Annexure II

Department of Biological Sciences
Aliah University, Kolkata

Draft Syllabus for 2-Years MSc in Microbiology (CBCS)

****Effective from 2021-22 onwards****

The postgraduate Degree Programme namely 'Master of Science in Microbiology' of Aliah University will be offered with the following POs and PSOs

Programme Outcomes (POs):

PO-1: Core competency: Students will acquire core competency in the subject, and in allied subject areas.

PO-2: Analytical ability: The students will be able to demonstrate the knowledge in understanding research and addressing practical problems.

PO-3: Communication skills: Students will gain a standard communication skill and will be able to read and understand documents with in-depth analyses and logical arguments. Students will be well-versed in speaking and communicating their ideas or findings to a wider audience.

PO-4: Research ability: Application of various scientific methods to address different questions by formulating the hypothesis, data collection and critically analyse the data to decipher the degree to which their scientific work supports their hypothesis.

PO-5: Critical Thinking and problem-solving ability: An increased understanding of fundamental concepts and their applications of scientific principles is expected at the end of the program. Students will become critical thinkers and acquire problem solving capabilities.

PO-6: Digitally equipped: Students will acquire digital skills and integrate the fundamental concepts with modern tools.

PO-7: Ethical and Psychological strengthening: Students will also strengthen their ethical and moral values and shall be able to deal with psychological weaknesses.

PO-8: Team Player: Students will learn team workmanship in order to serve efficient institutions, industry and society.

PO-9: Independent Learner: Apart from the subject specific skills, generic skills, especially in programs of biological sciences, the program outcome would lead to gain knowledge and skills for further higher studies, competitive examinations and employment.

Programme Specific Outcomes (PSOs)

PSO-1: Students will be able to understand the concepts of microbiology as applicable to diverse areas such as medical, industrial, environment, genetics, agriculture, food and others.

PSO-2: Students will be able to demonstrate key practical skills/competencies in working with microbes for study and use in the laboratory as well as outside, including the use of good microbiological practices.

PSO-3: Students will be competent enough to use microbiology knowledge and skills to analyze problems involving microbes, articulate these with peers/ team members/ other stakeholders, and undertake remedial measures/ studies etc.

PSO-4: Students will be able to develop a broader perspective of the discipline of Microbiology to enable him/her to identify challenging societal problems and plan his professional career to develop innovative solutions for such problems.

PSO-5: Students will be able to demonstrate competency in laboratory safety and in routine and specialized microbiological laboratory skills applicable to microbiological research or clinical methods.

PSO-6: Students will be able to communicate scientific concepts, experimental results and analytical arguments clearly and concisely, both verbally and in writing.

PSO-7: Students will be able to assess how microorganisms are used as model systems to study basic biology, genetics, metabolism and ecology.

PSO-8: Students will be able to explain why microorganisms are ubiquitous in nature; inhabiting a multitude of habitats and occupying a wide range of ecological habitats and play an integral role in disease, microbial and immunological methodologies are used in disease treatment and prevention

PSO-9: Students will be able to understand the vital role of microorganisms in biotechnology, fermentation, medicine, and other industries important to human wellbeing. They will also be able to understand that microorganisms have an indispensable role in the environment, including biogeochemical cycles, bioremediation and others.

PSO-10: Students will be able to demonstrate the following laboratory skills: aseptic and pure culture techniques, preparation of and viewing samples for microscopy, use appropriate methods to identify microorganisms, estimate the number of microorganisms in a sample, and use common lab equipment and other common microbiological laboratory works; immunological and biochemical assays; molecular biological techniques etc.

The postgraduate Degree Programme namely 'Master of Science in Microbiology' of Aliah University will be consist of:

1. Core Course (CCT and CCP): [Total Paper: 13; Total Credit: 13x4=52]

Discipline specific compulsory basic course. Minimum *10 theory* papers (each of 4 credits i.e. totalling minimum 10x4 = 40 credit points) and *3 practical* papers (each of 4 credits i.e. totalling minimum 3x4 = 12 credit points) based on the 10 theory core course papers are mandatory.

2. Discipline Specific Elective Course (DET and DEP): [Total Paper: 4 ; Total Credit: 4x4=16]

Discipline specific elective courses (choice based) which are more advanced or specialized would be offered in the Semester- III and IV. 4 papers (2 theory and 2 practical) each of 4 credits totalling 4x4 = 16 credit points have to be chosen out of the 6 papers offered.

3. Generic Elective Course (GEC): [Total Paper: 2; Total Credit: 2x4=8]

Interdisciplinary elective course (choice based) to be opted from a discipline other than one's main discipline (s) of choice in the Semester-III and IV. 2 papers each of 4 credits totalling 2x4 = 8 credit points have to be chosen out of the 4 papers offered.

4. Aliah University Compulsory Course (AUC): [Non-credit]

There will be a Compulsory Course on "Elementary Arabic and Islamic Studies" having no credit points in Semester-I.

5. Ability Enhancement Compulsory Course (AEC): [Non-credit]

There will be a Compulsory Course on Disaster management/ Human Rights/ Value Education/ Yoga/ Soft Skills having no credit points in Semester-II.

6. Project and Dissertation (PRJ): [Total Paper: 1 ; Total Credit: 1x4=4]

Students have to work on a specific project and will write a dissertation on it followed by a presentation in Semester IV. (1 paper of 4 credit totalling 1x4 = 4 credit points).

List of Core Course Theory (CCT) Papers

1. MICPGCCT01 : Prokarya
2. MICPGCCT02 : Acellular world and Eukarya
3. MICPGCCT03 : Cell Biology
4. MICPGCCT04 : Principles of Biochemistry
5. MICPGCCT05 : Microbial Physiology and Metabolism
6. MICPGCCT06 : Microbial Genetics
7. MICPGCCT07 : Biostatistics and Bioinformatics
8. MICPGCCT08 : Immunobiology
9. MICPGCCT09 : Molecular Biology
10. MICPGCCT10 : Environmental Microbiology

List of Core Course Practical (CCP) Papers

1. MICPGCCP01 : Core Course Practical I
2. MICPGCCP02 : Core Course Practical II
3. MICPGCCP03 : Core Course Practical III

List of Discipline Specific Elective (DET and DEP) Papers

1. MICPGDET01 : Microbial Pathogenicity
2. MICPGDET02 : Food and Industrial Microbiology
3. MICPGDET03 : Bioprocess Engineering
4. MICPGDEP01 : Discipline Elective Practical I
5. MICPGDEP02 : Discipline Elective Practical II
6. MICPGDEP03 : Discipline Elective Practical III

List of Generic Elective Course (GEC) Papers

(To be opted by the students of other disciplines)

1. MICPGGEC01 : Microbial Technology
2. MICPGGEC02 : Biophysics and Bioethics
3. MICPGGEC03 : Biotechnology and Entrepreneurship
4. MICPGGEC04 : Drug Designing

Semester-wise curriculum plan

Sl. No.	Course Title	Course Code	Credits	Marks
Semester I				
1	Prokarya	MICPGCCT01	**4**	**50**
2	Acellular world and Eukarya	MICPGCCT02	**4**	**50**
3	Cell Biology	MICPGCCT03	**4**	**50**
4	Principles of Biochemistry	MICPGCCT04	**4**	**50**
5	Core Course Practical I	MICPGCCP01	**4**	**50**
6	Elementary Arabic and Islamic Studies	PGAUC01	**0**	**0**
* PGAUC01: Aliah University Compulsory Course				
Semester II				
7	Microbial Physiology and Metabolism	MICPGCCT05	**4**	**50**
8	Microbial Genetics	MICPGCCT06	**4**	**50**
9	Biostatistics and Bioinformatics	MICPGCCT07	**4**	**50**
10	Immunobiology	MICPGCCT08	**4**	**50**
11	Core Course Practical II	MICPGCCP02	**4**	**50**
12	Disaster Management/ Human Rights & Value Education/ Yoga & Life Skills (Any one)	PGAEC01	**0**	**0**
***** PGAEC01: Ability Enhancement Compulsory Course				
Semester III				
13	Molecular Biology	MICPGCCT09	**4**	**50**
14	Core Course Practical III	MICPGCCP03	**4**	**50**
15	*Discipline Elective Paper I	MICPGDET01	**4**	**50**
16	*Discipline Elective Practical I	MICPGDEP01	**4**	**50**
17	#Generic Elective Paper I	MICPGGEC01	**4**	**50**
* Discipline Elective- 1 Theory (MICPGDET01) and 1 Practical (MICPGDEP01) to be chosen out of 6 options # Generic Elective- 1 Paper (MICPGGEC01) to be chosen out of 4 options by the students of other disciplines				
Semester IV				
18	Environmental Microbiology	MICPGCCT10	**4**	**50**
19	**Discipline Elective Paper II	MICPGDET02	**4**	**50**
20	**Discipline Elective Practical II	MICPGDEP02	**4**	**50**
21	##Generic Elective Paper II	MICPGGEC02	**4**	**50**
22	Project and Dissertation	MICPGPRJ01	**4**	**50**
* Discipline Elective- 1 Theory (MICPGDET02) and 1 Practical (MICPGDEP02) to be chosen out of 6 options # Generic Elective- 1 Paper (MICPGGEC02) to be chosen out of 4 options by the students of other disciplines				
Total Credits / Total Marks			**80**	**1000**

Contents of Core Course Theory (CCT) Papers

Paper Code: MICPGCCT01
Paper Title: Prokarya

Course Objectives	Course Outcomes
1. Understanding the origin and evolution of life 2. Understanding the molecular details of prokaryotic cells 3. Understanding the nutritional requirements and environmental effects and diversity of prokaryotes. 4. To learn different classical and modern microbiological techniques.	Students will learn: 1. How life originated on the Earth and through geological time scale how living organisms evolved. 2. Molecular details of each and every component of prokaryotic cells. 3. Nutritional requirements and effects of environmental factors on growth of microorganisms and can formulate media and growth conditions for cultivation of different microorganisms. 4. Different classical techniques for microbiological study as well as modern techniques to cultivate anaerobic microorganisms and to assess uncultivated microorganisms. 5. Potential application of Major groups of Bacteria and Archaea. Extremophiles and their mechanism of adaptation.

Unit I: Evolutionary Microbiology

Origin of basic bio-molecules, Abiotic synthesis of organic monomers and polymers; concept of Oparin & Haldane; Experiment of Miller (1953); origin of first cell; Evolution of prokaryotes; Endosymbiosis and Origin of eukaryotic cells; origin of unicellular & multicellular organisms. The evolutionary time scale; eras, periods and epoch; major events in the evolutionary time scale. History and major events in the development of microbiology.

Unit II: Microbial cellular details

Cell size, shape and arrangement, Cell-wall: Composition and detailed structure of Gram-positive and Gram-negative cell walls, Archaebacterial cell wall, Gram and acid-fast staining mechanisms, lipopolysaccharide (LPS), spheroplasts, protoplasts, and L-forms. Effect of antibiotics and enzymes on the cell wall. Cell Membrane: Structure, function and chemical composition of bacterial and archaeal cell membranes; glycocalyx, capsule, flagella, endoflagella, fimbriae and pili. Cytoplasm: Ribosomes, mesosomes, inclusion bodies, nucleoid, chromosome and plasmids Endospore: Structure, formation, stages of sporulation. Motility and taxis (Chemotaxis, Phototaxis, magnetotaxis).

Unit III: Prokaryotic diversity

Estimates & indices of diversity. Culture dependent and independent methods for exploring diversity. Prokaryotic taxonomy - classical and modern (polyphasic). Prokaryote and eukaryote species concept. Diversity, Occurrence, characteristics and potential application of Major groups of *Bacteria* and *Archaea*. Extremophiles and their mechanism of resistance.

Unit IV: Microbiological techniques

Pure culture isolation: Streaking, serial dilution and plating methods; cultivation; principles and techniques of maintenance and preservation/stocking of pure cultures; synchronous and asynchronous culture, batch, fed batch and continuous culture; cultivation of anaerobic bacteria; assessing non-culturable bacteria.

Unit V: Nutrition and Growth

Nutritional requirements in bacteria and nutritional categories; Culture media: components of media, natural and synthetic media, chemically defined media, complex media, selective, differential, indicator, enriched and enrichment media. Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation. Chemical methods of microbial control: disinfectants, types and mode of action. Methods of prokaryotic cell division (Proteins involved; molecular aspects), Definitions of growth, logarithmic representation of bacterial populations, phases of growth, calculation of generation time and specific growth rate, measurement of microbial growth, diauxic growth curve. Environmental and nutritional factors affecting growth.

Suggested Readings

1. Tortora GJ, Funke BR and Case CL. (2008). Microbiology: An Introduction. 9th edition. Pearson Education
2. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms.14th edition. Pearson International Edition
3. Cappucino J and Sherman N. (2010). Microbiology: A Laboratory Manual. 9th edition. Pearson Education Limited
4. Wiley JM, Sherwood LM and Woolverton CJ. (2013) Prescott's Microbiology. 9thEdition. McGraw Hill International.
5. Atlas RM. (1997).Principles of Microbiology.2nd edition. W M. T. Brown Publishers.
6. Pelczar MJ, Chan ECS and Krieg NR.(1993). Microbiology.5th edition. McGraw Hill Book Company.
7. Stanier RY, Ingraham JL, Wheelis ML, and Painter PR. (2005). General Microbiology. 5th edition. McMillan.

Paper Code: MICPGCCT02
Paper Title: Acellular world and Eukarya

Course Objectives	**Course Outcomes**
This course is designed to give the students 1. Understanding of acellular organisms like viruses, viroids and prions 2. Diversity of the eukaryotic world 3. Economic significance of various organisms	After completion of the course students will understand 1. Structure and replication of acellular organisms 2. Different types of life cycles of Algae, Fungi etc 3. Pathogenic forms of these organisms 4. Economic significance

Unit I: Nature and Properties of Viruses

Discovery of viruses, nature and definition and distinctive properties of viruses. Theories of viral origin. Structure of viruses: capsid symmetry, enveloped and non-enveloped viruses. Types of envelope and their composition. Isolation, purification and cultivation of viruses; assay of plant, animal and bacterial viruses. Viral taxonomy: Classification and nomenclature of different groups of viruses. Concept of viroids, virusoids, satellite viruses and prions.

Unit II: Bacteriophages

Diversity, classification, one step multiplication curve. Details of lytic and lysogenic phages: lambda, T4, T7, M13, lytic cycle, lysogeny, viral replication, nucleic acid and protein synthesis - concept of early and late proteins. Regulation of transcription in lambda phage - molecular mechanism of lytic-lysogenic conversion.

Unit III: Plant and Animal Viruses

Modes of viral propagation: persistent, non-persistent, vertical and horizontal. Salient features of viral nucleic acids; diversity and classification of plant and animal viruses. Interaction of viruses with cellular receptors and entry into the cell. Multiplication, replication maturation and release strategies of different plant (TMV) and animal (Adenovirus, Retrovirus, Hepatitis viruses, Herpes virus, Influenza virus; vaccinia, Ebola virus, Encephalitis etc.) viruses. Assembly, budding, maturation and cellular trophism of HIV; molecular biology of genetic shift and drift in influenza virus. Oncogenic viruses and their roles in cancer.

Unit IV: Algae

Algal Diversity, distribution, nutrition, mode of reproduction, Life cycle patterns, ecological significance of major algal taxa. Phycotoxins, economic importance including role in agriculture and human affairs -algal pigments, biofuels, hydrogen production, important bioactive molecules, role of algae in sustainable environment.

Unit V: Fungi

Fungal Diversity, modes of reproduction, ecological significance, mycotoxins, fungal associations with algae (lichens), plants (endophytes, mycorrhizal fungi), animals and humans. Economic importance, Secondary metabolites from fungi.

Unit VI: Eukaryotic Microorganisms

Host parasite interactions. Classification of Protozoa, general biology of protozoal cell, process of reproduction in common protozoal classes, importance of protozoa in soil and water ecosystems. Important human and veterinary parasites, life cycle and biology of *Plasmodium, Entamoeba, Leishmania, Wuchereria, Fasciola, Schistosoma*.

Suggested Readings

1. Tortora GJ, Funke BR and Case CL. (2008). Microbiology: An Introduction. 9th edition. Pearson Education
2. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms.14th edition. Pearson International Edition
3. Cappucino J and Sherman N. (2010). Microbiology: A Laboratory Manual. 9th edition. Pearson Education Limited
4. Wiley JM, Sherwood LM and Woolverton CJ. (2013) Prescott's Microbiology. 9th Edition. McGraw Hill International.
5. Atlas RM. (1997).Principles of Microbiology.2nd edition. WM.T.Brown Publishers.
6. Pelczar MJ, Chan ECS and Krieg NR. (1993). Microbiology.5th edition. McGrawHill Book Company.
7. Stanier RY, Ingraham JL, Wheelis ML, and Painter PR. (2005). General Microbiology. 5th edition. McMillan.

Paper Code: MICPGCCT03
Paper Title: Cell Biology

Course Objectives	**Course Outcomes**
This course is designed to give the students ● Basic idea of cell structure including macromolecules, membranes, and organelles. ● Cell signalling, communication and cell transport ● Cell division: process and regulation; and cell culture- types and methods ● Cell culture: basic concepts and applications	On completion of this course the students will be able to: ● Students will understand the structures and purposes of basic components of prokaryotic and eukaryotic cells, especially macromolecules, membranes, and organelles. ● Students will understand different cellular components in cell signalling, communication and transport. ● They will know the different types of cell culture and methods involved in it ● Students will apply their knowledge of cell biology to selected examples of changes or losses in cell function. These can include responses to environmental or physiological changes, or alterations of cell function brought about by mutation

Unit I: Structure of Cell

Plasma membrane: Structure and transport of small molecules; Protein and Small Molecule Trafficking: Receptor-mediated endocytosis; intra-cellular transport, lysosomes, organelle biogenesis; extra-cellular transport: biogenesis of membrane proteins, protein modification, glycosylation; pumps, channels and transporters; Extracellular matrix; Structure and organization of Microtubules, Intermediate filaments and Microfilaments

Unit II: Cell signalling

Hormones and their receptors, cell surface receptors, signalling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signalling pathways, bacterial and plant two-component systems, light signalling in plants, bacterial chemotaxis and quorum sensing.

Unit III: Cell cycle and cancer

Cell cycle and its regulation, Genetic rearrangements in progenitor cells, oncogenes, tumor suppressor genes, cancer and the cell cycle, virus-induced cancer, metastasis, angiogenesis, interaction of cancer cells with normal cells, apoptosis, autophagy, anoikis; therapeutic interventions of uncontrolled cell growth. Stem cell: Embryonic stem cells (ESC) and Adult stem cells (ASC).

Unit IV: Cell culture and Cell biology techniques

Introduction and historical background of animal cell culture. Types of cell culture. Basic characteristics of tissue culture media. Basic equipment and facilities in animal cell culture. Types of culture media and culture wares. Sterilization methods for culture wares and culture media. Maintenance of a cell line and storage of cells; Microscopy- Brightfield, Phase Contrast, Confocal & Electron Microscopy; Immunofluorescence, and Cell fractionation, FACS

Suggested Readings

1. Cell and Molecular Biology: Concepts and Experiments, 6th edition (2009), Gerald Karp, Wiley. ISBN- 978-0470483374.
2. The World of the Cell, 7th edition (2008), Becker, Kleinsmith, Hardin and Bertoni. Benjamin Cummings, ISBN-13: 978-0805393934.
3. The Cell: A Molecular Approach, 6th edition (2013), Cooper and Hausman; Sinauer Associates, Inc. ISBN- 13:978-1605351551.
4. Essential Cell Biology, 7th edition (2009), Alberts, Bray, Hopkin, Johnson, Lewis, Raff, Roberts and Walter. Garland Science. ISBN-13:978-0815341291.
5. Molecular Cell Biology, 7th edition (2012), Lodish, Berk, Kaiser, Krieger, Bretscher, Ploegh, Amon and Scott. W. H. Freeman. ISBN-13: 978-1429234139

Paper Code: MICPGCCT04
Paper Title: Principles of Biochemistry

Course Objectives	**Course Outcomes**
This course is designed to give the students ● The understanding of acids, bases and buffers and their relevance in living systems. ● The information about the structure and function of various biomolecules such as carbohydrate, protein (including their role as biocatalysts) and nucleic acids. ● The knowledge about enzyme and catalysis ● Use of various techniques involved in biochemical analysis.	After completion of the course, a student will be able to achieve these outcomes: ● The students will learn about the chemical structures of carbohydrates, and their structural and metabolic role in cellular systems. ● The students will learn about structure and function of lipids, circulating lipids and inflammatory lipid mediators etc. ● They will also learn about primary, secondary, tertiary, quaternary structure of proteins. ● The students will understand about the structure and function of nucleosides and nucleotides. ● The students will learn about the enzymes and various enzymatic mechanisms in the biological system. ● Students will learn the application of various techniques used in biochemical analysis.

Unit I: Introduction

Chemical basis of life; water; concepts of acid and base, reaction kinetics, pH, buffer; Biomolecular hierarchy; Macromolecules; Molecular assemblies: Stabilizing interactions.

Unit II: Carbohydrates

Definition, classification and structure of carbohydrates; Isomers; Sugar derivatives; Structure, occurrence, properties and functions of Disaccharides and Polysaccharides. Suitability in the context of their different

functions- cellular structure; energy storage; signalling; Glycosylation of other biomolecules - glycoproteins and glycolipids.

Unit III: Amino acids and Proteins

Amino acids: structure and functional group properties and reactions; Peptides and covalent structure of proteins; Protein structure: Elucidation of primary and higher order. End group analysis and protein sequencing. Forces stabilizing protein structure; Structure-function relationships in model proteins like ribonuclease A; myoglobin; hemoglobin; chymotrypsin etc.; Tools to characterize expressed protein.

Unit IV: Nucleic acid

Structure, diversity and functions; DNA: Double helical structure, A-DNA, B- DNA & Z-DNA; The RNA world-Structure, types and roles of RNA; Nucleic acid Sequencing; G-Quadruplex.

Unit V: Lipids

Fatty acid: structure and functions; Lipids in the formation of membranes; Saponification structural lipids; Lipid functions: cell signals, cofactors, pigments; Lipoproteins.

Unit VI: Enzymes

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. Structure and function of Vitamins and coenzymes. Immobilized enzymes and their applications.

Unit VII: Bioenergetics

Basic principles; Laws of thermodynamics, free energy, entropy, high energy bonds; Coupled processes.

Unit VIII: Basic Techniques in Biochemistry

Biomolecule purification by various types of chromatography, estimation by using colorimeter/spectrophotometer and characterization by spectroscopy and electrophoresis.

Suggested Readings

1. Campbell, MK (2012) Biochemistry, 7th ed., Published by Cengage Learning
2. Campbell, PN and Smith AD (2011) Biochemistry Illustrated, 4th ed., Published by Churchill Livingstone
3. Tymoczko JL, Berg JM and Stryer L (2012) Biochemistry: A short course, 2nd ed., W. H. Freeman
4. Berg JM, Tymoczko JL, Gatto Jr, GJ and Stryer L (2019) Biochemistry, 9th Edition, W. H. Freeman and Company
5. Nelson DL and Cox MM (2017) Lehninger Principles of Biochemistry, 7th Edition, W.H. Freeman and Company,
6. Voet, D. and Voet J.G (2005) Biochemistry 3rd edition, John Wiley and Sons.
7. Segel Irvin H (1997) Biochemical Calculations, 2nd Ed., John Wiley and Sons, New York.
8. Palmer, T (2001) Enzymes: Biochemistry, Biotechnology & Clinical chemistry, Horwood Pub. Co, Eng.

Paper Code: MICPGCCT05
Paper Title: Microbial Physiology and Metabolism

Course Objectives	Course Outcomes
1. To understand metabolic diversity and potential of microorganisms 2. Understanding the detailed pathways and pathway-networks for photosynthesis, respiration and fermentation. 3. Understanding the pathways of nitrogen metabolism and chemolithotrophy in microorganisms. 4. To understand biosynthesis and degradation of different biomolecules.	By the end of this course, the students will be able to: 1. Describe the growth characteristics of the microorganisms which require different nutrient for growth and the associated mechanisms of energy generation for their survival like autotrophs, heterotrophs, chemolithoautotrophs etc. 2. Differentiate concepts of aerobic and anaerobic respiration and how these are manifested in the form of different metabolic pathways in microorganisms. 3. Understand the pathways of nitrogen metabolism and chemolithotrophy in microorganisms. Will also understand biosynthesis and degradation of different biomolecules.

Unit I: Microbial Photosynthesis

Major groups of photosynthetic prokaryotic microorganisms. Ultrastructure of reaction center, arrangements of light harvesting pigments, light reaction & electron flow in photosynthesis, photophosphorylation, and bioenergetics. CO2 fixation pathways, RUBISCO-structure and molecular regulation of light and dark reactions

Unit II: Aerobic respiration

Regulation and energetics of hexose and pentose metabolism - Embden-Meyerhoff pathway, Entner-Doudroff pathway, Pentose phosphate pathway, glyoxylate pathway, Krebs' cycle, oxidative and substrate level phosphorylation, reverse TCA cycle, gluconeogenesis- Pasteur effect;. Mitochondrial Electron Transport chain. Bioenergetics of ETC and oxidative phosphorylation, mechanism of oxidative phosphorylation. Inhibitors of electron Transport chain.

Unit III: Anaerobic respiration and Fermentation

Electron transport & bioenergetics of anaerobic respiration (NO3 respiration, SO4 respiration, H2- respiration, Halo- respiration), Acetogenesis, Methanogenesis. Fermentation – Lactic acid (homo and heterolactic) fermentations, mixed acid, propionic acid, butyric acid, acetone-butanol etc. Secondary fermentation

Unit IV: Nitrogen metabolism

Biochemistry of biological nitrogen fixation, properties of nitrogenase enzyme and its regulation, alternate and oxygen insensitive nitrogenase, nitrogenase assay. Ammonia assimilation with respect to glutamine synthetase, glutamate dehydrogenase, glutamate synthetase, their properties and regulation. Anammox reactions and Comammox organisms.

Unit V: Chemolithtrophy

Iron, Carbon, Hydrogen and Sulphur oxidation, Methanotrophy, ATP synthesis in *Halobacterium.*

Unit VI: Biosynthesis and degradation of biomolecules

Biosynthesis (shikimate family) and degradation of amino acids; protein turnover. Biosynthesis and oxidation of saturated and unsaturated fatty acids. Biosynthesis of purine and pyrimidine bases

Suggested Readings

1. Madigan MT, and Martinko JM (2014).Brock Biology of Microorganisms.14th edition. Prentice Hall International Inc.
2. Moat AG and Foster JW. (2002). Microbial Physiology.4th edition. John Wiley & Sons
3. Reddy SR and Reddy SM. (2005). Microbial Physiology. Scientific Publishers India
4. Gottschalk G. (1986). Bacterial Metabolism.2nd edition. Springer Verlag
5. Stanier RY, Ingrahm JI, Wheelis ML and Painter PR. (1987). General Microbiology. 5th edition, McMillan Press
6. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology.9th edition. McGraw

Paper Code: MICPGCCT06
Paper Title: Microbial Genetics

Course Objectives	Course Outcomes
1. To understand the organization of genes and genomes in prokaryotes 2. Understand the mechanisms of mutation and repair systems and their role in genome evolution. 3. To understand in detail the structure and function of the extra-chromosomal elements like plasmid and transposons and their role in genome evolution. 4. Understanding in detail the different modes of horizontal gene transfer and their roles in microbial evolution.	By the end of this course, the students will learn about 1. Genome organization of model organisms namely E.coli and Saccharomyces, and the molecular mechanisms that underlie mutations. 2. Developed a fairly good knowledge about the three well known mechanisms of horizontal gene transfer by which genetic material is transferred among the microorganisms - namely transformation, transduction and conjugation. 3. Will be able to describe different types of the extrachromosomal elements or the plasmids; the nature of the transposable elements in the prokaryotic and the eukaryotic cells. 4. Hands on skills of isolation of plasmid DNA from bacterial cells and its visualization by performing agarose gel electrophoresis.

Unit I: Mendelian Genetics

Genotype, Phenotype; Monohybrid, Dihybrid cross; Mendel's Laws: Dominance, excessiveness, segregation, independent assortment, autosomal & sex-linked inheritance; Deviation from Mendelian inheritance; Chromosome theory of inheritance: Allele, multiple alleles, pseudoallele, complementation tests, Extensions of Mendelian genetics; Allelic interactions; Concept of Incomplete dominance and co-dominance, Epistasis, penetrance and expressivity.

Unit II: Mutations and Repair

Experimental evidence for DNA as genetic material (Experiments of Griffith, Avery and MacLeod; Hershey and Chase); Experimental evidence for RNA as genetic material (TMV).

Mutations and mutagenesis: Definition and types of Mutations; Physical and chemical mutagens; Molecular basis of mutations; Functional mutants (loss and gain of function mutants); Uses of mutations. Reversion and suppression: True revertants; Intra- and inter-genic suppression; Ames test; Mutator genes.

Genetic Analysis in Bacteria: isolating mutants, genetic characterization of mutants, complementation tests.

Repair: Reversal of UV damage in prokaryotes: photoreactivation, base excision and nucleotide excision repair, post-replicational repair, mismatch repair, SOS repair, error prone repair. Mechanisms of different genetic recombination

Unit III: Plasmids

Properties of plasmids, functions encoded by plasmids, plasmid structure, types of plasmids – F plasmid, R Plasmids, colicinogenic plasmids, Ti plasmids, linear plasmids, yeast- 2µ plasmid, plasmid replication and partitioning, host range, plasmid-incompatibility, plasmid amplification, regulation of copy number, curing of plasmids.

Unit IV: Mechanisms of Genetic Exchange

Transformation - Discovery, mechanism of natural competence; Importance of natural transformation, artificially induced competence. Conjugation- Discovery, mechanism (Gram negative and Gram Positive), Hfr and F' strains; interrupted mating technique and time of entry mapping; plasmid-attracting pheromones. Transduction - Generalized transduction, specialized transduction, LFT & HFT lysates, role of transduction in bacterial evolution. Mapping by recombination and co-transduction of markers. Genetic crosses in bacteria.

Unit V: Phage Genetics

Features of T4 genetics, Genetic basis of lytic versus lysogenic switch of phage lambda

Unit VI: Transposable elements

General Properties of Transposons; Prokaryotic transposable elements – Insertion Sequences, composite and non-composite transposons, Replicative and Non replicative transposition, Mu transposon; Eukaryotic transposable elements - Yeast (Ty retrotransposon), Drosophila (P elements), Maize (Ac/Ds); Uses of transposons and transposition - transposon mutagenesis.

Suggested Readings

1. Klug WS, Cummings MR, Spencer, C, Palladino, M (2011). Concepts of Genetics, 10th Ed. Benjamin Cummings
2. Krebs J, Goldstein E, Kilpatrick S (2013). Lewin's Essential Genes, 3rd Ed., Jones and Bartlett Learning
3. Pierce BA (2011) Genetics: A Conceptual Approach, 4th Ed., Macmillan Higher Education Learning
4. Watson JD, Baker TA, Bell SP et al. (2008) Molecular Biology of the Gene, 6th Ed., Benjamin Cummings
5. Gardner EJ, Simmons MJ, Snustad DP (2008). Principles of Genetics.8th Ed. Wiley-India
6. Russell PJ. (2009). i Genetics- A Molecular Approach. 3rd Ed, Benjamin Cummings.
7. Sambrook J and Russell DW. (2001). Molecular Cloning: A Laboratory Manual. 4th Edition, Cold Spring Harbour Laboratory press
8. Maloy SR, Cronan JE and Friefelder D (2004) Microbial Genetics 2nd ED, Jones and Barlett Publishers

Paper Code: MICPGCCT07
Paper Title: Biostatistics and Bioinformatics

Course Objectives	**Course Outcomes**
• To introduce students to the basic concepts of statistics, probability and probability distributions. • To teach them the different probability distributions and their application in statistical analysis • To familiarize them with various tests of fit analysis methods. • To introduce the concept of database, in-silico tools for biological sciences • To expose them about the various stages of drug development.	After completion of the course the students would be 1. Well versed with sampling methods for biological sciences and their statistical analysis. 2. Able to analyze of data for test of fit analysis 3. Able to access the various biological databases and retrieve the information 4. Enabled to analyze the data using different in-silico tools.

Unit I: Descriptive Statistics

a) Data in Biology: Development in biostatistics, samples and populations, techniques of sampling (random and stratified), sampling and non-sampling errors, variables in biology, univariate and bivariate frequency distributions

b) Measures of Central Tendency: means, mode, median.

c) Measures of Dispersion: Range, standard deviation, coefficient of variance and covariance.

d) Measures of Skewness: Pearson's coefficients of skewness; coefficient of skewness using moments. Measures of Kurtosis.

Unit II: Probability and Probability Distributions

a) Probability: Basic concepts, addition and multiplication rules of probability, conditional probability

b) Probability Distributions: Probability mass function, probability density function and distribution function. Binomial distribution, Poisson distribution, normal distribution and exponential distribution along with their properties and relationships.

Unit III: Correlation and Linear Regression

a) Correlation Analysis: Scatter diagrams, Pearson's and Spearman's coefficients of correlation, coefficient of determination.
b) Regression Analysis: Method of least squares, equations of lines of regression and their applications in biostatistics.

Unit IV: Hypothesis Testing

a) Sampling distributions and standard error, null and alternate hypothesis, basic concept and illustrations of type I and type II errors, concept of confidence interval estimation.
b) Student's t-distribution: test for single mean, difference of means and paired t- test, chi-square distribution.

Unit V: Biological databases and genome browsers

Introduction to various databases and their classification (primary and secondary databases) e.g. NCBI, DDBJ, EMBL, ENSEMBL, UCSC and their uses

Unit VI: Sequence alignment

Local and global sequence alignments (Needleman-Wunsch and Smith-Waterman algorithms), pair-wise (BLAST and FASTA algorithms) and multiple sequence alignment (Clustal W) and its importance. s-value and e-value, p value.

Unit VII: Phylogenetic analysis

Basic concepts of phylogenetic analysis, rooted/uprooted trees, approaches for phylogenetic tree construction (UPGMA, Neighbor joining, Maximum parsimony, Maximum likelihood).

Unit VIII: Structure predictions for nucleic acids and proteins

Approaches for the prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models, Basic approaches for protein structure predictions, comparative modeling, fold recognition/threading and *ab- initio* prediction

Unit IX: Overview of drug development

Drug life cycle, stages of drug discovery and strategic issues in drug discovery. Lead Generation; HTS, clinical trials, characterization of binding site, virtual screening, protein-ligand interactions, prediction of pharmacological properties, Lipinski's rule of five, concept of energy minimization and force fields, introduction to rational drug design using example, Introduction to drug databases

Suggested Readings

1. Bioinformatics: Sequence and Genome analysis, 2nd edition (2004), David W. Mount, Cold Spring Harbour Laboratory Press. ISBN-13: 978-0879697129.
2. Bioinformatics: A practical guide to the analysis of genes and proteins, 3rd edition (2004), Andreas D. Baxevanis and B.F. Francis Ouellette, John Wiley and Sons. ISBN-13: 978-0471478782.
3. The Process of New Drug Discovery and Development, 2nd edition (2006), C.G. Smith and J.T. O"Donnell, Informa Healthcare, ISBN-13: 978-0849327797.
4. Cheminformatics (2003), J. Gasteiger, Thomas Engel; Wiley-VCH. ISBN: 9783527618279.
5. Molecular modeling - Principles and Applications, 2nd edition (2003), A. R. Leach, Pearson Education Limited, UK. ISBN 13: 9780582382107.
6. Cheminformatics in Drug Discovery (2006), edited by. T.I. Opera; Wiley Publishers, ISBN: 9783527604203.
7. Primer of Biostatistics, 7th edition (2011), Stanton Glantz, McGraw-Hill Medical. ISBN-13: 978-0071781503.
8. Biostatistics: A Foundation for Analysis in the Health Sciences, 10th edition (2013), Wayne W Daniel and Chad L. Cross, Wiley. ISBN-13: 978-1118302798.
9. Principles of Biostatistics, 2nd edition (2000), Marcello Pagano and KimberleeGauvrean, Thompson learning. ISBN-13: 978-0534229023.
10. Biostatistical Analysis, 5th edition (2009), Jerrold H. Zar, Pearson. ISBN-13: 978-0131008465.

Paper Code: MICPGCCT08
Paper Title: Immunobiology

Course Objectives	Course Outcomes
• To make the students understand the anatomy of the immune system, and components and functioning of humoral and cell mediated immune responses. • To introduce the students to various detection systems and to the development of monoclonal antibody and hybridoma technology in general. • To broaden the knowledge of students about vaccinology and tumour immunology. • To make them understand antibody genes and antibody engineering. • To broaden the knowledge of students about intricacies of the host system in sub/optimum/hyper immune responses and various immunological techniques. • To make the students understand the role of the immune system in hypersensitivity and autoimmune complications.	After completion of the course, a student will be able to achieve these outcomes: • Students will gain an overview of the immune system including cells, organs and receptors. • They will understand the structure and functions of different classes of immunoglobulins, the genetic basis of antibody diversity and the importance of humoral, cell-mediated and innate immune responses in combating pathogens. • They will also understand mechanisms involved in different types of hypersensitivity, and the importance of conventional vs recombinant vaccines. • They will be acquainted with the importance of antigen-antibody interaction in disease diagnosis. • Students will be in a position to explain the principles of tolerance, autoimmunity and the role of immunity in protection against pathogens.

Unit I: Fundamental concepts and anatomy of the immune system
Three fundamental concepts in immunology: Specificity, discrimination of self from non-self and memory; Haematopoiesis and its regulation; Cells and Organs of immune system; Lymphatic system; Lymphocyte circulation; Lymphocyte homing; Mucosal and Cutaneous associated Lymphoid tissue.

Unit II: Immune cell receptors
Detailed structure and development of B cell (Ig) and T cell (TcR) receptors; Structure of CD4, CD8, MHC-I, MHC-II molecules, cellular adhesion molecules (ICAM, VCAM, selectins, integrins); Pattern Recognition Receptors (PRRs) and Toll-like receptors (TLR); Markers of suppressor / regulatory cells - CD4+, CD25+, Foxp3+, Treg , iNKT.

Unit III: Genetic organization
Organization of the genes for B and T cell receptors. Genetic organization of MHC-I and MHC-II complex (both HLA and H-2). Molecular mechanisms responsible for generating diversity of antibodies and T cell receptors. Antigen Processing and Presentation; Peptide loading and expression of MHC-I and MHC-II molecules.

Unit IV: Immune response and signalling
Humoral and cell-mediated immune response; Inflammatory events and signalling; Innate immune response and pattern recognition; Recent advances in innate immune response especially NK-DC interactions; Important cytokines and their role in immune mechanisms: TNF, IFN-γ, IL-1, IL-2, IL-4, 1L-6, 1L-12, IL-17, TGFb; Co-stimulation and inhibitory signalling; Cell signalling through MAP kinases and NF-kB;

Unit V: Tolerance and autoimmunity
Central and peripheral tolerance, and their mechanism; Mechanisms of autoimmunity; Immune checkpoints, Autoimmune components of diabetes mellitus (DM), multiple sclerosis (MS), pernicious anemia; Infections leading to autoimmune diseases.

Unit VI: Immunological disorders and hypersensitivity
Immunodeficiencies: Deficiency/ defects of T cells, B cells, and phagocytic cells; Comparative study of Type I-V hypersensitivities with examples.

Unit VII: Transplantation and tumor immunology

Alloreactive response; Graft rejection and GVHD; HLA-matching; Use of CRISPR-Cas for generating transgenic animals for xenotransplantation; Tumor antigens, immune response to tumors and immunotherapy of tumors.

Unit VII: Immunological Techniques

Precipitation and agglutination; RIA; ELISA; ELISPOT assay; Western blotting; immunofluorescence; Flow cytometry and immunoelectron microscopy; Hybridoma technology and monoclonal antibodies; Antibody engineering including bispecific antibodies; Phage display; Development of animal models for studying diseases.

Unit VIII: Vaccinology

Active and passive immunization; Live; killed; Attenuated; Subunit vaccines; Vaccine technology- Role and properties of adjuvants; Vaccines based on recombinant DNA, mRNA, peptide and protein; Conjugate vaccines; Plant-based vaccines; Reverse vaccinology.

Suggested Readings

1. Kuby Immunology by Kindt TJ, Goldsby RA, Osborne BA, Kuby J: 6th edition. New York. WH Freeman; 2006.
2. Cellular and Molecular Immunology by Abbas AK, Lichtman AH, Pillai S: Saunders Elsevier; 2007.
3. Immunobiology: The immune system in health and disease by Janeway CA, Travers P, Walport M, Shlomchik MJ: 6th edition. New York. Garland Science Publishing; 2005.
4. Fundamental Immunology by Paul WE: 4th edition. New York. Raven Press; 2000.
5. Roitt's Essential Immunology by Delves PJ, Martin SJ, Burton DR, Roitt IM; 11th edition. Blackwell Publishing/Oxford Univ. Press; 2006.

Paper Code: MICPGCCT09
Paper Title: Molecular Biology

Course Objectives	**Course Outcomes**
1. Understanding the detailed molecular structure, organization, and function of genetic material of prokaryotes and eukaryotes. 2. To understand molecular mechanisms of cellular processes like DNA replication, Transcription, Post-transcriptional processes, Translation, and Post-translational processes etc. 3. Understanding the regulation of all the molecular processes. 4. Provide an overview of cell structure and function at the molecular level, including the flow of information from genes to proteins, and regulation of cellular processes in prokaryotes and eukaryotes.	1. Students will understand the scientific process, in the context of learning the fundamental biological and chemical 'facts' of molecular biology. 2. Students will gain skills required to effectively do scientific research. Students will learn to implement the scientific method by proposing hypotheses to explain biological phenomena, designing and conducting experiments to test these hypotheses, and critically interpreting the resulting data. 3. Explain that the growth, development, and behavior of organisms are activated through the expression of genetic information in context. 4. Students will be able to Describe and discuss the properties and biological significance of the major classes of molecules found in living organisms and the relationship between molecular structure and biological function 5. Represent and illustrate the structural organization of genes and the control of gene expression 6. Conceptualize and describe protein synthesis, modification, folding etc.

Unit I: Genetic material

The structure of DNA and RNA; Melting of DNA, Superhelicity, Comparative Organization and features of Microbial Genomes and Eukaryotic Genomes

Unit II: DNA replication

Arrangement of replicons in a genome, Various modes of replication, continuous, discontinuous synthesis, various replication Enzymes, Replication Fork and priming, leading and lagging strand, elongation, termination, Plasmid replication, specific features of replication in Prokaryotes and Eukaryotes, action of topoisomerases, Telomere maintenance and Chromatin Assembly, Single stranded DNA replication, Relationship between DNA replication and cell cycle, DNA copy number maintenance.

Unit III: Recombination and Repair of DNA

DNA repair and recombination, DNA Mismatch Repair, Double Strand Break Repair, Recombination as a molecular biology tool. CRISPR-Cas9, Principle, Variations involved and applications.

Unit IV: Transcription

Transcription machinery of prokaryotes, various transcription enzymes and cofactors, initiation, elongation and termination, sigma factors, Transcription machinery of eukaryotes, various forms of RNA polymerase and cofactors, initiation, elongation and termination, promoters, enhancers, silencers, activators, effect of chromatin structure, regulation of transcription.

Unit V: Post-transcriptional processes

RNA processing, splicing, capping and polyadenylation, rRNA and tRNA processing, RNA Editing; RNAi and miRNAs, Antisense RNA, Post-transcriptional gene regulation

Unit VI: Operon

Gene structure, concept of Operon, Lac and Trp operon, organization and role in regulation of expression

Unit VII: Translation

The genetic code and protein structure, Mechanisms of translation in prokaryotes, Mechanisms of translation in eukaryotes, initiation complex, ribosomes and tRNA, factors, elongation and termination, *in vitro* translation systems, polycistronic/ monocistronic synthesis, Regulation of translation, RNA instability, inhibitors of translation, stringent response in bacteria

Unit VIII: Post-translational processes

Protein modification, inteins and exteins, folding, chaperones, transportation; The Signal Hypothesis, proteasome

Suggested Readings

1. Gene IX by Benjamin Lewin, Jones and Bartlett Publishers, Sudbury, Massachusetts, 2007.
2. Molecular Biology by R.F. Weaver, 4th edition, McGraw Hill. New York. USA, 2007.
3. Molecular Biology of the Gene by J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick, 6th edition, Benjamin Cummings, San Francisco, USA, 2007.
4. Molecular Biology of the Cell by B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P. Walter, 5th edition, Garland Science, New York and London, 2007.
5. Biochemistry (5th edition) by J.M. Berg, J.L. Tymoczko, L. Stryer, W.H. Freeman and Company, New York, USA, 2008.
6. Current Protocols in Molecular Biology Edited by: Fred M. Ausubel; Roger Brent; Robert E. Kingston; David D. Moore; John A. Smith; Kevin Struhl, John Wiley and Sons, Inc. 2007

Paper Code: MICPGCCT10
Paper Title: Environmental Microbiology

Course Objectives	Course Outcomes
1. To understand the microbial diversity in different environments/habitats. 2. To understand different types of interactions of microorganisms among themselves, with plants, animals or environments. 3. To understand different methods or systems of Waste Management and Water Treatment. 4. Understanding the role of microorganisms in bioremediation, mineral recovery, and as biofertilizer and insecticides.	By the completion of this course, the students will be able to learn: 1. Different types of environments and habitats where microorganisms grow including the microbiomes of the human gut and animal gut. 2. The important roles microorganisms play in maintaining healthy environment by degradation of solid/liquid wastes; how these activities of microorganisms are used in sewage treatment plants, production of activated sludge and functioning of septic tanks. 3.Have understood the significance of BOD/COD and various tests involving use of enumerating fecal E.coli for assessing quality of water. 4. Have developed the practical skills for conducting experiments to assess the BOD/COD of wastewaters and their interpretation; practically assess the portability of drinking water by the use of standard microbiological tests.

Unit I: Microorganisms and their Habitats

Structure and function of ecosystems. Terrestrial environment: soil profile and soil microflora – rhizospheric and non- rhizospheric. Aquatic environment: microflora of freshwater ecosystems and marine habitats (benthic and pelagic microflora). Atmosphere: Aeromicroflora and dispersal of microbes, phylloplane microflora. Animal environment: Microbes in/on human body & animal (ruminants) body. Extreme habitats and their inhabitants

Unit II: Microbial Interactions

Microbe interactions: Mutualism, synergism, syntrophism, commensalism, competition, amensalism, parasitism, predation. Microbe- Plant interaction: Symbiotic and non-symbiotic interactions. Microbe-animal interaction: Microbes in ruminants, nematophagous fungi and symbiotic luminescent bacteria.

Unit III: Waste Management and Water Treatment

Solid waste management: sources and types of solid waste, methods of solid waste disposal (composting and sanitary landfill). Liquid waste management: Composition and strength of sewage (BOD and COD), primary, secondary (oxidation ponds, trickling filter, activated sludge process and septic tank) and tertiary sewage treatment. Applications of Anammox and Comammox organisms in sewage treatment. Potability of water: treatment and safety of drinking (potable) water, methods to detect potability of water samples: (a) standard qualitative procedure: presumptive test/MPN test, confirmed and completed tests for faecal coliforms (b) Membrane filter technique and (c) Presence/absence tests.

Unit IV: Microorganisms in bioremediation and mineral recovery

Principles and degradation of common pesticides, organic (hydrocarbons, oil spills) and inorganic (metals) matter, biosurfactants and their uses; Bioleaching of copper, gold and uranium

Unit V: Microbial biofertilizer and insecticides

Types of microbial bio-fertilizers and microbes used (PGPR, symbiotic N2 fixers, Non-symbiotic N2 fixers, Phosphate solubilizers and mycorrhizal biofertilizers), characteristics of inoculant, production of inoculant biomass, formulation & packaging technology and field application.

General account of microbes used as bio-insecticides and their advantages over synthetic pesticides, *Bacillus thuringiensis* – production and field applications; Viruses – cultivation and field applications.

Suggested Readings

1. Atlas RM and Bartha R. (2000). Microbial Ecology: Fundamentals & Applications. 4th edition. Benjamin/Cummings Science Publishing, USA
2. Madigan MT, Martinko JM and Parker J. (2014). Brock Biology of Microorganisms.14th edition. Pearson/ Benjamin Cummings

3. Maier RM, Pepper IL and Gerba CP. (2009). Environmental Microbiology. 2nd edition, Academic Press
4. Okafor, N (2011). Environmental Microbiology of Aquatic & Waste systems. 1st edition, Springer, New York
5. Singh A, Kuhad, RC & Ward OP (2009). Advances in Applied Bioremediation. Volume 17, Springer- Verlag, Berlin Hedeilberg
6. Coyne MS. (2001). Soil Microbiology: An Exploratory Approach. Delmar Thomson Learning.
7. Lynch JM & Hobbie JE. (1988). Microorganisms in Action: Concepts & Application in Microbial Ecology. Blackwell Scientific Publication, U.K.
8. Martin A. (1977). An Introduction to Soil Microbiology. 2ndedition. John Wiley & Sons Inc. New York & London.
9. Stolp H. (1988). Microbial Ecology: Organisms Habitats Activities. Cambridge University Press, Cambridge, England.
10. Subba Rao NS. (1999). Soil Microbiology.4th edition. Oxford & IBH Publishing Co. New Delhi.
11. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology.9th edition. McGraw Hill Higher Education.

Contents of Core Course Practical (CCP) Papers

Paper Code: MICPGCCP01
Paper Title: Core Course Practical I

SECTION A: Cell Biology

1. Isolation of mitochondria and their visualization with Janus green B
2. *In situ* visualization of microfilaments and microtubules by fluorescent labeling.
3. *In silico* analysis (sequence comparison) of mitochondrial and chloroplast genes for identification of the loci for interspecific discrimination.
4. Immunostaining of nuclei
5. Immunostaining of chloroplast.
6. Immunostaining of mitochondria.
7. Demonstration of
   a. cell culture media preparation
   b. visualization of cells in culture
   c. maintenance of cell culture

SECTION B: Biochemistry

I. Basic and standardization Methods

1. Preparation of Acid & Alkali solutions and acid-base titration.
2. Concept of pH. Measuring pH of different solutions
3. Preparation of buffers: Acetate, Phosphate and Tris buffers.
4. pH meter titration of amino acids and separation of aliphatic, aromatic and polar amino acids by TLC

II. Estimation of micromolecules

1. Estimation of inorganic phosphate
2. Estimation of sugar (glucose)
3. Estimation of Amino acid (Tyrosine)
4. Estimation of Base (Guanine)

III. Estimation of macromolecules

1. Determination of Blue Value of Starch
2. Estimation of Proteins
3. Estimation of nucleic acids (DNA)

IV. Enzyme kinetics

1. An enzyme purification theme (such as E. coli alkaline phosphatase or any other enzyme.
   (a) Preparation of cell-free lysates.
   (b) Ammonium sulfate precipitation.
   (c) Ion-exchange / Affinity / Gel filtration chromatography.
   (e) Assessing the purity of protein by PAGE.
   (f) Enzyme Kinetic Parameters: Km, Vmax and Kcat.
   (g) Determination of Units and specific activity of an enzyme.

Paper Code: MICPGCCP02
Paper Title: Core Course Practical II

SECTION A: Microbial Diversity

1. Laboratory rules, safety and regulation, First Aid and ethics.
2. Staining: simple, negative, Gram's, flagella, and endospore.
3. Study of bacterial motility by hanging-drop method.
4. Culture techniques and microbe handling: Pure culture isolation by serial dilution – plating and dilution streaking methods; slating and stabbing of cultures.
5. Culture preservation & revival: -80°C glycerol stock & Lyophilization.
6. Biochemical characterization of pure prokaryotic isolates.
7. Identification of Algae, fungi & eukaryotic microorganisms through permanent slides.
8. Isolation and enumeration of bacteriophages (PFU) from water/sewage sample using double agar layer technique (plaque assay).
9. Determination of phage titer & multiplicity of infection.
10. Study of structural details of major bacterial, plant and animal viruses (Demonstration only).

SECTION B: Metabolism

1. Study of presence of bacteriochlorophyll(s) and other light harvesting pigment in any pigmented bacteria.
2. Utilization pattern of different carbon and nitrogen sources by *E.coli*.
3. Study of anaerobic respiration by using NO3and/or SO4 as terminal electron acceptor.
4. Isolation of denitrifying bacteria from natural sample.
5. Enrichment culture of prokaryotes: Sulpur Oxidizers and phosphate solubilizer.
6. Isolation and characterization of any one type of chemolithotrophic microorganisms.
7. Effect of environmental factors on microbial growth: temperature, pH, osmotic pressure.

SECTION C: Bioinformatics

1. Sequence alignment using BLAST and Clustal W.
2. Phylogenetic analysis using PHYLIP.
3. Microarray analysis using Bioconductor.
4. Molecular format conversion and hands-on molecular visualization program for displaying, animating and analyzing large bio-molecular systems using 3-D graphics.
5. Homology Modeling using SPDBV, model structure refinement using SPDBV and model validation using What Check and Pro Check.
6. Comparing structures, mutations, studying interactions creating electrostatic potential diagrams.
7. Virtual screening and molecular docking using AUTODOCK.
8. Computer-based practicals using any statistical software like 'R'. MATLAB, SPSS, Spreadsheets, etc. to understand the following concepts:
    a. Graphical data representation
    b. Measures of central tendency and dispersion
    c. Probability and probability distributions: binomial, Poisson and normal distribution
    d. Correlation and linear regression analysis
    e. Student's t- test
    f. Chi-square test

Paper Code: MICPGCCP03
Paper Title: Core Course Practical III

SECTION A: Molecular Biology

1. Isolation of plasmid DNA.
2. Isolation of genomic DNA.
3. Estimation of purity & concentration of DNA.
4. Amplification of DNA by PCR
5. Preparation of competent cells and determination of transformation efficiency
6. Restriction digestion analysis by agarose gel electrophoresis.
7. Ligation of DNA fragments.
8. Cloning of a DNA fragment
9. Alpha-complementation / Blue-white screening
10. Isolation of total protein and estimation by Bradford method.
11. Overexpression of proteins and analysis by SDS-PAGE
12. Purification of recombinant protein
13. Western Blotting analysis

SECTION B: Microbial Genetics

1. Preparation of master and replica plates.
2. Study the effect of chemical (HNO2) and physical (UV) mutagens on bacterial cells.
3. Study of survival curve of bacteria after exposure to ultraviolet (UV) light.
4. Study of photoreactivation mechanism of DNA repair
5. Study of different conformations of plasmid DNA through Agaraose gel electrophoresis
6. Curing of plasmid
7. Demonstration of Bacterial Conjugation
8. Demonstration of bacterial transformation and transduction
9. Demonstration of AMES test.

Contents of Discipline Specific Elective Course (DET and DEP) Papers

Paper Code: MICPGDET01
Paper Title: Microbial Pathogenicity

Course Objectives	Course Outcomes
The objective of this course is to make the students understand various attributes which make the microbes pathogenic or disease-causing, the emergence of newer pathogens with relevance to India and the various tools for their local or global spread. The students would also learn the mechanisms of resistance of bacteria to antibiotics and the role of newer vaccines in controlling infectious diseases. The course would also enable students to describe the molecular diagnostic methods and automated equipment which may be used for diagnosis of diseases caused by microorganisms.	Upon successful completion of the course, the student will be able: 1: To understand classical and molecular determinants of disease-causing microbes 2: To describe the characteristics of newer disease-causing bacteria and viruses 3: To study and critique the various molecular tools available to work on the molecular epidemiology of disease-causing microorganisms 4: To study and evaluate mechanisms underlying resistance of bacteria to antibiotics, spread of resistance and the use of newer vaccines to control infectious diseases 5: To gather information as to how the infectious diseases may be diagnosed using newer diagnostic tools and what automated equipment are available for use in diagnostic microbiology laboratories.

Unit I: Classical view of microbial pathogenicity

Define pathogenicity and virulence; Quantitative measures of virulence: minimal lethal dose (MLD), MIC, LD50, ID50, TCID50. Virulence determinants: colonization, toxins, enzymes and invasiveness. Facultative/obligate intracellular pathogens

Unit II: Molecular microbial pathogenicity

Molecular Koch's postulates, multiplicity of virulence features, coordinated regulation of virulence genes, two component signal transudation systems and environmental regulation of virulence determinants, antigenic variation; clonal and panmictic nature of microbial pathogens, type I-IV secretion systems, biofilms.

Unit III: Emerging and re-emerging pathogens

v. cholera O: 139, X-MDR *M. tuberculosis*, *Helicobacter pylori*, Enterohaemorrhagic *E. coli* (EHEC), *Cryptosporidium parvum*, Lyme disease, SARS virus, Bird flu, prions, AIDS, Dengue Hemorrhagic Fever, and *Chlamydiae*, opportunistic fungal pathogens. Mechanisms of emergence of new pathogens: microbial change and adaptation, horizontal gene transfer (HGT), pathogenicity islands (PAI), role of integrons.

Unit IV: Transmission, pathogenesis, symptoms and control of common bacterial, viral, fungal and protozoan diseases

Unit V: Molecular microbial epidemiology

Objectives of microbial epidemiology. Biochemical and Immunological tools - biotyping, serotyping, phage typing, FAME, Curie Point PyMS, protein profiling, multilocus enzyme electrophoresis (MLEE); Molecular typing: RFLP (ribotyping, IS based), RAPD, 16S-23S IGS, ARDRA, rep (REP, ERIC, BOX)-PCR, PFGE, AFLP, MLST, MVLST, VNTR, SNP, Microarray and whole genome sequence; GIS; MALDI based identification of pathogenic bacteria.

Unit VI: Antimicrobials and their mode of action

Antibacterial agents: Different modes with one examples: Inhibitor of nucleic acid synthesis; Inhibitor of cell wall synthesis; Inhibitor of cell membrane function; Inhibitor of protein synthesis; Inhibitor of metabolism. Antifungal agents; Antiviral agents; Antibiotic resistance

Unit VII: Antimicrobial resistance

Multidrug resistance, strategies involved, with examples: extended spectrum β-lactamases (ESBL), XMDR *M. tuberculosis*, Mecithillin-resistant *S. aureus* (MRSA).

Suggested Readings

1. Jawetz, Melnick, &Adelberg's Medical Microbiology by Brooks GF, Butel JS, Morse SA, Melnick JL, Jawetz E, Adelberg EA . 23rd edition. Lange Publication. 2004.
2. Cellular Microbiology by Cossart P, Boquet P, Normark S, Rappuoli R eds. 2nd edition. American Society for Microbiology Press. 2005.
3. Bacterial Pathogenesis: A molecular approach by Salyers AA and Whitt DD eds. American Society for Microbiology Press, Washington, DC USA. 2002.
4. Pathogenomics: Genome analysis of pathogenic microbes by Hacker J and Dorbindt U. ed. Wiley-VCH. 2006.
5. Molecular Microbiology: Diagnostic Principles and Practice by Persing DH, Tenover FC, Versalovic J, Tang Y, Unger ER, Relman DA, White TJ eds. American Society for Microbiology Press, 2004.
6. Infectious Disease Epidemiology: Theory and Practice by Nelson KE, Williams CM, Graham NMH eds. An Aspen Publication. 2001.

Paper Code: MICPGDET02
Paper Title: Food and Industrial Microbiology

Course Objectives	**Course Outcomes**
The course will enable students to understand the taxonomical classification, phenotypic and biochemical identification of food associated molds, yeasts, yeast-like fungi and bacteria. The role of microbes in food spoilage, preservation and various food borne diseases will be discussed. The course will enable students to apply the learning of microbiology concepts toward the exploitation of microbial population for industrial and human benefits. The strategies for development of microbial strains, process optimization, large scale production and product recovery will be covered for industrially relevant microbial products and therapeutic proteins.	Upon successful completion of the course, the student: 1: Will be aware of fermentation protocols for production of microbial biomass 2: Gather information regarding microbes causing food intoxications and food-borne infections. 3: Knows traditional food preservation techniques 4: Will have gained insight on industrially important microbes 5: Understands the concept of sterilization methods and principles of batch and continuous processes 6: Learns about the design, types of fermenters and various critical components of bioreactors

Unit I: Microbiology of Foods

Vegetables, fruits, milk, fermented and non-fermented milk products, fresh meats, poultry and non-dairy fermented foods.

Unit II: Food Preservation

Microbial spoilage of foods; Food preservation: Chemical, physical and biological methods.

Fermentation processes: Production of milk and milk products, plant-based products, fish products, meat products and food beverages. Food-borne diseases, Lantibiotics.

Unit III: Bioreactor Types and Operation

Control batch reactors, fed-batch reactors, CSTR reactors, various types of bioreactors for microbial, animal, plant cell culture, fluidized bed reactor, bubble column, air lift fermenter, packed bed, trickle bed etc. parallel and series bioreactor. Impellers, stirrer, glands and bearings, packed gland seal, mechanical seal, magnetic drives, baffles, different types of spargers, computer based advance controllers for bioreactors, Downstream processing.

Unit IV: Bioreactor Design

Introduction, general design information, design of bioreactors, basic function of a bioreactor design, mass and energy balance, materials of construction for bioprocess plant, mechanical design of process equipment, utilities for biotechnology production plants.

Unit V: Applications of Process Technology

Production of cell biomass and some primary metabolites, e.g. ethanol, acetone-butanol and any two amino acids. Microbial production of industrial enzymes: glucose isomerase, cellulase & lipases. Bioconversion, Transformation, Biofuels.

Suggested Readings

1. Modern Industrial Microbiology & Biotechnology by N. Okafer, Scientific Publishers, Enfield, USA., 2007.
2. Industrial Microbiology: An Introduction by Waites, Morgan, Rockey & Highton, Blackwell Science, 2001.
3. Modern Food Microbiology, 4th edition by J.M. Jay, Springer, 2006.
4. Fundamental Food Microbiology, 3rd edition by B. Ray., CRC press, 2006.
5. Food Microbiology: Fundamentals and Frontiers, 2nd edition by Michael P. Doyle, Larry R. Beuchat, Thomas
   J. Montville, ASM press, 2001.
6. Bioprocess Technology- fundamentals and applications, S O Enfors & L Hagstrom (1992), RIT, Stockholm.

Paper Code: MICPGDET03
Paper Title: Bioprocess Engineering

Course Objectives	**Course Outcomes**
The course will help students to understand various applications of microbes for the development of various products of agriculture, industrial and clinical application. The knowledge of recombinant technology, bioreactors and optimization strategies will be beneficial in development of production processes.	Upon successful completion of the course, the student: 1: Will learn about various industrially relevant microbial products and their production process, role of biotechnology in environment management 2: Learns about the designing of recombinant heterologous expression systems such as E. coli, yeast, mammalian and insect cells. 3: Learns about sterilization at reactor scale and different types of sterilization strategies 4: Attains knowledge about designing large scale industrial processes and types of cultivation strategies 5: Understands different types of regulatory approvals required for drug development and difference between biologics, biosimilars and biobetters

Unit I: Microbial biotechnology

Biotechnology and its applications in microbial processes. role of microbial biotechnology in environment management

Unit II Improvement of Microbial strains

Strains development, selection of hyper producers, microbial products, metabolic engineering in development of industrial products

Unit III: Recombinant gene expression platforms:
Development of recombinant heterologous expression systems e.g. E. coli, yeast, mammalian and insect cells. Plant cells as bio-factories. Control parameters in stability of these expression platforms at industrial scale.

Unit IV: Designing large scale industrial processes
Application of bioprocess engineering in microbial product development, batch fermentation, fed-batch fermentation, type of bioreactors, designs and control parameters in a fermenter, high cell density cultivation strategies, continuous cultivation processes, measurement of growth and product formation kinetics, limiting parameters in large scale process development, oxygen mass transfer coefficient. Downstream processing.

Unit V Sterilization:
Different types of sterilization strategies, sterilization of large scale bioreactors, calculation of heating, holding and cooling time

Unit VI: Development of microbial products:
Fermented milk products, probiotics, malt beverages, wines, distilled liquors, recombinant biomolecules and therapeutic proteins, vaccines production, DNA based vaccines, antibody production, therapeutic enzymes, industrially important enzymes and green fuel production, Development of bio-pesticides and bio-fertilizers

Unit VII Regulatory approvals and clinical trials:
Good laboratory practice (GLP), Current Good Manufacturing Practice (CGMP), different phases of clinical trials, difference between biologics, biosimilar and bio-better, development of biosimilars and generic biomolecules, analysis of process economics 8

Suggested Readings:
1. Principles of Fermentation Technology by P. Stanbury, A. Whitaker, S. Hall. 3 rd edition. Butterworth-Heinemann. 2016.
2. Modern Industrial Microbiology & Biotechnology by N. Okafor. 1st edition. CRC Press, USA. 2007.
3. Microbial Biotechnology: Fundamentals of Applied Microbiology by A.N. Glazer and H. Nikaido. 2 nd edition. Cambridge University Press. 2007.
4. Pharmaceutical Biotechnology: Concepts and Applications by G. Walsh. John Wiley & Sons Ltd. 2007.
5. Pharmaceutical Biotechnology: Fundamentals and Applications by J.A.D. Crommelin, R. D. Sindelar, and B. Meibohm. 4 thEdition. Springer. 2013.

Paper Code: MICPGDEP01
Paper Title: Discipline Elective Practical I

SECTION A: Microbial Pathogenicity

1. To study cultural and microscopic characteristics of selected pathogenic fungi *viz*. *Microsporum* sp., *Candida albicans*, and *Aspergillus* sp.
2. Isolation of bacteria from vegetables and fruits.
3. Biochemical and physiological tests for detection of pathogens in fruits and vegetables, eg; Arginine hydrolysis for *Pseudomonas.*
4. Isolation of soilborne pathogens from plant tissue and soil.
5. Effects of processing methods in vegetables;
6. Bacterial counts in blanched vegetables.
7. Bacterial counts in unblanched vegetables.
8. Bacterial counts in frozen vegetables.

SECTION B: Immunology

1. Antibody titre by ELISA.
2. Double diffusion, immuno-electrophoresis and radial Immunodiffusion.
3. Complement fixation test.
4. Determination of blood groups.
5. Isolation and purification of IgG from serum or IgY from chicken egg.
6. SDS-PAGE, Immunoblotting, Dot blot assays
7. Blood smear identification of leucocytes by Giemsa stain
8. Separation of leucocytes by Dextran density gradient method
9. Separation of mononuclear cells by Ficoll-Hypaque.

Paper Code: MICPGDEP02
Paper Title: Discipline Elective Practical II

SECTION A: Food and Industrial Microbiology

1. To make wine from different juices by fermentation.
2. To study microbiology of vegetables, fruits, milk and milk products.
3. To test the quality of milk.
4. To demonstrate production of curd and cheese.
5. To study the production of wine from grape juice.
6. Microbial Growth kinetics-Determination of specific growth rate (mmax), saturation constant (KS) and growth yield (YX/S) in batch culture.
7. Determination of KLa by sulphite oxidation method.
8. Determination of KLa in a bioreactor by dynamic method.
9. Determination of thermal death rate constant and decimal reduction time for *E. coli*.
10. Disruption of microbial cells (Baker's yeast) for the release of the intracellular protein.
11. Bio-transformation of sucrose into high fructose syrup by immobilized cell of *Saccharomyces cerevisiae*

SECTION B: Environmental Microbiology

1. Analysis of soil - pH, moisture content, water holding capacity, percolation, capillary action.
2. Analysis of BOD, TOC of waste-water.
3. Study of microflora of soil, fresh water (pond) and air.
4. Study of microflora of waste-water and drinking water.
5. Assessment of microbiological quality of water (Presumptive test, Confirmatory test, Completed test for coliform; IMVIC reactions)
6. Study the presence of microbial activity by detecting (qualitatively) enzymes (dehydrogenase, amylase, phosphatase, and urease) in soil.
7. Isolation of Rhizobium from root nodules.
8. Isolation of phosphate solubilizing bacteria.
9. Isolation of heavy metal resistant bacteria,
10. Isolation of cellulolytic bacteria from soil sample,
11. Isolation of hydrocarbon(s) or pesticides(s) degrading bacteria.
12. Metabolic fingerprinting of microbes by BIOLOG.
13. Preparation of total DNA from soil and water, and amplification of 16S rDNA

Paper Code: MICPGDEP03
Paper Title: Discipline Elective Practical III

1. Effect of denaturation (heat/urea/guanidium chloride/BME) on UV absorption spectra of proteins.
2. Study of structural changes of proteins at different pH/solvent/temperature using UV spectrophotometry.
3. Analysis, identification and comparison of various spectra (UV, NMR, MS, IR) of simple organic compounds.
4. Separation of nucleotides/amino acids using TLC
5. Paper chromatography.
6. Agarose gel electrophoresis
7. SDS - Polyacrylamide gel electrophoresis
8. Calculation of electrophoretic mobility
9. Study of autoradiographs
10. Analysis of electropherograms

Contents of Generic Elective Course (GEC) Papers

(To be opted by the students of other disciplines)

Paper Code: MICPGGEC01
Paper Title: Microbial Technology

Course Objectives	Course Outcomes
1. Understanding basic features of microorganisms, their classification, growth and metabolism. 2. Role of microorganisms in agriculture, food and dairy industry 3. Students will be exposed to microbial fermentation technology 4. Knowledge about the production of microbial biomass 5. To know in depth about the production of antibiotics, and commercial application of enzymes. 6. Provide an overview of renewable bioenergy using microorganisms. 7. In depth knowledge about microbiology of wastewater and soild waste management.	On successful completion of this unit students will be able to 1. Understand general characters of Bacteria, Algae, Fungi and Protozoa, their classification, growth and metabolism as well as role of microbes in extreme environment 2. Develop an awareness on the role of microorganisms in agriculture, food and dairy industry. Isolation, preservation and maintenance of microbial cultures, microbial metabolites and their overproduction. 3. Learn the components of microbial fermentation process of solid state, static and submerged fermentation. 4. Understand the production of microbial biomass of plant growth promoting rhizobacteria, mushroom cultivation and processing, bioformulation of biopesticides and biofertilizers. 5. Production of Penicillin, Tetracycline and peptide antibiotics as well as microbial production and commercial application of Amylases, Proteases, Lipases. 6. They will be acquainted with the knowledge of methane production by anaerobic digestion of waste organic material, bioethanol and biobutanol production using microorganisms. 7. Develop an awareness on microbiology of waste water and solid waste treatment including treatment of industrial effluents by microorganisms

Unit I: Basic features of microorganisms

General characters of microorganisms- Bacteria, Algae, Fungi and Protozoa. Classification of bacteria; Bacterial growth and metabolism. Microbes in Extreme Environment – Special features of the thermophilic, methanogenic and halophilic archaea; Photosynthetic bacteria, Cyanobacteria; microbes in other extreme conditions – Deep Ocean, and space.

Unit II: Role of microorganisms in agriculture, food and dairy industry

Role of microorganisms in agriculture, food and dairy industry; Isolation and selection of Agriculturally important and industrially important microorganisms; Preservation and maintenance of microbial cultures; Various Microbial metabolites and their Overproduction. Microbial enzymes for food, detergent and pharma industry.

Unit III: Microbial Fermentation Technology

Microbial substrates and Media formulation; Components of microbial fermentation process; Types of fermentation processes- Solid state, Static and submerged fermentations; Types of Bioreactors: Stirred tank reactor, bubble column; Downstream processing. Fermented beverages-beer, wine and other alcoholic beverages. Production of Ethanol, Citric acid; Amino acids and vitamins; Microbial preparation of Tempeh, sauerkraut, Cheese, yogurt. Probiotics. Single cell protein.

Unit IV: Production of Microbial Biomass

Production of Microbial Biomass - Baker's Yeast, Mushroom cultivation and processing; Plant growth promoting rhizobacteria (PGPR); Biopesticides - *Bacillus thuringiensis, Trichoderma harzianum*, *Beauveria bassiana*. Biofertilizers *Rhizobium*, *Azospirillum*, *Azotobacter*, *Gluconacetobacter*, *Azorhizobium*, phosphobacteria - Mycorrhizae - Blue Green Algae and *Azolla*.

Unit V: Production of Antibiotics

Production of Antibiotics-Penicillin, Tetracycline and peptide antibiotics; Bioweapons and Bioshields; Microbial production and commercial applications of Amylases, Proteases, Lipases; Microbial transformation, Production of Insulin, Interleukin, growth hormones using rDNA technology.

Unit VI: Renewable bioenergy using microorganisms

Methanogenesis, Methane production by anaerobic digestion of waste organic materials. Bioethanol and Biobutanol production by using microorganisms. Biohydrogen Generation, Microbial Fuel. Biodiesel from algae.

Unit VII: Microbiology of wastewater and solid waste treatment

Microbiology of wastewater and solid waste treatment - biological, aerobic, anaerobic, primary, secondary and tertiary treatments; Activated sludge and Anaerobic digestion process. Treatment of industrial effluents by microorganisms; Composting; Microbiology of degradation of xenobiotics; Bioremediation of insecticides, pesticides and heavy metals.

Suggested Readings

1. Bacterial Metabolism - G. Gottschalk, Springer
2. Food Microbiology - M.R. Adams & M.O. Moss, RSC
3. Microorganisms in Our World - R.M. Atlas, Mosby
4. Principles of Fermentation Technology -P. FStanbury, A. Whitaker, S. J. Hall, Butterworth-Heinemann
5. Biotechnology. A Textbook of Industrial Microbiology- W. Crueger and A. Crueger, Sinauer Associates Gerald Reed.
6. Industrial Microbiology-L. E. J. R Casida, New Age Publisher
7. Advances in Enzyme Biotechnology– P.Shukla and I. Pletschke -Eds, Springer-Verlag
8. Advances in Fermentation technology-A. Pandey, C.Lasroche, C.R. Soccol and C. Dussop,Asiatech publishers Inc.
9. Industrial Biotechnology – A.S. Mathuriya, Ane Books Pvt. Ltd.

Paper Code: MICPGGEC02
Paper Title: Biophysics and Bioethics

Course Objectives	**Course Outcomes**
● To educate students about the properties and preparation of buffers, and various basic analytical techniques like dialysis, filtration, spectroscopy, fluorescence techniques, chromatographic techniques, centrifugation techniques and their applications in industrial and research fields. ● The course is also meant to familiarize the students with radioactivity and the applications of radioisotopes in research. ● Also to familiarize students to some more advanced techniques used in biological research	● Students should be able to gather knowledge about the preparation? types, and uses of buffers used in biochemical studies. ● Students should be able to know the principle, working and instrumentation of various chromatographic techniques in detail. ● They will also be able to understand the details of principle, working and instrumentation of various electrophoretic techniques. ● Students should be able to understand the theory and principle of centrifugation. They will be able to differentiate between different types of centrifuges. Also they will be able to enumerate various applications of centrifugation techniques in research. ● Students should be able to understand the different types of radiation emitted by radioisotopes and their measurement. They will know the applications of radioisotopes in biological research, medicine and diagnosis. Also they will understand the research significance and measurement of less abundant non-radioactive isotopes. ● Students should be able to understand the principle, methods and applications of protein crystallization; theory, types, instrumentation and applications of various spectrometry,

Unit I: Separation Techniques
Different methods of protein precipitation: Precipitation using inorganic salts (salting out) and organic solvents, isoelectric precipitation, Dialysis, Ultrafiltration, Lyophilization.

Unit II: Centrifugation
Basic principles; Mathematics & theory (RCF; Sedimentation coefficient etc); Types of centrifuge - Microcentrifuge; High speed & Ultracentrifuges; Preparative centrifugation; Differential & density gradient centrifugation; Applications (Isolation of cell components); Analytical centrifugation; Determination of molecular weight by sedimentation velocity & sedimentation equilibrium methods.

Unit III: Chromatography
Basic principles; Adsorption and partition chromatography; Partition coefficient; Performance parameters; Modes of chromatography; Different types of chromatography: Paper Chromatography, Thin Layer Chromatography; Gel filtration Chromatography, Ion Exchange Chromatography, Affinity Chromatography, Gas Liquid Chromatography; LPLC and HPLC; IMAC; Preparative and analytical applications.

Unit IV: Electrophoresis
Basic Principle; Paper electrophoresis; Gel electrophoresis; discontinuous gel electrophoresis; PAGE: SDS-PAGE, Native gels, denaturing gels, Isoelectric Focusing of proteins, 2D gel; Agarose gel electrophoresis; PFGE; Buffer systems in electrophoresis; Detection and identification (staining procedures); Molecular weight determination; Protein and nucleic acid blotting.

Unit V: Spectroscopy and Crystallography
Molecular spectroscopy; UV-Visible, Raman, IR spectroscopy; Fluorescence spectroscopy; FRET; Bimolecular fluorescence complementation assay; Theory and application of Circular Dichroism; Mass spectrometry; NMR; PMR; ESR and Plasma Emission spectroscopy. Theory and application of X-Ray Crystallography.

Unit VI: Microscopy
Principles and applications of Microscopy; Fluorescence; Phase contrast; Confocal; Scanning and Transmission and Cryo- Electron microscopy.

Unit VII: Analysis of protein-DNA and protein-protein interactions
Gel retardation assay; DNA foot-printing by DNase I and chemical methods; Yeast one-hybrid assay, ChIP- chips. Yeast two hybrids, three-hybrids, split hybrids and reverse hybrids. Co-immunoprecipitations; GFP and FRET; Phage display.

Unit VIII: Radioisotopes
Radioisotopes and their use in biology and diagnostics; autoradiography; radioactive labeling of biological macromolecules.

Unit IX: Bioethics
Philosophy and Theories of Bioethics; Clinical ethics; Research Ethics.

Suggested Readings

1. Physical Biochemistry: Principles and Applications, 2nd edition (2009), David Sheehan, JohnWiley
2. Cell and Molecular Biology: Concepts and Experiments, 6th edition (2009), Gerald Karp, Wiley
3. Gene cloning and DNA analysis, 6th edition (2010), T.A. Brown. Wiley-Blackwell
4. Principles of Gene Manipulation and Genomics, 7th edition (2006), S.B. Primrose and R.M. Twyman. Blackwell Scientific
5. Human Molecular Genetics, 3rd edition (2003), Tom Strachan and Andrew Read; Garland Science Publishers
6. Immunology, 6th edition, (2006), J. Kuby, W.H. Freeman and Company, New York

Paper Code: MICPGGEC03
Paper Title: Biotechnology and Entrepreneurship

Course Objectives	Course Outcomes
The overall aim of the course is to give the students an insight into the field of bioentrepreneurship, i.e. business within the life sciences.	At the end of the course the student will be able to: ● Explain the importance of embarking on self-employment ● Understand company Law and commercial knowhow for biotechnological ventures ● Identify issues in protection of biotechnology inventions ● Adapt biosafety and bioethics principles ● Demonstrate a general understanding of the central role that business development plays for the biomedical industry ● Write, and critically review a business plan ● Perform a basic market analysis in the life science sector ● Analyse and critically assess a case study

Unit I: Introduction to Biotechnology
Biotechnology: definition, history, thrust areas; Elements of Bioprocess Engineering; Biotech Industries; Basic concepts of GLP, GMP and FDA; Scope and Importance of Biotechnology and allied fields. Role of Biotechnology in economic development of society.

Unit II: Entrepreneur and Entrepreneurship
Introduction; Entrepreneur and Entrepreneurship; Role of entrepreneurship in economic development; Entrepreneurial competencies and motivation; Institutional Interface for Small Scale Industry/Enterprises.

Unit III: Introduction to Bio-entrepreneurship
Definition of Bioentrepreneurship, traits of an entrepreneur; Copyright, Patents, trademark, plant breeders and farmers' rights, biodiversity related issues; Biopiracy, International and Indian business policies with the focus on Bio and Pharmaceutical products.- BIRAC

Unit IV: Planning a Small Scale Enterprises
Opportunity Scanning and Identification; Creativity and product development process; Market survey and assessment; choice of technology and selection of site. Financing new/small enterprises; Techno Economic Feasibility Assessment; Preparation of Business Plan; Forms of business organization/ownership.

Unit V: Case study of any three of the following enterprises (startup, various stages in establishment, etc.,)
1) Biotechnology Company
2) Pharma company
3) Apiculture company
4) Aquaculture company
5) Mushroom farming company
6) Horticulture company

Suggested Readings
1. G.G. Meredith, R.E.Nelson and P.A. Neek, The Practice of Entrepreneurship, ILO, 1982.
2. Dr. Vasant Desai, Management of Small Scale Enterprises, Himalaya Publishing House, 2004.
3. Patzelt, Holger, Brenner, Thomas (Eds.). Handbook of Bioentrepreneurship. Springer, 2008.
4. A Handbook for New Entrepreneurs, Entrepreneurship Development Institute of India, Ahmedabad, 1988.
5. Bruce R Barringer and R Duane Ireland, Entrepreneurship: Successfully Launching New Ventures, 3rd ed., Pearson Edu., 2013.
6. Lee, James W., 2013. Advanced Biofuels and Bioproducts. Springer New York,
7. C. T. Hou, Jei-Fu Shaw, 2008. Biocatalysis and Bioenergy Wiley.

Paper Code: MICPGGEC04
Paper Title: Drug Designing

Course Objectives	Course Outcomes
This course will explore the process of drug development, from target identification to final drug registration. It will present drug development as a process involving target selection, lead discovery using computer-based methods and combinatorial chemistry/high-throughput screening. Safety evaluation, bioavailability, clinical trials, and the essentials of patent law will also be discussed. Along the way you will learn about molecular recognition, computer aided drug design, and toxicology as applied to the development of new medicines	Upon completion of the course, the student will 1. will understand the various stages of drug development from target identification to final drug registration. 2. will be able to generate lead using computer-based methods and combinatorial chemistry/high-throughput screening. 3. will understand safety evaluation, bioavailability, clinical trials, and the essentials of patent law

Unit I: Introduction to Drug Discovery and Development
Stages of drug discovery and development; Lead discovery and Analog Based Drug Design; Rational approaches to lead discovery based on traditional medicine, Random screening, Non-random screening, serendipitous drug discovery, lead discovery based on drug metabolism, lead discovery based on clinical observation; Analog Based Drug Design: Bioisosterism, Classification, Bioisosteric replacement. Any three case studies, ADMET, Lipinski rule of 5.

Unit II: Quantitative Structure Activity Relationship (QSAR)
SAR versus QSAR, History and development of QSAR, Types of physicochemical parameters, experimental and theoretical approaches for the determination of physicochemical parameters such as Partition coefficient, Hammet's substituent constant and Tafts steric constant. Hansch analysis, Free Wilson analysis, 3D-QSAR approaches like COMFA and COMSIA.

Unit III: Molecular Modeling and virtual screening techniques
CADD, Virtual Screening techniques: Drug likeness screening, Concept of pharmacophore mapping and pharmacophore-based Screening, Molecular docking: Rigid docking, flexible docking, manual docking, Docking based screening. De novo drug design. Introduction to molecular mechanics and quantum mechanics. Energy Minimization methods and Conformational Analysis, global conformational minima determination.

Unit IV: Informatics & Methods in drug design
Introduction to Bioinformatics, chemoinformatics. ADME databases, chemical, biochemical and pharmaceutical databases.

Suggested Readings

1. Bioinformatics: Sequence and Genome analysis, 2nd edition (2004), David W. Mount, Cold Spring Harbour Laboratory Press. ISBN-13: 978-0879697129.
2. The Process of New Drug Discovery and Development, 2nd edition (2006), C.G. Smith and J.T. O"Donnell, Informa Healthcare, ISBN-13: 978-0849327797.
3. Cheminformatics (2003), J. Gasteiger, Thomas Engel; Wiley-VCH. ISBN: 9783527618279.
4. Molecular modeling - Principles and Applications, 2nd edition (2003), A. R. Leach, Pearson Education Limited, UK. ISBN 13: 9780582382107.
5. Cheminformatics in Drug Discovery (2006), edited by. T.I. Opera; Wiley Publishers, ISBN: 9783527604203.