SYLLABUS FOR M. Sc. BIOTECHNOLOGY

(Adopting Remodeled DBT Proposed Syllabus)

For the Academic Batch 2022-24

Berhampur University

Bhanja Bihar-760007

Odisha, India

About the M.Sc. Biotechnology Course

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under 'Make in India', 'Skill India' and 'Startup India' initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India's emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship. DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT revised the Syllabus through a Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives. The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education keeping CBCS pattern into account. The revised course curriculum totals to 96 credits comprising of theory, practical, technology-based topics, electives and dissertation etc.

M.Sc. Biotechnology

Paper code	Title	Credits	Internal marks	End sem Marks	Total Marks
SEMESTER-I					
BIOT-C-101	Biochemistry	3	20	80	100
BIOT-C-102	Cell and Molecular Biology	3	20	80	100
BIOT-C-103	Microbiology	3	20	80	100
BIOT-C-104	Genetics	3	20	80	100
BIOT-C-105	Basics of Mathematics and Statistics	2	20	80	100
BIOT-C-106	Basics of Chemistry and Physics	2	20	80	100
BIOT-C-107	Research Methodology and Scientific Communication Skills	2	20	80	100
BIOT-P-108	Laboratory I: Biochemistry and Analytical Techniques	4	0	100	100
BIOT-P-109	Laboratory II: Microbiology	2	0	100	100
	SEMESTER-I TOTAL	**24**	**140**	**760**	**900**
SEMESTER-II					
BIOT-C-201	Genetic Engineering	3	20	80	100
BIOT-C-202	Immunology	3	20	80	100
BIOT-C-203	Bioinformatics	3	20	80	100
BIOT-C-204	Genomics and Proteomics	3	20	80	100
BIOT-C-205	Molecular Diagnostics	2	20	80	100
BIOT-S-206	Critical Analysis of Classical Papers	2	100	-	100
BIOT-E-207*	Elective I	3	20	80	100
BIOT-P-208	Laboratory III: Molecular Biology and Genetic Engineering	3	0	100	100
BIOT-P-209	Laboratory IV: Immunology	2	0	100	100
BIOT-VAC-210	Biological Tools and Techniques	NC	20	80	100
	SEMESTER-II TOTAL	**24**	**220**	**680**	**900**
SEMESTER-III					
BIOT-C-301	Bioprocess Engineering and Technology	3	20	80	100
BIOT-C-302	Emerging Technologies	2	20	80	100
BIOT-C-303	Plant and Animal Biotechnology	3	20	80	100
BIOT-C-304	Bio-entrepreneurship	2	20	80	100
BIOT-C-305	Intellectual Property Rights, Biosafety and Bioethics	2	20	80	100
BIOT-CT-300#	CBCT course (Interdisciplinary Elective)	4	20	80	100
BIOT-S-307	Project Proposal Preparation & Presentation	2	100	-	100
BIOT-P-308	Laboratory V: Plant and Animal Biotechnology & Bioprocess Engineering and Technology	3	0	100	100
BIOT-P-309	Laboratory VI: Bioinformatics	2	0	100	100
BIOT-D-310	Dissertation	2	100	0	100
BIOT-VAC-311	Journal Club Presentation	NC	100	-	100
	SEMESTER III TOTAL	**25**	**320**	**680**	**1000**

Paper code	Title	Credits	Internal marks	End sem Marks	Total Marks
SEMESTER-IV					
BIOT-D-401	Dissertation	20	60	240	300
BIOT-E-402**	Elective-II	3	20	80	100
BIOT-AC-403	Cultural Heritage of South Odisha	NC	10	40	50
SEMESTER IV TOTAL		**23**	**80**	**320**	**400**
GRAND TOTAL		**96**	**--**	**--**	**3200**

Elective Papers

BIOT-E-207* Elective I: (A). Biological Imaging (B). Vaccines (C). Environmental Biotechnology (D) Microbial Technology.

BIOT-E-402 Elective II:** (A). Drug Discovery and Development (B). Nanobiotechnology (C). Protein Engineering (D). Metabolic Engineering and Metabolomics

CBCT (Inter Disciplinary Elective) Papers (# Students have to Choose one of the following courses except BIOT-CT-300)

BIOT-CT-300: Biotechnology in Human Welfare (Offered by Dept. of Biotechnology)
BOTA-CT-300: Economic Botany (Offered by Dept. of Botany)
ENVS-CT-300: Population and Environmental Issues (Offered by Dept. of Environment Studies)
MARB-CT-300: Environmental Impact Assessment (Offered by Dept. of Marine Science)
ZOOL-CT-300: Conservation Biology (Offered by Dept. of Zoology)

Value added course (VAC): BIOT-VAC-210 and BIOT-VAC-311

Guidelines for conducting value added courses (VAC)

Value Added Course is not mandatory to qualify for any programme and shall be offered as non-credit course in the 2nd and 3rd semester. It is a teacher assisted learning course open to students of the concerned department and the students shall register along with other courses in that particular semester. Classes for a VAC can be reflected in the time table. The value-added courses may be also conducted during weekends / vacation period. A student will be permitted to register only one Value Added Course in a Semester. The course can be offered only if there are at least 10 students opting for it where the total strength is 50. In case of lower strength, it will proportionate.

Duration: The duration of value-added course is 30 hours with a combination 18 hours (60%) of theory and 12 hours (40%) of practical. However, the combination of theory and practical shall be decided by the course teacher with the approval of the Head of the Department.

Add On Course (AC) :

BIOT-AC-403: Cultural Heritage of South Odisha

Code Used

BIOT- Biotechnology, **BOTA**- Botany, **ENVS**- Environmental Studies, **MARB**- Marine Biology, **Zool**- Zoology **C-** Core, **E-** Elective, **S-**Seminar, **P-** Practical, **D-** Dissertation**, CT-** Interdisciplinary Elective (Choice Based Credit Transfer)**, VAC-** Value Added Course**, AC-** Add On Course, **NC**- Non-Credit course

Semester One

BIOT-C-101 Biochemistry

Credits

3

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

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

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

Unit I **Chemical basis of life** 5 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.
Protein Structure 5 lectures	Structure-function relationships: amino acids – structure and functional group properties, Hierarchical organization of protein, Ramachandran plot, evolution of protein structure, protein degradation and molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin *etc.*; Basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.
Unit II **Enzyme Kinetics** 5 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.
Structure and Function of DNA & RNA and lipids 5 lectures	Self-assembly of lipids, micelle, bio-membrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

Unit III **Bioenergetics** 8 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; F1-F0 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
Unit IV **Glycobiology & Metabolism** 12 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. Calvin cycle and pentose phosphate pathway; glycogen metabolism and its regulation; 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; target of rapamycin (TOR) & Autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.

Recommended Textbooks and References:

1. Stryer, L. (2015). *Biochemistry*. (8th ed.) New York: Freeman.
2. Lehninger, A. L. (2012). *Principles of Biochemistry* (6th ed.). New York, NY: Worth.
3. Voet, D., & Voet, J. G. (2016). *Biochemistry* (5th ed.). Hoboken, NJ: J. Wiley & Sons.
4. Dobson, C. M. (2003). *Protein Folding and Misfolding*. Nature, 426(6968), 884-890. doi:10.1038/nature02261.
5. Richards, F. M. (1991). *The Protein Folding Problem*. Scientific American, 264(1), 54-63. doi:10.1038/scientificamerican0191-54.

BIOT-C-102
Cell and Molecular Biology

Credits

3

Course Objectives

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

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?

Unit I **Dynamic organization of cell** 8 lectures	Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes.
Unit II **Chromatin structure and dynamics** 12 lectures	Chromatin organization - histone and DNA interactome: structure and assembly of eukaryotic and prokaryotic DNA polymerases, DNA-replication, repair and recombination; chromatin control: gene transcription and silencing by chromatin Writers, -Readers and –Erasers; Transcriptional control: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors, transcriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small 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 **Cellular signalling, transport and trafficking** 3 lectures	Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.
Cellular processes 7 lectures	Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and transmembrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.
Unit IV **Manipulating and studying cells** 2 lectures	Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.
Genome instability and cell transformation 8 lectures	Mutations, proto-oncogenes, oncogenes and tumor suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; 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 including activation; oncogenes as transcriptional activators.

Recommended Textbooks and References:

1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2008). *Molecular Biology of the Cell* (5th Ed.). New York: Garland Science.
2. Lodish, H. F. (2016). *Molecular Cell Biology* (8th Ed.). 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. (2013). *The Cell: A Molecular Approach* (6th Ed.). Washington: ASM; Sunderland.
5. Hardin, J., Bertoni, G., Kleinsmith, L. J., & Becker, W. M. (2012). *Becker's World of the Cell*. Boston (8th Ed.). Benjamin Cummings.
6. Watson, J. D. (2008). *Molecular Biology of the Gene* (5th ed.). Menlo Park, CA: Benjamin/Cummings.

BIOT-C-103
Microbiology

Credits

3

Course Objectives

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

Student Learning Outcomes

Students should be able to:

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

Unit I **Microbial characteristics** 10 lectures	Introduction to microbiology and microbes, history & scope of microbiology, morphology, structure, growth and nutrition of bacteria, bacterial growth curve, bacterial culture methods; bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation; antimicrobial resistance.
Unit II **Microbial diversity** 10 lectures	Microbial taxonomy and evolution of diversity, classification of microorganisms, criteria for classification; classification of bacteria; Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria, Mycobacteria and Mycoplasma. Archaea: Halophiles, Methanogens, Hyperthermophilic archaea, Thermoplasm; eukarya: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes.
Unit III **Control of microorganisms** 4 lectures	Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, biological control of microorganisms.

Virology 6 lectures	Virus and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles – viroids and prions.
Unit IV **Host-microbes interaction** 10 lectures	Host-pathogen interaction, ecological impact of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbes and nutrient cycles; microbial communication system; bacterial quorum sensing; microbial fuel cells; prebiotics and probiotics.

Recommended Textbooks and References:

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

BIOT-C-104
Genetics

Credits

3

Course Objectives

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

Student Learning Outcomes

Students should be able to:

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

Unit I **Genetics of bacteria and bacteriophages** 12 lectures	Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of gene.
Unit II **Yeast genetics** 8 lectures	Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, complementation groups, transposon mutagenesis, synthetic lethality, genetic epistasis
Unit III ***Drosophila* genetics as a model of higher eukaryotes** 6 lectures	Monohybrid & dihybrid crosses, back-crosses, test-crosses, analyses of autosomal and sex linkages, screening of mutations based on phenotypes and mapping the same, hypomorphy, genetic mosaics, genetic epistasis in context of developmental mechanism.
Plant genetics 4 lectures	Laws of segregation in plant crosses, inbreeding, selfing, heterosis, maintenance of genetic purity, gene pyramiding.

Unit IV **Population genetics and genetics of evolution** 6 lectures	Introduction to the elements of population genetics: genetic variation, genetic drift, neutral evolution; mutation selection, balancing selection, Fishers theorem, Hardy Weinberg equilibrium, linkage disequilibrium; in-breeding depression & mating systems; population bottlenecks, migrations, Bayesian statistics; adaptive landscape, spatial variation & genetic fitness.
Quantitative genetics of complex traits (QTLs) 4 lectures	Complex traits, mapping QTLs, yeast genomics to understand biology of QTLs.

Recommended Textbooks and References:

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

BIOT-C-105
Basics of Mathematics and Statistics

Credits

2

Course Objectives

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

Student Learning Outcomes

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

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

Unit I **Algebra** 6 lectures	Linear equations, functions: slopes-intercepts, forms of two-variable linear equations; constructing linear models in biological systems; quadratic equations (solving, graphing, features of, interpreting quadratic models etc.), introduction to polynomials, graphs of binomials and polynomials; Symmetry of polynomial functions, basics of trigonometric functions, Pythagorean theory, graphing and constructing sinusoidal functions, imaginary numbers, complex numbers, adding-subtracting-multiplying complex numbers, basics of vectors, introduction to matrices.
Unit II **Calculus** 4 lectures	Differential calculus (limits, derivatives), integral calculus (integrals, sequences and series etc.).
Unit III **Mathematical models in biology** 4 lectures	Population dynamics; oscillations, circadian rhythms, developmental patterns, symmetry in biological systems, fractal geometries, size-limits & scaling in biology, modeling chemical reaction networks and metabolic networks.
Unit IV **Statistics** 6 lectures	Probability: counting, conditional probability, discrete and continuous random variables; Error propagation; Populations and samples, expectation, parametric tests of statistical significance, nonparametric hypothesis tests, linear regression, correlation & causality, analysis of variance, factorial experiment design

Recommended Textbooks and References:

1. Stroud, K. A., & Booth, D. J. (2009). *Foundation Mathematics*. New York, NY: Palgrave Macmillan.
2. Aitken, M., Broadhursts, B., & Haldky, S. (2009) *Mathematics for Biological Scientists*. Garland Science.
3. Billingsley, P. (1986). *Probability and Measure*. New York: Wiley.
4. Rosner, B. (2000). *Fundamentals of Biostatistics*. Boston, MA: Duxbury Press.
5. Daniel, W. W. (1987). *Biostatistics, a Foundation for Analysis in the Health Sciences*. New York: Wiley.

BIOT-C-106
Basics of Chemistry and Physics

Credits

2

Course Objectives

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

Student Learning Outcomes

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

Unit I **Basic physics for biologists-I** 5 lectures	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;
Unit II **Basic physics for biologists-II** 7 lectures	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 III **Basic chemistry for biologists** 6 lectures	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, Arrhenius

	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;
Unit IV **Basic chemistry for biologists** 6 lectures	States of matter - vapor pressure, phase diagrams, surface tension, boiling and melting points, solubility, capillary action, suspensions, colloids and solutions; acids, bases and pH - Arrhenius 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 phosphorylation 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 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.

BIOT-C-107
Research methodology and scientific communication skills

Credits
2

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

Student Learning Outcomes
Students should be able to:
- Understand history and methodologies of scientific research, applying these to recent published papers;
- Understand and practice scientific reading, writing and presentations;
- Appreciate scientific ethics through case studies.

Unit I **History of science and science methodologies** 4 lectures	Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology
Unit II **Preparation for research** 6 lectures	Choosing a mentor, lab and research question; maintaining a lab notebook.
Unit III **Process of communication** 5 lectures	Concept of effective communication- setting clear goals for communication; determining outcomes and results; initiating communication; avoiding 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, PowerPoint; 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 **Scientific communication** 9 lectures	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, software for 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 - 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.

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. *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.

BIOT-P-108 Laboratory I: Biochemistry and analytical techniques

Credits

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

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

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

Syllabus	
	1. Preparing various stock solutions and working solutions that will be needed for the course. 2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation. 3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert's Law. 4. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography. 5. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution's choice). a) Preparation of cell-free lysates b) Ammonium Sulfate precipitation c) Ion-exchange Chromatography d) Gel Filtration and Affinity Chromatography e) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method f) Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification) g) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis h) Enzyme Kinetic Parameters: Km, Vmax and Kcat. 6. Experimental verification that absorption at OD260 is more for denatured DNA as compared to native double stranded DNA. reversal of the same following DNA renaturation. Kinetics of DNA renaturation as a function of DNA size. 7. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools. (Optional Experiments) 8. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy).

	9. Determination of mass of small molecules and fragmentation patterns by Mass Spectrometry.

Recommended Textbooks and References:

1. Swati Agarwal and Suphiya Khan (2019) Advanced lab practices in Biochemistry and Molecular Biology. Willey
2. David T Plummer (2006) An Introduction to Practical Biochemistry (3rd Edition) TMH publications

BIOT-P-109 Laboratory II: Microbiology

Credits

2

Course Objectives

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

Student Learning Outcomes

Students should be able to:

- Isolate, characterize and identify common bacterial organisms;
- Determine bacterial load of different samples;
- Perform antimicrobial sensitivity tests;
- Preserve bacterial cultures.

Syllabus

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

Recommended 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. Bailey & Scott's Diagnostic Microbiology.

Semester Two

BIOT-C-201 Genetic Engineering

Credits

3

Course Objectives

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

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.

Unit I **Introduction and tools for genetic engineering** 5 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.
Different types of vectors 7 lectures	Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene 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 **Different types of PCR techniques** 8 lectures	Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.
Unit III **Gene manipulation and DNA-protein interaction** 10 lectures	Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit IV **Gene silencing and genome editing technologies** 10 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 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.*

BIOT-C-202
Immunology

Credits

3

Course Objectives

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

Student Learning Outcomes

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

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

Unit I **Immunology: fundamental concepts and overview of the immune system** 5 lectures	Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens: immunogens, haptens; Major Histocompatibility Complex: MHC genes, MHC and immune responsiveness and disease susceptibility, Organs of immune system, primary and secondary lymphoid organs
Immune response generated by B and T lymphocytes 8 lectures	Immunoglobulins - basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self & non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses,

	ADCC; cytokines: properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation, Hapten-carrier system.
Unit II **Antigen-antibody interactions** 6 lectures	Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques: RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence microscopy, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosensor assays for assessing ligand –receptor interaction; CMI techniques: lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs
Immunogenetics 5 lectures	Major histocompatibility complex genes and their role in autoimmune and infectious diseases, HLA typing, human major histocompatibility complex (MHC), Complement genes of the human major histocompatibility complex: implication for linkage disequilibrium and disease associations, genetic studies of rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis, genetics of human immunoglobulin, immunogenetics of spontaneous control of HIV, KIR complex.
Unit III **Vaccinology** 8 lectures	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, generation of monoclonal antibodies, 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 IV **Clinical immunology** 8 lectures	Immunity to infection : bacteria, viral, fungal and parasitic infections (with examples from each group); hypersensitivity: Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; treatment of autoimmune diseases; transplantation: immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology: tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency: primary immunodeficiencies, acquired or secondary immunodeficiencies, autoimmune disorder, anaphylactic shock, immunosenescence, immune exhaustion in chronic viral infection, immune tolerance, NK cells in chronic viral infection and malignancy.

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. (2012). *Fundamental Immunology*. New York: Raven Press.
5 Goding, J. W. (1996). *Monoclonal Antibodies: Principles and Practice: Production and Application of Monoclonal Antibodies in Cell Biology, Biochemistry, and Immunology.* London: Academic Press.
6 Parham, P. (2005). *The Immune System*. New York: Garland Science.

BIOT-C-203
Bioinformatics

Credits

3

Course Objectives

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

Student Learning Outcomes

Student should be able to:

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

Unit I **Bioinformatics basics** 10 lectures	Bioinformatics basics: Computers in biology and medicine; Introduction to Unix and Linux systems and basic commands; Database concepts; Protein and nucleic acid databases; Structural databases; Biological XML DTD's; pattern matching algorithm basics; databases and search tools: biological background for sequence analysis; Identification of protein sequence from DNA sequence; searching of databases similar sequence; NCBI; publicly available tools; resources at EBI; resources on web; database mining tools.
Unit II **DNA sequence analysis** 5 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.
Multiple sequence analysis 5 lectures	Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTALW and CLUSTALX for multiple sequence alignment; submitting DNA protein sequence to databases: where and how to submit, SEQUIN, genome centres; submitting aligned sets of sequences, updating submitted sequences, methods of phylogenetic analysis.
Unit III **Protein modelling** 8 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 IV **Protein structure prediction and virtual library** 8 lectures	Protein structure prediction: protein folding and model generation; secondary structure prediction; analyzing secondary structures; protein loop searching; loop generating methods; homology modelling: potential applications, description, methodology, homologous sequence identification; align structures, align model sequence; construction of variable and conserved regions; threading techniques; topology fingerprint approach for prediction; evaluation of alternate models; structure prediction on a mystery sequence; structure aided sequence techniques of structure prediction; structural profiles, alignment algorithms, mutation tables, prediction, validation, sequence based methods of structure prediction, prediction using inverse folding, fold prediction; significance analysis, scoring techniques, sequence-sequence scoring; protein function prediction; elements of in silico drug design; Virtual library: Searching PubMed, current content, science citation index and current awareness services, electronic journals, grants and funding information.

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.

BIOT-C-204
Genomics and Proteomics

Credits

3

Course Objectives

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

Student Learning Outcomes

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

Unit I **Basics of genomics** 4 lectures	Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast; Minimal Cell genome; Reverse Genetics
Genome mapping 6 lectures	Genetic and physical maps; markers for genetic mapping; methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, in situ hybridization, comparative gene mapping.
Unit II **Genome sequence projects** 5 lectures	Genome Sequencing Strategies: Principles and Methodology; Human Genome Project, genome sequencing projects for microbes, plants and animals, accessing and retrieving genome project information from the web.

Comparative genomics 5 lectures	Comparative Genomics: Structural and Functional aspects; Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence.
Unit III **Functional genomics** 10 lectures	Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in genome, gene function- forward and reverse genetics, gene ethics;
Unit IV **Proteomics & Metabolomics** 10 lectures	Aims, strategies and challenges in proteomics; proteomics technologies: 2D-PAGE, isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, proteome databases. Protein-protein and protein-DNA interactions; protein chips and functional proteomics; clinical and biomedical applications of proteomics; introduction to metabolomics, Metabonomics, lipidomics, metagenomics and systems biology.

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.

BIOT-C-205 Molecular Diagnostics

Credits

2

Course Objectives

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

Student Learning Outcomes

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

Unit I **Genome biology in health and disease** 3 lectures	DNA, RNA, Protein: An overview; chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs
Genome: resolution, detection & analysis 5 lectures	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 II **Detection and identification of microbial diseases** 4 lectures	Direct detection and identification of pathogenic-organisms that are slow growing or currently lacking a system of in vitro cultivation as well as genotypic markers of microbial resistance to specific antibiotics.
Detection of inherited diseases 4 lectures	Exemplified by two inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: Fragile X Syndrome: Paradigm of new mutational mechanism of unstable triplet repeats, von-Hippel Lindau disease: recent acquisition in growing number of familial cancer syndromes.
Unit III **Molecular oncology** 6 lectures	Detection of recognized genetic aberrations in clinical samples from cancer patients; types of cancer-causing alterations revealed by next-generation sequencing of clinical isolates; predictive biomarkers for personalized onco-therapy of human diseases such as chronic myeloid leukemia, colon, breast, lung cancer and melanoma as well as matching targeted therapies with patients and preventing toxicity of standard systemic therapies.
Unit IV **Diagnostic metabolomics & Quality assurance** 4 lecture	Metabolite profile for biomarker detection the body fluids/tissues in various metabolic disorders by making using LCMS & NMR platforms. Quality oversight; regulations and approved testing.

Recommended Textbooks and References:

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

BIOT-C-206
Critical Analysis of Classical Papers

Credits

2

Course Objectives

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

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.

How does the Course Module work? Students may be divided in groups and each group may be responsible for one classical 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 one classical paper, other than the one he/she presented/discussed. A list of sixteen classic papers and some suggested reference materials:

Syllabus **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. 4. Transposable mating type genes in *Saccharomyces cerevisiae* James Hicks, Jeffrey N. Strathern & Amar J.S. Klar; Nature 282, 478-483,1979 **Note:** This paper provided evidence for 'cassette hypothesis' of yeast mating type switches *i.e.* interconversion of mating types in yeast *(S. cerevisiae)* occurs by DNA rearrangement. 5. Messelson & Stahl experiment demonstrating semi-conservative replication of DNA. Meselson M and Stahl FW.; Proc Natl Acad Sci U S A. 1958 Jul 15;44(7):671-82 **Note:** The experiment demonstrating semi-conservative mode of DNA replication is referred to as "the most beautiful experiment in biology" 6. *In vivo* alteration of telomere sequences and senescence caused by mutated *Tetrahymena* telomerase RNAs Guo-Liang Yu, John D. Bradley, Laura D. Attardi & Elizabeth H. Blackburn; Nature 344, 126-132, 1990 **Note:** This paper demonstrates that the telomerase contains the template for telomere synthesis 7. Tanksley, S., Young, N., Paterson, A. *et al.* RFLP Mapping in Plant Breeding: New Tools for an Old Science. *Nat Biotechnol* **7,** 257–264 (1989). 8. Mechanisms for initiating cellular DNA replication. F. Bleichert, M. R. Botchan, J. M. Berger; Science 24, 6327 (2017)
Syllabus **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.
Syllabus **Developmental Biology**	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.
Syllabus **Genetics & Genomics**	1. Chromosome catastrophes involve replication mechanisms generating complex genomic rearrangements. P. Liu, A. Erez, S. C. S. Nagamani, S. U. Dhar, K. E. Kołodziejska, A. V. Dharmadhikari, et al.; Cell 2011 Vol. 146 Issue 6 Pages 889-903; **Note:** Chromosome catastrophe phenomenon termed chromothripsis, in which numerous genomic rearrangements are apparently acquired in one single catastrophic event, was described in multiple cancers. Here, they have discussed that constitutionally acquired CGRs (Complex genomic Rearrangements) share similarities with cancer chromothripsis. 2. Gene annotation: prediction and testing. J. L. Ashurst and J. E. Collins; Annual Review of Genomics and Human Genetics 2003 Vol. 4 Issue 1 Pages 69-88. **Note:** This review describes the current methods of gene prediction, manual assessment, comparative analysis, and experimental verification contributing to the production of a human gene-set. 3. Coming of age: ten years of next-generation sequencing technologies

	S. Goodwin, J. D. McPherson and W. R. McCombie; Nature Reviews Genetics 2016 Vol. 17 Issue 6 Pages 333-351. **Note:** This Review evaluates various approaches used in NGS and how recent advancements in the field are changing the way genetic research is carried out. Details of each approach along with its benefits and drawbacks are discussed. Finally, various emerging applications within this field and its exciting future are explored. 4. Genome-wide high-resolution mapping and functional analysis of DNA methylation in Arabidopsis. X. Zhang, J. Yazaki, A. Sundaresan, S. Cokus, S. W.-L. Chan, H. Chen, et al.; Cell 2006 Vol. 126 Issue 6 Pages 1189-1201. **Note:** In this paper they have reported the first comprehensive DNA methylation map of an entire genome, at 35 base pair resolution, using the flowering plant Arabidopsis thaliana as a model. 5. Radiation hybrid mapping: a somatic cell genetic method for constructing high-resolution maps of mammalian chromosomes. D. R. Cox, M. Burmeister, E. R. Price, S. Kim and R. M. Myers; Science 1990 Vol. 250 Issue 4978 Pages 245-250. **Note:** In this paper, the development of a somatic cell genetic mapping approach, radiation hybrid (RH) mapping, which provides a general method for ordering DNA markers spanning millions of base pairs of DNA at the 500-kb level of resolution. And the use of RH mapping, in conjunction with PFGE, to construct a high-resolution map of the proximal 20 Mb of the long arm of human chromosome 21 is described. 6. The menu of features that define primary microRNAs and enable de novo design of microRNA genes. W. Fang and D. P. Bartel; Molecular cell 2015 Vol. 60 Issue 1 Pages 131-145. **Note:** This paper is about the generation of artificial pri-miRNAs, designed de novo, without reference to any natural sequence yet processed more efficiently than natural pri-miRNAs. 7. The linear arrangement of six sex linked factors in Drosophilla ,as shown by their mode of action. (1913) J. Exp. Zool. 14: 43-59. (The Founder MS on Chromosome Map)
Syllabus **Biochemistry**	1. The discovery of the alpha helix and beta sheet, the principal structural features of proteins. D. Eisenberg; Proceedings of the National Academy of Sciences 2003 Vol. 100 Issue 20 Pages 11207-11210. **Note:** PNAS papers by Linus Pauling, Robert Corey, and Herman Branson in the spring of 1951 proposed the alpha-helix and the beta-sheet, now known to form the backbones of tens of thousands of proteins. They deduced these fundamental building blocks from properties of small molecules, known both from crystal structures and from Pauling's resonance theory of chemical bonding that predicted planar peptide groups. Earlier attempts by others to build models for protein helices had failed both by including nonplanar peptides and by insisting on helices with an integral number of units per turn. In major respects, the Pauling–Corey–Branson models were astoundingly correct, including bond lengths that were not surpassed in accuracy for >40 years. However, they did not consider the hand of the helix or the possibility of bent sheets. They also proposed structures and functions that have not been found, including the alpha-helix. 2. Protein folding in the cell. M.-J. Gething and J. Sambrook; Nature 1992 Vol. 355 Issue 6355 Pages 33-45. **Note:** A review article which compile the knowledge of in-vivo protein folding theories and mechanisms.

	3. The structure of proteins: two hydrogen-bonded helical configurations of the polypeptide chain. L. Pauling, R. B. Corey and H. R. Branson; Proceedings of the National Academy of Sciences 1951 Vol. 37 Issue 4 Pages 205-211. **Note:** This paper describes about hydrogen boning in protein folding and describes the spiral structure of the protein. 4. Molecular mechanism of protein folding in the cell. J. E. Rothman and R. Schekman; Cell 2011 Vol. 146 Issue 6 Pages 851-854 **Note:** F.-Ulrich Hartl and Arthur Horwich will share this year's Lasker Basic Medical Science Award for the discovery of the cell's protein-folding machinery, exemplified by cage-like structures that convert newly synthesized proteins into their biologically active forms. Their fundamental findings reveal mechanisms that operate in normal physiologic processes and help to explain the problems that arise in diseases of protein folding.
Syllabus **Immunology & Infectious Diseases**	1. Temperature triggers immune evasion by *Neisseria meningitidis* E. Loh, E. Kugelberg, A. Tracy, Q. Zhang, B. Gollan, H. Ewles, et al.; Nature 2013 Vol. 502 Issue 7470 Pages 237-240. **Note:** This paper demonstrates that mechanisms of meningococcal immune evasion and resistance against complement increase in response to an increase in ambient temperature. 2. TLR4 polymorphisms, infectious diseases, and evolutionary pressure during migration of modern humans. B. Ferwerda, M. B. McCall, S. Alonso, E. J. Giamarellos-Bourboulis, M. Mouktaroudi, N. Izagirre, et al.; Proceedings of the National Academy of Sciences 2007 Vol. 104 Issue 42 Pages 16645-16650 **Note:** In this study, they investigated whether the differences in the TLR4 polymorphism haplotypes in various populations of the three large continental masses, Africa, Eurasia, and America, could have been the result of local evolutionary pressures by infection during or after the out-of-Africa migration of modern humans. And also analyzed the prevalence of the TLR4 haplotypes formed by these two SNPs in various populations from these continents and compared the phenotype of the two most prevalent TLR4 haplotypes with the wild-type (ancestral) TLR4. 3. Cytoplasmic LPS activates caspase-11: implications in TLR4-independent endotoxic shock. J. A. Hagar, D. A. Powell, Y. Aachoui, R. K. Ernst and E. A. Miao; Science 2013 Vol. 341 Issue 6151 Pages 1250-1253. **Note:** In this report, they have reported, that contamination of the cytoplasm by lipopolysaccharide (LPS) is the signal that triggers caspase-11 activation in mice.
Syllabus **Microbiology**	1. Mutations of bacteria from virus sensitivity to virus resistance. S. E. Luria and M. Delbrück; Genetics 1943 Vol. 28 Issue 6 Pages 491. **Note:** In this paper, it is demonstrated that in bacteria, genetic mutations arise in the absence of selective pressure rather than being a response to it. 2. Gene recombination in the bacterium *Escherichia coli*. E. Tatum and J. Lederberg; Journal of bacteriology 1947 Vol. 53 Issue 6 Pages 673-684. **Note:** in this paper a type of sexual reproduction like gene transfer in bacteria, other than transformation is studied. Bacteria can go through a phase in which two bacteria exchange genetic material with one another by passing a piece of DNA across a bridge-like connection.

	3. Replica plating and indirect selection of bacterial mutants. J. Lederberg and E. M. Lederberg; Journal of bacteriology 1952 Vol. 63 Issue 3 Pages 399-406. **Note:** This paper concerns an approach to this problem that makes use of a replica plating technique which facilitates the handling of large numbers of bacterial clones for classification on a variety of media. 4. A programmable dual-RNA–guided DNA endonuclease in adaptive bacterial immunity. M. Jinek, K. Chylinski, I. Fonfara, M. Hauer, J. A. Doudna and E. Charpentier; science 2012 Vol. 337 Issue 6096 Pages 816-821. **Note:** CRISPR-Cas system Cas) systems provide bacteria and archaea with adaptive immunity against viruses and plasmids by using CRISPR RNAs (crRNAs) to guide the silencing of invading nucleic acids. This study reveals how CRISPR-Cas technology can be a potential tool for the RNA-programable genome editing.

BIOT-P-208
Laboratory III: Molecular Biology and Genetic Engineering

Credits

Course Objectives

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

Student Learning Outcomes

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

Syllabus	1. Concept of lac-operon: a. Lactose induction of B-galactosidase. b. Glucose Repression. c. Diauxic growth curve of *E. coli* 2. UV mutagenesis to isolate amino acid auxotroph 3. Phage titre with epsilon phage/M13 4. Genetic Transfer-Conjugation, gene mapping 5. Plasmid DNA isolation and DNA quantitation 6. Restriction digestion and mapping of Lambda DNA 7. Restriction Enzyme digestion of plasmid DNA 8. Agarose gel electrophoresis 9. Polymerase Chain Reaction and analysis by agarose gel electrophoresis 10. Vector and Insert Ligation 11. Preparation of competent cells 12. Transformation of *E.coli* with standard plasmids, Calculation of transformation efficiency 13. Confirmation of the insert by Colony PCR and Restriction mapping 14. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in *E.coli*, SDS-PAGE analysis 15. Purification of His-Tagged protein on Ni-NTA columns a. Random Primer labeling b. Southern hybridization

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.

BIOT-P-209
Laboratory IV: Immunology

Credits

2

Course Objectives

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

Student Learning Outcomes

Students should be able to:

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

Syllabus	
	1. Selection of animals, preparation of antigens, immunization and methods of blood collection, serum separation and storage. 2. Antibody titer 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 and their cryopreservation. 10. Separation of mononuclear cells by Ficoll-Hypaque and their cryopreservation. 11. Demonstration of ELISPOT. 12. Demonstration of FACS.

Recommended Textbooks and References:

1. Practical Immunology. Franck C. Hay and Olwyn M. R. Westwood Wiley-Blackwell, 4t edition.
2. A Handbook of Practical and Clinical Immunology, G. P. Talwar & S. K. Gupta. 2nd edition CBS Publication.

BIOT-VAC-210
Biological Tools and Techniques

Credits

NC

Course Objectives

This course is encompassing several basic technologies that experimental researchers are employing in regular basis. The objectives of this course are to teach principles, methodology and instrumentation to students so as to appreciate current-day research tool-kit better

Student Learning Outcomes

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

Unit I **pH, Centrifugation & Chromatography** 10 lectures	Determination of pH, pH meter. Centrifugation techniques – Instrumentation, Types, Principles, and Methodology. Chromatography- Instrumentation, Types (HPLC, GC, Affinity, Ion-exchange), Principles, and Methodology.
Unit II **Spectrophotometry & Spectroscopy** 10 lectures	Spectrophotometry– laws of absorption of light. UV, Visible, and IR spectrophotometry. Spectroscopy- Mass spectroscopy principles, LC-MS, MALDI-TOF. Nuclear Magnetic Resonance (NMR) spectroscopy, X-ray Spectroscopy- principle and uses.
Unit III **Microscopy** 10 lectures	Microscopy- Light, Fluorescence (Compound, Phase contrast, Fluorescence, Confocal). Live cell imaging and Molecular interaction studies using modern microscopic methods. Electron Microscopy.
Unit IV **Molecular Biology tools** 10 lectures	Principle and applications of Electrophoresis (Agarose and Polyacrylamide), Nucleic acid purification, yield analysis; Polymerase Chain Reaction, RT and qRT PCR. DNA sequencing methods.

Recommended Textbooks and References:

1. Keith Wilson and John Walker (2000) Practical Biochemistry. 8th Edition, Willey
2. Rodney Boyer (2000) Modern Experimental Biochemistry, 3rd Edition,

Semester Three

BIOT-C-301
Bioprocess Engineering and Technology

Credits

3

Course Objectives

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

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

Unit I **Basic principles of biochemical engineering** 4 lectures	Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics
Stoichiometry and models of microbial growth 4 lectures	Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.
Unit II **Bioreactor design and analysis** 8 lectures	Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformation; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.
Unit III **Downstream processing and product recovery** 8 lectures	Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.
Fermentation economics	Isolation of micro-organisms of potential industrial interest; strain

4 lectures	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 IV **Applications of enzyme technology in food processing** 4 lectures	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
Applications of microbial technology in food process operations and production, biofuel and biorefinery 4 lectures	Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria – production and applications in food preservation; biofuels and biorefinery

Recommended Textbooks and References:

3. Shuler, M. L., & Kargi, F. (2002). *Bioprocess Engineering: Basic Concepts.* Upper Saddle River, NJ: Prentice Hall.
4. Stanbury, P. F., & Whitaker, A. (2010). *Principles of Fermentation Technology*. Oxford: Pergamon Press.
5. Blanch, H. W., & Clark, D. S. (1997). *Biochemical Engineering.* New York: M. Dekker.
6. Bailey, J. E., & Ollis, D. F. (1986). *Biochemical Engineering Fundamentals*. New York: McGraw-Hill.

BIOT-C-302 Emerging Technologies

Credits 2

Course Objectives

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

Student Learning Outcomes

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

Unit I **Optical microscopy methods** 8 lectures	**Basic Microscopy**: Light Microscopy: lenses and microscopes, resolution: Rayleigh's Approach, Darkfield; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy: what is fluorescence, what makes a molecule fluorescent, fluorescence microscope; optical arrangement, light source; filter sets: excitation filter, dichroic mirror, and barrier, optical layout for image capture; CCD cameras; back illumination, binning; recording color; three CCD elements with dichroic beam splitters,

	boosting the signal. **Advanced Microscopy**: Confocal microscope: scanning optical microscope, confocal principle, resolution and point spread function, light source: gas lasers & solid-state, primary beam splitter; beam scanning, pinhole and signal channel configurations, detectors; pixels and voxels; contrast, spatial sampling: temporal sampling: signal-tonoise ratio, multichannel images. nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence, advantages of two-photon excitation, tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, three-dimensional reconstruction; advanced fluorescence techniques: FLIM, FRET, and FCS, Fluorescence Lifetime, Fluorescence Resonant Energy Transfer (FRET), Fluorescence Correlation Spectroscopy (FCS), Evanescent Wave Microscopy; Near-Field and Evanescent Waves, Total Internal Reflection Microscopy; Near-Field Microscopy; Beyond the Diffraction Limit: Stimulated Emission Depletion (STED), Super-Resolution Summary, Super-Resolution Imaging with Stochastic Optical Reconstruction Microscopy (STORM) and Photoactivated Localization Microscopy (PALM).
Unit II **Mass spectroscopy** 4 lectures	Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.
Systems biology 3 lectures	High throughput screens in cellular systems, target identification, validation of experimental methods to generate the omics data, bioinformatics analyses, mathematical modeling and designing testable predictions.
Unit III **Structural biology** 8 lectures	X-ray diffraction methods, solution & solid-state NMR, cryo-electron microscopy, small angle X-ray scattering, Atomic force microscopy.
Unit IV **CRISPR-CAS** 6 lectures	History of its discovery, elucidation of the mechanism including introduction to all the molecular players, development of applications for in vivo genome engineering for genetic studies, promise of the technology as a next generation therapeutic method.
Nanobodies 4 lectures	Introduction to nanobodies, combining nanobody with phage-display method for development of antibody against native proteins, nanobody as a tool for protein structure-function studies, use of nanobodies for molecular imaging, catabolic antibodies using nanobodies.

Recommended 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). P*hysical Biology of the Cell*. New York: Garland Science.
4. Nelson, P. C., Radosavljević, M., & Bromberg, S. (2004). *Biological Physics: Energy, Information, Life*. New York: W.H. Freeman.
5. Huang, B., Bates, M., & Zhuang, X. (2009). *Super-Resolution Fluorescence Microscopy.* Annual Review of Biochemistry, 78(1), 993-1016. doi:10.1146/annurev. biochem.77.061906.092014.
6. Mohanraju, P., Makarova, K. S., Zetsche, B., Zhang, F., Koonin, E. V., & Oost, J. V. (2016). *Diverse*

Evolutionary Roots and Mechanistic Variations of the CRISPR-Cas Systems. Science, 353(6299). doi:10.1126/science.aad5147.

7. Lander, E. (2016). *The Heroes of CRISPR.* Cell, 164(1-2), 18-28. doi:10.1016/j. cell.2015.12.041.
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.

BIOT-C-303
Plant and Animal Biotechnology

Credits

3

Course Objectives

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

Student Learning Outcomes

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

Unit I **Plant tissue culture and animal cell culture** 10 lectures	Plant tissue culture: historical perspective; totipotency; organogenesis; Somatic embryogenesis; establishment of cultures – callus culture, cell suspension culture, media preparation – nutrients and plant hormones; sterilization techniques; applications of tissue culture - micropropagation; somaclonal variation; androgenesis and its applications in genetics and plant breeding; germplasm conservation and cryopreservation; synthetic seed production; protoplast culture and somatic hybridization - protoplast isolation; culture and usage; somatic hybridization - methods and applications; cybrids and somatic cell genetics; plant cell cultures for secondary metabolite production. Animal cell culture: brief history of animal cell culture; cell culture media and reagents; culture of mammalian

	cells, tissues and organs; primary culture, secondary culture, continuous cell lines, suspension cultures; application of animal cell culture for virus isolation and in vitro testing of drugs, testing of toxicity of environmental pollutants in cell culture, application of cell culture technology in production of human and animal viral vaccines and pharmaceutical proteins.
Unit II **Plant genetic manipulation** 10 lectures	Genetic engineering: Agrobacterium-plant interaction; virulence; Ti and Ri plasmids; opines and their significance; T-DNA transfer; disarmed Ti plasmid; Genetic transformation - Agrobacterium-mediated gene delivery; cointegrate and binary vectors and their utility; direct gene transfer - PEG-mediated, electroporation, particle bombardment and alternative methods; screenable and selectable markers; characterization of transgenics; chloroplast transformation; marker-free methodologies; advanced methodologies - cisgenesis, intragenesis and genome editing; molecular pharming - concept of plants as biofactories, production of industrial enzymes and pharmaceutically important compounds.
Unit III **Animal reproductive biotechnology and vaccinology** 8 lectures	Animal reproductive biotechnology: structure of sperms and ovum; cryopreservation of sperms and ova of livestock; artificial insemination; super ovulation, embryo recovery and in vitro fertilization; culture of embryos; cryopreservation of embryos; embryo transfer technology; transgenic manipulation of animal embryos; applications of transgenic animal technology; animal cloning - basic concept, cloning for conservation for conservation endangered species; Vaccinology: history of development of vaccines, introduction to the concept of vaccines, conventional methods of animal vaccine production, recombinant approaches to vaccine production, modern vaccines
Unit IV **Plant and animal genomics** 4 lectures	Overview of genomics – definition, complexity and classification; need for genomics level analysis; methods of analyzing genome at various levels – DNA, RNA, protein, metabolites and phenotype; genome projects and bioinformatics resources for genome research – databases; overview of forward and reverse genetics for assigning function for genes.
Molecular mapping and marker assisted selection 8 lectures	Molecular markers - hybridization and PCR based markers RFLP, RAPD, STS, SSR, AFLP, SNP markers; DNA fingerprinting-principles and applications; introduction to mapping of genes/QTLs; marker-assisted selection - strategies for Introducing genes of biotic and abiotic stress resistance in plants: genetic basis for disease resistance in animals; molecular diagnostics of pathogens in plants and animals; detection of meat adulteration using DNA based methods.

Recommended 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. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA*. Washington, D.C.: ASM Press.
7. Brown, T. A. (2006). *Gene Cloning and DNA Analysis: an Introduction*. Oxford: Blackwell Pub.
8. Primrose, S. B., & Twyman, R. M. (2006). *Principles of Gene Manipulation and Genomics*. Malden, MA: BlackwellPub.
9. Slater, A., Scott, N. W., & Fowler, M. R. (2003). *Plant Biotechnology: The Genetic Manipulation of Plants*. Oxford: Oxford University Press.
10. Gordon, I. (2005). *Reproductive Techniques in Farm Animals*. Oxford: CAB International.
11. Levine, M. M. (2004). *New Generation Vaccines.* New York: M. Dekker.
12. Pörtner, R. (2007). *Animal Cell Biotechnology: Methods and Protocols*. Totowa, NJ: Humana Press.

BIOT-C-304 Bio-entrepreneurship

Credits

2

Course Objectives

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

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. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.

Unit I **Innovation and entrepreneurship in bio-business** 8 lectures	Introduction and scope in Bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.
Unit II **Bio markets- business strategy and marketing** 8 lectures	Negotiating the road from lab to the market (strategies and processes of negotiation with financiers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

Unit III **Finance and accounting** 8 lectures	Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology
Unit IV **Technology management** 8 lectures	Technology – assessment, development & upgradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

Recommended Textbooks and References:

1. Brenner T, Patzelt H (2008) *Handbook Bioentrepreneurship*. Enfield, NH: Science.
2. Innovation and Entrepreneurship in Biotechnology: An International Perspective by Damian Hine and John Kapeleris, Edward Elgar Publishing
3. Biotechnology Entrepreneurship, Starting, Managing and Leading Biotech companies, Craig Shimasaki, Academic Press, Elsevier

BIOT-C-305 Intellectual Property Rights, Biosafety, and Bioethics

Credits

2

Course Objectives

The objectives of this course are:

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

Student Learning Outcomes

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

- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

Unit I **Introduction to IPR** 5 lectures	Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to

	biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of 'prior art': invention in context of "prior art"; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.
Unit II **Patenting** 5 lectures	Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives
Unit III **Biosafety** 5 lectures	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 **National and international regulations** 5 lectures	International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – 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).
Bioethics 5 lectures	Introduction, ethical conflicts in biological sciences - interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research – cloning and stem cell research, Human and animal experimentation, animal rights/welfare, Agricultural biotechnology - Genetically engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – biopiracy.

Recommended Textbooks and References:

1. Sibi G (2021) Intellectual property Rights, Bioethics, Biosafety and Entreprneurship in Biotechnology. Willey India Pvt. Ltd.
2. Jhamb S and Jain S (2022) Intellectual property Rights, Innovation and Entrepreneurship Development. Edwin Publications
(Publications from WIPO should also be used)

BIOT-C-307
Project Proposal Preparation & Presentation

Credits

2

Course Objectives

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

Student Learning Outcomes

- Students should be able to demonstrate the following abilities:
- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

Syllabus **Project proposal preparation**	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.
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.
Syllabus **Oral presentation**	At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

BIOT-P-308
Laboratory V: Plant and Animal Biotechnology, Bioprocess Engineering & Technology

Credits

Course Objectives

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

Student Learning Outcomes

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

Syllabus **Plant Biotechnology**	1. Prepare culture media with various supplements for plant tissue culture. 2. Prepare explants of *Valleriana wallichii* for inoculation under aseptic conditions. 3. Attempt *in vitro* andro and gynogenesis in plants *(Datura stramonium)*. 4. Isolate plant protoplast by enzymatic and mechanical methods and attempt fusion by PEG (available material). 5. Culture *Agrobacterium tumefaciens* and attempt transformation of any dicot species. 6. Generate an RAPD and ISSR profile of *Eremurus persicus* and *Valleriana wallichii*. 7. Prepare karyotypes and study the morphology of somatic chromosomes of *Allium cepa, A. sativum, A. tuberosum* and compare them on the basis of karyotypes. 8. Pollen mother cell meiosis and recombination index of select species (one achiasmate, and the other chiasmate) and correlate with generation of variation. 9. Undertake plant genomic DNA isolation by CTAB method and its quantitation by visual as well as spectrophotometric methods. 10. Perform PCR amplification of 'n' number of genotypes of a species for studying the genetic variation among the individuals of a species using random primers. 11. Study genetic fingerprinting profiles of plants and calculate polymorphic information content.
Syllabus **Animal Biotechnology**	12. Count cells of an animal tissue and check their viability. 13. Prepare culture media with various supplements for plant and animal tissue culture. 14. Prepare single cell suspension from spleen and thymus. 15. Monitor and measure doubling time of animal cells. 16. Chromosome preparations from cultured animal cells. 17. Isolate DNA from animal tissue by SDS method. 18. Attempt animal cell fusion using PEG. 19.
Syllabus **Bioprocess**	20. Basic Microbiology techniques a. Scale up from frozen vial to agar plate to shake flask culture.

engineering and technology	b. Instrumentation: Microplate reader, spectrophotometer, microscopy. c. Isolation of microorganisms from soil samples. 21. Experimental set-up a. Assembly of bioreactor and sterilization. b. Growth kinetics. c. Substrate and product inhibitions. d. Measurement of residual substrates. 22. Data Analysis a. Introduction to Metabolic Flux Analysis (MFA). 23. Fermentation a. Batch. b. Fed-batch. c. Continuous. 24. Unit operations a. Microfiltrations: Separation of cells from broth. b. Bioseparations: Various chromatographic techniques and extractions. 25. Bioanalytics a. Analytical techniques like HPLC, FPLC, GC, GC-MS *etc.* for measurement of amounts of products/substrates.

Recommended Textbooks and References:

1. Shuler, M. L., & Kargi, F. (2002). *Bioprocess Engineering: Basic Concepts*. Upper Saddle River, NJ: Prentice Hall.
2. Stanbury, P. F., & Whitaker, A. (2010). *Principles of Fermentation Technology*. Oxford: Pergamon Press.
3. Blanch, H. W., & Clark, D. S. (1997). B*iochemical 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.

BIOT-P-309
Laboratory VI: Bioinformatics

Credits

2

Course Objectives

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

Student Learning Outcomes

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

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

Recommended Textbooks and References:

1. Bioinformatics - A Student's Companion Authors: Syed Ibrahim, K., Gurusubramanian, G., Zothansanga, Yadav, R.P., Senthil Kumar, N., Pandian, S.K., Borah, P., Mohan, S. Elsevier publications.

Semester Four

BIOT-D-401 Dissertation

Credits

22

(Semester III – 2 credits; and Semester IV- 20 credits)

Course Objectives

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

Student Learning Outcomes

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

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

Syllabus **Planning and performing 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
Syllabus **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 Electives for Semester II (BIOT-E-207)

A. Biological Imaging

Credits

3

Course Objectives

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

Student Learning Outcomes

On completion of this course, students shall be able to gain a complete overview of super-resolution field from fundamentals to state-of-art methods and applications in biomedical research. The students shall learn the comparative advantages and disadvantages of each technique, covers all key techniques in field of biomedical science. The students shall also learn how to use new tools to increase resolution in sub-nanometer-scale images of living cells and tissue, which leads to new information about molecules, pathways and dynamics and state-of-the-art examples of applications using microscopes.

Unit I **Widefield fluorescent microscopy** 3 lectures	One of the most basic techniques for live-cell imaging is widefield fluorescent microscopy. Standard inverted research grade microscopes can yield valuable results if you are imaging adherent cells, large regions of interest (such as organelles) or very thin tissue sections (less than 5 micrometer). In widefield, a CCD camera is usually used to capture images and the epi-fluorescence illumination source can be a mercury lamp, xenon lamp, LED's, etc. Each of light sources require carefully matched interference filters for specific excitation and emission wavelengths of your fluorophore of interest. With widefield microscopy, your specimen is only exposed to excitation light for relatively short time periods as the full aperture of emission light is collected by the objectives. Widefield fluorescence microscopy can be used in combination with other common contrast techniques such as phase contrast and differential interference contract (DIC) microscopy. This combination is useful when performing live-cell imaging to examine general cell morphology or viability while also imaging regions of interest within cells.
Unit II **Confocal laser scanning microscopy (CLSM)** 3 lectures	CLSM has ability to eliminate out-of-focus light and information. It is also possible to obtain optical serial sections from thicker specimens. A conjugate pinhole in optical path of confocal microscope prevents fluorescence from outside of focal plane from being collected by photomultiplier detector or imaged by camera. In CLSM, a single pinhole (and single focused laser spot) is scanned across specimen by scanning system. This spot forms a reflected epi-fluorescence image back on original pinhole. When specimen is in focus, fluorescent light from it passes through pinhole to detector. Any out-of-focus light is defocused at pinhole and very little of this signal passes through to

	detector meaning that background fluorescence is greatly reduced. The pinhole acts as a spatial filter for emission light from the specimen.
Spinning disc confocal microscopy (SDCM) 2 lectures	This method utilises a 'Nipkow Disc' which is a mechanical opaque disc which has a series of thousands of drilled or etched pinholes arranged in a spiral pattern. Each illuminated pinhole on disc is imaged by microscope objective to a diffraction-limited spot on region of interest on specimen. The emission from fluorophores passes back though Nipkow disc pinholes and can be observed and captured by a CCD camera. The effect of spinning disc is that many thousands of points on specimen are simultaneously illuminated. Using SDCM to examine a specimen means that real-time imaging (30-frames-per-second or faster) can be achieved, which is extremely useful if you are looking at dynamic changes within living cells over a wide spectrum of time-scales.
Unit III **Re-scan confocal microscopy** 8 lectures	Structured Illumination Microscopy; Correlative Nanoscopy: AFM Super-Resolution (STED/STORM); Stochastic Optical Fluctuation Imaging.
Unit IV **Light-sheet fluorescence microscopy (LSFM, or SPIM)** 2 lectures	This method enables one to perform live-cell imaging on whole embryos, tissues and cell spheroids in vivo in a gentle manner with high temporal resolution and in three dimensions. One is able to track cell movement over extended periods of time and follow development of organs and tissues on a cellular level. The next evolution of light-sheet fluorescence microscopy, termed lattice light-sheet microscopy as developed by Eric Betzig (Nobel Prize Laureate 2014 for PALM super-resolution microscopy) will even allow live-cell imaging with super-resolved in vivo cellular localization capabilities.
Super-resolved fluorescence microscopy 8 lectures	Super-Resolution in a Standard Microscope: From Fast Fluorescence Imaging to Molecular Diffusion Laws in Live Cells; Photoswitching Fluorophores in Super Resolution Fluorescence Microscopy; Image Analysis for Single-Molecule Localization Microscopy Deconvolution of Nanoscopic Images; Super-Resolution Fluorescence Microscopy of the Nanoscale Organization in cells; Correlative Live-Cell and Super-Resolution Microscopy and Its Biological Applications; SAX Microscopy and Its Application to Imaging of 3D-Cultured Cells; Quantitative Super-Resolution Microscopy for Cancer Biology and Medicine.

Recommended Textbooks and References:

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

B. Vaccines

Credits

3

Course Objectives

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

Student Learning Outcomes

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

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

Unit I **Fundamentals of immune system** 6 lectures	Overview of Immune system; Human Immune system: Effectors of immune system; Innate & Adaptive Immunity; Activation of the Innate Immunity; Adaptive Immunity; T and B cells in adaptive immunity; Immune response in infection; Correlates of protection.
Unit II **Immune response to infection** 9 lectures	Protective immune response in bacterial; viral and parasitic infections; Primary and Secondary immune responses during infection; Antigen presentation and Role of Antigen presenting cells: Dendritic cells in immune response; Innate immune response; Humoral (antibody mediated) responses; Cell mediated responses: role of CD4+ and CD8+ T cells; Memory responses: Memory and effector T and B cells, Generation and Maintenance of memory T and B cells.
Unit III **Immune response to vaccination** 8 lectures	Vaccination and immune response; Adjuvants in Vaccination; Modulation of immune responses: Induction of Th1 and Th2 responses by using appropriate adjuvants and antigen delivery systems - Microbial adjuvants, Liposomal and Microparticles as delivery systems; Chemokines and cytokines; Role of soluble mediators in vaccination; Oral immunization and Mucosal Immunity.
Unit IV **Vaccine types and design** 3 lectures	History of vaccines, Conventional vaccines; Bacterial vaccines; Viral Vaccines; Vaccines based on routes of administration: parenteral, oral, mucosal; Live attenuated and inactivated vaccine; Subunit Vaccines and Toxoids; Peptide Vaccine.
Vaccine technologies 4 lectures	New Vaccine Technologies; Rationally designed Vaccines; DNA Vaccination; Mucosal vaccination; New approaches for vaccine delivery; Engineering virus vectors for vaccination; Vaccines for targeted delivery (Vaccine Delivery systems); Disease specific vaccine design: Tuberculosis Vaccine; Malaria Vaccine; HIV/AIDS vaccine; New emerging diseases and vaccine needs (Ebola, Zika).

Recommended Textbooks and References:

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

C. Environmental Biotechnology

Credits

3

Course Objectives

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

Student Learning Outcomes

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

Unit I **Introduction to environment** 6 lectures	Introduction to environment; pollution and its control; pollution indicators; waste management: domestic, industrial, solid and hazardous wastes; strain improvement; Biodiversity and its conservation; Role of microorganisms in geochemical cycles; microbial energy metabolism, microbial growth kinetics and elementary chemostat theory, relevant microbiological processes, microbial ecology.
Unit II **Bioremediation** 6 lectures	Bioremediation: Fundamentals, methods and strategies of application (biostimulation, bioaugmentation) – examples, bioremediation of metals (Cr, As, Se, Hg), radionuclides (U, Te), organic pollutants (PAHs, PCBs, Pesticides, TNT *etc.*), technological aspects of bioremediation (*in situ, ex situ*).
Role of microorganisms in bioremediation 6 lectures	Application of bacteria and fungi in bioremediation: White rot fungi *vs* specialized degrading bacteria: examples, uses and advantages *vs* disadvantages; Phytoremediation: Fundamentals and description of major methods of application (phytoaccumulation, phytovolatilization, rhizofiltration, phytostabilization).
Unit IV **Biotechnology and agriculture** 11 lectures	Bioinsecticides: Bacillus thuringiensis, Baculoviruses, uses, genetic modifications and aspects of safety in their use; Biofungicides: Description of mode of actions and mechanisms (e.g. Trichoderma, Pseudomonas fluorescens); Biofertilizers: Symbiotic systems between plants – microorganisms (nitrogen fixing symbiosis, mycorrhiza fungi symbiosis), Plant growth promoting rhizobacteria (PGPR) – uses, practical aspects and problems in application.
Unit V **Biofuels** 11 lectures	Environmental Biotechnology and biofuels: biogas; bioethanol; biodiesel; biohydrogen; Description of the industrial processes involved, microorganisms and biotechnological interventions for optimization of production; Microbiologically enhanced oil recovery (MEOR); Bioleaching of metals; Production of bioplastics; Production of biosurfactants: bioemulsifiers; Paper production: use of xylanases and white rot fungi.

Recommended Textbooks and References:

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

D. Microbial Technology

Credits

3

Course Objectives

The objectives of this course are to introduce students to developments/ advances made in field of microbial technology for use in human welfare and solving problems of the society.

Student Learning Outcomes

On completion of this course, students would develop deeper understanding of the microbial technology and its applications.

Unit I **Introduction to microbial technology** 6 lectures	Microbial technology in human welfare; Isolation and screening of microbes important for industry – advances in methodology and its application; Advanced genome and epigenome editing tools (e.g., engineered zinc finger proteins, TALEs/TALENs, and the CRISPR/Cas9 system as nucleases for genome editing, transcription factors for epigenome editing, and other emerging tools) for manipulation of useful microbes/ strains and their applications; Strain improvement to increase yield of selected molecules, e.g., antibiotics, enzymes, biofuels.
Environmental applications of microbial technology 6 lectures	Environmental application of microbes; Ore leaching; Biodegradation - biomass recycle and removal; Bioremediation - toxic waste removal and soil remediation; Global Biogeochemical cycles; Environment sensing (sensor organisms/ biological sensors); International and National guidelines regarding use of genetically modified organisms in environment, food and pharmaceuticals.
Unit III **Pharmaceutical applications of microbial technology** 8 lectures	Recombinant protein and pharmaceuticals production in microbes – common bottlenecks and issues (technical/operational, commercial and ethical); Attributes required in industrial microbes (Streptomyces sp., Yeast) to be used as efficient cloning and expression hosts (biologicals production); Generating diversity and introduction of desirable properties in industrially important microbes (Streptomyces/Yeast); Microbial cell factories; Downstream processing approaches used in industrial production process (Streptomyces sp., Yeast).
Unit IV **Food applications of microbial technology** 8 lectures	Application of microbes and microbial processes in food and healthcare industries - food processing and food preservation, antibiotics and enzymes production, microbes in targeted delivery application – drugs and vaccines (bacterial and viral vectors); Nonrecombinant ways of introducing desirable properties in Generally recognized as safe (GRAS) microbes to be used in food (e.g., Yeast) - exploiting the existing natural diversity or the artificially introduced diversity through conventional acceptable techniques (mutagenesis, protoplast fusion, breeding, genome shuffling, directed evolution etc.).
Unit V **Advances in microbial technology** 8 lectures	Microbial genomics for discovery of novel enzymes, drugs/ antibiotics; Limits of microbial genomics with respect to use in human welfare; Metagenomics and metatranscriptomics – their potential, methods to study and applications/use (animal and plant health, environmental clean-up, global nutrient cycles & global sustainability, understanding evolution), Global metagenomics initiative - surveys/projects and outcome,

	metagenomic library construction and functional screening in suitable hosts – tools and techniques for discovery/identification of novel enzymes, drugs (e.g., protease, antibiotic) etc.

Recommended Textbooks and References:

1. Lee, Y. K. (2013). *Microbial Biotechnology: Principles and Applications*. Hackensack, NJ: World Scientific.
2. Moo-Young, M. (2011). *Comprehensive Biotechnology*. Amsterdam: Elsevier.
3. Nelson, K. E. (2015). Encyclopedia of Metagenomics. *Genes, Genomes and Metagenomes: Basics, Methods, Databases and Tools*. Boston, MA: Springer US.
4. *The New Science of Metagenomics Revealing the Secrets of Our Microbial Planet*. (2007). Washington, D.C.: National Academies Press.
5. Journals: (a) Nature, (b) Nature Biotechnology, (c) Applied microbiology and biotechnology, (d) Trends in Biotechnology, (e) Trends in Microbiology, (f) Current opinion in Microbiology, (g) Biotechnology Advances, (h) Genome Research)
6. Websites: http://jgi.doe.gov/our-science/

Recommended Electives for Semester IV (BIOT-E-402)

A. Drug Discovery and Development

Credits

3

Course Objectives

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

Student Learning Outcomes

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

Unit I **Target identification and molecular modelling** 7 lectures	Identification of target or drug leads associated with a particular disease by a number of different techniques including combinations of molecular modeling, combinatorial libraries and high-throughput screening (HTS); Conceptualizing the automation of the HTS process and the importance of bioinformatics and data processing in identification of lead compounds; Rational drug design, based on understanding the three-dimensional structures and physicochemical properties of drugs and receptors; Modelling drug/ receptor interactions with the emphasis on molecular mechanisms, molecular dynamics simulations and homology modelling; Conformational sampling, macromolecular folding, structural bioinformatics, receptor-based and ligand-based design and docking methods, in silico screening of libraries, semi-empirical and ab-initio methods, QSAR methods, molecular diversity, design of combinatorial libraries of drug-like molecules, macromolecular and chemical databases.
Unit II **Lead optimization** 6 lectures	Identification of relevant groups on a molecule that interact with a receptor and are responsible for biological activity; Understanding structure activity relationship; Structure modification to increase potency and therapeutic index; Concept of quantitative drug design using Quantitative structure–activity relationship models (QSAR models) based on the fact that the biological properties of a compound are a function of its physicochemical parameters such as solubility, lipophilicity, electronic effects, ionization, stereochemistry, etc.; Bioanalytical assay development in support of in vitro and in vivo studies (LC/MS/MS, GC/MS and ELISA).
Unit III **Preclinical development** 4 lectures	Principles of drug absorption, drug metabolism and distribution - intestinal absorption, metabolic stability, drug-drug interactions, plasma protein binding assays, metabolite profile studies, Principles of toxicology, Experimental design for preclinical and clinical PK/PD/TK studies, Selection of animal model; Regulatory guidelines for preclinical PK/ PD/TK studies; Scope of GLP, SOP for conduct of clinical & non clinical testing, control on animal house, report preparation and documentation Integration of non-clinical and preclinical data to aid design of clinical studies
Drug manufacturing 4 lectures	Requirements of GMP implementation, Documentation of GMP practices, CoA, Regulatory certification of GMP, Quality control and Quality assurance, concept and philosophy of TQM, ICH and ISO 9000; ICH guidelines for Manufacturing, Understanding Impurity Qualification Data, Stability Studies.
Unit IV **Clinical trial design** 4 lectures	Objectives of Phase I, II, III and IV clinical studies, Clinical study design, enrollment, sites and documentation, Clinical safety studies: Adverse events and adverse drug reactions, Clinical PK, pharmacology, drug-drug interaction studies, Statistical analysis and documentation.

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

Recommended Textbooks and References:

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

B.Nanobiotechnology

Credits

3

Course Objectives

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

Student Learning Outcomes

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

Unit I **Introduction to nanobiotechnology** 5 lectures	Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.
Unit II **Nano-films** 4 lectures	Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterization
Nano-particles 4 lectures	Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

Unit III **Applications of nano-particles** 7 lectures	Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development
Unit IV **Nano-materials** 5 lectures	Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in sythesis, applications of nanobiocatalysis in the production of drugs and drug intermediates
Nano-toxicity 5 lectures	Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life Cycle Assessment, containment.

Recommended Textbooks and References:

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

Recent review papers in the area of Nanomedicine.

C. Protein Engineering

Credits

3

Course Objectives

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

Student Learning Outcomes

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

- Analyse structure and construction of proteins by computer-based methods;
- Describe structure and classification of proteins;
- Analyse purity and stability of proteins and explain how to store them in best way;
- Explain how proteins can be used for different industrial and academic purposes such as structure determination, organic synthesis and drug design.
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Unit I **Introduction to protein engineering** 8 lectures	Overview of protein structure and its hierarchical architecture; Protein engineering - Features of proteins that can be engineered including affinity and specificity; Spectroscopic properties; Stability to changes in parameters as pH, temperature and amino acid sequence, aggregation propensities, etc.; Experimental methods of protein engineering: Rational designing, Directed evolution like site directed mutagenesis, Module shuffling, Guided protein recombination, etc. Protein engineering with unnatural amino acids and its applications.

Unit II **Stability of protein structure** 8 lectures	Forces stabilizing proteins – Van der waals, electrostatic, hydrogen bonding and weakly polar interactions, hydrophobic effects; Entropy – enthalpy compensation. Methods of measuring stability of a protein; Spectroscopic methods to study physicochemical properties of proteins: far-UV and near-UV CD; Fluorescence; UV absorbance; ORD; Hydrodynamic properties–viscosity, hydrogen-deuterium exchange; Brief introduction to NMR spectroscopy – emphasis on parameters that can be measured/obtained from NMR and their interpretation
Unit III **High through-put approaches protein Engg. & Enzyme kinetics** 10 lectures	Optimization and high throughput screening methodologies like GigaMetrix, High throughput microplate screens etc., Application to devices with bacteriorhodopsin as an example; Engineering antibody affinity by yeast surface display; Applications to vaccines, Peptidomimetics and its use in drug discovery. Immobilization of Enzymes: Methods and application to industry and research. Enzyme kinetics studies. Kinetics of immobilized enzymes, effect of solute partition & diffusion on the kinetics of immobilized enzymes. Enzyme electro-catalysis (Biosensors): General approach to immobilization of enzymes into electrodes. Measurement of enzyme activity, Regeneration of cofactors. Abzymes and its application.
Unit IV **Computational approaches** 8 lectures	Computational approaches to protein engineering: sequence and 3D structure analysis, Data mining, Ramachandran map, Mechanism of stabilization of proteins from psychrophiles and thermophiles vis-à-vis those from mesophiles; Protein design, Directed evolution for protein engineering and its potential. Protein and enzyme engineering case studies for its stability, specificity and affinity- Protease, Lipase and Lysozyme.

Recommended Textbooks and References:

1. Edited by T E Creighton, (1997), *Protein Structure: a Practical Approach*, 2nd Edition, Oxford university press.
2. Cleland and Craik, (2006), *Protein Engineering, Principles and Practice*, Vol 7, Springer Netherlands.
3. Mueller and Arndt, *Protein Engineering Protocols*, 1st Edition, Humana Press.
4. Ed. Robertson DE, Noel JP, (2004), *Protein Engineering Methods in Enzymology*, 388, Elsevier Academic Press.
5. J Kyte; (2006), *Structure in Protein Chemistry*, 2nd Edition, Garland publishers.
6. W. Gerhartz (1990) Enzymes in industry: Production and application, VCH Publishers, New York

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D. Metabolic Engineering and Metabolomics

Credits

3

Course Objectives

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

Student Learning Outcomes

On completion of this course, students should be able to understand the basic principles of cellular metabolism and its engineering principles.

Unit I **Introduction to metabolic engineering** 8 lectures	Elements of Metabolic Engineering: Historical perspective and introduction; Importance of metabolic engineering; Paradigm shift; Information resources; Scope and future of metabolic engineering; Building blocks of cellular components; Polymeric biomolecules; Protein structure and function; Biological information storage – DNA and RNA
Unit II **Cellular metabolism** 8 lectures	Review of cellular metabolism: Transport mechanisms and their models; Enzyme kinetics; Mechanisms and their dynamic representation; Regulation of enzyme activity versus regulation of enzyme concentration; Regulation of metabolic networks; Regulation of at the whole cell level; Examples of important pathways; Case studies and analytical-type problems.
Unit III **Material and Energy Balances** 8 lectures	Material and Energy Balances: Material and energy balances; Basis for simplification of reaction; Elemental balances; Component balances and the link with macroscopic measurements; Examples of construction of elemental and component balances.
Unit IV **Metabolic Flux Analysis and Control Theory** 5 lectures	Metabolic Flux Analysis and control theory: The theory of flux balances; Derivation of the fundamental principle; Degree of freedom and solution methods; Moore-Penrose inverse and Tsai-lee matrix construction; Examples of applications of flux analysis introduction Metabolic Control Theory; Control coefficients; Elasticity coefficients; Summation and connectivity theorems; Case Studies and examples.
Metabolomics 5 lecture	Metabolic Engineering Practice: The concept of metabolic pathway synthesis; Need for pathway synthesis, Examples for illustration; Overall perspective of MFA, MCA and MPA and their applications; Three success case studies. Metabolomics: Introduction to metabolomics: Metabolome, Metabolomics, Metabolite profiling, Metabolome fingerprinting, Role of Biomarker in metabolomics, Tools of metabolome studies- NMR, MS, GC, LC, GC-MS and LC-MS etc., Metabolome projects of plant and human, Future of metabolomics.

Recommended Textbooks and References:

1. Metabolomics- Ute Roessner, 2012. InTech Publishers
2. Metabolomics, A Powerful Tool in Systems Biology. Jens Nielsen, Michael C Jewett, 2007. Springer.
3. Metabolic Engineering: Principles and Methodologies- George Stephanopoulos, Aristos A. Aristidou, Jens Nielsen, 1998

Recommended CBCT (Inter Disciplinary) Elective for Semester III
(BIOT-CT-300/ BOTA-CT-300/ENVS-CT-300/ MARB-CT-300/ Zool-CT-300)

BIOT-CT-300 Biotechnology in Human Welfare

Credits

4

Course Objectives

The objectives of this course are to provide inter disciplinary overview of the concepts and their applications in the field of Agriculture, Environment, Health and industry etc.

Student Learning Outcomes

On completion of this course, students shall be able to gain a complete overview of various concepts of Biotechnology, methods and applications in welfare of Mankind. The students shall learn the comparative advantages and disadvantages of several basic technique of Biotechnology.

Unit I **Basic Concepts Biotechnology** 12 lectures	Basic Concepts of Biotechnology and its applications, Recombinant DNA technology; gene cloning, human genome project, Tools of Bioinformatics
Unit II **Agricultural and Environmental Biotechnology** 12 lectures	**Agricultural and Environmental Biotechnology:** Application in Breeding, Nitrogen fixation, Transfer of pest resistance genes to plants, Interaction between plants and microbes, Qualitative improvement of livestock. Crop plant genome project Chlorinated and non-chlorinated organ pollutant degradation; degradation of hydrocarbons and agricultural wastes, stress management, development of biodegradable polymers
Unit III **Medical and Pharmaceutical Biotechnology** 12 lectures	Development of therapeutic agents, recombinant live vaccines, gene therapy, Diagnostics; Principle of DNA fingerprinting, Stem cell Biology, Ethical issues in Biotechnology research
Unit III **Industrial Biotechnology** 12 lectures	Introduction to bioprocess technology. Range of bioprocess technology and its chronological development. Basic principle of fermentation technology. Types of microbial culture and its growth kinetics– Batch, Fed batch and Continuous culture.

Recommended Textbooks and References:

1. John E. Smith. Biotechnology (2009) 5th Edition, Cambridge University Press
2. S. Ignacimuthu Biotechnology: An Introduction (2012) 2nd Edition, Narosa Publishing House Ltd., India

OR

BOTA-CT-300 Economic Botany

Credits

4

Course Objectives

Objectives of the paper is to provide basic idea on origin, history, domestication, cultivation and use of various cereal, legumes, oil seeds, fruits & vegetable, tree species, and medicinal plants

Student Learning Outcomes

Students after completion of this course are expected to get a holistic understanding on origin, history, domestication, cultivation and use of various cereal, legumes, oil seeds, fruits & vegetable, tree species, and medicinal plants .

Unit I **Cereals & Legumes** **Lectures:12**	Origin, history, domestication, botany, cultivation, production and use of: Cereals: Wheat, rice, maize, sorghum, pearl millet and minor millets. Pulses: Pigeon pea, chickpea, black gram, green gram, cowpea, soyabean, pea, lentil, horse gram, lab-lab bean.
Unit II **Oil seeds & Tree plants** **Lectures:12**	Origin, distribution, cultivation, production and utilization of economic plants of following groups such as Plant of agro-forestry importance: Teak, Sal Acacia, Sesbania, Neem etc. Fibres: cotton, silk cotton, jute, sunnhemp. Oilseeds: Groundnut, sesame, castor, rape seed, mustard, sunflower, safflower, niger, oil palm, coconut and linseed.
Unit III **Fruits & Vegetables** **Lectures:12**	Origin, distribution, classification, production and utilization of Fruits: mango, banana, citrus, guava, grapes and other indigenous fruits; apple, plum, pear, peach, cashewnut and walnut; Vegetables: tomato, brinjal, okra, cucumber, cole crops, gourds etc.
Unit IV **Medicinal Plants** **Lectures:12**	Important medicinal and aromatic plants: Sarpagandha, Belladonna, Cinchona, Nux-Vomica, Vinca, Mentha And Glycirrhiza, Plantago etc.; Narcotics: Cannabis, Datura, Gloriosa, Pyrethrum and opium. Important Spices and condiments Ginger, Garlic, Cinnamon, Cardamom, Cumin, Foeniculum etc.

Recommended Textbooks and References:

1. Economic Botany: S. L. Kochhar, Cambridge University Press
2. Economic Botany- Principle & Practices: G.E. Wickens, Kluwer Academic Publishers
3. Economic Botany & Ethnobotany: Afroz Alam, Willey

OR

ENVS-CT-300 Population & Environmental Issues

Credits

4

Course Objectives

Objectives of the paper is to provide basic idea on population demography, energy crisis, environmental pollution and population studies.

Student Learning Outcomes

Students after completion of this course are expected to get a holistic understanding on various aspects of population demography, energy crisis, environmental pollution and population studies.

Unit I **Demographic Overview** **Lectures:12**	Introduction, History of human population growth, The demographic transition: India and World; Projections of population growth, Effects of human population growth, Unsustainable lifestyle – increased consumerism

Unit II **Energy Crisis** **Lectures:12**	Energy Crisis: Background, Possible causes (Energy demand and consumption, Production capacity and dependence on imports); Ecologically friendly alternatives and Possible Measures
Unit III **Environmental Contamination** **Lectures:12**	Ambient Air pollution, Indoor air pollution and Health Impacts Surface water pollution, Ground water pollution and Health Impacts. Solid Waste Pollution and Sustainable Solid Waste Management; Hazardous waste pollution, Radioactive waste, Electronic waste and Biomedical waste
Unit IV **Ecological Footprints and Carrying Capacity** **Lectures:12**	Ecological footprints: Concepts, perspectives, carbon footprint, water footprint, Overshoot of ecological footprint and biocapacity of planet Earth, Resources Depletion.

Recommended Textbooks and References:

1. Cunningham WP and Cunningham MA (2002). Principles of Environmental Science: Inquiry and Applications. McGraw Hill Publications, New Delhi, 418 pp.
2. Johri R (2009). E-Waste: Implications, regulations, and management in India and current global best practices. TERI Press, New Delhi. 330 pp.
3. McKillop A and Newman S (2005). The Final Energy Crisis. Pluto Press, London. 325 pp.
4. Miller GT Jr. (1996). Living in The Environment: Principles, Connections, and Solutions. 9th Edition. Wadsworth Publishing Company, New York. 727 pp.
5. Park C (2001). The Environment: Principles and Applications. 2nd Edition, Routledge Publishers, London and New York, 598 pp.
6. Galli A (2010). Stomping on biodiversity: humanity's growing Ecological Footprint. In: Commonwealth Ministers Reference Book. Pp. 156-159.
7. McKinney ML and Schoch RM (1998). Environmental Science: Systems and Solutions. Jones and Bartlett Publishers, Boston. 639 pp.
8. MoEF (2009). State of Environment Report, India – 2009. Ministry of Environment and Forests, New Delhi
9. Sengupta B (2000). Environmental standards for ambient air, automobiles, fuels, industries and noise. Central Pollution Control Board, New Delhi, India. 78 pp.
10. WHO (2006). World Health Report 2006, World Health Organization, Geneva.

OR

MARB-CT-300 Environmental Impact Assessment & Management Plans

4 Credits

Course Objectives

Objectives of the paper is to provide basic idea on Environmental Impact, their assessment and management strategies in different conditions.

Student Learning Outcomes

Students after completion of this course are expected to get a holistic understanding on Environmental Impact, their assessment and management strategies in during various condition including climate change.

Unit I **Lectures:16**	Introduction to Environmental Impact Assessment. Environmental impact Statement and Environmental Management Plan. EIA notifications of Government of India from time to time. Guidelines for Environmental audit.

Unit II **Lectures:16**	Environmental Impact Assessment (EIA) Methodologies. Generalized approach to impact Assessment. EIA processes, Scoping EIA methodologies, Procedure for reviewing Environmental impact analysis and statement. Environmental Management Plan and its monitoring, Evaluation of proposed actions.
Unit III **Lectures:16**	Nexus between development and environment, Socio-economic impacts, Aid to decision making, Formulation of development actions, Sustainable development, categorization of projects under EIA, project planning and implementation, Impact prediction, Mitigation measures.
Unit IV **Lectures:16**	Introduction to. Selection of appropriate procedures, Restoration and rehabilitation technologies. Landuse policy for India. Urban planning for India. Rural planning and landuse pattern. Environmental priorities in India and sustainable development. CRZ notifications and Environmental Impact Assessment in coastal zone. Coastal zone management plans of India.

Recommended Textbooks and References:

1. W.P. Cunningham, 2010: Principles of Environmental Science.
2. Satsangi and A.Sharma 2015: Environmental Impact Assessment and Disaster Management.
3. R.R.Barthwal 2002: Environmental Impact Assessment.
4. R.Paliwal and L.Srivastava, 2014: Policy Intervention Analysis- Environmental Impact Assessment.
5. C.H.Ecceleston, 2004: Environmental Impact Assessment.
6. J. Hou, 2015: New Urbanism: The future City is Here.
7. James R. Craig, 2010: Earth Resources and the Environment.
8. J. Glassion, 2011: Introduction to Environmental Impact Assessment.
9. Glasson J., Therivel R., Chadwick A, (2005): Introduction to environmental impact assessment Taylor & Francis Group, London and NewYork.
10. Morris P., Therivel R., (2009): Methods of Environmental Impact Assessment 2009, 3rd edition, Routledge, Taylor & Francis Group, London and NewYork.
11. Morris P., Therivel R., (2001): Methods of Environmental Impact Assessment 2001, 2nd edition, Spon Press, Taylor & Francis Group, London and NewYork.
12. Eccleston C. H., (2011): Environmental Impact Assessment 2011, CRC Press, Taylor & FrancisGroup.

OR

ZOOL-CT-300 Conservation Biology

Credits

4

Course Objectives

Objectives of the paper is to provide basic idea on Biodiversity, measuring biodiversity, international and national efforts, molecular phylogeny and different conservation measures to conserve biodiversity.

Student Learning Outcomes

Students after completion of this course are expected to get a holistic understanding on biodiversity and its importance, phylogeny, inculcate the value of bio-resources and develop compassion toward bio-resources.

Unit I **Basic Concepts** **Lectures:16**	Biodiversity (genetic diversity, species diversity, ecosystem diversity) and its use, Causes of biodiversity losses, IUCN red list of threatened species, Invasive species, Alien species, Indicator species, Keystone species, Umbrella species, Flagship species, Charismatic species

Unit II **Measuring Biodiversity** **Lectures:16**	Alpha, Beta and Gamma diversity, Species Richness(S), Evenness(E), Simpson index(D), Shannon-Weiner Index (H'), idea on biodiversity calculator software
Unit III **International and National efforts for conserving biodiversity** **Lectures:16**	National Act and International Act related to Biodiversity Conservation: Biological diversity Act 2002, National Biodiversity Authority, People Biodiversity Registrar, Convention on Biological diversity, Cartagena Protocol and Nagoya Protocol, Sustainable Development Goal and Biodiversity, Aichi Biodiversity Targets, CITES, WWF
Unit IV **Conservation Measures and Molecular Phylogeny** **Lectures:16**	In-situ conservation (Indian context) (Sanctuaries, National and Biosphere reserves) and Ex-situ conservation (Indian context) (Botanical gardens, zoos, cryopreservation, gene bank), NCBI data base, basic idea on phylogenetic tree, Construction and interpretation of molecular phylogeny tree based on COI and 16s rRNA gene sequences using MEGA and other tools

Recommended Textbooks and References:

1. Fundamental of Ecology: O.P Odum
2. Campbell Biology: Reece, Urry,Cain et al.

Recommended VA (Value added Semester IV (BIOT-AC-403)

Cultural Heritage of South Odisha

Non-Credit course

Course Objectives

Kabi Samrat Upendra Bhanja is the master-spirit of Odia Language and Culture during Medieval period. The campus of Berhampur University has been rightly named after Kabi Samrat Upendra Bhanja as 'BHANJA BIHAR'. South Odisha is the adorable storehouse of literary and cultural wealth of ancient and medieval Odisha which has elicited remarkable national acclaim. This course has been introduced with a view to familiarizing all the P.G. Students of Berhampur University with the excellent craftsmanship exemplified by the literary stalwarts including Kabi Samrat Upendra Bhanja along with the Arts, Culture and Folk Tradition of South Odisha.

Student Learning Outcomes

The teaching imparted to the P.G. students of Berhampur University on the various dimensions of the literary and cultural heritage of South Odisha will help them to acquire a valuable understanding of the same. They will be inspired adequately to take the positives learnt from the course and use them in future in their personal literary and cultural pursuits and thereby promote the literature and culture of Odisha on a global scale. .

Unit I	Literary works of Kabi Samrat Upendra Bhanja
Unit II	Other Litterateurs of South Odisha
Unit III	Cultural Heritage of South Odisha
Unit IV	Folk and Tribal Traditions of South Odisha