Scientific Publications.
2. Green, M. R., & Sambrook, J. (2012). *Molecular cloning: A laboratory manual*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
3. Brown, T. A. (2006). *Genomes* (3rd ed.). New York: Garland Science Pub.
4. Selected papers from scientific journals, particularly Nature & Science.
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

Genomics & Proteomics - *2 Credits*

Course Code: BT412

Course Objectives:

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

Student Learning Outcomes:

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

Syllabus:

Unit I (3 lectures)

Basics of Genomics and Proteomics

Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.

Unit II (4 lectures)

Genome Mapping

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 (3 lectures)

Genome Sequencing Projects

Human Genome Project, genome sequencing projects for microbes, plants and animals, accessing and retrieving genome project information from the web.

Unit IV (5 lectures)

Comparative Genomics

Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand the evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence.

Unit V (5 lectures)

Proteomics

Aims, strategies and challenges in proteomics; proteomics technologies: 2D-PAGE, isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, proteome databases.

Unit VI (8 lectures)

Functional Genomics and Proteomics

Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in the 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 Mode of Assessment:

Mode of Assessment: Components	External Examination	Class Tests	Assignments/ Seminar/Project/Quiz
Weightage (%)	60%	20%	20%

Recommended Textbooks and References:

1. Primrose, S. B., Twyman, R. M., Primrose, S. B., & Primrose, S. B. (2006). *Principles of gene manipulation and genomics*. Malden, MA: Blackwell Pub.
2. Liebler, D. C. (2002). *Introduction to proteomics: Tools for the new biology*. Totowa, NJ: Humana Press.
3. Campbell, A. M., & Heyer, L. J. (2003). *Discovering genomics, proteomics, and bioinformatics*. San Francisco: Benjamin Cummings.

Immunology - *3 credits*

Course Code: BT413

Course Objectives:

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

Student Learning Outcomes:

Students should be able to –

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

Syllabus:

Unit I (5 lectures)

Immunology fundamental concepts and anatomy of the immune system

Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens - immunogens, haptens; Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility.

Unit II (8 lectures)

Immune responses generated by B and T lymphocytes

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

Unit III (6 lectures)

Antigen-antibody interactions

Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosenor 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 (8 lectures)

Vaccinology

Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology- role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; antibody genes and antibody engineering- chimeric, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine.

Unit V (8 lectures)

Clinical Immunology

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

Unit VI (5 lectures)

Immunogenetics

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, genetics of human immunoglobulin, immunogenetics of spontaneous control of HIV, KIR complex.

Recommended Mode of Assessment:

Components	External Examination	Class Tests	Assignment/Seminar/ Project/Quiz
Weightage (%)	60%	20%	20%

Recommended Textbooks and References:

1. Kindt, T. J., Goldsby, R. A., Osborne, B. A., & Kuby, J. (2006). *Kuby immunology*. New York: W.H. Freeman.
2. Brostoff, J., Seaddin, J. K., Male, D., & Roitt, I. M. (2002). *Clinical immunology*. 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. (1993). *Fundamental immunology*. New York: Raven Press.
5. Goding, J. W. (1986). *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.

Molecular Diagnostics – *2 credits*

Course Code: BT414

Course Objectives:

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

Student Learning Outcomes:

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

Syllabus:

Unit I (4 lectures)
Genome Biology in Health & Disease
DNA, RNA, Protein: An overview; chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs.

Unit II (5 lectures)
Genome: Resolution, Detection & Analysis
PCR: Real-time; ARMS; Multiplex; ISH; FISH; ISA; RFLP; DHPLC; DGGE; CSCE; SSCP; Nucleic acid sequencing: new generations of automated sequencers; Microarray chips; EST; SAGE; microarray data normalization & analysis; molecular markers: 16S rRNA typing; Diagnostic proteomics: SELDI-TOF MS; Bioinformatics data acquisition & analysis.

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

Unit IV (4 lectures)

Detection & Identity of Microbial Diseases

Direct detection & identification of pathogenic-organisms that are slow growing or currently lacking a system of *invitro* cultivation as well as genotypic markers of microbial resistance to specific antibiotics.

Unit V (4 lectures)

Detection of Inherited Diseases

Exemplified by two inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: - Fragile X Syndrome: Paradigm of the new mutational mechanism of the unstable triplet repeats, von-Hippel Lindau disease: recent acquisition in the growing number of familial cancer syndromes.

Unit VI (5 lectures)

Molecular Oncology

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 VII (1 lecture)

Quality Assurance & Control

Quality oversight; regulations and approved testing.

Recommended Mode of Assessment:

Components	External Examination	Class Tests	Assignments/Seminar/Project/Quiz
Weightage (%)	60%	20%	20%

Recommended Textbooks and References:

1. Campbell, A. M., & Heyer, L. J. (2006). *Discovering genomics, proteomics, and bioinformatics*. San Francisco: Benjamin Cummings.
2. Brooker, R. J. (2009). *Genetics: Analysis & principles*. New York, NY: McGraw-Hill.
3. Glick, B. R., Pasternak, J. J., & Patten, C. L. (2010). *Molecular biotechnology: Principles and applications of recombinant DNA*. Washington, DC: ASM Press.
4. Coleman, W. B., & Tsongalis, G. J. (1997). *Molecular diagnostics: For the clinical laboratorian*. Totowa, NJ: Humana Press.

Research Methodology and Scientific Communication Skills – *2 credits*

Course Code: BT415

Course Objectives:

- To give a background on the history of science, emphasizing the methodologies used to do research
- To use the framework of these methodologies for understanding effective lab practices and scientific communication
- To use the framework of these methodologies to understand and appreciate scientific ethics.

Student Learning Outcomes:

- Understanding of the history and methodologies of scientific research, applying these to recent published papers
- Understanding and practicing scientific reading, writing, presentations
- Appreciating scientific ethics through case studies.

Syllabus:

Unit I: (8 hours)

History of Science and Science Methodologies

Empirical science; The scientific method; Interrogative perturbation experiments and controls; Deductive and inductive reasoning; Descriptive science; Reductionist vs holistic biology.

Unit II: (3 hours)

Preparation for Research

Choosing a mentor, lab and research question; Maintaining a lab notebook with date-wise entry.

Unit III: (5 hours)

Process of Communication

Concept of effective communication- Setting clear goals for communication; Determining outcomes and results; Initiating communication; Avoiding repetitions & breakdowns while communicating; Creating value in conversation; Barriers to effective communication; Non-verbal communication-

Interpreting non-verbal cues; Importance of body language, Power of effective listening; recognizing cultural differences

Presentation skills - Formal presentation skills; Preparing and presenting using Over Head Projector, Power Point slides with clearly legible fonts without crowding the content; Defending Interrogation; Scientific poster preparation & presentation; Participating in group discussions

Computing Skills for Scientific Research

Web browsing for information search; search engines and their mechanism of searching; Hidden Web and its importance in Scientific research; Internet as a medium of interaction between scientists; Effective email strategy using the right tone and conciseness.

Unit IV: (9 hours)

Scientific Communication

Technical Writing Skills - Types of reports; Layout of a formal report; Scientific writing skills - Importance of communicating science; Problems while writing a scientific document; Plagiarism; Scientific publication writing: Elements of a scientific paper including Abstract, Introduction,

Materials & Methods, Results, Discussion, References; Drafting titles and framing abstracts; Publishing scientific papers - the peer review process and problems, recent developments such as open access and non-blind review; Plagiarism; Characteristics of effective technical communication; Scientific presentations; Ethical issues; Scientific misconduct.

Mode of Assessment:

Components	Theory Examination	Class Tests	Assignment/Seminar/Project/Quiz
Weightage (%)	25	25	50

Recommended Textbooks and References:

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). Washington, D.C.: National Academies Press.
3. Gopen, G. D., & Smith, J. A. (n.d.). The Science of Scientific Writing. *American Scientist, 78*(Nov-Dec 1990), 550-558.
4. Mohan, K., & Singh, N. P. (2010). *Speaking English effectively*. Delhi: Macmillan India.
5. Movie: Naturally Obsessed, The Making of a Scientist.

Laboratory III: Immunology - *3 credits*

Course Code: BT417

Course Objectives:

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

Student Learning Outcomes:

Students should be able to –

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

Syllabus:

1. Selection of animals, Preparation of antigens, Immunization and methods of bleeding, serum separation and storage.
2. Antibody titre by ELISA method.
3. Double diffusion, Immuno-electrophoresis and Radial Immuno diffusion.
4. Complement fixation test.
5. Isolation and purification of IgG from serum or IgY from chicken egg.
6. SDS-PAGE, Immunoblotting, Dot blot assays.
7. Blood smear identification of leucocytes by Giemsa stain.
8. Separation of leucocytes by dextran method.
9. Demonstration of Phagocytosis of latex beads.
10. Separation of mononuclear cells by Ficoll-Hypaque.
11. Flowcytometry, identification of T cells and their subsets.
12. Lymphoproliferation by mitogen / antigen induced.
13. Lymphnode Immunohistochemistry (direct and indirect peroxidase assay).
14. Hybridoma technology and monoclonal antibody production.
15. Immunodiagnostics using commercial kits.
16. Enzyme-Linked ImmunoSpot (ELISPOT) assay.

Laboratory IV: Molecular Biology & Genetic Engineering – *5 credits*

Course Code: BT418

Course Objectives:

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

Student Learning Outcomes:

Students should be able to gain hands-on experience on 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 120 Hours (15 WK)**:**

1. Concept of lac-operon:
   (a) lactose induction of β-galactosidase.
   (b) Glucose Repression.
   (c) Diaxie growth curve of E.coli.
2. UV mutagenesis to isolate amino acid auxotroph.
3. Phage titre with λ phage/M13.
4. Genetic Transfer-Conjugation, gene mapping.
5. Plasmid DNA isolation and DNA quantitation.

6. Restriction Enzyme digestion of plasmid DNA.
7. Agarose gel electrophoresis.
8. Polymerase Chain reaction.
9. DNA Ligation.
10. Preparation of competent cells.
11. Transformation of E.coli with standard plasmids, Calculation of transformation efficiency.
12. Confirmation of the insert, Miniprep of recombinant plasmid DNA, Restriction mapping.
13. Purification of His-Tagged protein on Ni-NTA columns.

Recommended Mode of Assessment:

Components	Experiments/Journals	Quiz/Assignments	Final Examination
Weightage (%)	60	20	20

Recommended Textbooks and References:

1. Green, M. R., & Sambrook, J. (2012). *Molecular cloning: A laboratory manual*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.

SEMESTER - III

Bioprocess Engineering and Technology – *3 credits*

Course Code: BT501

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.

Student Learning Outcomes:

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 in a bioproduction process.
- Critically analyze any bioprocess from an economics/market point of view.
- Give an account of important microbial/enzymatic industrial processes in food and fuel industry.

Syllabus:

Unit I (4 lectures)

Basic principles of Biochemical engineering

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

Unit II (4 lectures)

Stoichiometry and Models of Microbial Growth

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

Unit III (8 lectures)

Bioreactor Design and Analysis

Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformations; immobilized cell systems; large scale animal and plant cell cultivation;

fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.

Unit IV (8 lectures)

Downstream Processing and Product Recovery

Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.

Unit V (4 lectures)

Fermentation Economics

Isolation of micro-organisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling; effluent treatment and disposal.

Unit VI (4 lectures)

Applications of enzyme technology in food processing

Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. and their downstream processing; baking by amylases, deoxygenation and desugaring by glucoses oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing.

Unit VII (4 lectures)

Applications of Microbial Technology in food process operations and production, biofuels and biorefinery

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

Recommended Mode of Assessment:

Components	External Examination	Class Tests	Assignment/Seminar/ Project/Quiz
Weightage (%)	60	20	20

Recommended Textbooks and References:

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

Bioentrepreneurship - *2 Credits*

Course Code: BT502

Course Objectives:

The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

Student Learning Outcomes:

Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies.

Syllabus:

Unit I (4 lectures)

Basics of Bioentrepreneurship

Importance of entrepreneurship; advantages of being entrepreneur - freedom to operate; introduction to bioentrepreneurship – biotechnology in a global scale; Scope in bioentrepreneurship; types of bio-industries – biopharma, bioagri, bioservices and bioindustrial; innovation – types, out of box thinking; skills for successful entrepreneur – creativity, leadership, managerial, team building, decision making; opportunities for bioentrepreneurship-entreprenuership development programs of public and private agencies (MSME, DBT, BIRAC, Startup & Make in India); patent landscape, IP protection & commercialization strategies.

Unit II (5 lectures)

Accounting and Finance

Business plan preparation; business feasibility analysis by SWOT, socio-economic costs benefit analysis; funds/support from Government agencies like MSME/banks and private agencies like venture capitalists:/angel investors for bioentrepreneurship; business plan proposal for 'virtual startup company'; statutory and legal requirements for starting a company/venture; basics in accounting practices: concepts of balance sheet, profit and loss statement, double entry

bookkeeping; collaborations & partnerships; information technology for business administration and expansion.

Unit III (5 lectures)

Business Strategy

Entry and exit strategy; pricing strategy; negotiations with financiers, bankers, government and law enforcement authorities; dispute resolution skills; external environment/ changes; avoiding/managing crisis; broader vision–global thinking; mergers & acquisitions.

Unit IV (5 lectures)

Marketing

Market conditions, segments, prediction of market changes; identifying needs of customers; Market linkages, branding issues; developing distribution channels - franchising; policies, promotion, advertising; branding and market linkages for 'virtual startup company'.

Unit V (7 lectures)

Knowledge Centre and R&D

Knowledge centres e.g., in universities, innovation centres, research institutions (public & private) and business incubators; R&D for technology development and upgradation; assessment of technology development; managing technology transfer; industry visits to successful bio-enterprises, regulations for transfer of foreign technologies; quality control; technology transfer agencies; Understanding of regulatory compliances and procedures (CDSCO, NBA, GLP, GCP, GMP)

Recommended Mode of Assessment:

Components	Theory Examination	Assignment/seminar/ project/site visit reports
Weightage (%)	60	40

Recommended Textbooks and References:

1. Adams, D. J., & Sparrow, J. C. (2008). *Enterprise for life scientists: Developing innovation and entrepreneurship in the biosciences*. Bloxham: Scion.
2. Shimasaki, C. D. (2014). *Biotechnology entrepreneurship: Starting, managing, and leading biotech companies*. Amsterdam: Elsevier. Academic Press is an imprint of Elsevier.
3. Onetti, A., & Zucchella, A. (n.d.). *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.
5. Desai, V. (2009). *The Dynamics of Entrepreneurial Development and Management*. New Delhi: Himalaya Pub. House.

Critical Analysis of Classical Papers - *2 credits*

Course Code: BT503

Course Objectives:

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

Student Learning Outcomes:

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

Syllabus:

How does the Course Module work? There are sixteen classical papers. Students may be divided in sixteen groups and each group may be responsible for one paper. Each week there may be a 1.5 hour presentation cum discussion for each of the papers. At the end of the semester each student will be asked to write a mini-review (2-3 pages long) on any of the sixteen papers, other than the one he/she presented/discussed.

A list of sixteen classic papers and some suggested reference materials:

Molecular Biology	
1	Studies on the chemical nature of the substance inducing transformation of Pneumococcal types: Induction of transformation by a desoxyribonucleic acid fraction isolated from Pneumococcus type III.
	Avery OT, Macleod CM, McCarty M.; J Exp Med. 1944 Feb 1;79(2):137-58.
	Note: This paper demonstrates that DNA is the transforming Principle originally described by Fredrick Griffith.
2	Independent functions of viral protein and nucleic acid in growth of bacteriophage
	Hershey AD and Chase M.; J Gen Physiol. 1952 May;36(1):39-56.
	Note: This paper demonstrates that DNA, and not protein, component of phages enter bacterial cells.
3	Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid
	Watson JD and Crick FH; Nature. 1953 Apr 25;171(4356):737-8
	Note: In this one page paper Watson and Crick first described the structure of DNA double helix
	Study help - Watson_Crick_Nature_1953_annotated
4	Transposable mating type genes in Saccharomyces cerevisiae
	James Hicks, Jeffrey N. Strathern & Amar J.S. Klar; Nature 282, 478-483,1979
	Note: This paper provided evidence for 'cassette hypothesis' of yeast mating type switches i.e. interconversion of mating types in yeast (S. cerevisiae)

	occurs by DNA rearrangement.
5	Messelson and Stahl experiment demonstrating semi-conservative replication of DNA
	Meselson M and Stahl FW.; Proc Natl Acad Sci U S A. 1958 Jul 15;44(7):671-82
	Note: The experiment demonstrating semi-conservative mode of DNA replication is referred to as "the most beautiful experiment in biology"
6	In vivo alteration of telomere sequences and senescence caused by mutated Tetrahymena telomerase RNAs
	Guo-Liang Yu, John D. Bradley, Laura D. Attardi & Elizabeth H. Blackburn; Nature 344, 126-132, 1990
	Note: This paper demonstrates that the telomerase contains the template for telomere synthesis
Cell Biology	
1	A protein-conducting channel in the endoplasmic reticulum
	Simon SM AND Blobel G.; Cell. 1991 May 3;65(3):371-80
	Note: This paper demonstrates the existence of a protein conducting channel
	Study help - A brief history of Signal Hypothesis
2	Identification of 23 complementation groups required for post-translational events in the yeast secretory pathway
	Novick P, Field C, Schekman R.; Cell. 1980 Aug;21(1):205-15
	Note: In this groundbreaking paper Randy Schekman's group used a mutagenesis screen for fast sedimenting yeast mutants to identify genes involved in cell secretion
3	A yeast mutant defective at an early stage in import of secretory protein precursors into the endoplasmic reticulum
	Deshaies RJ and Schekman R.; J Cell Biol. 1987 Aug;105(2):633-45
	Note: Using another yeast mutation screen Schekman lab identifies Sec61, a component of ER protein Conducting Channel (PCC)
	Suggested reference paper - A biochemical assay for identification of PCC.
4	Reconstitution of the Transport of Protein between Successive Compartments of the Golgi
	Balch WE, Dunphy WG, Braell WA, Rothman JE.; Cell. 1984 Dec;39(2 Pt 1):405-16
	Note: This paper describes setting up of an in vitro reconstituted system for transport between golgi stacks which eventually paved the way for identification of most of the molecular players involved in these steps including NSF, SNAP etc.
5	A complete immunoglobulin gene is created by somatic recombination
	Brack C, Hirama M, Lenhard-Schuller R, Tonegawa S.; Cell. 1978 Sep;15(1):1-14
	Note: This study demonstrates DNA level molecular details of somatic rearrangement of immunoglobulin gene sequences leading to the generation of functionally competent antibody generating gene following recombination.
6	A novel multigene family may encode odorant receptors: a molecular basis for odor recognition
	Buck L and Axel R; Cell. 1991 Apr 5;65(1):175-87
	Note: This paper suggests that different chemical odorants associate with

	different cell-specific expression of a transmembrane receptor in Drosophila olfactory epithelium where a large family of odorat receptors is expressed.
7	Kinesin walks hand-over-hand
	Yildiz A, Tomishige M, Vale RD, Selvin PR.; Science. 2004 Jan 30;303(5658):676-8
	Note: This paper shows that kinesin motor works as a two-headed dimeric motor walking hand-over-hand rather than like an inchworm on microtubule tract using the energy of ATP hydrolysis.
Developmental Biology/ Genetics	
1	Mutations affecting segment number and polarity in Drosophila
	Christiane Nusslein-Volhard and Eric Weischaus; Nature 287, 795-801, 1980
	Note: This single mutagenesis screen identified majority of the developmentally important genes not only in flies but in other metazoans as well.
2	Information for the dorsal--ventral pattern of the Drosophila embryo is stored as maternal mRNA
	Anderson KV and Nüsslein-Volhard C; Nature. 1984 Sep 20-26;311(5983):223-7
	Note: This landmark paper demonstrated that early dorsal-ventral pattern information is stored as maternal mRNA in flies and devised the method of identifying genes encoding such genes
3	Hedgehog signalling in the mouse requires intraflagellar transport proteins
	Huangfu D, Liu A, Rakeman AS, Murcia NS, Niswander L, Anderson KV.; Nature. 2003 Nov 6;426(6962):83-7
	Note: One of the architects of original fly mutagenesis screens conducted a mouse mutagenes screen which identified a gene Kif3a as a major component of hedgehog signaling pathway. Eventually this discovery revolutionizes our understanding of mechanisms of action of signaling pathways by demonstrating central role of cillia in it.
	Suggested Reference paper - Design and execution of a embryonic lethal mutation screen in mouse

Recommended Mode of Assessment:

At the end of the course, assessment may be done with each student may be asked to write a mini-review (2-3 pages) on any of the sixteen papers, other than the one paper the student may have presented/discussed in the class.

Emerging Technologies – *2 Credits*

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 the basic principles of the new principles to the students and make them appreciate the current-day research tool-kit better.

Student Learning Outcomes:

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

Syllabus:

Unit I (8 lectures)

Optical Microscopy Methods

The Light Microscopy**:** lenses and microscopes**,** resolution: Rayleigh's Approach**,** Darkfield; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy: what is fluorescence? what makes a molecule fluorescent?**,** the 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 beamsplitters**,** boosting the signal; confocal microscope: scanning optical microscope**,** confocal principle**,** resolution and point spread function**,** light source: gas lasers & solid-state**,** primary beamsplitter; beam scanning**,** pinhole and signal channel configurations**,** detectors; pixels and voxels; contrast**,** spatial sampling: temporal sampling: signal-to-noise ratio**,** multichannel images. nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence**,** advantages of two-photon excitation**,** tandem scanning (spinning disk) microscopes**,** deconvolving confocal images; image processing**,** three-dimensional reconstruction; advanced fluorescence techniques: FLIM, FRET, and FCS**,** Fluorescence Lifetime**,** Fluorescence Resonant Energy Transfer (FRET)**,** Fluorescence Correlation Spectroscopy (FCS)**,** Evanescent Wave Microscopy; Near-Field and Evanescent Waves**,** Total Internal Reflection Microscopy; Near-Field Microscopy; Beyond the Diffraction Limit**:** Stimulated Emission Depletion (STED)**,** Super-Resolution Summary**,** Super-Resolution Imaging with Stochastic Optical Reconstruction Microscopy (STORM) and Photoactivated Localization Microscopy (PALM).

Unit II (4 lectures)

Mass Spectroscopy

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 (3 lectures)

Systems Biology

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 (3 lectures)

Structural Biology

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

Unit V (6 lectures)

CRISPR-CAS

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 (4 lectures)

Nanobodies

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 Mode of Assessment:

Assessment	External Examination	Internal tests	Take-home assignments	Overall quality of engagement in the class	Seminars
Weightage (%)	30%	30%	10%	10%	20%

Recommended Textbooks and References:

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. *Annu. Rev. Biochem. 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.
8. Ledford, H. (2016). The unsung heroes of CRISPR. *Nature, 535*(7612), 342-344. doi:10.1038/535342a.
9. Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J. A., & Charpentier, E. (2012). A Programmable Dual-RNA-Guided DNA Endonuclease in Adaptive Bacterial Immunity. *Science, 337*(6096), 816-821. doi:10.1126/science.1225829.
10. Hamers-Casterman, C., Atarhouch, T., Muyldermans, S., Robinson, G., Hammers, C., Songa, E. B., Hammers, R. (1993). Naturally occurring antibodies devoid of light chains. *Nature, 363*(6428), 446-448. doi:10.1038/363446a0.
11. Sidhu, S. S., & Koide, S. (2007). Phage display for engineering and analyzing protein interaction interfaces. *Current Opinion in Structural Biology, 17*(4), 481-487. doi:10.1016/j.sbi.2007.08.007.
12. Steyaert, J., & Kobilka, B. K. (2011). 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. Verheesen, P., & Laeremans, T. (2012). Selection by Phage Display of Single Domain Antibodies Specific to Antigens in Their Native Conformation. *Single Domain Antibodies,* 81-104. doi:10.1007/978-1-61779-968-6_6.
15. Li, J., Xia, L., Su, Y., Liu, H., Xia, X., Lu, Q. Reheman, K. (2012). Molecular Imprint of Enzyme Active Site by Camel Nanobodies. *Journal of Biological Chemistry J. Biol. Chem., 287*(17), 13713-13721. doi:10.1074/jbc.m111.336370.
16. Sohier, J., Laurent, C., Chevigné, A., Pardon, E., Srinivasan, V., Wernery, U. Galleni, M. (2013). Allosteric inhibition of VIM metallo-β-lactamases by a camelid nanobody. *Biochemical Journal, 450*(3), 477-486. doi:10.1042/bj20121305.
17. Chakravarty, R., Goel, S., & Cai, W. (2014). Nanobody: The "Magic Bullet" for Molecular Imaging? *Theranostics, 4*(4), 386-398. doi:10.7150/thno.8006.

Intellectual Property Rights, Biosafety and Bioethics – *2 Credits*

Course Code: BT505

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 learn biosafety and risk assessment of products derived from biotechnology and regulation of such products.
- To understand ethical issues in biological research.

Student Learning Outcomes:

Students should be able to –

- 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 biosafety and risk assessment of products derived from recombinant DNA research and environment release of genetically modified organisms, national and international regulations.
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

Syllabus:

Unit I (5 lectures)

Introduction to IPR

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

Unit II (5 lectures)

Patenting

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

Unit III (5 lectures)

Biosafety

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

Unit IV (5 lectures)

National and International Regulations

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

Unit V (5 lectures)

Bioethics

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

Recommended Mode of Assessment:

Components	Theory Examinations	Practicals (Assignment/Seminar/ Project/Quiz)
Weightage (%)	60	40

Recommended Textbooks and References:

1. Ganguli, P. (2001). *Intellectual property rights: Unleashing the knowledge economy*. New Delhi: Tata McGraw-Hill Pub.
2. *Complete Reference to Intellectual Property Rights Laws*. (2007). Snow White Publication Oct.
3. Kuhse, H. (2010). *Bioethics: An anthology*. Malden, MA: Blackwell.
4. Office of the Controler General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/
5. World Trade Organisation. http://www.wto.org
6. World Intellectual Property Organisation. http://www.wipo.int
7. International Union for the Protection of New Varieties of Plants. http://www.upov.int
8. National Portal of India. http://www.archive.india.gov.in
9. National Biodiversity Authority. http://www.nbaindia.org
10. Recombinant DNA Safety Guidelines, 1990 Department of Biotechnology, Ministry of Science and Technology, Govt. of India. Retrieved from http://www.envfor.nic.in/divisions/csurv/geac/annex-5.pdf
11. Wolt, J. D., Keese, P., Raybould, A., Fitzpatrick, J. W., Burachik, M., Gray, A., Wu, F. (2009). Problem formulation in the environmental risk assessment for genetically modified plants. *Transgenic Research*, 19(3), 425-436. doi:10.1007/s11248-009-9321-9

12. Craig, W., Tepfer, M., Degrassi, G., & Ripandelli, D. (2008). An overview of general features of risk assessments of genetically modified crops. *Euphytica, 164*(3), 853-880. doi:10.1007/s10681-007-9643-8
13. Guidelines for Safety Assessment of Foods Derived from Genetically Engineered Plants. 2008.
14. Guidelines and Standard Operating procedures for confined field trials of regulated genetically engineered plants. 2008. Retrieved from http://www.igmoris.nic.in/guidelines1.asp.
15. Alonso, G. M. (2013). Safety Assessment of Food and Feed Derived from GM Crops: Using Problem Formulation to Ensure "Fit for Purpose" Risk Assessments. Retrieved from http://biosafety.icgeb.org/inhousepublications/collectionbiosafetyreviews.

Project Proposal – *2 credits*

Course Code: BT506

Course Objectives:

The main purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills.

Student Learning Outcomes:

Students should be able to demonstrate the following abilities -

- to formulate a scientific question.
- to present scientific approach to solve the problem.
- to interpret, discuss and communicate scientific results in written form.
- to gain experience in writing a scientific proposal.

Syllabus:

Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.
Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.
Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc.
Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Recommended Mode of Assessment:

Assessment will be made by evaluation of the project proposal submitted by the student.

Project Proposal Presentation – *2 credits*

Course Code: BT607

Course Objectives:

The objectives of this course are to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes:

Students should be able to learn how to present and explain their research findings to the audience affectively.

Syllabus:

Poster Presentation: Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.
Oral Presentation: At the end of their project, presentation will have to be given by the students to explain in detail the work done by them. Along with summarizing their findings they should also be able to discuss the future outcomes of their work.

Recommended Mode of Assessment:

Assessment will be made during the student presentations and discussions.

Research Seminar – *1 credit*

Course Code: BT508

Course Objectives:

The objectives of this course are to train the students to evaluate research papers, to assess quality of the papers and how the papers are refereed and published as well as learn how to get the papers published.

Student Learning Outcomes:

Students should be able to –

- Critically analyse the research papers from different upcoming topics.
- Understand the weaknesses and strengths of the paper and what additional experiments could have been done to strengthen the research study.
- Understand the context of the paper and identify important questions.
- Acquire the skills in paper writing and getting it published.

Syllabus:

Student presentations: Each student will need to present one paper during the term. They should select research papers, which deal with upcoming or most recent scientific findings/breakthrough and technologies developed.
Class evaluations and discussions: Every week, each student will be asked to write a short review and evaluations of the paper presented in the class and then indulge in discussion with flaws of the paper, important questions and impact of the overall paper. Recent technologies, can be discussed, where it can be applied.

Recommended Mode of Assessment:

Assessment will be made during the student presentation and discussions.

Laboratory: Bioprocess Engineering and Technology – *3 credits*

Course Code: BT510

Course Objectives:

The objectives of this laboratory course are to provide *in practicum* training to students in upstream and downstream unit operations.

Student Learning Outcomes:

Students should be able to –

- Gain ability to investigate, design and conduct experiments, analyze and interpret data, and apply the laboratory skills to solve complex bioprocess engineering problems.
- 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, microscopy.

c) Isolation of microorganisms from soil samples.

2) Experimental set-up
   a) Assembly of 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.
5) Unit operations
   a) Microfiltrations: Separation of cells from broth.
   b) Bioseparations: Various chromatographies and extractions.
6) Bioanalytics
   a) Analytical techniques like HPLC, FPLC, GC, GC-MS etc. for measurement of amounts of products/substrates.

Recommended Mode of Assessment:

Components	External Examination	Class Experiments	Assignment/Seminar/ Project/Quiz
Weightage (%)	40	40	20

Recommended Textbooks and References:

1. Shuler, M. L., & Kargi, F. (2002). Bioprocess engineering: Basic concepts. Upper Saddle River, NJ: Prentice Hall.
2. Stanbury, P. F., & Whitaker, A. (1984). *Principles of fermentation technology*. Oxford: Pergamon Press.
3. Blanch, H. W., & Clark, D. S. (1997). *Biochemical engineering*. New York: M. Dekker.
4. Bailey, J. E., & Ollis, D. F. (1986). *Biochemical engineering fundamentals*. New York: McGraw-Hill.
5. El-Mansi, M., & Bryce, C. F. (2007). *Fermentation microbiology and biotechnology*. Boca Raton: CRC/Taylor & Francis.

SEMESTER – IV

Dissertation – *20 credits*

Course Code: BT511

Course Objectives:

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

Student Learning Outcomes:

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

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

Syllabus:

Planning & performing of experiments: Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.
Thesis writing: At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Recommended Mode of Assessment:

Assessment may be done by thesis evaluation, viva voce and final presentation.