Syllabus of M.Sc. in Molecular Microbiology at Institute of Health Sciences, Presidency University

Course Code	Title	T/P/S	Credit	Marks
	SEMESTER I (Total credit: 20; Total mark: 250)			
MLMB0701	Biochemistry & Microbial metabolism	T	4	50*
MLMB0702	Molecular Biology & Recombinant DNA technology	T	4	50*
MLMB0703	Microbiology & Cell biology	T	4	50*
MLMB0791	Biosafety & Practical on Biochemistry, Microbiology & Cell biology	P	4	50
MLMB0792	Practical on Molecular Biology & Recombinant DNA technology	P	4	50
	SEMESTER II (Total credit: 20; Total mark: 250)			
MLMB0801	Microbial genetics & Immunology	T	4	50*
MLMB0802	Host-microbe interaction & Analytical techniques	T	4	50*
MLMB0803	Bioinformatics & Genomics and Proteomics	T	4	50*
MLMB0891	Practical on Microbial genetics, Host-microbes interaction, & Bioinformatics	P	4	50
MLMB0892	Practical on Immunology & Analytical techniques	P	4	50
	SEMESTER III (Total credit: 20; Total mark: 250)			
MLMB0901	Food microbiology & Environmental microbiology	T	4	50*
MLMB0902	Emerging technologies	T	4	50*
MLMB0903	Bioprocess engineering and technology	T	4	50*
MLMB0991	Practical on Food & Environmental microbiology	P	4	50
MLMB0992	Practical on Bioprocess engineering and technology & Emerging technologies	P	4	50
	SEMESTER IV (Total credit: 20; Total mark: 250)			
MLMB1001	Biostatistics & Bioethics and Intellectual Property Right	T	4	50*
MLMB1091	Dissertation: Scientific writing and presentation	S	4	50
MLMB1092	Dissertation: Journal presentation and group discussion	S	4	50
MLMB1093	Dissertation: Thesis writing and defense	S	4	50
MLMB1094	Dissertation: Microbiological laboratory visit and Grand viva	S	4	50
	Total credit and marks:		**80**	**1000**

Theory (T): Credit-4, Contact hour per week-4 h; Practical (P)/Sessional (S): Credit-4, Contact hour per week-8 h

*50 marks of theory paper are distributed as 35 marks for End semester exam and 15 marks for continuous assessment

Aims and Objectives:

This program aims at providing molecular details of cellular and biochemical processes in diverse microorganisms, their physiology and their associations with different plants and animals in normal and disease conditions. Emphasis will be given to explaining the impact of microbes on our environment and our food, and how the knowledge can be utilized in industrial applications. To complement these topics, this program also provides knowledge of recent technological advances to study these processes and to understand how to utilize the acquired knowledge in designing or developing novel strategies for biomedical or industrial advancement.

Program Outcome (PO):

PO1: Acquire fundamental knowledge and skills

Students should gain fundamental knowledge of microbiology, and the molecular pathways in diverse microbes during their independent life cycle or during their interaction with other organisms. They should also acquire the skills to apply the principle in studying those molecular pathways in various domains of microbial world.

PO2: Critical thinking and research aptitude

Students should understand the fundamental gaps in existing knowledge, critically formulate hypothesis and develop inquisitiveness to address the questions applying the various techniques of molecular microbiology.

PO3: Effective communication and interpersonal skill

Students should engage in scientific discussion, and exchange of ideas through effective communications with their peers and mentors. They should also learn diverse oral presentations and acquire writing abilities in English. If required, students should be able to communicate in any other language he/she feels comfortable with others.

PO4: Ethics and biosafety practices

Students should understand the importance of ethics in research, should abide by the ethical practices, demonstrate proficiency in biosafety practices and acquire knowledge about intellectual properties rights (IPR).

PO5: Application and Integration of knowledge

Students should apply their analytical skillset of molecular microbiology to analyze the emerging problems of medical, agricultural, and industrial microbiology via interdisciplinary and transdisciplinary approaches.

PO6: Environment and Sustainability

Students should be able to understand the rationale of safety procedures and strategies to protect both themselves and the environment via holistic approaches of sustainable development.

Program Specific Outcome (PSO):

PSO1: Students should acquire specialized knowledge in microbial diversity, molecular basis of life, microbial genetics, interaction of microbes with animate and inanimate objects of the environment.

PSO2: Learn various techniques and its implication related to molecular biology and recombinant DNA technology, microbiology with its broader application in medical, agricultural, environment and industrial sector, bioprocess engineering, immunology, bioinformatics, and application of statistics in biology.

PSO3: Able to conceptualize and execute research projects in the field of microbial sciences.

PSO4: Understand the safety aspects in biology, good laboratory practices and demonstrate the same during laboratory work.

PSO5: Gain knowledge about ethical conduct in science, learn about intellectual properties rights and gather communication and presentations skills for the overall professional development.

Teaching-learning process

Teachers with expertise in a certain field will teach that module by having a proper idea of the curriculum, assessing learning needs, and establishing specific learning objectives. Teachers will be in continuous interaction with the students so that the various teaching and learning strategies can be implemented, while maintaining the students' motivation and curiosity about the subjects. Special care will be taken for underperforming students to make them feel confident about the subject.

Mode of assessment

Teaching will include lectures (online or offline), hands-on training, laboratory dissertations and microbiological laboratory visits. Evaluations will be in two parts- internal assessment and final assessment/examination. Both time-bound written and oral examinations will be held. The presentations and interactions during presentations will be evaluated in an objective manner. Quizzes and group discussions will be conducted for continuous assessment. Regular performance for the laboratory courses will also be assessed in an objective manner.

SEMESTER I

MLMB0701

A. Biochemistry **48 h**

Unit I: Chemical basis of life

Enthalpy, entropy and free energy; Spontaneity and equilibrium; Micelle; buffers and pH, ionic strength; Ionic and covalent bonds, Van der Waals forces, hydrogen bonds; Polarity and dipole moment; Hydrophobicity; Principles of absorption spectroscopy- Beer-Lambert's law; Chemical kinetics- order, rates and rate constant, Arrhenius equation; Basic stereochemistry

Unit II: Biomolecules and their function

Composition, function and metabolism of carbohydrates and lipids; Vitamins and cofactors in metabolism, their deficiencies and associated disorders

Unit III: Structure and function of nucleic acids, and proteins

Structure and function of nucleic acids, difference in RNA and DNA structure; A, B and Z-DNA. Structure of amino acids and peptides - Ramachandran plot, secondary and tertiary structures

Unit IV: Enzymology

Structure, classification, and general properties of enzymes; Active site and specificity of enzyme; Enzyme substrate complex, induced fit theory.

Enzyme kinetics and inhibition, Factors affecting enzyme activity. Abzymes and Isozymes; Overview of protein-ligand interaction

Enzyme inhibitors- types of inhibitors; Mechanism of enzyme inhibition- competitive, non-competitive, allosteric, and irreversible inhibition; Hill equation.

Enzyme regulation- allosteric regulation, covalent modification, zymogen activation.

Enzymes as therapeutic agents.

B. Microbial Metabolism **16 h**

Glycolysis and the TCA cycle, Entner–Doudoroff (ED) pathway, Pentose phosphate pathway. Biological nitrogen fixation, Role of glutamine synthetase, glutamate dehydrogenase and glutamine oxoglutarate aminotransferase in ammonia assimilation. Photosynthesis. Chemolithotrophy: Anaerobic Ammonium Oxidation, Acetogenesis, Methanogenesis, Peptidoglycan synthesis. Pasteur effect.

Course Outcome (CO):

On completion of this course students should be able to-

- Gain fundamental knowledge in biochemical processes, biomolecules, enzymes and microbial metabolism that are essential to understand any biological process happening in microbes.
- Gain critical thinking abilities in analyzing the molecular pathways regulating microbial metabolism.
- Gain analytical skills to determine various chemical parameters (such as pH, reaction rate, entropy, enthalpy, Km, Vmax etc) of different biochemical processes, occurring in vitro or inside of a microbe.

MLMB0702

A. Molecular biology **32 h**

Unit I: Chromatin structure and modifications

Chromatin organization- histone and DNA interactome; Structure and assembly of prokaryotic and eukaryotic DNA polymerases; DNA-replication, repair and recombination.

Unit II: RNA and Transcriptional control

Transcriptional initiation, elongation and termination; Structure and assembly of prokaryotic and eukaryotic RNA Polymerases; Post-transcriptional control; miRNAs and siRNAs; Structure and folds in RNA molecules- tRNA and microRNA; riboswitch and ribozymes; RNA transport, localization and function.

Unit III: Translational controls

Genetic code and its properties; Wobble hypothesis; prokaryotic and eukaryotic protein synthesis- initiation, elongation, termination; co- and post-translational modifications (acetylation, glycosylation, ubiquitination); Protein Folding and protein degradation, Protein trafficking and transport.

Unit IV: Control of gene expression at transcription and translation level

Regulation of gene expression in viruses, prokaryotic and eukaryotic genes, chromatin remodeling and gene silencing; Epigenetic regulation.

B. Recombinant DNA technology **32 h**

Unit I: Recombinant DNA technology

Restriction endonucleases, restriction mapping, DNA and RNA modifying enzymes (viz. polymerase, reverse transcriptase, ligase, alkaline phosphatases, terminal transferase, nuclease) Vectors (viz. Plasmid, Cosmid, Fosmid, Phagemid, BAC, YAC, PAC, HAC, and shuttle vectors).

Cloning methods (directional and gateway), introducing engineered plasmids into a bacterial cell - transformation, conjugation, and transduction; Identification and analysis of recombinant DNA clones.

Expression vectors – bacterial, yeast, insect, mammalian and plant expression systems; Yeast two-hybrid systems; Phage display

Construction of cDNA and genomic DNA libraries; use of transposon in genetic analysis; Genetic manipulation of microorganisms and strain improvement – Knock-down and knock-in system.

Unit II: Techniques in genetic engineering

PCR- designing primers; Different types of PCR- Allele Specific, Assembly, Asymmetric, Colony, Helicase dependent, Hot-start, Inverse, Methylation specific, multiplex, nested, Quantitative/Real-Time, RT-PCR, touchdown, touch up, VNTR etc. 5'-/3'-RACE, site-directed mutagenesis

Application of PCR in molecular diagnostics.

Methods of nucleic acid detection, Denaturing gradient gel electrophoresis (DGGE), DNA-protein interaction study - EMSA, DNA foot-printing; S1 nuclease mapping, RNase protection assay

Strategies of gene delivery - chemical, physical or mechanical method), Lentiviral/retroviral vectors and their usage in gene manipulation and delivery. Genome editing tools – CRISPR/Cas9, TALENs, ZFNs

Techniques in gene expression analyses - Reporter gene, Northern blot, Fluorescent in situ hybridization, Reverse transcription PCR, SAGE, DNA microarray, Tiling array, RNA-Sequencing.

Course Outcome (CO):

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

- Understand the detailed molecular mechanisms of central dogma of life, details of nucleic acids and nucleosomes, molecular regulation of gene expression at genetic and epigenetic levels at normal physiological conditions and how it differs under stressful or pathological conditions.
- Gain critical thinking ability to understand different strategies of recombinant DNA technology (RDT) starting from restriction mapping of DNA to the genome editing techniques and genetic engineering in microbes and higher eukaryotes
- Develop analytical skills to apply those continuously evolving RDT strategies (such as PCR, real-time PCR, gene sequencing etc) in molecular biology, biotechnology or diagnostic laboratories.

MLMB0703

A. Microbiology **32 h**

Unit I: Microbes and their general characteristics

Origin of life: Miller–Urey experiment; Evolution of prokaryotes and eukaryotes, Endosymbiotic theory, Prokaryotic diversity and taxonomy. Culture dependent and independent approach; Polyphasic taxonomy, species concept.

Morphology and ultra-structure of Bacteria, cellular component, flagella, pili, fimbriae, extracellular layers, cell wall, cell membrane, plasmids and episomes, endospore, cysts, bacterial chromosome, inclusion bodies and pigment; Growth kinetics and bacteria cultivation: Aerobic and anaerobic cultures, different phases of growth. Batch, continuous and synchronous culture, Chemotaxis (signal transduction in microbes), quorum sensing, biofilm formation, Phototaxis, magnetotaxis.

Extremophiles, Archaeal diversity, and characters; Virus- Classification, capsid, envelope, and genetic material; General characteristics and importance of protozoa, algae, fungi

Unit II: Antimicrobial agents and chemotherapy

Discovery of Chemotherapy, Magic bullets

Antibiotics: Antibiotic resistance crisis, Multidrug resistance in microbes, Mechanism of action of antibiotics (Penicillin, Streptomycin, Rifampicin, cepahlosporin, fluroquinoline, isoniazid etc.); Antimicrobial spectrum, Antimicrobial resistance vs tolerance

Methods of sterilization, disinfection, antimicrobial agent (antiseptics, sanitizer, germicide, antimicrobial agent), Chemical control- dye solutions, alcohol, acid, alkali, halogen, heavy metal, phenol, phenol derivatives, formaldehyde, ethylene oxide, detergents. Assessment of chemical disinfectant, chemotherapeutic agents-sulphonamides

B. Cell biology **32 h**

Unit I: Prokaryotic cell organization and cell division

Morphology and ultra-structure of bacteria; Cell shape and size of prokaryotes, prokaryotic cell membranes, cytoplasmic matrix, nucleoid, gas vacuole, ribosomes, inclusion bodies; Periplasmic space, capsules, slime layers, glycocalyx, flagella, fimbriae, and pili. Cell wall of bacteria and archaea; external components and protein secretion in prokaryotes

Plasmids and episomes, endospore, cysts in prokaryotes, germination in bacteria
Uncommon bacterial genera- *Rickettsia, Chlamydia, Myxobacteria,* and *Mycoplasma*.

Unit II: Cellular organization and cytoskeleton in eukaryotes
Cellular organelles, extracellular matrix; Structure of cell membrane, Cell-cell, and Cell-matrix interaction; Cytoskeleton and motor proteins; Microscopic techniques to visualize cells and organelles

Unit III: Cell Cycle and Cellular activities
Bacterial cell division cycle; Mitosis and meiosis and their regulation; Cell cycle and its regulation, checkpoints. Aneuploidy; Apoptosis, Necrosis and Autophagy; Proliferation and differentiation

Unit IV: Cell signaling
Signaling molecules; Receptors- G-protein coupled receptor, Receptor Tyrosine Kinase (RTK), cytokine receptors; Pathways of intracellular signal transduction.

Course Outcome (CO):
On completion of this course, students should be able to-

- Understand the origin, evolution, major categories and diversity of microorganisms, the key cellular components of the diverse nature of microbes, their growth, motility, different intracellular and extracellular signaling in cell-cell communication, interactions between microbes, hosts and environment, and the importance of emerging issues like drug resistance.
- Critically analyze biological processes of a cell of prokaryotic and eukaryotic origin, control of cellular growth and various signaling processes of prokaryotic and eukaryotic cells
- Develop skills to analyze microbial physiology, growth and interaction with other microbes and hosts.

MLMB0791: **Biosafety & Practical on Biochemistry, Microbiology & Cell biology** **128 h**

Unit-1: Principles and demonstration of Biosafety
Chemical and biohazard safety; Safety measurement for radioactive material; Social responsibility and Whistleblowing

- Demonstration of biosafety and chemical safety, Use of PPE

Unit-2: Practical on Biochemistry, Microbiology & Cell biology

1. Preparation of buffer and sterile filtration; Aseptic techniques in microbiology
2. Determination of unknown protein concentration by absorption spectroscopy
3. Extraction of cellular protein, and quantitation using Bradford method
4. Quantitative analysis of amino acids, nucleic acids (DNA and RNA), carbohydrates and lipids
5. Separation of circular and linear DNA by agarose gel electrophoresis
6. Determination of pH optima, Km, Vmax and Kcat of an enzyme (viz. alkaline phosphatase)
7. Isolation of bacteria from environmental samples (sample collection, serial dilution, media preparation, enrichment culture, spread plate and pour plate, CFU count, pure culture preparation, staining, and biochemical tests)
8. Storage and maintenance of microbial culture- cryopreservation and revival of bacterial culture

9. Determination of microbial cell number by hemocytometer

Course Outcome (CO):

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

- Familiarize with various lab safety protocols, basic laboratory instruments, their care and usage protocols, and measurement of the necessary parameters
- Utilize the basic knowledge in carefully and analytically conduct different experiments of biochemistry, microbiology and cell biology.

MLMB0792: Practical on Molecular Biology & Recombinant DNA technology **128 h**

1. Preparation of competent *E. coli* cells
2. Transformation of competent *E. coli* cells with a plasmid to determine transformation efficiency
3. Plasmid isolation and restriction digestion – mapping
4. Gene cloning and recombinant screening
5. Genomic DNA extraction from mammalian cells
6. Primer designing using web-based tools for gene cloning and real-time PCR detection
7. Nested PCR
8. RNA and cDNA preparation - Reverse Transcriptase PCR and Real-Time PCR (qPCR)
9. Molecular marker detection – RFLP
10. Concept of lac-operon: a) Lactose induction of b-galactosidase, b) Glucose Repression

Course Outcome (CO):

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

- Hands on training in various instruments and strategies to analyze macromolecules such as DNA and RNA
- Carefully and critically conduct different experiments utilizing various RDT techniques and concept of genetics to analyze those macromolecules.

SEMESTER II

MLMB0801

A. Microbial Genetics **32 h**

Unit I: Microbial genetics

Identification and selection of mutants; Plasmids - types, replication, partitioning, copy-number control; Methods of gene transfer in Bacteria - Transformation: natural transformation systems, mechanism, gene mapping by transformation; chemical and electrotransformation. Conjugation: discovery, nature of donor strains and compatibility, interrupted mating and temporal mapping, Hfr, chromosome transfer in other bacteria. Phage genetics: lytic and lysogenic switch; Virulent and temperate phage. Transduction: Generalized and specialized transduction; gene mapping by specialized transduction, mechanism of generalized transduction, abortive transduction; Transposons - prokaryotic and eukaryotic (yeast, maize, fruit fly).

Unit II: Yeast genetics

Isolation and characterization of auxotrophic and temperature-sensitive mutants, synthetic lethality, multicopy suppression. Meiotic crosses, tetrad analysis in yeast, and recombination mapping with tetrad, complementation, yeast mating-type switch.

Unit III: Genetics of higher eukaryotes

Human genetics - pedigree analysis, lod score for linkage testing, karyotypes, genetic disorders, DNA polymorphism in mapping; structure and function; polygenic inheritance.

B. Immunology **32 h**

Unit I: Introduction to Cellular and Molecular immunology

Fundamental concepts of the immune system: Innate immune response, adaptive immune response, B and T cell activation, complement pathway; Major Histocompatibility Complex- MHC genes, MHC and immune responsiveness and disease susceptibility, Vaccine technology, Immunotherapy.

Unit II: Immunodiagnostic techniques

Introduction to antigen-antibody reaction; In vitro diagnostic assays- precipitation, agglutination hemagglutination, RIA, ELISA, and its specific applications; Immunophenotyping by Flow cytometry; Development of immunodiagnostic kits. Cytogenetics techniques

Unit III: Hypersensitivity, inflammation, and transplantation immunology

Type I (Allergy), Type II (antibody-mediated) and Type III (immune complex-mediated) and Type IV (delayed-type) hypersensitivity reaction, chronic inflammation, autoimmunity, transplantation immunology

Course Outcome (CO):

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

- Gain fundamental knowledge of principles of microbial genetics, relationship between phenotype and genotype, genetic traits and mapping, phylogenetic and evolutionary conservation/divergence. Students should also learn immunology and immune responses during everyday life due to various pathological

conditions, and the importance of host-pathogen interactions in diseases

- Gain critical thinking ability to analyze microbial, and higher eukaryotic genetics.
- Develop analytical skills to apply the knowledge of microbial genetics and immunodiagnostics strategies in biotechnological interventions.

MLMB0802

A. Host-microbe interaction **48 h**

Unit I: Beneficial plant-microbes interaction

Plant-associated interfaces and interactions: Diversity and dynamics of microorganisms in Soil, Rhizosphere, Rhizoplane, Phyllosphere, Phylloplane, and different plant tissues. Physiological and biochemical processes underlying major symbiotic relationships. Various compounds in root exudates of different plant species. Direct and indirect mechanisms of microbes assisted plant growth promotion. plant-microbe interactions lead to symbiotic (Rhizobia, Frankie, and Mycorrhizal).

Unit II: Plant pathogen interaction

Molecular Basis of Pathogenicity development (enzyme, secretory proteins, toxin). Physiological and biochemical processes underlying major pathogenic relationships (host colonization, alteration of host cell behavior. Xanthomonas and Fusarium infection in plants. Anatomical & biochemical mechanisms of plants' resistance. Role of phytoalexins, PR proteins, phytoncides, plantibodies; programmed cell death. Control of diseases (chemical, physical, biological, and biotechnological). Resistance genes (R-genes) and their role in disease management; Role of transcription factors in modulating resistance mechanisms; Disease resistance related phytohormones (salicylic acid, jasmonic acid, ethylene, abscisic acid etc.)

Unit III: Human microbiome

Microbial communities in the human body, the role of Microbiota in human health; Microbial interactions with the host immune system; gut-brain axis; microbial diversity analysis; potential for microbiome-directed therapeutics to impact human disease.

Unit IV: Host pathogen interaction

Mechanism of microbial pathogenesis (bacteria, virus, yeast, parasites), genetics of pathogenicity, and virulence. Colonization, Association, Adhesion, and Invasion of host tissue. Alteration of host cell behavior by pathogens, pathogen-induced diseases: bacterial (*Vibrio*, *Tuberculosis, Helicobactor, Salmonella, Streptococcus, Pneumococcus, Clostridium*), Viral (Hepatitis, HIV, Influenza, Coronavirus and other emerging viruses oncogenic viruses). Hospital-acquired infections; Pathogenic fungi; Pathogenicity of parasites (*Plasmodium*, *Entamoeba, Naegleria, Leishmania, Trypanosoma*), mode of action, virulence, Pathogenicity islands.

B. Analytical techniques **16 h**

Principle of centrifugation, different types of centrifuges, Ultracentrifugation; Differential & density gradient centrifugation; Separation and analysis of proteins; Filtration and Dialysis

Principles of protein purification, Various chromatography techniques- Size exclusion chromatography, Ion exchange chromatography, Affinity chromatography

HPLC, FPLC, Gas chromatography

Course Outcome (CO):

On completion of this course students should be able to-

- Gain knowledge of interactions between microbes, hosts and environment, and the principles of microbial pathogenesis of diverse microbes and host-pathogen interaction.
- Gain critical thinking ability in analyzing human microbiome, and its application in health and diseases
- Develop analytical skills for the various analytical techniques used in most laboratories and industries.

MLMB0803

A. Bioinformatics **32 h**

Unit I: Introduction to Bioinformatics

Scope and applications of bioinformatics, global bioinformatics scenario, definition of terms- orthology, paralogy, xenology and analogy; Similarity and identity

Introduction to databases- types of databases, information retrieval system (Entrez and SRS) and database collaboration, file formats, sequence, structure and pathway databases of nucleotides and proteins

Unit II: Application of bioinformatics

Multiple Sequence Alignment, progressive method, iterative method; data searching tools for homologous sequences analysis - BLAST & FASTA; Sequence editors - BioEdit, BoxShade

Prediction tools- profile, motifs, domains and feature identification

Phylogenetic prediction: Phylogenetic tree construction - distance based method and character-based methods; Gene prediction, protein structure & functions prediction, Phylogenetic analysis package – MEGA

Unit III: Protein modeling

Protein structure prediction: protein folding and model generation; secondary structure prediction; Homology modeling: potential applications; Protein function prediction, In silico drug design

B. Genomics and Proteomics **32 h**

Unit I: Genomics

Concept of Genomics, Genome mapping – Genetic and physical mapping, Genetic markers; methods and techniques used for gene mapping, molecular/genetic markers in genome analysis – RFLP, AFLP, RAPD, VNTR, Microsatellite polymorphism, SSR, SNP; molecular markers linked to disease resistant genes Application of molecular markers in forensic, disease prognosis, genetic counseling and pedigree analyses; linkage analysis, cytogenetic techniques, Fluorescent In Situ Hybridization in gene mapping, somatic cell hybridization, and radiation hybrid maps

DNA-Sequencing – Maxam Gilbert and Sanger Dideoxy methods, Automated sequencing; Genome sequencing projects for microbes, plants and animals; Human Genome Project (HGP), Next-generation sequencing – Roche/454 pyrosequencing, Illumina (Solexa), SOLiD, Ion Torrent; Application of Next-Gen Sequencing technologies – Whole genome, Exome, 16S rRNA amplicon, RNA-Seq, ChIP-Seq, Methyl specific sequencing etc.; Contigs and genome reconstruction, de novo and reference based sequencing

Functional genomics, Application of genomics, Epigenomics, Proteogenomics, Structural genomics, Metagenomics, Comparative genomics, Personal Genomics, Pharmacogenomics/pharmacogenetics, Pharmacodynamics.

Unit II: Proteomics

Concept of Proteomics; Sample preparation, Gel-based proteomics - isoelectric focusing and two-dimensional gel electrophoresis (2-DGE), two-dimensional fluorescence difference in-gel electrophoresis (DIGE), mass spectrometry – different types of mass spectrometers (MALDI-TOF Q-TOF, LC-MS), protein and peptide sequencing; Multidimensional proteomics: SELDI-TOF. Quantitative proteomics - stable isotope labelling by amino acids in cell culture (SILAC), isotope-coded affinity tag (ICAT), isobaric tagging for relative and absolute quantitation (iTRAQ); Label-free proteomics.

Course Outcome (CO):

On completion of this course students should be able to-

- Comprehend the basic theory of various bioinformatics principles, algorithms, and computational tools to analyze sequences of DNA/RNA/proteins and related databases. . Students should also acquire knowledge and understanding of fundamentals of genomics and proteomics, and their applications
- Develop critical thinking ability in utilizing the diverse bioinformatics tools in predicting protein structure of microbes and molecular markers for various microbial signatures
- Gain the analytical skills to critically analyze big data (viz. genome mapping and sequencing) of healthy and pathological conditions, and to develop novel computational strategies for such application.

MLMB0891: Practical on Microbial genetics, Host-microbes interaction, Bioinformatics and Genomics 128 h

1. Yeast transformation and selection of transformants
2. Plaque assay using lambda phage
3. Isolation of endophytic bacteria from plant root /phylloplane and amplification of its 16S rRNA gene with universal primers.
4. Visualization of Mycorrhizal fungus in plant root
5. Assessment of plant physiological traits upon inoculation of beneficial and pathogenic microorganisms - monitoring of differential expression of ROS-related enzymes during plant-pathogen interaction
6. Study of host-parasite interaction and ingestion assay.
7. Antibiotic sensitivity of bacteria (MIC, MBC, and Paper disc)
8. Imaging bacteria and parasite cells
9. BLAST based logical searches, Sequence alignment and deductions (computational)
10. DNA sequencing analyses (computational)
11. 16S rRNA amplicon based Next Generation Sequencing analyses (Computational)

Course Outcome (CO):

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

- Isolate, characterize and identify common microorganisms and perform antimicrobial sensitivity tests
- Critically design and conduct computational assays using learnt tools
- Critically analyze and interpret microbial genomics and proteomics dataset

MLMB0892: Practical on Immunology & Analytical techniques 128 h

1. Isolation and purification of IgG from serum
2. Precipitation reaction by double immunodiffusion (Ouchterlony method) and radial immunodiffusion (Mancini's method)

3. Detection of antigens or antibodies by ELISA – Indirect and Sandwitch ELISA
4. Blood typing – A, B, AB and O
5. Immunoblotting assay for protein detection
6. Immunoprecipitation assay
7. Separation of cellular proteins on SDS-PAGE
8. Ammonium sulphate precipitation of a protein and dialysis
9. Purification of a recombinant protein by affinity chromatography

Course Outcome (CO):

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

- Familiarize with laboratory instruments and techniques used to perform various immunological and immunodiagnostic studies
- Conduct analytical experiments using the various instruments and strategies

SEMESTER III

MLMB0901

A. Food microbiology **32 h**

Unit I: Foodborne diseases

Sources of food contamination; factors influencing microbial growth in food. Food infections (sources, transmission, and control) by bacteria- *Brucella*, *Bacillus*, *Clostridium*, *Escherichia*, *Listeria*; Food intoxication (sources, transmission, and control) - Botulism, Staphylococcal, Mycotoxins & their types- aflatoxins, trichothecenes, fumonisins; foodborne outbreaks and lab testing procedures. Preventive measures. Molds, Algae, Protozoa, Viruses

Unit II: Food Preservation

Principles and methods of food preservation- physical (temperature, irradiation, drying, canning), modifications of atmosphere, control of water activity, compartmentalization; Chemical (Organic acids, food additives. class I and class II preservatives); Control by a combination of methods (Hurdle concept); Biopreservation; Food packaging- types of packaging materials, properties, and benefits, Canning

Unit III: Microbiology of Fermented Foods

History, scope, and importance of fermented foods; Microbial stress response in food, starter cultures, the microbiology of fermented foods. General methods of production - fermented vegetables, meat, beverages; Bread, dairy foods; Probiotics, prebiotics and synbiotics, nutraceuticals (Cr/Se yeast), functional foods, and their quality standards. Application of fungal pigments in the food industry, SCP- Nutritional & therapeutic importance.

B. Environmental Microbiology **32 h**

Unit I: Microbial ecology

Basic concept, development of the microbial community in the biosphere, biofilm
and its ecological implication. R & K selection, diversity indices. Ecological adjust, homeostasis and co-evolution.

Unit II: Soil microbiology

Soil as a Microbial Habitat, Microbial community structure in soil and its role in soil formation, autochthonous and allochthonous microorganisms, community structure, microbial interactions (competition, predation, cooperation, amensalism, predation, etc.). Rhizosphere and role of root exudate in microbial colonization.

Unit-III: Microorganisms in Air, Marine, and Freshwater Environments

Aero microbiology: Significance and assessment. aeroallergens and aero allergy, Types of the aquatic ecosystem-fresh water and marine habitat, zonation of the marine ecosystem, growth. Water as a Microbial Habitat, Nutrient Cycling in Marine and Freshwater Environments. Microbial adaptation in marine and freshwater environment, Winogradsky columns, Microbial Activity in Deep-Ocean Sediments. Marine Microorganisms as a Novel Resource for New Drugs, Microorganisms in Glaciers and Permanently Frozen Lakes, Microorganisms in Streams and Rivers, Oligotrophic and Eutrophic Lakes

Unit IV: Microbial Bioremediation

Concept of Bioremediation- process and organisms involved; Constraints and priorities of bioremediation.

Bioaugmentation; ex-situ and in-situ processes; intrinsic and engineered bioremediation. Methods of bioremediation: Bioleaching, phytostabilization, biosorption, biomineralization, bioaccumulation, biotransformation, phytoremediation, Phycoremediation. Xenobiotic and Polychlorinated Biphenyl degradation

Unit V: Biotechnology in Waste Management and Recent Advances

Microbial assessment of water quality, Indicator organisms in water pollution, Biosensors.

Sewage and Wastewater Treatment: Primary, Secondary, and Tertiary treatment, Sludge treatment and disposal. Composting of solid wastes, aerobic & anaerobic digestion: methane production, pros, and cons of the anaerobic process, Energy generation from waste.

Course Outcome (CO):

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

- Understand the fundamentals of food borne diseases and associated organisms, physical, chemical and biological basis of food preservation, and commercial importance of fermented food.
- Gain critical thinking ability to study microbial ecology and diversity in different habitats within the biosphere.
- Develop analytical skills to analyze various biotechnological remedial interventions against different types of pollutants, and strategies of waste management

MLMB0902

Emerging technologies **64 h**

Unit I: Optical microscopy methods

Basic Microscopy: Light microscopy- lenses and microscopes, resolution: Rayleigh's Approach, Darkfield; Phase Contrast; Differential Interference Contrast (DIC); Principles of electron microscopy

Fluorescence microscopy: Optical arrangement, light source; filter sets: excitation filter, dichroic mirror, and barrier, optical layout for image capture

Advanced Microscopy: Confocal microscope-principle, resolution and point spread function, light source: gas lasers & solid-state, detectors; Deconvolution

Unit II: Biophysical techniques

Protein folding- pathways of protein folding, diseases associated with protein folding, Analyzing protein structure and function- Fluorescence spectroscopy, FRET, Fluorescence anisotropy; Isothermal calorimetry; Circular Dichroism (CD) and Optical Rotatory Dispersion (ORD)

Principles of NMR, X-ray crystallography and Cryo-Electron Microscopy in structure determination

Unit III: Nanotechnology

Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and its applications; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials; Bio-inspired nanomaterials for a new generation of medicine; Nanomaterial for drug delivery, Nanoadjuvents for vaccine delivery; Theranostic nanoparticles and their implication in cancer therapy.

Unit IV: Metabolomics

Overview of metabolomics, basic sample preparation strategies- extraction, derivatization, Workflow for Metabolomics Tools of metabolome studies: NMR, MS, GC, LC, IR, HPCL and its application, Metabolome projects of plant and human; Targeted Vs Untargeted metabolomics; development of targeted assays for small molecules. Tools of metabolome studies: NMR, MS, GC, LC, IR and its future prospects.

Course Outcome (CO):

On completion of this course students should be able to-

- Understand the principles of various emerging techniques on advanced microscopy and biophysics
- Gain critical thinking ability to learn the application of nanotechnology in health, agriculture, and environmental conservation
- Gain the skills to analyze complex processes involving advanced spectrometric methods such as fluorescence, circular dichroism, FT-IR, NMR, cryo-EM and to use tools for metabolomic studies

MLMB0903

Bioprocess engineering and technology **64 h**

Unit I: Preparation and optimization of medium

Selection of medium composition, concept and methods of sterilization, microbial growth parameters and environmental factors, kinetics of batch and fed batch fermentation, environmental conditions. Synchronous culture, chemostat and turbidostat

Unit II: General concepts and application of fermentation

Fermentation- general concepts, applications, and structure of a fermenter; Range of fermentation process- microbial biomass, enzymes, metabolites, recombinant products, transformation process; Components of fermentation process. Types of fermentations- aerobic and anaerobic fermentation, submerged and solid-state fermentation, factors affecting submerged and solid-state fermentation, substrates used in solid-state fermentation and its advantages; Culture media- types, components, and formulations.

Sterilization: Batch and continuous sterilization. Bioreactors, membrane Bioreactors. Isolation, preservation, and maintenance of industrial microorganisms, kinetics of microbial growth and death, Monod model, sterilization of media for fermentation, air quality management and air sterilization. Measurement and control of fermentation parameters - pH, temperature, O_2

Unit III: Process development and optimization

Process development, Optimization- classical and statistical methods of optimization; Immobilization- different matrices, whole cell, and enzyme immobilization; Scale up of bioprocess, Analysis of batch, stability of microbial reactors, analysis of mixed microbial populations, specialized bioreactors (pulsed fluidized, photobioreactors).

Unit IV: Production of Microbial Biomass

Production of ethanol, citric acid; amino acids, wine, beer, vitamins; microbial enzymes Baker's yeast, mushroom. Production of biopesticides and biofertilizers: Microbial inoculants- Selection and establishment of nitrogen-fixing bacteria. Production of *Rhizobium, Azotobacter*, *Azospirilla*, *Azolla*, cyanobacteria and other nitrogen-fixing bacterial cultures. Quality control of bio inoculants; Phosphate solubilizing bacteria; mycorrhiza; plant growth

promoting rhizobacteria (PGPR); Composting and bio-composting, biocontrol microbial inoculants.

Unit V: Necessity of Downstream Processing

Overview of a bioprocess including upstream and downstream processing; Importance of downstream. Processing in biotechnology, characteristics of biological molecules and their separation characteristics based on stability; other biological properties, problems and requirements of bioproduct purification; Characteristics of biological mixtures; Downstream process economics.

Unit VI: Biomass Removal and Cell Disruption

Physico-chemical basis of bio-separation processes. Removal of particulate matter; biomass insoluble; flocculation and sedimentation, Cell disruption- mechanical, enzymatic, and chemical methods.

Course Outcome (CO):

On completion of this course students should be able to-

- Learn and appreciate the relevance of microorganisms from an industrial context, and the fundamental principles for basic methods in production technique for bio-based products.
- Critically analyze a biological production process, calculate yield and production rates of the same and interpret data obtained from various similar processes.
- Develop analytical skills to design and operate various fermenters for important microbial/enzymatic industrial processes in food and fuel industry, and to analyze any bioprocess for production of antibiotic, alcohol, amino acids and vitamins from market point of view for better strategies

MLMB0991: Food & Environmental microbiology **128 h**

1. Isolation of lactic acid-producing bacteria and production of fermented milk products/Sauerkraut
2. Enrichment of N_2-fixing bacteria from environmental samples and assessment of its secreted ammonia with Nessler's reagent.
3. Characterization of cellulose/ pectin decomposition, starch hydrolyzing microorganisms from environmental samples
4. Isolation and purification of amylase enzyme
5. Mushroom cultivation
6. Detection and enumeration of indicator and index microorganisms for foodborne pathogens (total enterobacteria, total coliform & aerobic spore former)
7. Identification of spoilage causing bacteria and fungi of food samples – fruits, vegetables, bread

Course Outcome (CO):

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

- Identify, isolate and characterize different types of microorganism from environment
- Perform various aspects of food processing and the processes used for different types of food products.
- Conduct related experiments using the available instruments and strategies

MLMB0992: Practical on Bioprocess engineering and technology and Emerging technologies 128 h

1. Laboratory fermenter sterilization, operations, monitoring and scale-up of selected strain.
2. Optimization of fermentation parameters (pH, temperature)
3. Fermentation of useful microbial products- alcohol and downstream processing.
4. Lyophilization of natural or synthetic products.
5. Green synthesis of nanoparticles
6. Synthesis of superparamagnetic iron oxide nanoparticles (SPION)
7. Mechanical and enzymatic process of microbial cell disruption
8. Downstream processing-Extraction and purification of microbial polysaccharide
9. Acquisition and analysis of fluorescent-labeled eukaryotic cell images

Course Outcome (CO):

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

- Use laboratory fermentor, identify industrially important microbial stain identification, perform microbial mass-scale production and different strategies of targeted downstream production
- Conduct experiments for nanomaterial synthesis using available instruments and learnt strategies
- Conduct fluorescence microscopy experiments to capture fluorescent images of wild type and genetically modified microbes

SEMESTER IV

MLMB1001

A. Biostatistics **32 h**

Unit I: Basics of Biostatistics

Principles and practice of statistical methods in biology; samples and populations; Data collection and graphical representation

Measures of central tendency- mean, median, mode; Measures of dispersion- range, mean deviation, coefficient of variation; standard deviation, standard error.

Unit II: Application of Biostatistics

Probability: counting, conditional probability, discrete and continuous random variables; Error propagation; Populations and samples, expectation, parametric tests of statistical significance, nonparametric hypothesis tests, linear regression, correlation & causality, calculation of Karl-Pearson's coefficient of correlation; analysis of variance, factorial experiment design; Use of biostatistics software.

B. Bioethics and Intellectual Property Rights **32 h**

Unit I: Bioethics

Overview of research misconduct, rules and regulations in India; data management; privacy policies, institutional and professional code of ethics and standards of practice

Ethical use of bioresources- agricultural ethics and transgenic crops, animal subjects; Protection of human subjects; stem cell ethics; eco sourcing-code of practice

Mentor-mentee responsibilities; Collaboration, Bias, Conflicts of Interest; Publication- plagiarism

Cyber Security Awareness; understanding phishing attacks, malware, antivirus software.

Unit II: Intellectual Property Right (IPR)

Concept and provisions of IPR; Patents, Trademarks, Copyright, Conditional information, Breeder's right. Patent-types, scope, criteria, applying for a patent. Protection of Biotechnological inventions.

Unit III: Quality, Ethical and Legal Implications

International standards, Quality accreditation and certification – NABH standards

Quality checks - quality assurance samples, master sample, internal controls, techniques and concepts of statistical quality control and statistical process control; Operational aspects – calibration, accuracy checks of quality control; FDA and EPA regulations for clinical use of DNA tests and commercial release of chemical products.

Course Outcome (CO):

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

- Understand various ethical rules related to research activities in industry or academia, different types of intellectual property rights in protecting products derived from biotechnology research
- Critically apply the essentials of product development in various microbiology industries and the process of obtaining patents
- Gain analytical skills for application of statistics in biological and biotechnological processes

MLMB1091

Dissertation: Scientific writing and presentation **128 h**

Preparation of a hypothesis-driven research proposal on molecular microbiology related topics, which should include a brief literature review, origin of proposal, significance and potential impact of the proposed research on ongoing scientific advancement, experimental design, pitfalls and alternative strategies (following the SERB format for three years of research funding); Both the written proposal, and an oral presentation of the proposed research will be assessed

MLMB1092

Dissertation: Journal presentation and group discussion **128 h**

Students will learn to read, understand, discuss and present recent research articles in molecular microbiology or biomedical sciences during the weekly departmental seminar

MLMB1093

Dissertation: Thesis writing and defense **128 h**

As part of an individual laboratory, students will be engaged in understanding the major research question of that lab, and will perform a project, which will train them in executing standard laboratory protocols, related techniques and technologies, data collection, data analysis, and ethical aspects of research. A written dissertation, and an oral presentation on the project will be assessed

MLMB1094

Dissertation: Microbiological laboratory visit and Grand Viva **128 h**

A. Microbiology lab visit

Students will visit the research laboratory of microbiology or industrial microbiology laboratory for more exposure. After coming back students will engage themselves in group discussions.

B. Grand Viva

This module will cover all the topics that have been covered in the two years of the course and the students' performance will be evaluated both on their thinking and analytical abilities in front of an expert panel.

Course Outcome (CO) of Dissertation (MLMB1091-1094):

On completion of this course students should be able to-

- Apply all the acquired knowledge throughout the courses in understanding and executing one small topic of research of their own interest in their choice of lab
- Critically read, analyze and present a recently published literature of related topic
- Build a novel hypothesis-driven research proposal with proper plan of experimental methods
- Generate a novel entrepreneurship idea that may be readily implemented
- Acquire presentation skills and etiquette of gathered knowledge, journals, own research idea and data, and novel plans of research and entrepreneurship idea

Suggested reading:

1. Voet, D., & Voet, J. G. Biochemistry (4th ed) Hoboken, NJ: J. Wiley & Sons.
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3. Lehninger, A. L. Principles of Biochemistry; New York, NY: Worth.
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6. Alberts, B. et al. Molecular Biology of the Cell (6th Ed.). New York: Garland Science.
7. Lodish, H. F. et al. (2016). Molecular Cell Biology (8th Ed.). New York: W.H. Freeman.
8. Cooper, G.M., Hausman, R.E. The Cell: a Molecular Approach (5th edition). Sinauer Associates
9. Russel. iGenetics: A molecular Approach, (3rd edition). Pearson
10. Snyder L. et al. Molecular genetics of bacteria (4th Ed.); ASM Press, Washington DC
11. Primrose & Twyman. Principle of gene manipulation and genomics (7th Ed.); Wiley Blackwell
12. Brown T.A. Gene cloning and DNA analysis: An introduction (6th Ed.); Wiley Blackwell
13. Andreas Hofmann, Samuel Clokie. Principles and Techniques of Biochemistry and Molecular Biology
14. Willey, J. M., Sherwood, L., Woolverton, C. J., Prescott, L. M., & Willey, J. M. (2011). Prescott's Microbiology. (10th edition) New York: McGraw-Hill.
15. Black, J.G., Black, L.J. Microbiology Principles and Explorations (9th Ed.). Wiley
16. Gerard J. Tortora, Berdell R. Funke, Christine L. Case. Microbiology by Tortora. Pearson Education
17. M.T. Madigan and J.M. Martinko. Biology of Microorganisms (14th Ed.) Pearson Prentice Hall, USA
18. Freifelder, D. Molecular biology: a comprehensive introduction to prokaryotes and eukaryotes.
19. K. R. Aneja. Experiments in Microbiology, Plant Pathology and Biotechnology. New Age International.
20. David White. The Physiology and Biochemistry of Prokaryotes. 4 th Edition. Oxford University Press.
21. Punt J, Stranford S, Owen J, Jones P, Kuby Immunology (8th Ed). Macmillan Learning
22. Delves PJ, Martin SJ, Burton DR, Roitt IM, Roitt's essential Immunology (13th Ed.). Wiley Learning
23. Abbas AK, Lichtman AH, Pillai S, Cellular and Molecular Immunology (10th Ed.). Elsevier Health Sc.
24. Salle AJ, Fundamental Principles of Bacteriology, (7th edition). Mc-Graw Hill Book Company Inc.
25. Lesk, A.M. 2005, 2nd edition, Introduction to Bioinformatics. Oxford University Press.
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27. Durbin R., Eddy S., Krogh A. and Mithchison G. 2007 Biological Sequence Analysis, Cambridge University Press.
28. Adams, M.R., Moss, M.O. Issues in Environmental Science, (2008), RSC Publishing
29. Sharma, P. D., & Sharma, P. D. (2012). Ecology and environment. Rastogi Publications.
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31. Haller, D. The Gut Microbiome in Health and Disease, 2018, Springer
32. Jay, J.M., Loessner, M.J., Golden, D.A. Modern Food Microbiology (7th Ed.)
33. Frazier W.C. Food Microbiology, Tata McGraw Hills Publishing Company Limited
34. Adams, M.R. and Moss, M.O. Food Microbiology (4th Ed.). New Age Int. (P) Ltd. Pub. New Delhi
35. P. F. Stanbury, Allan Whitaker, Stephen J. Hall. Principles of Fermentation Technology
36. Chattopadhyay K.K. Introduction to nanoscience and nanotechnology. (2009) Prentice Hall India learning private limited.
37. Jegan S.R. Nanobiotechnology- a technological revolution, Labmart academic publishing
38. Neelina H. Malsch (2005). Biomedical Nanotechnology. CRC Press
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