SYLLABUS FOR M. Sc. BIOTECHNOLOGY

(Adopting Remodeled DBT Proposed Syllabus)

For the Academic Batch 2024-26

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 ‘Start-up 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 (2021 – 2025) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology hub in terms of knowledge and innovation driven bioeconomy and biomanufacturing setups. It has also highlighted the importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship. DBT has taken a few 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 nine subject specific subcommittees comprising of 63 academicians, scientists and industry representatives. The members of the 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 and NEP 2020 into account. The revised course curriculum is of 96 credits comprising of theory, practical, technology-based topics, electives, journal club, bio-entrepreneurship and dissertation etc.

M.Sc. Biotechnology

Paper code	Title	Credits	Internal marks	End sem Marks	Total Marks
SEMESTER-I					
BIOT-C-101	Biochemistry	4	30	70	100
BIOT-C-102	Cell and Molecular Biology	4	30	70	100
BIOT-C-103	Genetics	3	30	70	100
BIOT-C-104	Microbiology	3	30	70	100
BIOT-C-105	Basic Mathematics, Biostatistics and Research Methodology	3	30	70	100
BIOT-C-106	Indian Knowledge System and Biotechnology	4	30	70	100
BIOT-P-107	Laboratory I: Biochemistry and Analytical Techniques	3	0	100	100
BIOT-P-108	Laboratory II: Microbiology	2	0	100	100
	SEMESTER-I TOTAL	**26**	**180**	**620**	**800**
SEMESTER-II					
BIOT-C-201	Genetic Engineering	4	30	70	100
BIOT-C-202	Immunology	3	30	70	100
BIOT-C-203	Basic and Emerging Technologies	3	30	70	100
BIOT-C-204	Genomics, Proteomics, and Metabolomics	3	30	70	100
BIOT-S-205	Critical Analysis of Classical Papers/ Seminar	2	100	-	100
BIOT-E-206*	Elective I	4	30	70	100
BIOT-P-207	Laboratory III: Molecular Biology and Genetic Engineering	3	0	100	100
BIOT-P-208	Laboratory IV: Immunology	2	0	100	100
BIOT-VAC-209	Biological Tools and Techniques	NC	30	70	100
	SEMESTER-II TOTAL	**24**	**250**	**550**	**800**
SEMESTER-III					
BIOT-C-301	Bioprocess Engineering and Technology	3	30	70	100
BIOT-C-302	Bioinformatics	3	30	70	100
BIOT-C-303	Intellectual Property Rights, Biosafety and Bioethics	2	30	70	100
BIOT-E-304**	Elective- II	4	30	70	100
BIOT-CT-300#	CBCT course (Interdisciplinary Elective)	4	30	70	100
BIOT-SW-305##	SWAYAM Course	2	-	100	100
BIOT-P-306	Laboratory V: (A) Plant Biotechnology & Bioprocess Technology OR (B) Animal Biotechnology & Bioprocess Technology	4	0	100	100
BIOT-P-307	Laboratory VI: Bioinformatics	2	0	100	100
BIOT-D-308	Dissertation and Presentation	2	100	0	100
BIOT-VAC-309	Journal Club Presentation	NC	100	-	100
	SEMESTER III TOTAL	**26**	**250**	**650**	**900**

Paper code	Title	Credits	Internal marks	End sem Marks	Total Marks
SEMESTER-IV					
BIOT-D-401	Dissertation	18	60	240	300
BIOT-C-402	Bioentrepreneurship	2	30	70	100
BIOT-E-403***	Elective-III	4	30	70	100
BIOT-AC-404	Cultural Heritage of South Odisha	NC	10	40	50
SEMESTER IV TOTAL		**24**	**120**	**380**	**500**
GRAND TOTAL		**100**	**--**	**--**	**3000**

Elective Papers

BIOT-E-206* Elective I: (A). Biological Imaging (B). Vaccines (C). Environmental Biotechnology (D) Microbial Technology.
BIOT-E-304 Elective II:** (A) Plant Biotechnology (B) Animal Biotechnology
BIOT-E-403* 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-209 and BIOT-VAC-309

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 for 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.

SWAYAM Course (BIOT-SW-305##)

The candidate has to complete atleast one SWAYAM Course during 1st - 3rd Semsester and submit the transcript and course completion certificate on or before the comencement of 3rd semester end-term examination.

Add On Course (AC) :

BIOT-AC-404: Cultural Heritage of South Odisha

Codes 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

4

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 Protein Structure**	Chemical basis of life: Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies. 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, haemoglobin, chymotrypsin etc.; Basic principles of protein purification; tools to characterize expressed proteins; Protein folding: pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding.
Unit II **Enzyme Kinetics**	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 haemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.
Unit III **Glycobiology, Lipids and Nucleic Acids**	Glycobiology: 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. 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. Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways.

Unit IV **Bioenergetics and Metabolism**	Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources of glucose; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; 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; 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.

Recommended Textbooks and References:

1. Stryer, L. (2023). *Biochemistry*. (10th ed.) New York: Freeman.
2. Lehninger, A. L. (2021). *Principles of Biochemistry* (8th ed.). New York, NY: Worth.
3. Voet, D., & Voet, J. G. (2018). *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/scientificamerican 0191-54.

BIOT-C-102
Cell and Molecular Biology

Credits

4

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**	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: nuclear membrane, nucleus, nucleolus and chromosome; Centromere and kinetochore, telomere and its maintenance.
Unit II **Chromatin structure and dynamics**	Organization of prokaryotic genome; Organization of eukaryotic genome: Histone, Non-Histone and DNA interactome, Nucleosome concept; Static vs Dynamic model of Chromosome organization; DNA structure and replication: Structure and assembly of eukaryotic and prokaryotic DNA polymerases, Mechanism of DNA-replication in prokaryotes and eukaryotes, Replication of Telomeric DNA; DNA repair and DNA recombination.

	Transcription in prokaryotes and eukaryotes: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors; Process of transcription-initiation, elongation and termination; Chromatin control of gene transcription: Regulation and silencing by chromatin -Writers, -Readers and–Erasers; post-transcriptional control: splicing and addition of cap and tail, mRNA transport cytoplasm, RNA interference by small non-coding RNAs (miRNAs and siRNAs); Translation: protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; Process of translation: initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code translation product cleavage, modification and activation.
Unit III **Cellular Processes and Methods to Study**	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. Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and trans-membrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.
Unit IV **Genome instability and cell transformation**	Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome. Viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.

Recommended 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
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 **Mendelian Genetics and its extensions**	Introduction to model organism in genetic studies, Monohybrid and Dihybrid Crosses, Back and Test crosses, Mapping populations; Mendelian principles: Dominance, Segregation and Independent Assortment. Extensions of Mendelism: Codominance, incomplete dominance, gene interactions and epistasis, Synthetic lethality, Pleiotropy, Genomic imprinting, Penetrance and expressivity, Phenocopy, Linkage and crossing over, Sex linkage, sex limited and sex influenced characters.
Unit II **Organellar genetics, Concept of gene and mapping of gene**	Extra chromosomal inheritance: Organellar genome; Inheritance of Mitochondrial and chloroplast genes, maternal inheritance; Concept of gene: Fine structure of gene, Allele, Multiple alleles, Pseudoallele. Gene mapping methods: Chromosome maps, Mapping of autosomal and sex-linked genes, Tetrad analysis, Pedigree analysis, mapping with molecular markers, mapping by using somatic cell hybrids. Mapping of genes in bacterial and phage chromosomes.
Unit III **Mutation, Epigenetics and Developmental Genetics**	Mutation: Types, causes and detection; Insertional mutagenesis, Transposon mutagenesis; Structural and numerical alterations of chromosomes: Deletion, duplication, inversion, translocation, ploidy mutation and their genetic implications; Genetic recombination and gene conversion; yeast mating type switch; Genetic screen: Enhancer, suppressor and modifier screens, Genetic complementation. Concept of epigenetics: Epigenome and epi-allele, Epigenetics and Monoallelic gene expression, Inheritance of epiallele, Epigenome projects; Developmental genetics with reference to model organisms: Genes for development in Drosophila- Embryonic development including body axis and body plan; Genetics of eye development in Drosophila; Development regulatory system in plants- Homeotic genes and their divergence. .
Unit IV **Population genetics and genetics of evolution**	Introduction to the elements of population genetics: Gene pool, Gene frequency, Hardy Weinberg genetic equilibrium and the factors (Selection, Mutation, Migration) influencing it, Gene flow and Genetic drift. Quantitative genetics: Genetic variation, Polygenic inheritance, heritability and its measurements, linkage disequilibrium; 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-104
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 & Diversity**	Introduction to microbiology and microbes, history & scope; Structural organization of prokaryotic cells- bacterial cell wall, capsule, flagella, pili, nucleoid, chromosome organization, ribosomes, plasmids. Microbial taxonomy and evolution of diversity, criteria for classification; classification of bacteria; Characteristics of Archaea, extremophiles, unculturable microbes; brief overview of eukaryotic microorganisms (algae, fungi, and protozoa)
Unit II **Microbial Growth and its Control**	Bacterial nutrition and nutritional categories. Bacteriological media and methods of cultivation and enumeration. Bacterial culture- synchronous, asynchronous, and continuous culture, chemostat principle. Bacterial growth- phases, mathematical expression of growth, generation time, specific growth rate. Control of microbial growth- physical and chemical methods, antimicrobial agents (antibacterial, antifungal, and antiviral) and their modes of action, biological control of microorganisms.
Unit III **Bacterial Genetics and Host-Microbe Interactions**	Bacterial genetics: mutation and recombination in bacteria, transformation, transduction and conjugation. Host-pathogen interaction, ecological impact of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbial communication system; bacterial quorum sensing; microbial fuel cells; prebiotics and probiotics.
Unit IV **Virus**	Virus: general properties of viruses, viral structure, taxonomy of virus, viral replication, Lytic and lysogenic cycles, mechanism of lytic and lysogenic decision in the temperate phages, cultivation and identification of viruses; Animal viruses and human diseases caused by viruses, Plant viruses and their transmission, sub-viral particles – viroids and prions.

Recommended Textbooks and References:

1. Willey, J. M., Sandman, K., & Wood, D. (2022). *Prescott's Microbiology*. McGraw-Hill.
2. Pelczar, M. J., Reid, R. D., & Chan, E. C. (2023). *Microbiology* (5th ed.). 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-105
Basics of Mathematics, Biostatistics and Research Methodologies

Credits

3

Course Objectives

The objective of this course is to give conceptual exposure of essential contents of mathematics, statistics and research methodologies 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.
- 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 **Algebra, Calculus and Mathematical models in biology**	Linear equations, functions: slopes-intercepts, forms of two-variable linear equations; constructing linear models in biological systems; quadratic equations; 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. Differential calculus, integral calculus. Population dynamics; oscillations, circadian rhythms, developmental patterns, symmetry in biological systems. modeling chemical reaction networks and metabolic networks.
Unit II **Statistics-I**	Populations and samples, Methods of sampling, Design of experiments, Classification and tabulation of data; histogram, frequency polygons; Measures of central tendencies – mean, median and mode; Measures of deviation skewness, kurtosis, range, chi-square, standard deviation, Testing hypothesis: Type-I and Type-II errors and level of confidence.
Unit III **Statistics-II**	Probability: Random variables and their distribution; normal distribution, binomial distribution and Poisson distribution; Introduction to probability theory, binomial probability, conditional probability; tests of statistical significance -parametric and nonparametric tests, linear regression, correlation & causality, analysis of variance, factorial experiment design, Statistics in genetics, Statistical software and their use.
Unit IV **Research Methodologies**	Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology. Choosing a mentor, lab and research question; maintaining a lab notebook. 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. 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. Stroud, K. A., & Booth, D. J. (2009). *Foundation Mathematics*. New York, NY: Palgrave Macmillan.
2. Aitken, M., Broadhursts, B., & Haldky, S. (2009) *Mathematics for Biological Scientists*. Garland Science.
3. Billingsley, P. (1986). *Probability and Measure*. New York: Wiley.
4. Rosner, B. (2000). *Fundamentals of Biostatistics*. Boston, MA: Duxbury Press.
5. Daniel, W. W. (1987). *Biostatistics, a Foundation for Analysis in the Health Sciences*. New York: Wiley.
6. Valiela, I. (2001). *Doing Science: Design, Analysis, and Communication of Scientific Research.* Oxford: Oxford University Press.
7. *On Being a Scientist: a Guide to Responsible Conduct in Research.* (2009). Washington, D.C.: National Academies Press.

BIOT- C-106
Indian Knowledge System and Biotechnology

Credits

4

Course Objectives

Objectives of the paper is to introduce students to various types of traditional knowledges in India in the field of Biotechnology.

Student Learning Outcomes

After completion of this course students are expected to get a holistic about ancient and traditional knowledge on Indian medicine, microbiology, fermentation technology, agriculture and plant biotechnology.

Unit I **Indian knowledge System and its protection**	Concept of Indian knowledge system and its importance; various kind of traditional knowledges in India; Protection of traditional knowledge through various enactments and Intellectual property rights; Legal frame works for protection of traditional knowledge: The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) act 2006; Plant Varieties Protection and Farmers Rights Act, 2001 (PPVFR Act); The Biological Diversity Act 2002 and Rules 2004; the protection of traditional knowledge bill, 2016; Geographical indications act 2003; Biopiracy.
Unit II **Indian knowledge System on medicines and biotechnology**	Ancient Indian Knowledge system and medical sciences; Introduction to Unani, Sidha and Ayurveda; Concept of health, pathogenesis, diagnosis and treatments in Ayurveda; Different disciplines of ayurveda and its importance ; Present status of Ayurveda and indigenous system of medicine: Yoga practice in Indian medical science; Government policies for conservation and translation on Traditional knowledge and indigenous system of medicines; Introduction to the ministry of AYUSH in India and its activities.

Unit III **Indian knowledge system on Microbiology and Fermentation technology**	Tracing Biotechnology through ages: Traditional knowledge in Fermenting alcohol; production of cheese, yoghurt and idli; Leavening of bread; production of enzymes; production of antimicrobial products and antibiotics; Production of amino acids and vitamins; production of energy and biogas; Concept of Bioconversion through ages.
Unit IV **Indian knowledge system on Agriculture and Plant Biotechnology**	Indian agriculture system through ages; Indigenous knowledge Practices in crop production and management, in plant protection and weed management, in farm machine & tools, in soil and water management, in medicinal & aromatic plants for disease diagnosis, in animal husbandry, in stored grain pests' management; Indian knowledge system in Food Security.

Recommended Textbooks and References:

1. Mahadevan et al. (2022) Introduction to Indian Knowledge system: Concepts and Applications, PHI learning Pvt. Ltd.
2. Trehan K (2013) Biotechnology. New Age international (p) Ltd.
3. Smith J E (2009) Biotechnology. Cambridge University Press
4. Goel D, Parashar S (2013). IPR, Biosafety and Bioethics. Pearson

BIOT-P-107 Laboratory I: Biochemistry and analytical techniques

Credits: 3

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-108 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

4

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 0utcomes

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**	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	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 II **Different types of PCR techniques**	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**	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 and application of microarrays – genomic arrays, cDNA arrays and protein 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**	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**	History of immunology, Components of innate and acquired immunity; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); Organs of immune system, primary and secondary lymphoid organs. Innate immune response; phagocytosis; complement and inflammatory responses, ADCC; mucosal immunity; antigens: immunogens, haptens; Major Histocompatibility Complex, antigen processing and presentation- endogenous antigens, exogenous antigens.
Unit II **Immune response generated by B and T lymphocytes & Antigen-antibody interactions**	Immunoglobulins - basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; 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.

	Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques: RIA, ELISA, Western blotting, ELISPOT assay, flow cytometry CMI techniques: lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis detection assays.
Unit III **Immunogenetics & Vaccinology**	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. 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, dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine.
Unit IV **Clinical immunology**	Immunity to infection: bacteria, viral, fungal and parasitic infections (with examples from each group); hypersensitivity: Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; treatment of autoimmune diseases; transplantation: immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology: tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency: primary immunodeficiencies, acquired or secondary immunodeficiencies, autoimmune disorder, immunosenescence, immune exhaustion in chronic viral infection, immune tolerance, NK cells in chronic viral infection and malignancy.

Recommended Textbooks and References:

1. Punt, J., Stranford, S., Jones, P., & Oven J.A. (2018). *Kuby Immunology*. New York: W.H. Freeman.
2. Abbas, A.K., Lichtman, A.H., Pillai, S. (2021). *Cellular and Molecular Immunology.* Elsevier
3. Murphy, K., Weaver, C., & Berg, L.J. (2022). *Janeway's Immunobiology.* New York: Garland Science.
4. Brostoff, J., Seaddin, J. K., Male, D., & Roitt, I.M. (2002). *Clinical Immunology.* London: Gower Medical Pub.
5. Paul, W. E. (2012). *Fundamental Immunology*. New York: Raven Press.

BIOT-C-203
Basic & Emerging Technologies

Credits

3

Course Objectives

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

Student Learning Outcomes

Students should learn the 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.

Unit I **Microscopy**	Light Microscopy: resolution and numerical aperture: Bright field; Darkfield; Phase Contrast; Differential Interference Contrast (DIC) microscopy. Fluorescence microscopy: fluorescence principle, optical arrangement, filter sets: excitation filter, dichroic mirror, and barrier filter; Confocal microscope: principle, resolution and point spread function. Multiphoton microscopy: principles and advantages of two-photon excitation; Advanced fluorescence techniques: FLIM, FRET, FRAP, TIRFM. Super-resolution microscopy: Basic principles and techniques: STED, STORM, and PALM. Electron microscopy: SEM, TEM, Cryo-electron microscopy: principles, design and applications.
Unit II **Spectroscopy & Structural Biology**	Laws of absorption of light, absorption spectra. UV, Visible, and IR spectroscopy. Mass spectroscopy- principles, ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides LC-MS, nano LC-MS, MALDI-TOF. Principle design and applications of X-ray diffraction; Small angle X-ray scattering, Nuclear Magnetic Resonance (NMR) spectroscopy, principle and uses; Atomic force microscopy- principle and uses.
Unit III **Centrifugation & Chromatography**	Centrifugation– Principles, Basics of Sedimentation, Types: Density gradient and Differential centrifugation, Ultracentrifugation. Chromatography- Principle (adsorption, partition), types of chromatography (Paper, TLC, Column, Gas, Affinity and Ion-exchange, HPLC).
Unit IV **Electrophoresis**	Electrophoresis: General principles, electrophoresis of proteins (SDS-PAGE, native gels, gradient gels, isoelectric focusing gels and two-dimensional gels), electrophoresis of nucleic acids (Agarose, pulse-field and sequencing gels).

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, Proteomics and Metabolomics

Credits

3

Course Objectives

The objective of this course is to provide introductory knowledge concerning various omics techniques 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 **Genomics & Genome Mapping**	Brief overview of prokaryotic and eukaryotic genome organization; Extra-nuclear genome: bacterial plasmids, mitochondria and chloroplast; Minimal Cell genome. Genetic and physical maps; Molecular markers and gene mapping, physical mapping, linkage analysis, QTL analysis; Cytogenetic techniques for gene mapping: In situ hybridization, FISH, somatic cell hybridization, radiation hybrid maps, optical mapping; Comparative gene mapping and synteny map.
Unit II **Genome Sequencing Projects & Comparative Genomics**	Genome Sequencing methods: Sangers sequencing, Automated Sequencing, Pyrosequencing, NGS (Illumina, Pacbio and Nanopore); Whole genome sequencing project: Strategies of whole genome sequencing, Human Genome Project, Arabidopsis genome project. Functional annotation of genes and gene families 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.
Unit III **Transcriptomics & Functional Genomics**	Transcriptome and Transcriptomics; EST, SAGE, CAGE, Microarray and RNA-seq methods; differential gene expression analysis. Identification and functional annotation of gene; mining functional genes in genome, gene function- forward and reverse genetics.
Unit IV **Proteomics & Metabolomics**	Proteome and proteomics; strategies and techniques for proteome analysis: 2D-PAGE, mass spectrometry, LC/MS-MS, MALDI-TOF, peptide fingerprinting, proteome databases. Protein-protein and protein-DNA interactions; yeast 2-hybrid and 3-hybrid system, functional proteomics; applications of proteomics. Introduction to metabolomics, strategies and methods of metabolomics, targeted and untargeted metabolomics, lipidomics, metabolite footprinting, Metabonomics and its applications.

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 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-207
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-208
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. Western blotting. 7. Dot blot assay. 8. Blood smear identification of leucocytes by Giemsa stain. 9. Separation of leucocytes by dextran method. 10. Demonstration of Phagocytosis of latex beads and their cryopreservation. 11. 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-209
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**	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**	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**	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**	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;
- 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 & Models of microbial growth kinetics**	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. 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**	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**	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. 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**	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. 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:

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

BIOT-C-302
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**	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 (Naïve string, Robin-Karp, Finite automata and Knuth-Morris Pratt); 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**	DNA sequence analysis: GenBank 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	Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTAL Omega 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, phylogenetic analysis.
Unit III **Protein modelling**	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.
Unit IV **Protein structure prediction and virtual library**	Protein structure prediction: protein folding and model generation; secondary structure prediction; analyzing secondary structures; protein loop searching; loop generating methods; homology modelling: potential applications, homologous sequence identification; align structures, align model sequence; construction of variable and conserved regions; structure prediction on a mystery sequence; sequence based methods of structure prediction, prediction using inverse folding, fold prediction; 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-303
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**	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**	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**	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**	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	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-P-306
Laboratory V: A. Plant Biotechnology and Bioprocess Technology

Credits

Course Objectives

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

Student Learning Outcomes

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

Syllabus **Plant Biotechnology**	1. Prepare culture media with various supplements for plant tissue culture. 2. Preparation of explants for inoculation under aseptic conditions. 3. Attempt *in vitro* andro and gynogenesis in plants. 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. 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. Undertake plant genomic DNA isolation by CTAB method and its quantitation by visual as well as spectrophotometric methods. 9. 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. 10. Study genetic fingerprinting profiles of plants and calculate polymorphic information content.
Syllabus **Bioprocess technology**	11. Basic Microbiology techniques a. Scale up from frozen vial to agar plate to shake flask culture. b. Instrumentation: Microplate reader, spectrophotometer, microscopy. c. Isolation of microorganisms from soil samples. 12. Experimental set-up a. Assembly of bioreactor and sterilization. b. Growth kinetics. c. Substrate and product inhibitions. d. Measurement of residual substrates. 13. Data Analysis a. Introduction to Metabolic Flux Analysis (MFA). 14. Fermentation a. Batch, b. Fed-batch, c. Continuous. 15. Unit operations a. Microfiltrations: Separation of cells from broth. b. Bioseparations: Various chromatographic techniques and extractions. 16. 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.
6. Chawla H. S. (2007) Plant Biotechnology: A Practical approach. Oxford and IBH

BIOT-P-306 Laboratory V: B. Animal Biotechnology and Bioprocess Technology

Credits 4

Course Objectives

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

Student Learning Outcomes

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

Syllabus **Animal Biotechnology**	1. Prepare culture media with various supplements for animal tissue culture. 2. Adherent and suspension culture, cell passage, counting of cells and checking their viability. 3. Cell proliferation assay. 4. Separation of mononuclear cells by Ficoll-Hypaque and their cryopreservation. 5. Prepare single cell suspension from spleen and thymus. 6. Monitor and measure doubling time of animal cells. 7. Chromosome preparations from cultured animal cells. 8. Isolation of DNA from animal tissue by SDS method. 9. Attempt animal cell fusion using PEG.
Syllabus **Bioprocess engineering and technology**	10. Basic Microbiology techniques a. Scale up from frozen vial to agar plate to shake flask culture. b. Instrumentation: Microplate reader, spectrophotometer, microscopy. c. Isolation of microorganisms from soil samples. 11. Experimental set-up a. Assembly of bioreactor and sterilization. b. Growth kinetics. c. Substrate and product inhibitions. d. Measurement of residual substrates. 12. Data Analysis Introduction to Metabolic Flux Analysis (MFA).

	13. Fermentation a. Batch. b. Fed-batch. c. Continuous. 14. Unit operations a. Microfiltrations: Separation of cells from broth. b. Bioseparations: Various chromatographic techniques and extractions. 15. Bioanalytics a. Analytical techniques like HPLC, FPLC, GC, GC-MS *etc.* for measurement of amounts of products/substrates.

Recommended Textbooks and References:

1. Freshney, RA, Amanda, CD (2021). Freshney's Culture of Animal Cells, Wiley, Blackwell
2. Shuler, M. L., & Kargi, F. (2002). *Bioprocess Engineering: Basic Concepts*. Upper Saddle River, NJ: Prentice Hall.
3. Stanbury, P. F., & Whitaker, A. (2010). *Principles of Fermentation Technology*. Oxford: Pergamon Press.
4. Blanch, H. W., & Clark, D. S. (1997). B*iochemical Engineering*. New York: M. Dekker.
5. Bailey, J. E., & Ollis, D. F. (1986). *Biochemical Engineering Fundamentals*. New York: McGraw-Hill.
6. El-Mansi, M., & Bryce, C. F. (2007). *Fermentation Microbiology and Biotechnology*. Boca Raton: CRC/Taylor & Francis.

BIOT-P-307
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 Clustal Omega. 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. 15. Data analysis using R and Python.

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.

BIOT-C-308
Dissertation and 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 Presentation**	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. Students will have to present the topic of their project proposal.

Semester Four

BIOT-D-401 Dissertation

Credits

18

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.

BIOT-C-402
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**	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**	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**	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**	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

Recommended Electives for Semester II (BIOT-E-207)

A. Biological Imaging

Credits

4

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**	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)**	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)	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**	Structured Illumination Microscopy; Correlative Nanoscopy: AFM Super-Resolution (STED/STORM); Stochastic Optical Fluctuation Imaging.
Unit IV **Light-sheet fluorescence microscopy (LSFM, or SPIM)**	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	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

4

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**	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**	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**	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**	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	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

4

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**	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**	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	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**	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**	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

4

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**	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	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**	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**	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**	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)

Recommended Electives for Semester III (BIOT-E-304)

BIOT-E-304
A. Plant Biotechnology

Credits

4

Course Objectives

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

Student Learning Outcomes

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

Unit I **Concept of Plant Tissue Culture and Methods**	Plant Tissue Culture Concepts and Methods: Concept of totipotency and plasticity, Tissue Culture Media and its composition, Plant growth regulators; Initiation and establishment of culture: Explant preparation, Single cell culture, Suspension culture, Callus culture, Microspore culture, Embryo rescue. Micropropagation: Organogenesis, Somatic embryogenesis, Artificial seed; Protoplast technology: Isolation and culture of protoplast, Somatic hybridization, Screening and selection of Somatic hybrid and cybrids.
Unit II **Secondary metabolites and its production**	Biotechnology of secondary metabolites: Secondary metabolites of plant origin and its type; Production of secondary metabolites through tissue culture, Factors affecting the production and its optimization. Bioreactor based production of secondary metabolites and its kinetic studies, isolation and purification of secondary metabolites, Biotransformation with case studies.
Unit III **Plant genetic engineering and its applications**	Plant genetic Engineering and its applications: Concept of genetic transformation: Vector based (Agrobacterium, Virus) and Direct transformation (Gene gun, Electroporation, Microinjection, etc.); Transgene stability and gene silencing, Chloroplast transformation. Application of Genetic Transformation: Herbicide resistance, Insect resistance, Disease resistance, Promoter tagging, Activation tagging, Molecular farming, Terminator seed technology; Products of Genetic Transformation: Case studies for Bt cotton, golden rice and Flavr Savr tomato.

Unit IV **Plant molecular breeding and its applications**	Plant Molecular breeding: Molecular markers- Types, Principle, applications in plant biotechnology- in SITL and QTL mapping, physical mapping, map based cloning. Marker assisted selection (MAS), Genomic selection, Genome wide analysis based selection (GWAS), genome editing, Express Breeding (Speed breeding).

Recommended Textbooks and References:

1. Chawla, H. S. (2009). *Introduction to Plant Biotechnology*. Enfield, NH: Science.
2. Razdan, M. K. (2003). *Introduction to Plant Tissue Culture*. Enfield, NH: Science.
3. P. K. Gupta (2010). *Plant Biotechnology,* Rastogi Publications
4. *A. C. Cassell, A.C., Jones, P.W. Somaclonal variation as a tool for crop improvement-* Kluwer Academic Publishers, Dordrecht.
5. Newmann, K.H. W. Barz, W., Reinhard, E. *Primary and Secondary Metabolism of Plant Cell Culture,* Springer-Verlag, Berlin.
6. *Dodds, J.H. In vitro Methods for Conservation of Plant Genetic Resources- Chapman and Hall, U.K.*
7. Slater, A., Scott, N. W., & Fowler, M. R. (2008). *Plant Biotechnology: An Introduction to Genetic Engineering*. Oxford: Oxford University Press.
8. Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). *Biochemistry & Molecular Biology of Plants*. Chichester, West Sussex: John Wiley & Sons.
9. Umesha, S. (2013). *Plant Biotechnology.* The Energy And Resources.
10. Glick, B. R., & Pasternak, J. J. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA*. Washington, D.C.: ASM Press.
11. Brown, T. A. (2018). *Gene Cloning and DNA Analysis: an Introduction*. Oxford: Blackwell
12. Primrose, S. B., & Twyman, R. M. (2006). *Principles of Gene Manipulation and Genomics*. Malden, MA: Blackwell Pub.
13. Slater, A., Scott, N. W., & Fowler, M. R. (2003). *Plant Biotechnology: The Genetic Manipulation of Plants*. Oxford: Oxford University Press.

BIOT-E-304
B. Animal Biotechnology

Credits

4

Course Objectives

The objectives of this course are to introduce students to the principles, practices and application of animal biotechnology, animal cell 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 biotechnology and their applications.

Unit I **Animal Cell Culture-I**	Brief history of animal cell culture, Laboratory design, layout, equipment, and materials, Aseptic techniques, safety protocols, Cell Culture vessels, preparation of cell culture media and reagents, serum-free media development and sterilization, culture of mammalian cells and tissues, primary culture, secondary culture, suspension cultures, preparation of suspension cells for cytology, Three-dimensional culture: Organotypic culture and histotypic culture, Organ culture. Growth curve, establishment of cell line, cell counting, Cloning and selection.

Unit II **Animal Cell Culture-II & Application of Animal Model System**	Methods of cell separation, cryopreservation, cytotoxicity studies, Necrosis and apoptosis (mechanism & assays) Characterisation: cell morphology, cell analysis by staining, antigenic markers, differentiation, transformation, Immortalisation, 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. Production of monoclonal antibodies.
Unit III **Stem cell Biology**	Overview of stem cells: self-renewal, pluripotency, and differentiation, Origin, differentiation potential, and application of Embryonic stem cell, somatic stem cells, and induced pluripotent stem cells (iPSCs), Stem Cell Culture Techniques: Media and conditions for maintaining stem cells, Feeder layers and extracellular matrix components, Gene Editing in Stem Cells, Methods to induce differentiation, Stem cell therapy, applications of stem cell biology in tissue engineering and regenerative medicine.
Unit IV **Animal reproductive biotechnology**	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.

Recommended Textbooks and References:

1. Davis, AC, Freshney RA (2021). Culture of animal cells. Willey Blackwell
2. Knoepfler P (2013) Stem Cells: An Insider's Guide" World scientific publishing.
3. Lanza R (2021) Essentials of Stem Cell Biology and Therapy. Academic Press
4. Glick, B. R., & Pasternak, J. J. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA*. Washington, D.C.: ASM Press.
5. Gordon, I. (2005). *Reproductive Techniques in Farm Animals*. Oxford: CAB International.
6. Levine, M. M. (2004). *New Generation Vaccines.* New York: M. Dekker.
7. Pörtner, R. (2007). *Animal Cell Biotechnology: Methods and Protocols*. Totowa, NJ: Humana Press.

Recommended Electives for Semester IV (BIOT-E-403)

A. Drug Discovery and Development

Credits

4

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**	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**	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**	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	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**	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	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

4

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**	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** **Nano-particles**	Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterization 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**	Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development
Unit IV **Nano-materials**	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	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

4

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.
-

Unit I **Introduction to protein engineering**	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**	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**	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

D. Metabolic Engineering and Metabolomics

Credits

4

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**	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**	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**	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**	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	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**	Basic Concepts of Biotechnology and its applications, Recombinant DNA technology; gene cloning, human genome project, Tools of Bioinformatics
Unit II **Agricultural and Environmental Biotechnology**	**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**	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**	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**	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**	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**	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**	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**	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**	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**	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**	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	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	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	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	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**	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**	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**	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**	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