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M.Sc. MICROBIOLOGY

SEMESTER – I

19PMBCC101	Core 1: Biomolecules	4hrs/wk	4 Credits

Course Description:

Aim of the course is to explore and understand different aspects of structure and function of living things by introducing chemistry of life at molecular level which reveals the biochemical organization and hierarchical assembly of smaller molecule into complexes responsible for specific biological processes. Course give explanation of molecular interaction and bond involve in biomolecules, which is key for formation of new and more complex molecule along with buffering in biological system. Course covers structure and function of carbohydrates, protein, lipids and nucleic acids as well as relationship between structure and function.

Course Purpose:

This course designed to provide a firm foundation in biochemistry to understand and analyze the basic molecular unit of life. Topics include the structure and function of major biomolecules. The course fulfils the basic biochemistry knowledge required in pharma, health, food and other sectors. The course provides an overview of the main aspects of biochemistry by relating molecular interactions in particular and their effects on the organism as a whole, especially related to human biology.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K1 to K4)**
CO_1	Comprehend and analyze concept of biomolecules and biochemical processes.	K1, K2
CO_2	Relate chemical interactions between molecules in biological systems.	K1, K2
CO_3	Evaluate structure and role of various biological molecules.	K2
CO_4	Interpret various phenomenon associated with biomolecules.	K3

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CO_5	Predict and determine the physiological problems related to biomolecules.	K2

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Module-I: Molecular properties of water and Acid- Base concepts 9 hrs

- Water as solvent for molecules in cell: Bonding: bond angles and lengths
- Conformations of molecules: Tautomerism and resonance.
- Forces between molecules and chemical groups
- Acids and Bases: Titration curves, pH and pH scale, its measurement and significance in biological systems.
- Buffers: weak acid and weak base, dissociation constant of weak acid and base, pKa values and their importance, Henderson–Hasselbach equation; significance of buffer in biological system

Module-II: Carbohydrates 10 hrs

- Introduction, natural occurrence and physiological importance; classification and structure of carbohydrates
- Chirality and isomerism in carbohydrate; configuration in sugars: Fischer's projection and Haworth's representation; oxidation and reduction of sugars
- Monosaccharide and Disaccharides: structures, characteristics, functions and sources
- Polysaccharides: Homo and hetero polysaccharides, its structure and function.
- Glycoconjugates: Proteoglycans, Glycoprotein, Glycolipid, Carbohydrates as informational molecules.

Module-III: Amino acids and proteins 11 hrs

- Structures and classification of amino acids, uncommon amino acids, amino acids as zwitter ion, peptide bond and its characteristics.
- Structure of proteins: primary and secondary structure; structure and function of fibrous proteins and lipoprotein
- Structure of proteins: tertiary and quaternary structure; structure and function of globular proteins (Myoglobin and Hemoglobin), cooperativity, ligand binding, protein denaturation
- Oxygen transport, oxygen dissociation curve, factor affecting dissociation curve
- Amino acid sequencing of proteins and its significance

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Module-IV: Lipids **9 hrs**

- Fatty acids - properties and classification, saturation and unsaturation of fatty acid, factor affecting melting point of fatty acid
- Lipids - importance, classification and properties, storage lipid (triacylglycerol)
- Phospholipids, glycolipid, sphingolipids, alcohols of lipid (cholesterol and ergosterol)
- Structure and biological role of prostaglandins, thromboxanes and leukotrienes
- Lipids as signal molecules, cofactors and pigments

Module-V: Nucleic Acids **9 hrs**

- Structures, characteristics and functions of nucleotides and unusual nucleotides
- Structure of DNA & RNA, different conformations of DNA, types of RNA
- Denaturation & renatuartion of DNA, renatuartion kinetics, hypochromocity
- Properties of DNA such as super coiling and sequence dependent changes in DNA melting
- Structure of genomic and organelle DNA in eukaryotes

Pedagogic tools:

- Chalk and Board
- PPT and Videos.
- Assignment
- Group discussion

Text books:

1. Nelson, D. L., Lehninger, A. L., & Cox, M. M. (2008). Lehninger principles of biochemistry. Macmillan.Stryer – Biochemistry. 7th edition (1st, 2017 Hard cover). W.H.Freeman & Co.
2. Voet, D., & Voet, J. G. (2011). Biochemistry, 4th Edition (22nd November, 2010), New York: John Wiley & Sons Inc.

Reference Books:

1. Devlin, T.M. (2010).Textbook of Biochemistry with Clinical Correlations, 7th Edition John Wiley & Sons Inc.

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2. Hames, B. D., & Hooper, N. M. (2000). Instant Notes in Biochemistry, 2nd Edition Bios Scientific Pub.
3. Rodwell, V. W. et al. (2015), Harper's Illustrated Biochemistry. 30th Edition. New York, N.Y.McGraw-Hill Education LLC.
4. Satyanarayana, U. (2008). Biochemistry. Kolkata, India: 2nd Edition Books and Allied (p) Ltd.

Suggested reading / E-resources

- https://www.extension.harvard.edu/academics/courses/introduction-biochemistry
- https://www.bioc.cam.ac.uk/
- https://libguides.library.usyd.edu.au/

Suggested MOOCs

- https://oli.cmu.edu/jcourse/webui/guest/join.do?section=biochemABSTRACT ALGEBRA
- https://ocw.mit.edu/courses/biology/7-01sc-fundamentals-of-biology-fall-2011/biochemistry/
- https://swayam.gov.in/course/4017-biochemistry

Methods of assessing the course outcomes

Components of CIA: 40 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	1st 2 units	1 1/2 hours	5 (Set for 30)	20
	Test 2	All 5 units	3 hours	15 (Set for 60)	
B	Assignment	-	-	08	
C	Class activity	-	-	12	20
				Grand Total	40
Assignment	• Concept mapping • Group discussion				
Class activity	• Concept based question • Class test				

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19PMBCC102	Core 2: Microbial Cell Biology and Physiology	4 hrs/wk	4 Credits

Course Description:

The course deals with understanding of bacterial and eukaryotic cell with sub-cellular structures. It explains on fundamental concept of electron carriers and allied aspects. The course covers the mechanism of photosynthesis and mechanism of transport system. The course appreciates various aspects of physiological responses in microbes.

Course Purpose:

- To make the students understand the bacterial cell and sub-cellular structures.
- To give student in depth knowledge on fundamental concept of electron carriers and allied aspects
- To make the students understand bacterial photosynthesis and process of it
- To give in depth knowledge on mechanism of bacterial transport system
- To give in depth knowledge on various selected aspects of physiological responses

Course Outcomes: Upon competition of this course the learner will be able to		
CO NO.	**CO statement**	**Blooms Taxonomy Level (K1 to K4)**
CO1	Demonstrate the structures and functions of cell and sub-cellular organelles	K2
CO2	Inspect energy generating mechanisms in bacteria	K4
CO3	Elucidating the transport system of bacteria	K2
CO4	Illustrate the adaptation process of microorganisms during different environmental conditions	K2
CO5	Summarize the aspects of microbial interactions	K2

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Module 1: Cellular Ultra-structure and Cytoskeleton **10 hrs**

- Ultra structure of Cell Wall and Plasma membrane of prokaryotes and eukaryotes
- Prokaryotic cell structures: Capsule, Flagella, Pili, Cell Inclusions and storage materials, Gas vesicles, Spores, Ribosomes
- Cell organelles in eukaryotes
- Cytoskeleton: Ultra structure and functions of Microtubules, microfilaments and associated proteins
- Eukaryotic Cell Cycle – Mitosis and Meiosis

Module 2: Electron Transfer Reactions **10 hrs**

- The Electron Carriers and their organization
- ATPase – structure and function
- Coupling Sites - Q Loops, Q Cycles, and Proton Pumps
- The Chemiosmotic Theory and Electrochemical Energy
- Electron transport chain in Mitochondria

Module 3: Bacterial and Plant Photosynthesis **10 hrs**

- The Structure of Photosynthetic and cell Membranes in Bacteria
- Efficiency of Photosynthesis, Photosynthetic Pigments
- The Transfer of Energy from the Light-Harvesting Pigments to the Reaction Centre
- Photosynthesis in plants
- Photosynthetic mechanism in green sulphur bacteria

Module 4: Transport Systems in Bacteria and Eukaryotes **9 hrs**

- Energy Sources for Transportation
- Energy-Dependent Transport
- Extracellular Protein Secretion
- GERL system
- Protein targeting (to ER and lysosome)

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Module 5: Microbial Physiology **9 hrs**

- Flagella, motility and process of chemotaxis-uptake utilization of substrates
- Sporulation and germination
- Microbial biofilms; physiology and collective recalcitrance of microbial biofilm communities:
- Microbial stress responses: Heat, temperature, pH
- Microbial energy stores - Microbial fuel cells and applications

Text Books:

1. Karp, G. (2009). Cell and Molecular Biology: Concepts and Experiments 6th Edition with Study. John Wiley & Sons.
2. David W, James D, James T. D, Clay F (2012).The Physiology And Biochemistry of Prokaryotes, 4th Ed (illustrated). Oxford University Press, Inc.

Reference Books:

1. Moat, A.G., Foster. J.W., Spector, M.P. (2009). Microbial Physiology, 4th Edition Wiley India Pvt Ltd.
2. S C Rastogi (2010). Cell and Molecular Biology. 3rd Edition New Age Publishers.
3. Nelson, D. L., Lehninger, A. L., & Cox, M. M. (2008). Lehninger principles of biochemistry. Macmillan.Stryer – Biochemistry. 7th edition (1st, 2017 Hard cover). W.H.Freeman & Co.
4. Madigan, M.T., Martinko, J.M., Bender KS et al (2015). Brock Biology of Microorganisms, 14th Edition Pearson San franscisco.
5. Black Jacquelyn G., Black Laura J. (2015). Microbiology: Principles and Exploration, 9th Edition Wiley Publication.
6. Berk, A., Zipursky, S., & Lodish, H. (2000). Molecular Cell Biology. 4th Edition New York: W.H. Freeman

Suggested Reading /E-resources:

- web.iitd.ac.in/~amittal/SBL101_Essentials_Cell_Biology.pdf
- nptel.ac.in/courses/102103012/

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- https://www.coursehero.com/file/21132808/Microbial-Phisiology-and-Genetics-Notes

Suggested MOOCs:

- https://www.pasteur.fr/en/e-learning-mooc
- http://www.edx.org/learn /cellular-biology

Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through

Components of CIA: 40 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 units	$1^{1/2}$ hours	5 (Set for 30)	20
	Test 2	All 5 units	3 hours	15 (Set for 60)	
B	Assignment	-	-	12	20
C	Class activity	-	-	08	
Grand Total					40
Assignment	• Concept mapping (4 M) • Presentation (8 M)				
Class activity	• Group Discussion (4 M) • Activity learning (Think – Pair – Share) (4M)				

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19PMBCC103	Core 3: Microbial Diversity and Evolution	4 hrs / wk	4 Credits

Course Description:

The Course covers theory for knowing microbial evolution process and species concept, classification and phylogeny. The course also gives a detail overview on microbial taxonomy.It also discusses regarding diversity among different groups of bacteria and difference in habitat, morphology, physiology and economical attributes of various group of Archaebacteria. The course also emphasizes on difference in habitat, morphology, physiology and economical attributes of various group of Extremophiles and concept of metagenomics to study uncultivable microorganisms.

Course Purpose:

To make the student understand

- Theories for knowing microbial evolution process, and species concept
- Different techniques of microbial taxonomy and understand phylogeny, phylogenetic tree with its construction mechanism
- The difference in habitat, morphology, various group of eubacteria
- The difference in habitat, morphology, adaptation mechanism and economical attributes of various group of extremophiles and archaebacteria
- The concept of metagenomics to study uncultivable microorganisms

Course Outcomes: Upon competition of this course the learner will be able to		
CO NO.	**CO statement**	**Blooms Taxonomy Level (K1 to K4)**
CO1	Elucidating the concepts of evolution	K2
CO2	Elucidating the diversity of different groups of microbes	K2
CO3	Interpreting different microbial classification systems	K2
CO4	Analyze and Compare diverse adaptive parameters of extremophiles	K2,K4
CO5	Employ the tools for studying the diversity of bacteria	K3

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Module 1: Microbial diversity and Evolution **10 hrs**

- Concepts of microbial evolution – Theories on origin of microbial life on earth
- Chronometers and chronological distances, paradox in establishing evolutionary distances
- Concept of Species and microbial nomenclature
- General concepts regarding biodiversity: Definition, diversity/species richness and species abundance.

Module 2: Microbial Taxonomy **10 hrs**

- Taxonomy, binomial nomenclature Molecular basis of microbial classification: Methods of 16S r-RNA analysis, (Signature Sequence), DGGE, TGGE,ARDRA
- Prokaryotic taxanomy- Classical and Modern (Polyphasic approach, fatty acid profiling)
- Phylogeny, Phylogenetic trees, types and construction of phylogenetic trees
- A brief overview on Bergey's manual of systematic bacteriology
- Tools of Molecular markers studies

Module 3: Diversity of Eubacteria **10 hrs**

- Diversity of Gram positive bacteria
- Diversity of Gram negative bacteria
- Diversity of Actinobacteria
- Diversity of Cyanobacteria and Microalgae

Module 4: Archaebacteria and Extremophiles **8 hrs**

- Introduction to extremophiles
- Habitat, biodiversity, adaptive strategies and biotechnological potential - Thermophiles, Halophiles, Psychrophiles , halophiles, acidophiles and alkalophiles
- Archaebacteria - Distribution of Archaebacteria
- Archaeal cell components & mechanism of adaptation
- Biotechnological potential of Archaebacteria

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Module 5: Metagenomics **10 hrs**

- Concepts and importance of studying uncultivable microorganisms
- Concept of Metagenomics for combined study of cultivable and uncultivable microorganisms
- Diversity studies of unculturable microorganisms
- Sequence based and Function based studies of unculturable microorganisms

Text Books:

1. Joanne W, Linda S, Chris W. (2002). Prescott's Microbiology, 10th Edition, New York: WCB McGraw Hill publication.
2. Madigan, M.T., Martinko, J.M., Bender KS et al (2015). Brock Biology of Microorganisms, 14th Edition Pearson Sanfranscisco.

Reference Books:

1. Horikoshi, K., Antranikian, G., Bull, A.T., Robb, F.T., Stetter, K.O. (2011). Extremophiles Handbook. 1st Edition Springer Japan.
2. Brian K. Hall, Benedikt Hallgrimsson (2014). Strickberger's Evolution, 5th Edition Jones & Bartlett Publishers
3. Ronald M. Atlas and Richard Bartha. Microbial Ecology (1997). Fundamentals and Applications. 4th Edition Pearson Publications.
4. Stanier, R.Y. (1987). General Microbiology. 5th Edition Palgrave Macmillan publication.
5. Joanne W, Linda S, Chris W. (2002). Prescott's Microbiology, 10th Edition, New York: WCB McGraw Hill publication.
6. Tim F. (2007). The Third Domain: The Untold Story of Archaea and the Future of Biotechnology. 1st Edition Joseph Henry Press.

Suggested Reading /E-resources:

- https://www.edx.org/course/extremes-life-microbes-diversity-kyotoux-003x-1nptel.ac.in/courses/102103012/
- https://www.ibiology.org/microbiology/microbial-diversity/
- nptel.ac.in/courses/102103015/34

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Suggested MOOCs:

- https://www.pasteur.fr/en/e-learning-mooc
- https://www.mooc-list.com/course/extremes-life-microbes-and-their-diversity-edx
- https://www.microbe.net/2015/02/22/open-courses-and-course-materials-on-microbiology-of-the-built-environment/

Methods of assessing the course outcomes

Components of CIA: 40 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 units	$1^{1/2}$ hours	5 (Set for 30)	20
	Test 2	All 5 units	3 hours	15 (Set for 60)	
B	Assignment	-	-	10	20
C	Class activity	-	-	10	
				Grand Total	40
Assignment	• Concept mapping (4M) • Unannounced quiz (6M)				
Class activity	• Application card (5 M) • Activity learning (Think – Pair – Share) (5M)				

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19PMBCC104	Core Combined Practical-1 Microbial and Biochemical Techniques	12hrs/wk	6 Credits

Course Description:

The course is designed to give hands on exposure on different experimental aspects of cell biology, microbial diversity and evolution and microbial cell biology and physiology.

Course Purpose:

- To enable the students in designing and performing experiments related to bacterial nutrition and growth and evaluate the effect of various chemicals, antibiotics and physical parameters on bacteria.
- To give the students hands-on experience in techniques for isolation and identification of microbes (bacteria, fungi, algae, virus) from environmental samples
- To understand the metabolic activities of bacteria through experimentation

To identify and perform environmental monitoring based on pre-defined and standard parameters

Course Outcomes: Upon competition of this course the learner will be able to		
CO NO.	**CO statement**	**Blooms Taxonomy Level (K1 to K4)**
CO1	Define the principle, remember the protocol and demonstrate the result of an set of experiments (Expt: 2,8)	K2,K3
CO2	Apply the basic concepts of microbiology in designing experiment and analyzing the obtained data. (Expt: 1,3,12,13,14)	K3,K4
CO3	Perform experiment and analyze the data to evaluate certain parameters and explain its significance. (Expt: 4,5,6,9,10)	K2,K4
CO4	Construct an experiment based on requirements and analyze the result obtained in testing hypothesis or prediction for a well defined purpose **(**Expt: 7,11**)**	K3,K4

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Practicals: Microbial and Biochemical Techniques

Module 1: Microbial Diversity

1. Staining methods for the study of bacterial cell morphology-
   A. Gram Staining
   B. Capsule Staining
   C. Endospore staining
2. Isolation of soil actinomycetes and its identification
3. Isolation and identification of yeast from soil samples
4. Study of antagonism between bacteria or fungi
5. Enumeration of bacteria by viable count technique
6. Enumeration of bacteria by total count technique
7. Isolation and Identification of pH, temperature and salt tolerant bacteria from environmental sources

Module 2: Microbial Physiology

1. Study of Turbidometric growth curve of *E.coli* and derivation of Growth rate & Generation time
2. Study of diauxic growth curve of bacteria
3. Study of motility in bacteria
4. Study of biofilm formation in bacteria by microtiter dish biofilm assay
5. Effect of environmental parameters on bacterial growth

Module 3: Biomolecules

1. Estimation of DNA by DPA Method
2. Estimation of RNA by Orcinol Method
3. Isolation and estimation of Chlorophyll
4. Total Protein quantification by Folin-Lowry Method
5. Total Protein quantification by Bradford Method
6. Estimation of reducing sugar by Coles Method
7. Estimation of reducing sugar by Nelson-Somogyi method
8. Estimation of reducing sugar by Anthrone reagent
9. Determination of Acid value of given Lipid sample
10. Estimation of ascorbic acid from given sample

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Text Books:

1. K. R. Aneja. (2003). Experiments in Microbiology, Plant Pathology and Biotechnology. 4th Revised Edition New Age International.
2. D.K. Maheshwari, and R.C. Dubey. (2014). Practical Microbiology, (Revised Edition). S. Chand & Company Ltd.

Reference Books:

1. Alfred Brown and Heidi Smith. Benson's Microbiological Applications, Laboratory Manual in General Microbiology. 14 edition (October 4, 2016). Complete Version McGraw-Hill Higher Education;
2. Cappuccino, James G., Sherman, Natalie S.1983. Microbiology: A Laboratory Manual. 11th Edition Pearson Publishing.
3. Plummer Mu, David T. (1988). Plummer Introduction to Practical Biochemistry. Tata 3rd Edition McGraw-Hill Education.

Methods of assessing the course Outcomes:

The COs of the course will be assessed through

Components of CIA: 100 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	70% Practical completion	9 Hours 6 Hours = Day 1 3 Hours = Day 2	50 (Set for 100)	50
B	Assignment			20	20
C	Laboratory activity			30	30
				Grand Total	100
Test 1	• Journal = 10M • Viva = 10M • Spotting = 10M • Conceptual questions = 20M				
Assignment	• Assignment 1(MCQ) = 10M • Assignment 2(Protocol submission) = 10M				
Laboratory activity	• Lab Practical Exhibition = 20 M • Application card = (10M)				

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Semester II

19PMBCC201	Core 5: Microbial Genetics	4 hrs/wk	4 Credits

Course Description:

This course encompasses the study of biological systems at the molecular and genetic level. This course is segregated into units elucidating gene and chromosome structure; population genetics; DNA structure, topology, DNA replication; transcription and translation. Furthermore, the course emphasizes on protein trafficking and regulation of gene expression.

Course Purpose:

This course aims to provide understanding of genome, classical genetics and population genetics to students. It also has emphasis on mechanism behind central dogma of molecular biology. This course is designed in such a way that students will be able to comprehend the basic and advanced concepts in molecular biology. It will facilitate students to understand how molecular biology forms the foundation of biotechnology in different research areas.

Course Outcomes: Upon competition of this course the learner will be able to		
CO NO.	**CO statement**	**Blooms Taxonomy Level (K1 to K4)**
CO1	Recall and understand Mendalian and non Mendalian concepts, mechanism of linkage and population genetics	K1, K2
CO2	Explain and apply various gene transfer methods and mutation techniques	K2, K3
CO3	Explain and analyze mechanism behind DNA replication and repair systems	K2, K4
CO4	Explain and compare mechanisms associated with various transcriptional and post transcriptional system with a brief understanding of various types of RNA	K2, K3

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CO5	Discuss and analyze mechanisms behind translation and gene regulation systems	K2, K4

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Module 1: Classical and Population Genetics **10 hrs**

- Mendelian inheritance: Inheritance patterns & Laws of Heredity
- Gene Interaction: Allelic Interaction (Dominance, Incomplete Dominance & Co-Dominance), Non allelic Interaction (Supplementary, Complementary & Duplicative genes, Epistasis)
- Linkage & Linkage Maps
- Sex Determination and Extra Chromosomal Inheritance
- Genetic Drift & Hardy Weinberg Law of equilibrium

Module 2: Gene transfer methods and Mutation **10 hrs**

- Conjugation – Discovery, F plasmid and molecular mechanism
- Transformation –Discovery, types and molecular mechanism
- Transduction - Discovery, types and molecular mechanism
- Recombination (Homologous and non-homologous recombination, Site specific recombination, Chi sequences, FLP/FRT and Cre/Lox recombination)
- Mutagens and Mutation- Types and effects of mutations

Module 3: Replication and Repair **8 hrs**

- Enzymes and accessory proteins involved in DNA Replication
- Replication - Initiation, Elongation and Termination in Prokaryotes
- Replication - Initiation, Elongation and Termination in Eukaryotes
- FidelityofReplication
- DNA repair mechanisms (Mismatch repair, Excision repair, Photo reactivation, Recombinational repair, SOS response and others)

Module 4: Transcription and Post-transcriptional processing **10 hrs**

- Structure and types of RNA - mRNA, rRNA, tRNA, snRNA, miRNA, siRNA, aRNA, tmRNA, lnc RNA, dsRNA and Ribozymes
- Promoters (Types and Strength), Transcription factors, Enhancers, Activators, Repressors and RNA Polymerases
- Prokaryotic and Eukaryotic transcription - Initiation, Elongation andTermination
- Post transcriptional processing (Splicing, 5’ capping, 3’Polyadenylation)
- Export of RNA and RNA stability

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Module 5: Translation, Post-translational modifications and Gene regulation 10 hrs

- Translation - Initiation, Elongation and Termination in Prokaryotes and eukaryotes
- Post-translational modifications
- Transport of proteins, Protein stability, turnover and degradation
- Regulators of gene expression (Activators, Repressors, RNAs, and others)
- Gene Regulation and Gene Expression - Operon concept (lac, trp andara)

Pedagogic tools:

- Chalk and Board
- Presentations
- Videos
- Assignments
- Group discussion

Text Book:

1. Griffiths, A. J. F., Gilbert W. M., Lewontin, R.C.& Miller, J. H. (2002). Modern Genetic Analysis, Integrating Genes and Genomes. 2nd Edition, W. H. Freeman Publishers.
2. Brown, T. A. (2017). Genomes 4. 4th Edition Illustrated, annotated New York Garland science.

Reference Books:

1. Gardner E. J., Simmons M. J., Snustad D. P. (2012) Principles Of Genetics, 8th Edition, John Wiley and Sons Ltd Publication.
2. Weaver, R. (2011). Molecular biology, 5th Edition McGraw Hill Publication.
3. Watson, J. D., Baker, T. A., Bell, S. B., Gann, A., Levine, M., & Losick, R. (2014). Molecular biology of the gene. 7th Edition. New York: Pearson Education.
3. Malacinski G. M. (2008). Freifelder'S Essentials Of Molecular Biology. 4th Edition Narosa Publishers
4. Nelson, D. L., Lehninger, A. L., & Cox, M. M. (2008). Lehninger principles of biochemistry. Macmillan.Stryer – Biochemistry. 7th edition (1st, 2017 Hard cover). W.H.Freeman & Co.
4. Krebs J. E., Goldstein E. S., Kilpatrick S. T., (2017) Lewin's Genes XII. 12th Edition Jones and Bartlett Learning Publishers

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Suggested readings / e-resources:

- https://onlinelibrary.wiley.com/journal/molecular Biology
- https://www.genome.gov/10005911/genetic-education-resources-for-teachers/
- https://learn.genetics.utah.edu/
- https://www.pdfdrive.com/genetics-and-molecular-biology-jhu-biology-dr-robert-schleif-e405976.html

Suggested MOOCs

- https://www.mooc-list.com/tags/molecular-genetics

Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through

Components of CIA: 50 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	All 5 Modules	$2^{1/2}$ hours	15 (Set for 50)	
B	Assignment	-	-	12	30
C	Class activity	-	-	18	
Grand Total					50
Assignment	• Assignment 1: From Module 1 & 2 (6M) • Assignment 2: From Module 3 & 4 (6M)				
Class activity	• Group Discussion: From Module 5 (6M) • Application card : From All Modules (6M) • Quiz/ Case study: From All Modules (6M)				

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19PMBCC202	Core 6: Analytical Techniques	4 hrs/wk	4 Credits

Course Description:

This course introduces learners to various analytical principles and methods encompassing various domains of life sciences. The course describes principles of operation and application of modern instrumentation imparting fundamental knowledge for them. The course is divided into five Modules- microscopy and radioactivity, spectrophotometry, centrifugation and electrophoresis, chromatography and biophysics.

Course Purpose:

The goal of the course is to reinforce theoretical and analytical skills for basic and advanced instrumentation. The course is designed to facilitate students with sufficient comprehension of theoretical approaches which can be analyzed and applied in practical and experimental problem solving.

Course Outcomes: Upon completion of this course, the learner will be able to

CO No.	CO Statement	Blooms taxonomy Level (K_1 to K_6)
CO1	Recall basic principles of instrumentation	K1
CO2	Classify and demonstrate various analytical techniques for biological applications	K2
CO3	Select and utilize appropriate instrumentation method for sample identification, analysis and problem solving	K3, K4
CO4	Explain and interpret data according to application	K2
CO5	Compare and choose between various analytical methods for sample analysis	K1,K2

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Module 1: Microscopy, Radio isotopic and Biophysical techniques 12 hrs

- Microscopic techniques: - Bright field, Dark field, Fluorescent Microscopy, Phase contrast Microscopy, Confocal Microscopy, Polarizing Microscopy, Electron Microscopy (SEM & TEM), Atomic Force Microscopy.
- Radioisotopes & half-life of isotopes; Pattern and Rate of Radioactive Decay; Modules and Measurement of Radioactivity.
- Overview of Radiation Dosimetry, Cerenkov radiation; Applications of isotopes in biologicalstudy.
- Flow Cytometry (FACS)
- Introduction to Biosensors, Principle, Characteristics of Ideal Biosensor, Classification and Applications of Biosensors.

Module2: Spectroscopic Techniques for Quantitative Analysis 8 hrs

- Electromagnetic Radiation: Basic Principles, Interaction of Electromagnetic Radiation with matter, Physical Phenomena of Interaction.
- UV-Visible spectroscopy
- Atomic Absorption Spectroscopy (AAS)
- Flame photometry and Atomic Emission Spectroscopy(AES)
- Circular Dichroism (CD) and Optical Rotatory Dispersion (ORD)

Module3: Spectroscopic Techniques for Structural Analysis 8 hrs

- Infrared (IR/FTIR)
- Raman Spectroscopy
- Magnetic Resonance (NMR) and Electron Spin Resonance (ESR)
- Theory and application of MALDI-TOF
- X-ray Diffraction (XRD) and overview of Crystallography and Energy Dispersive X-Ray Spectroscopy

Module 4: Chromatography Techniques 12 hrs

- Chromatography: Theory and Principle
- Chromatographic Performance Parameters: Dead and Retention time, Retention and Selectivity Factor, , Resolution, Selectivity, Peak shape, Peak broadenings, Column

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efficiency, Theoretical plate model (HETP) and Rate Theory.

- Partition theory: Retention & Differential migration mechanism, Equilibrium between two phases, Properties of solvents (MP), Stationary phase and supporting phase.
- Planar & Column Chromatography: Paper & TLC, HPTLC, Normal and Reverse-phase, Gel permeation, Ion exchange, Adsorption, Partition, Hydrophobic interaction and Affinity chromatography.
- Analytical Chromatography: GC, HPLC, UHPLC.

Module 5: Electrophoresis & Centrifugation 8 hrs

- Electrophoresis: Basic Principles of electrophoresis; Support Media.
- Zone Electrophoresis : Paper electrophoresis, Cellulose acetate electrophoresis, gel electrophoresis (native/denature/gradient PAGE) and 2D electrophoresis
- Moving boundary electrophoresis: Capillary electrophoresis, Immuno electrophoresis
- Centrifugation: Basic principles; Settling Time and Velocity, Types of Rotor, Sedimentation Coefficient, Relative Centrifugal Force (RCF).
- Types of centrifuges of centrifuges: Preparative centrifugation & Analytical centrifugation.

Text Books:

1. Wilson, K., & Walker, J. (2010). Principles and Techniques of Biochemistry and Molecular Biology (7th Edition). Cambridge University Press.
2. Avinash Upadhyay, Kakoli Upadhyay and Nirmalendu Nath (2016). Biophysical Chemistry.4th Edition Himalaya Publishing House Pvt. Ltd.

Reference Books:

1. Mark F. Vitha. (2018).Chromatography: Principles and Instrumentation. Wiley Publishers.
2. Joseph Goldstein, Dale E Newbury, David C Joy (2013). Scanning Electron Microscopy and X-Ray Microanalysis: Third Edition Paperback edition Springer Publishers.
3. Ahluwalia V. K. (2015) Instrumental method of chemical analysis, Ane Books Pvt. Ltd., New Delhi.
   Edward L. Alpen (1990) Radiation Biophysics, 2nd Edition, Academic Press,USA.
4. Veerakumari L. (2015) Bioinstrumentation. Kindle Edition (1st Edition).MJP

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Publishers, Chennai.

Suggested readings / e-resources

- https://study.com/academy/lesson/analytical-chemistry-techniques-methods.html
- https://onlinelibrary.wiley.com/doi/10.1002/9780470277577.ch2
- https://www.pdfdrive.com/handbook-of-spectroscopy-d24195656.html
- https://www.pdfdrive.com/modern-analytical-chemistry-d15015320.html

Suggested MOOCs

- https://www.mooc-list.com/tags/spectroscopy
- https://www.coursera.org/learn/spectroscopy
- https://www.coursera.org/lecture/spectroscopy/nmr-spectroscopy-introduction-XCWRu

Methods of assessing the course outcomes

Components of CIA: 50 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	1st 2 units	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	All 5 units	$2^{1/2}$ hours	15 (Set for 50)	
B	Assignment			12	30
C	Class activity			18	
Grand Total					**50**
Assignment	• Concept mapping: From Module 3 (6M) • Student generated handbook: From all modules (6M)				
Class activity	• One-minute paper: From Module 1 & 2 (6M) • Situation based question: From Module 4 (6M) • Group Discussion: From Module 5 (6M)				

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19PMBCC203	Core 7: Immunology and Medical Microbiology	4 hrs/wk	4 Credits

Course Description:

The course deals with understanding the range of cells involved in immune system and its interaction with pathogens. It explains fundamental concepts deals with host pathogen interaction. The course appreciates the all interactions between pathogen and its host cell.

Course Purpose:

The course aims to provide the basic understanding of immune system with its interaction and applications. It also gives an insight on host parasite interaction. The course also makes the student understand the preventive measures for diseases.

Course Outcomes: Upon competition of this course the learner will be able to		
CO NO.	**CO statement**	**Blooms Taxonomy Level (K1 to K4)**
CO1	Define and describe the cells and organs of immune system and distinguish between innate and adaptive immune responses	K1,K4
CO2	Understand the structure and function of antigens and antibodies, basis of their interaction and carry out diagnostic tests based on these interactions	K2
CO3	Comprehend the molecular basis of transplantation immunology and predict its success in different scenarios	K2
CO4	List out medically important microbes, understand mechanism of their pathogenesis	K1,K2
CO5	Choose prevention and control strategies for pathogens	K3

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Module 1: Basics of Immunology **8 hrs**

- Introduction and types of Immunity: Innate, Acquired, Active and Passive
- Cells of immune systems : Heamatopoiesis, Lymphocytes, Monocytes, Granulocytes Dendritic cells and Mast cells
- Organs of immune systems : Primary & Secondary lymphoid organs
- Antigens: Characteristics types, epitopes, factors affecting antigenicity.
- Antibody: Basic Structures, functions, classes, immunoglobulin variants, mechanism of antibody formation, monoclonal & Polyclonal antibody. Antigen antibody interactions

Module 2: Immune system **9 hrs**

- Immune response : Cell mediated, antibody mediated, MHC, immunological memory Complement system, Hypersensitivity
- Immunology of tissue transplantation : Transplantation immunology, graft acceptance and rejection, clinical manifestation and prevention of graft rejection
- Tumor Immunology : Basics of cancer, Tumor antigens, Tumor evasion of immune system, tumor immunotherapy
- Immunodeficiency diseases [Primary Immunodeficiency (AIDS) and Secondary Immunodeficiency (SCID)],
- Autoimmune diseases - Organ specific (Graves' disease,) Systemic Autoimmune Diseases (Rheumatoid Arthritis).

Module 3: Epidemiology and host–parasite relationship **9 hrs**

- Signs, symptoms and syndrome of disease, stages of infectious diseases
- Infection and their types
- Bacteraemia, septicaemia, pyamia, toxaemia and Viremia
- Host Microbe interaction: Process of Infection, Pathogenicity, Virulence and infection Microbial adherence, Penetration of epithelial cell layers
- Events in infection following penetration, Microbial virulence factors

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Module 4: Medically important organisms 12 hrs

- Identification, pathogenicity, diagnosis and prevention/control of disease caused by the following organisms:
- Gram positive bacteria: *Staphylococci*, *Streptococci*, *Corynebacterium*, *Mycobacterium*, *Bacillus*
- Gram negative bacteria: *Pneumococci*, *Neisseriae* (*Gonococci* & *meningococci*) *Salmonella*, *Shigella*, *Vibrio*, *Enterobacter*, *Clostridium*
- Miscellaneous bacteria: Spirochetes – *Treponema*, *Leptospira*, *Rickettsia*
- Fungus : *Blastomyces*, *Coccodiodomyces*, *Candida*, Opportunistic mycoses *Aspergillus*

Module 5: Disease management and Control 10 hrs

- Epidemic, Endemic, Pandemic, Zoonotic and Exotic, Dynamics of disease transmission: Causative or etiological agents, sources of reservoir of infection
- Protozoa: Protozoan diseases - Malaria, Leishmaniasis and Filariasis
- Viruses : Pox virus, Herpes virus (HSV I & II) Adenovirus, Picorna virus, Orthomyxoviruses, (influenza), Paramyxoviruses (Mumps and Measles), Rhabdoviruses, Hepatitis viruses, HIV, DENV, Ebolavirus
- Drug resistance mechanism
- Vaccines: Conventional and Modernapproaches

Text books:

1. R. Ananthanarayanan and C K Jayaram Panicker (1997) Text of Microbiology, Orient Longman.
2. Owen, J.A., Kuby J, Punt, J., Stranford, S.A. (2013) Kuby Immunology 7th Edition Macmillan Publication.

Reference Books:

1. Abul Abbas Andrew H. Lichtman Shiv Pillai (2017) Cellular and Molecular Immunology 9th Edition, Elsevier Publication
2. Mackie and McCartney (1996) Medical Microbiology, Practical Medical Microbiology Churchill Livingstone.
3. Shanson, D.C., Wright, P.S.G, (1982) Microbiology in Clinical Practice.

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4. Finegold, S.M., Baron, E.J. Bailey, W.R (1990) Bailey and Scott's Diagnostic Microbiology 8th Edition, Published by Mosby, St. Louis, MO.
5. Smith, C.G.C.(1976) Epidemiology and Infections. Medowfief Press Ltd., Shildon, England.
6. Male, D., Brostoff, J., Roth, D.B., Roitt I.V. (2012) Immunology. Elsevier Publication.
7. Rose, N.R. (2002) Manual of Clinical Laboratory and Immunology 6th Edition. ASM Publications.

Pedagogic tools:

- Chalk and Board
- PPT and Videos.
- Assignment

Suggested readings / e-resources

- https://www.immunopaedia.org.za/
- https://study.com/academy/topic/immunology.html
- https://onlinelibrary.wiley.com/journal/immunology

Suggested MOOCs

- https://www.mooc-list.com/course/immune-system-new-developments-research-part-1-edx
- https://www.mooc-list.com/tags/microbiology

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Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through Components of CIA: 40 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 Modules	$1^{1/2}$ hours	5 (Set for 30)	20
	Test 2	All 5 Modules	3 hours	15 (Set for 60)	
B	Assignment	-	-	12	20
C	Class activity	-	-	08	
Grand Total					40
Assignment	• Model Preparation: From All Modules (08M) • Mass Communication: From All Modules (04M)				
Class activity	• Mind Map: From All Modules (08M)				

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19PMBCC204	Core 8: Microbial Metabolism	4 hrs/wk	4 Credits

Course Description:

The course deals with understanding the range of bacterial metabolism (diverse metabolic capabilities) and energy production in the bacterial cell. It explains fundamental concepts deals with enzyme and its mechanism. The course appreciates the all basic metabolic reactions occurs in cell.

Course Purpose:

- To make the students understand the basics of metabolism i.e. energy generation and utilization mechanism
- To give student in depth knowledge on fundamental concept of enzymes with its mechanism and regulation
- TomakethestudentsunderstandtheutilizationofbiomoleculeslikeCarbohydrate, lipid and proteins.

Course Outcomes: Upon competition of this course the learner will be able to		
CO NO.	**CO statement**	**Blooms Taxonomy Level (K1 to K4)**
CO1	Relate different metabolic processes	K1
CO2	Understand regulation of metabolic processes	K2
CO3	Analyze and Interpret the basics of metabolism	K4, K2
CO4	Experiment with various physicochemical parameters to determine their role in biochemical reactions	K3
CO5	Classify the enzymes	K2

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Module 1: Carbohydrate Metabolism **10 hrs**

- Glycolysis and its regulation, ED Pathway
- Pentose phosphate pathway
- TCA cycle, Anaplerotic reactions, Glyoxylate cycle.
- Gluconeogenesis with its regulation
- PHB biosynthesis pathway

Module 2: Lipid Metabolism **10 hrs**

- β-oxidations of saturated even chain fatty acids
- Biosynthesis of bacterial fatty acids
- Biosynthesis of bacterial phospholipids
- Biosynthesis of lipopolysaccharides (LPS)
- Biosynthesis of Isoprenoids

Module 3: Protein and nucleotide metabolism **10 hrs**

- Biosynthesis of amino acids: Glutamate. Aspartate and Tryptophan
- Biodegradation of amino acids: Deamination, Transamination, Decarboxylation
- Nucleotide biosynthesis by Salvage pathway
- Nucleotide biosynthesis by *denovo* pathway
- Regulation of nucleotide biosynthesis pathways

Module 4: Basics of Enzymology **9 hrs**

- Concept of Thermodynamics for enzyme catalyzed reactions
- Enzymes : Definition, properties, specificity, active site, activation of enzymes
- Mechanisms of action of enzymes (lock and key, induced fit, ping-pong)
- Enzymes: classification and nomenclature of enzymes, Enzyme Module, specific activity, turnover rnumber.
- Enzyme kinetics – Single substrate enzyme catalyzed reactions

Module 5: Mechanism of enzyme action **9 hrs**

- Enzyme catalysis: Chemical nature of enzyme catalysis Ex. Lysozyme, Pyruvate Kinase and alcoholde hydrogenase
- Enzyme inhibition: Irreversible, reversible (competitive, uncompetitive, incompetitive) and metabolic antagonism
- Enzyme regulation: allosteric, covalent modification and feedback inhibition

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- Multienzyme: pyruvate dehydrogenase complex, isozymes: lactate dehydrogenase.
- Cooperativity: Positive and Negative

Pedagogic tools:

- Chalk and Board
- PPT and Videos.
- Assignment

Text books

1. Nelson, D. L., Lehninger, A. L., & Cox, M. M. (2008). Lehninger principles of biochemistry. Macmillan. Stryer – Biochemistry. 7th Edition (1st, 2017 Hard cover). W. H. Freeman &Co.
2. Trevor P and Bonner P (2004) Enzymes, 3rd edition. East – West Press Pvt Ltd. New Delhi.

Reference Books:

1. Voet, D. & Voet, J. G. (2011). Biochemistry, 4th Edition (22nd November, 2010). John Wiley & Sons Inc, New York .
2. Mathews, C. K., Van Holde, K. E., & Ahern, K. G. (2000). Biochemistry. 2000. 3rd Edition San Francisco Calif.: Addison-Wesley.
3. Zubay G. L. (1998), Biochemistry, the University of Michigan, Wm. C. Brown Publishers,USA
4. Moat, A.G., Foster. J.W., Spector, M.P. (2009). Microbial Physiology, 4th Ed: Wiley India Pvt Ltd.
5. Copeland Robert A.(2000) Enzymes: A Practical Introduction to Structure, Mechanism, and Data Analysis, 2nd edition, John Wiley & Sons, Inc., Publication
6. Rodwell, V. W. et al. (2015), Harper's Illustrated Biochemistry. 30th ed. New York, N.Y.: McGraw-Hill EducationLLC.
7. Berg, J. M., Tymoczko, J. L., Stryer, L., & Stryer, L. (2002). *Biochemistry*. NewYork: W.H. Freeman.

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Suggested reading / E-resources

- https://www.extension.harvard.edu/academics/courses/introduction-biochemistry
- https://www.bioc.cam.ac.uk/
- https://libguides.library.usyd.edu.au

Suggested MOOCs

- https://oli.cmu.edu/jcourse/webui/guest/join.do?section=biochemABSTR ACT ALGEBRA
- https://ocw.mit.edu/courses/biology/7-01sc-fundamentals-of-biology-fall- 2011/biochemistry/
- https://swayam.gov.in/course/4017-biochemistry

Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through Components of CIA: 40 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 Modules	$1^{1/2}$ hours	5 (Set for 30)	20
	Test 2	All 5 Modules	3 hours	15 (Set for 60)	
B	Assignment	-	-	12	20
C	Class activity	-	-	08	
Grand Total					40
Assignment	• Compilation of metabolic terminologies: From All Modules (8M) • Mass communication: From All Modules (4M)				
Class activity	• Concept map: From Module 5 (8M)				

19PMBCC205	Core 9: Combined Practical 2 Molecular Techniques	8 hrs/wk	4 Credits

Course Description:

The course is designed to give hands on exposure on different experimental aspects of molecular biology, analytical techniques, immunology and medical microbiology and microbial metabolism.

Course Purpose:

The course intended to enable the students in understanding the properties of macromolecules. It also gives the students hands-on experience in different basic and advanced analytical tools and techniques. The course familiarizes students with different immunological and serological tech.

Course Outcomes: Upon competition of this course the learner will be able to

CO NO.	CO statement	Blooms Taxonomy Level (K1 to K4)
CO1	Isolate and purify DNA, RNA, protein (Module 1 : Exp 1,2,3,4)	K3
CO2	Select different analytical tools to demonstrate various techniques (Module 1: Exp 6,7; Module 2: Exp 1,2,3,4,5,6,7; Module 3: Exp 6)	K3, K2, K1
CO3	Perform experiment, analyze the data and explain its significance. (Module 1- Exp - 5,6,7; Module 2- Exp-2,5,6 ; Module 3- Exp: 1,2,3; Module 4- Exp1, 2, 3, 4)	K2, K3, K4
CO4	Understand the different metabolic and immunological interactions **(**Module 3-Exp 4,5,6,7, Module 4- Exp 1,2,3,4**)**	K3, K4

Module 1: Molecular Biology

1. Problems based on Mendelian genetics
2. Problems based on Hardy-Weinberg law
3. DNA Isolation from bacteria
4. Plasmid Isolation
5. Spectrophotometric analysis of nucleic acid (DNA and RNA)
6. Tm value of DNA
7. RNA Isolation

Module 2: Analytical Techniques

1. Separation of cell organelles by sucrose gradient centrifugation
2. Comparative analysis for separation of amino acids in paper and TLC
3. SDS PAGE of protein
4. Demonstration of instrument of High Performance Liquid Chromatography
5. Demonstration of instrument of Atomic Emission Spectroscopy
6. Determination of lambda max of dye
7. Analysis of compound by IR spectroscopic technique(Demonstration)

Module 3: Immunology and Medical Microbiology

1. Total & Differential Count of blood cells
2. Isolation and identification of clinically important microbes from clinical specimens from any two clinical samples (throat swab, sputum, nasal swab, urine, blood, stool)
3. Identification of pathogens on selective, differential and enrichment media
4. Drug susceptibility testing, Kirby Bauer Method
5. Determination of MIC
6. Precipitation reaction and Agglutinations(slide)
    a. ODD
    b. RIA
    c. ELISA
7. Blood grouping and Rh typing

Module 4: Microbial Metabolism

1. Determination of Km and Vmax value of amylase enzyme.
2. To study the effect of pH and temperature on the activity amylase.
3. Effect of Enzyme Inhibitors on Enzyme Activity.
4. Study of various metabolic activities of bacteria: IMViC
5. Carbohydrate fermentation
    - Oxidative Fermentive test
    - Urea hydrolysis
    - H_2 Sproduction
    - Lipid hydrolysis

Reference Books:

1. K. R. Aneja. Experiments in Microbiology, Plant Pathology and Biotechnology. New Age

International, 2007.4th Revised Edition(2003)

2. Alfred Brown and Heidi Smith. Benson's Microbiological Applications, Laboratory Manual in General Microbiology. McGraw-Hill Higher Education; 14 edition (October 4, 2016). Complete Version 14thEdition.
3. D.K. Maheshwari, and R.C. Dubey. Practical Microbiology, (Revised Edition). S. Chand & Company Ltd(2014).
4. Cappuccino, James G., Sherman, Natalie S.1983. Microbiology: A Laboratory Manual. Pearson Publishing.11th Edition.
5. Plummer Mu, David T. Plummer Introduction to Practical Biochemistry. Tata McGraw- Hill Education, 3rd edition(1988).
6. Sambrook, J., Fritsch, E. F., & Maniatis, T. (1989). *Molecular cloning* (Vol. 2, pp. 14-9). New York: Cold spring harbor laboratory press.

Methods of assessing the course Outcomes:

The COs of the course will be assessed through Components of CIA: 100 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	70 % Practical completion	9 Hours 6 Hours = Day1 3 Hours = Day2	50 (Set for 100)	50
B	Assignment			20	20
C	Laboratory activity			30	30
				Grand Total	100
Test 1	• Record book = 10 Marks • Viva = 10 Marks • Spotting = 10 Marks • Problem solving exercise = 20 Marks				
Assignment	• Assignment 1= From Module 1 (10M) • Assignment 2 = From Module 2 (10M)				
Laboratory activity	• Lab Practical Exhibition = From Module 3 (20 M) • Application card = From Module 4 (10M)				

Annexure I

Shree M. & N. Virani Science College (Autonomous), Rajkot

Department of Applied Microbiology

SCHEME OF INSTRUCTION AND EXAMINATIONS

M.Sc. Microbiology

Semester-III									
Course Code	**Course**	**Hrs of Instruction / week**			**Exam Duration (Hrs)**	**Max Marks**			**Credit**
		Th	**Pr**	**Tu**		**CIA**	**SEE**	**Total**	
Part-I : Core Courses (CC)									
Core (Theory)									
19PMBCC301	**Core 10:** Bioinformatics	4	2	-	3	90	60	150	4+1
19PMBCC302	**Core 11:** Industrial Microbiology	4	2	-	3	90	60	150	4+1
19PMBCC303	**Core 12:** Gene Manipulation Techniques	4	2	-	3	90	60	150	4+1
19PMBCC304	**Core 13:** Microbial Ecology (self study)	1	-	-	2.5	50	50	100	3
Discipline Specific Elective Core (DSE-Core)									
19PMBDC301/ 19PMBDC302	**Discipline Specific Elective-** Environmental Microbiology and Biotechnology / Food and Dairy Microbiology	4	2		2.5	50	50	100	4+1
	Project/ Internship/ Training		2		-	-	-	-	2*
Generic Elective (GE)									
19PMBGE01	From common PG Pool	2			-	100	-	100	2
Part-II : Competency Enhancement Courses (CEC)									
.									
CEC- I									
19PMBCE02	Online / Professional certification courses/STC	-			-	Remarks			2

CEC- II							
19PMBCE03	Summer Training	1	-	Remarks			1
Total		**30**				**750**	**28**
Summer Training for a period of 3-4 weeks in the vacation between Semester II and Semester III will be an essential for earning the degree of Masters in Microbiology.							
***For those who want to leave the programme after Semester III. For others the credits will be awarded in semester IV**							
Online/Professional certification course/STC must be completed any time between Semester I-III and details of which must be submitted to CoE in or before Semester IV							

Feedback of faculties over Sem III

Sr No.	Name of faculty member	Course Name	Suggested changes
1	Dr. Nutan Prakash	**Core 10:** Bioinformatics	No change
2	Dr. Mousumi Das	**Core 11:** Industrial Microbiology	No change
3	Dr. Varun Shah	**Core 12:** Gene Manipulation Techniques	No change
4	Dr. Mousumi Das	**Core 13:** Microbial Ecology (self study)	No change
5	Abhijeet Joshi	Generic Elective (GE)	No change
6		Online / Professional certification courses/STC	No change
7		Summer Training	Evaluation norms for 2019 20 are revised

Semester III

18MMBCC301	Core 10: Bioinformatics	4 + 2 hrs/wk	4 + 1 Credits

Course Description:

This course is designed to give students both a theoretical background and a working knowledge of the techniques employed in bioinformatics. The course emphasized on the biological databases, sequence analysis, phylogenetic analysis, structural bioinformatics and drug discovery. Students will gain practical experience with bioinformatics tools and develop basic skills in the collection and presentation of bioinformatics data.

Course Purpose:

This course aims to provide students with a practical and hands-on experience with bioinformatics tools and databases. Students will be trained in the basic theory and application of programs used for database searching, protein and DNA sequence analysis, and prediction of protein structure and function. These principals underlie much of modern bioinformatics, and students will be shown how they apply to many of the basic bioinformatics methods that are of common use in the field.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level(K_1 to K_6)**
CO1	Browse, search, and retrieve biological data from public repositories	**K2**
CO2	Upload new sequences onto GenBank, perform text and sequence-based searches, and analyze the results	**K3**
CO3	Edit raw Sanger sequence data for phylogenetic analysis (edit chromatograms, identify Contamination, align sequences, remove ambiguously aligned sites)	**K4**
CO4	Reconstruct phylogenetic analysis using various tools, interpret the result and produce publication ready trees	**K5**
CO5	Use programs for visualizing and analyzing protein structures.	**K2**

Module 1: Introduction and Bioinformatics Resources **12 hrs**

- Introduction to Bioinformatics: history,role, scope and current perspective.
- Nucleic acid sequence database: GenBank, ENA, DDBJ.
- Protein Resources: SWISS-PROT, TrEMBL, PROSITE, Pfam, PRODOM.
- Structure database: PDB, NDB
- Small Molecule database: DrugBank, PubChem, ZINC

Module 2: Sequence Analysis **12 hrs**

- Biological sequences file formats: genbank, fasta, gcg, msf, nbrf-pir etc.
- Basic concepts of sequence alignment,
- Pair wise alignment- Global, local, dot plot and its applications.
- Words method of alignment- FASTA and its variations, BLAST- Filtered and gapped BLAST
- Multiple sequence alignment: Concept, Algorithm, tools and importance

Module 3: Molecular Phylogeny& primer designing **12 hrs**

- Primer designing
- Definition and description of phylogenetic trees,
- A primer on computational phylogenetic analysis.
- Tree construction methods: distance based; character based
- Tree Evaluation: Bootstrap and its computational aspects

Module 4: Structural Bioinformatics and Drug designing **12 hrs**

- Structural Bioinformatics: Introduction, coordinate systems, Visualization & presentation of structure.
- Secondary structure: algorithms of Chou Fasman, GOR methods.
- Tertiary Structure: Homology modeling, threading method.
- Protein structure Alignment & structure assessment methods
- Introduction to drug discovery: History, analogue and structural drug discovery, ligand designing and optimization, Molecular docking – concept and methods.

Module 5: List of Practicals **24 hrs**

1. Retrieval of biological sequences from major databases
2. Editing of chromatogram, Elimination of contamination and submission of sequence to Genbank
3. Sequence Alignments – Pair wise & multiple sequence alignments
4. Sequence similarity search for a given sequence in biological databases using BLAST and FASTA.
5. Primer Designing
6. Calculate Properties of a protein based on its primary structure using tools at EXPASY molecular Biology Server
7. Find out secondary structure of a protein whose structure is already available at Protein Data Bank (PDB)
8. Protein databank retrieval & Protein Visualization (RASMOL, SPDB VIEWER, PROTEIN EXPLORER)
9. Predict Secondary structure of a protein using Chou & Fasman Method
10. Take a PDB file from PDB bank. Plot the Ramachandran map for the same

Pedagogic tools:

- Chalk and Talk
- Power point presentation
- Animations
- Videos

Text books:

1. Lesk, A. (2014). Introduction to bioinformatics 4th Edition Oxford University Press
2. David W Mount, (2004) Bioinformatics: Sequence and Genome Analysis, 2nd Edition Cold Spring Harbor Laboratory Press

Reference books:

1. Caroline St. Clair, Jonathan E. Visick (2013) Exploring Bioinformatics: A Project-Based Approach 2nd Edition Jones & Bartlett Learning Publication
2. Shui Quing Ye, (2008) Bioinformatics: A practical approach 1st Edition Chapmann & Hall

3. Baxevanis Andreas, D., Davison Daniel, B., Page Roderic, D. M., Petsko Gregory, A., Stein Lincoln, D., & Stormo Gary, D. (2003). Current protocols in bioinformatics. John Wiley & Sons.
4. Higgens, D. G., Taylor, W. R., & Webster, D. M. (2000). Protein Structure Prediction: Methods and Protocols. Springer Science & Business Media.
5. Rastogi, S. C., Rastogi, P., & Mendiratta, N. (2008). Bioinformatics Methods and Applications: Genomics Proteomics and Drug Discovery 3rded. PHI Learning Pvt. Ltd.
6. Baxevanis, A. D., & Ouellette, B. F. (2004). Bioinformatics: a practical guide to the analysis of genes and proteins (Vol. 43). John Wiley &Sons.
7. Xiong, J. (2006). Essential bioinformatics. Cambridge University Press.
8. Eidhammer, I., Jonassen, I. T., William, R., & Inge Jonassen, W. R. T. (2004). Protein Bioinformatics: An algorithmic approach to sequence and structure analysis (Vol. 1). John Wiley& Sons.

Suggested readings / e-resources

- https://www.mrc-lmb.cam.ac.uk/rlw/text/bioinfo_tuto/introduction.html
- https://spdbv.vital-it.ch/TheMolecularLevel/Matics/

Suggested MOOCs

- https://onlinecourses.nptel.ac.in/noc18_bt01/preview
- https://nptel.ac.in/courses/102103044/
- https://nptel.ac.in/courses/105107173/57

Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through

Components of CIA: 90 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	All 4 Modules	3 hours	15 (Set for 60)	
	Practical CIA 1	75% of practical completion	3 hours	30 (Set for 60)	30
B	Assignment	-	-	20	40
C	Class activity	-	-	20	
Grand Total					90
Assignment	• Concept Mapping - 10 • Student generated hand book– 10				
Class activity	• Spot Test at the end of each Practical - 10 • Quiz at the end of each practical session – 10				

18MMBCC302	Core 11: Industrial Microbiology	4 + 2 hrs/wk	4 + 1 Credits

Course Description:

The course is intended to give an overview of fermentation basics, detailed features of constructional design, monitoring and control of fermentors and the applications in industrial level. The course also provides the analysis of sterilization kinetics, automation, and scale up of fermentation process. At lab scale level, upstream and downstream productions steps of few of the important bioactive molecules are also shared in this course in detail.

Course Purpose:

The purpose of the course is to make the students familiarize with fermentation basics, introductory aspects of fermentor & bio-process associated governing parameters. After completion, student should get acquainted with fermentation process development and control during production and should learn the media kinetics, mass transfer of oxygen & other critical parameters affecting sterilization. The students are expected to gain knowledge on upstream and downstream process of selected microbial product and get acquainted practically with techniques like screening, production, assay & recovery at lab scale level.

Course Outcomes: Upon completion of this course the learner will be able to		
CO NO.	**CO Statement**	**Blooms Taxonomy Level (K1to K5)**
CO1	Apply the basics of fermentations; analyze the process of control systems; scale up operations; different upstream and downstream processes ;	**K3,K4**
CO2	Relate the constructional features of different types of fermentors; modes of sterilization; batch, continuous and fed batch fermentations	**K2**
CO3	Apply the knowledge to choose important process parameters at its basic and statistical level with real time operation in any fermentation process	**K3**
CO4	Analyze and compare the different types of fermentors; sterilization operations; fermentation modes; upstream and downstream processes on bioproducts	**K3, K4**
CO5	Apply the practical skill & hypothesize the outcome for microbial fermentation	**K3, K5**

Module 1: Introduction to fermentation 12 hrs

- Fermentation basics: Definition, types of fermentations, screening & preservation of industrial microorganisms
- Strain improvement techniques: Molecular approaches, Directed evolution & selection
- Substrates (C and N sources- synthetic an agro wastes) for microbial Fermentations & associated factors (minerals, buffers, growth factors, antifoam agents) for fermentation
- Media optimization- Types of different media optimization (Basic & statistical designing)
- Fermentation economics (important upstream and downstream process parameters)

Module 2: Bioreactor types and microbial growth kinetics 12 hrs

- Design and construction of bioreactor- body construction, pH, temp, Antifoam, dissolved oxygen control
- Aeration and agitation system –design and types of Baffles and spargers
- Major types of bioreactors (general features in construction and their applications)
- Batch and continuous fermentation – effect of substrate concentration on growth kinetics
- Mass transfer of oxygen, Determination of KLa, factors affecting KLa, fluid rheology

Module 3: Sterilization, automation & product recovery 12 hrs

- Sterilization of media, air and fermentor
- Comparatives study of batch and continuous sterilization
- Instrumentation & control – measuring process variables
- Unit operations in DSP- broth conditioning, ultrasonication, super Critical fluid extraction, applications of chromatography

1. Finishing /polishing of products- crystallization, drying , packaging

Module 4: Product recovery and important microbial products formation 12 hrs

2. Mushrooms
3. Vitamin B12
4. Amino acids: Glutamic acid
5. Xanthan gum (EPS)

6. Immobilization types for whole cells /enzymes and their applications

Module 5: List of Practicals **24 hrs**

- Screening of amylase producing bacteria
- Bioassay of penicillin by *Bacillus subtilis*
- Laboratory fermentation & estimation of Ethyl Alcohol by *Saccharomyces cerevisiae*
- Immobilization of yeast cells by Ca^{2+} alginate entrapment method & Determination of viability of immobilized cells by invertase activity
- Estimation of Citric Acid by Simple Acid Base Titration
- Product enrichment operation – solvent precipitation

Pedagogic tools:

- Chalk and Board
- Presentations
- Videos
- Assignments
- Class activity

Text Books:

1. Patel, A. H. (2015). Industrial Microbiology 2nd Edition Macmillan Publishers India.
2. K. R. Aneja (2017). Experiments in Microbiology, Plant Pathology and Biotechnology. 5th Revised Edition, New Age International Publishers

Reference Books:

- Plummer M., Plummer D. T. Introduction to Practical Biochemistry (2006). 3rd edition, Tata McGraw- Hill Education.
- Shuler M.L. and Kargi F., (2016). Bioprocess Engineering. Basic Concepts.2nd Edition. Pearson Publishing India Education Services Pvt. Ltd.

- Stanbury, P.F., Whittaker, A. and Stephen, H. (2008). Principles of Fermentation Technology, 2nd Edition. Elsevier Publication.
- Waites, M.J., Morgan, N.L., Rockey, J.S., Higton, G. (2001). Industrial Microbiology: An Introduction: 1st Edition Wiley-Blackwell scientific publication
- Prescott and Dunn's Industrial Microbiology (2004) 4th Edition, CBS Publishers & Distributors.
- Okafor N., Okeke B.C. (2018). Modern Industrial Microbiology and Biotechnology 2nd Edition CRC Press Publication.
- Baltz, R.H., Demain, A.L., & Davies, J.E. (2010). Industrial Microbiology & Biotechnology. 3rd edition, ASM Press., Washington DC.
- Mathuriya, A.S. (2009). Industrial Biotechnology. Ane Books Pvt.Ltd. New Delhi.

Suggested readings / e-resources:

- https://epgp.inflibnet.ac.in/ahl.php?csrno=26
- https://www.omicsonline.org/scholarly/industrial-microbiology-journals-articles-ppts-list.php

Suggested MOOCs

- https://www.class-central.com/course/nptel-bioreactors-5801
- https://www.mooc-list.com/course/industrial-biotechnology-coursera
- https://www.mooc-list.com/course/industrial-biotechnology-edx

Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through

Components of CIA: 90 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	All 4 Modules	3 hours	15 (Set for 60)	
	Practical CIA 1	75% of practical completion	3 hours	30 (Set for 60)	30
B	Assignment	-	-	20	40
C	Class activity	-	-	20	
Grand Total					90
Assignment	• Student generated hand book - 10 • Model making - 10				
Class activity	• Concept mapping - 10 • Spot Test at the end of each Practical - 10				

18MMBCC303	Core 12: Gene Manipulation Techniques	4 + 2 hrs/wk	4 + 1 Credits

Course Description:

The course delivers an insight on basic and advanced detailing of cloning tolls, vectors, strategies applied and its assessment criteria for selections of clones. The course intended to deliver few basic and advanced application fields employing genetic engineering for human welfare. The practical's basically covering the some basic and advanced experiments commonly used in genetic engineering studies.

Course Purpose:

The course aims to provide an insight with basics of gene cloning tools, vectors. It familiarizes with cloning assessment techniques. The course gives a basis of the application of genetic engineering in human welfare. Besides this it also provides hands on exposure on technical aspects of genetic engineering.

Course Outcomes: Upon completion of this course the learner will be able to		
CO NO.	**CO Statement**	**Blooms Taxonomy Level (K1to K5)**
CO1	Describe and enlist the tools associated with gene cloning techniques; & application of genetic engineering in human welfare	**K1,K3**
CO2	Illustrate the stages of cloning techniques	**K2,K3**
CO3	Differentiate gene insertion techniques by using DNA marker techniques	**K4**
CO4	Design gene cloning techniques	**K5**
CO5	Interpret the results , apply the experiments and develop skills for handling tools in genetic engineering	**K2,K3,K5**

Module 1: Molecular Tools for Gene Cloning **12 hrs**

- Endo and Exo Nucleases; Restriction Enzymes
- Other Enzymes - Alkaline Phosphatase, Ligase, Reverse transcriptase, DNA Polymerase, Polynucleotide phosphorylase & kinase, Methylase and other modifying enzymes

1. Adaptors & Linkers, Homopolymer tailing
2. Reporter and Marker genes
3. Probe preparation (Radiolabelled & Non-radiolabelled)

Module 2: Cloning Vectors **12 hrs**

- General characteristics of plasmids
- General characteristics of Cloning and Expression Vectors; Shuttle vectors
- pBR 322, pUC19, lambda based vectors, Cosmids, Phagemids, M13

4. BAC and YAC
5. Host (prokaryotic and eukaryotic) systems for expression

Module 3: Cloning Strategies **12 hrs**

1. Genomic library preparation
2. Blue white selection of clones
3. Sequence - (Colony hybridization, PCR and Chromosome walking) based screening methods
4. Function - (Functional activity, Immunological, South-Western and North-Western) based screening methods
5. c-DNA Synthesis & Cloning

Module 4: Advanced Techniques of Genetic Engineering **12 hrs**

1. DNA markers:- RFLP, RAPD, AFLP, micro & minisatellites

- DNA sequencing (Sanger and Maxam Gilbert methods); and Next Generation Sequencing
- CRISPR CAS9 System
- Gene Therapy
- Gene silencing (Antisense RNA, RNA interference); Gene knock out

Module 5: List of Practicals: **24 hrs**

- To prepare insert for cloning
- To prepare vector for Restriction digestion

- To perform Ligation
- To prepare bacterial competent cell
- To perform bacterial Transformation by using Blue – White selection method

Text books:

- S.B. Primrose, R.M. Twyman and R. W. Old. (2013) Principles of Gene Manipulation and Genomics. 7th Edition, (Kindle Ed.)Wiley-Blackwell Publication
- J. Sambrook and D.W. Russell. (2012) Molecular Cloning: A Laboratory Manual, 4th Edition, Volume 1-3, CSHL

Reference Books:

- Dale Jeremy W., Schantz Malcolm von, Plant Nicholas D. (2012) From Genes to Genomes: Concepts and Applications of DNA Technology 3rd Edition. John Wiley and Sons Ltd
- Brown T.A. (2016). Gene Cloning and DNA Analysis: An Introduction, 7th Edition Wiley-Blackwell
- Nicholl Desmond S. T. (2018) An Introduction to Genetic Engineering, 3rd revised Edition, Cambridge University Press.
- Howe Christopher (2015) Gene Cloning and Manipulation 2nd Edition, Cambridge University Press.

Suggested readings / e-resources:

- https://www.journals.elsevier.com/journal-of-genetic-engineering-and-biotechnology

Suggested MOOCs

- https://www.mooc-list.com/course/genomic-technologies-clinical-diagnostics-next-generation-sequencing-futurelearn
- https://www.coursera.org/learn/dna-decoded

Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through

Components of CIA: 90 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	All 4 Modules	3 hours	15 (Set for 60)	
	Practical CIA 1	75% of practical completion	3 hours	30 (Set for 60)	30
B	Assignment	-	-	20	40
C	Class activity	-	-	20	
Grand Total					90
Assignment		• Presentation / Poster - 20			
Class activity		• Quiz - 20			

18MMBCC304	Core 13: Microbial Ecology (self study)	1 hrs/wk	3 Credits

Course Description:

This course deals with basic understanding about distribution of microorganisms, their adaptation and role in different habitats. The course is differentiated into the theoretical modules to cover the interaction of microorganisms with natural and artificial entities.

Course Purpose:

This course intent is to provide better understanding of microorganisms in different habitats and help to student to co-relate its role within it.

Course Outcomes: Upon completion of this course the learner will be able to		
CO NO.	**CO Statement**	**Blooms Taxonomy Level (K1to K5)**
CO1	Differentiate various microbial interactions	**K4**
CO2	Express relationship of microorganisms with biotic and abiotic factors	**K2**
CO3	Subdivide microorganisms as per ecological, morphological and reproductive characteristics	**K4**
CO4	Choose the microbes in controlling of different environmental pollutions	**K3**
CO5	List the name of microbes present in various biogeochemical interactions	**K1**

Module 1: Microbial Life: History, Diversity, Habitat & Ecological Studies

- Introduction: Roots of Microbial Ecology, Characteristics of Microbial Life
- Diversity of Eukarya - Protist, Fungal and Algal Diversity.
- Ecological Niche
- Types of Habitats
- Microbial Ecology Studies: Sampling and Sample Storage

Module 2: Living Together: Microbial Communities

- Microbial community Ecology, Biomat and Biofilm, Dispersal, Succession, and Stability
- Diversity Indices
- Connections between Metazoans and Microorganisms: Co-occurrence Patterns
- Structure of Microbial Food Webs, Effects on Food Webs
- Microbial Community**:** Plankton in Marine Ecosystems, Hot Springs

Module 3: Interactions between Living Worlds

- Microbe–Microbe Interactions**:** Classification of Microbial Interactions
- Interactions between Microorganisms and Plants**:** Mycorrhizae, Nitrogen-Fixing Bacteria and Higher Plants,
- Detrimental Activities of Microorganisms on Plants (Fungal parasites)
- Interactions between Microorganisms and Animals**:** Parasitism, Mutualism, Microbial–Vertebrate Interactions
- Evolutionary and Ecosystem Insights from Deep-Sea Vents Symbioses

Module 4: Microbial Processes Contributing to Biogeochemical Cycles

- Carbon Cycle
- Nitrogen cycle: Nitrification, Denitrification, Ammonification
- Nitrogen fixation
- Sulfur Cycle**:** Organic Sulfur Metabolism, Inorganic Sulfur Metabolism
- Phosphorus Cycle

Module 5: Microbes at Work

- Overview of aerobic / anaerobic biodegradation
- Design and Implementation of Bioremediation**:** Bioreactor, Biofarming
- Commercial leaching methods(Iron and Copper)
- Plant growth promoting bacterial endophytes
- Lignin and cellulose degradation by microbes

Text Books:

1. J McArthur (2006) Microbial Ecology - An Evolutionary Approach, 1st Edition, Academic Press

Reference Books:

- Barton Larry L., Northup Diana E.(2011) Microbial Ecology, 1st Edition Wiley-Blackwell
- Atlas, R.M., Bertha, R. (2002). Microbial Ecology, 4th Edition: Pearson Education India

Suggested readings / e-resources:

- https://aem.asm.org

Suggested MOOCs

- https://www.class-central.com/course/coursera-protists-evolution-and-ecology-of-microbial-eukaryotes-12005
- https://www.class-central.com/course/nptel-applied-environmental-microbiology-10083
- https://www.mooc-list.com/course/extremes-life-microbes-and-their-diversity-edx
- https://www.mooc-list.com/course/introduction-ecosystems-futurelearn

18MMBDC301	Discipline Specific Elective- Environmental Microbiology & Biotechnology	4+2 hrs/wk	4+1 Credits

Course Description:

This course encompasses various aspects of Biotechnological applications in environmental science. The course is segregated into modules throwing lights on theoretical and practical aspects of global environmental issues, solid and liquid waste management, bioremediation and biodegradation strategies, environmental analysis and microbial ecology. Additionally, course also emphasizes on sustainable environmental management through non-conventional technologies like Bioplastics, Biofertilizers and Biofuels.

Course Purpose:

This course intent to provide better understanding of Biotechnological applications and their role in sustainability of environment. It will help students to comprehend more on global environmental issue and their remedies. It will facilitate students to gain knowledge on different solid and liquid waste management methods supported by experiments. Students will able to realize the role of Biotechnology in ecofriendly aspects like Biodegradation, Biofertilizers, Bioleaching and Biofuel. The course is designed in such a way that it will help students to understand microbial aspects of soil, water and air, which will strengthen their fundamental knowledge and career opportunity.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO1	Infer the global issues of environment and their impact on society	K4
CO2	Comply waste management system and apply the same in field	K5, K3
CO3	Summarize the process of biodegradation and remediation	K2
CO4	Interpret existing and emerging technologies that are important in the area of environmental biotechnology	K3
CO5	Design and explain practical approaches of environmental biotechnology	K5

Module 1: Basics of Environmental Biotechnology **12 hrs**

- Introduction to Environmental Biotechnology
- Global environmental problems: Ozone depletion, Greenhouse effect and Acid rain
- Global environmental problems: Eutrophication
- Global environmental problems: Biomagnification
- Assessment of air quality using principles of Sedimentation, Impaction, Impingement, Suction and Filtration.

Module 2: Bioremediation, Biodegradation & Biodeterioration 12 hrs

- Scope and characteristics of contaminants
- Bioremediation: In situ bioremediation; Bioventing, Biosparging and Ex-situ bioremediation
- Degradation of Hydrocarbons**:** Aliphatic hydrocarbons and Aromatic hydrocarbons
- Biodegradation of Xenobiotics, degradation of DDT
- Biodeterioration of Natural and processed material

Module 3: Waste Management 12 hrs

- Solid waste - Sources, generation and classification
- Management methods of solid waste- Land filling, Recycling, Composting, Pyrolysis and Incineration
- Anaerobic digestion and types of digester: Standard rate digester and High rate digester
- Liquid waste - Sources and types of liquid waste
- Treatment schemes for waste water - Aerobic processes: Activated sludge, Trickling filter

Module 4: Application of Environmental biotechnology 12 hrs

- Bioplastic: properties, applications and degradation
- Microbial Enhance Oil recovery
- Algal biofuels
- Potability of water, Microbial assessment of water, Drinking water purification.
- Industrial waste management (Antibiotic, dyestuff, dairy industries)

Module 5: List of Practicals 24 hrs

- Estimation of Sulfate (SO_4^{2-}) of water sample.
- Estimation of Nitrate (NO_3^-) Nitrogen in water sample.

- Determination of Biological oxygen demand (BOD) of sewage sample.
- Determination of chemical oxygen demand (COD) of sewage sample.
- Isolation of the hydrocarbons degrading bacteria.
- Determination of Ca-Mg hardness and alkalinity of water sample.
- Estimation of heavy metals in water/soil by Atomic absorption spectrophotometry (demonstration).

Pedagogic tools:

- Chalk and Board
- Power point presentation
- Videos
- Field visit
- Group discussion

Text books:

1. Rittmann B. and Mccarty P. (2017) Environmental biotechnology. 1st Edition McGraw Hill Education.
2. Chatterji, A. K. (2011). Introduction to Environmental Biotechnology. PHI Learning Pvt. Ltd.

Reference Books:

1. Alexander, M. (1999). Biodegradation and Bioremediation. Academic Press San Diego CA.
2. Jogdand, S. N. (2015). Environmental biotechnology. Himayala Publishing House

Suggested readings / e-resources

- http://www.sense.nl/courses/past/10844520/Advanced-Course-on-Environmental-Biotechnology
- https://onlinecourses.nptel.ac.in/noc18_ce01/preview
- https://www.edx.org/course/creating-a-pro-renewables-environment
- https://ep.jhu.edu/programs-and-courses/575.703-environmental-biotechnology

Suggested MOOCs

- https://www.mooc-list.com/tags/environmental-protection
- https://www.class-central.com/report/swayam-moocs-course-list/

Methods of assessing the course outcomes

Components of CIA: 50 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	First Two Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	First Four Modules	$2^{1/2}$ hours	15 (Set for 50)	
	Practical CIA	All Practicals included in Module V	3 hours	15 (Set for 30)	15
B	Assignment			05	15
C	Class activity			10	
				Grand Total	**50**

Assignment	2. Concept mapping - 5
Class activity	• One-minute paper - 05 • Spot Test (From Module 5) - 05

18MMBDC302	Discipline Specific Elective Food and Dairy Microbiology	4 + 2 hrs/wk	4 + 1 Credits

Course Description:

The course deals with function of microorganisms in food and dairy products. The harmful and beneficial interactions of microbes are enlightened for better understanding and applications of microorganisms in food and dairy products. The course also covers the growth controlling strategies for microorganisms. The course also covers technical aspects to develop skills for isolation, identification of microbes related to food and dairy sectors.

Course Purpose:

This course aims to provide students to get acquainted with basic food quality assurance standards and its implications in industrial level. It also emphasizes to gain knowledge on food processing & packaging techniques associated in food industries. Besides this, the course helps to get aware on different preservation techniques of food and food products and microbial spoilages concerned with it. The course enlightens on nutritional components, preservation techniques, pro and pre biotics associated with dairy food products. The course also provides a platform for practicing with technical aspects of different experiments conducted for isolation, identification, bioassay of food and dairy microbes and the products.

Course Outcomes: Upon completion of this course the learner will be able to		
CO NO.	**CO Statement**	**Blooms Taxonomy Level (K1 to K5)**
CO1	Explain the interactions between microorganisms and the food and milk environment, and factors influencing their growth and survival	**K2**
CO2	Interpret the significance and beneficial activities of microorganisms in food and milk	**K2**
CO3	Distinguish the characteristic identifiable features of food borne diseases and spoilage microorganisms	**K4**
CO4	Choose an appropriate method for food and milk preservation	**K3**
CO5	Evaluate , explain & compare the different technical skills used for food and dairy related microbe cultivation, identification, and assaying of products	**K5, K4**

Module 1: Food Microbiology **12 hrs**

1. Introduction to Food Microbiology
2. Factors affecting interactions of microorganisms with food: intrinsic and extrinsic factors

3. Food quality standards and control system Food industries and QA in production, ISO certifications
4. Microbial flora associated with fresh foods
5. Food standard and safety regulations: BIS, ISI, FSSAI, FDA, CODEX, HACCP

Module 2: Food Processing and Packaging Technology **12 hrs**

1. Scope, importance and principles of food processing.
2. Application of enzymes in food processing
3. Processing of fruits, vegetables, cereals, pulses, meat and fishes
4. Introduction to packaging, principles of development of protective packaging
5. Food additives and adulterants

Module 3: Food spoilage and Preservation **12 hrs**

1. Microbial spoilage of food : Fresh and canned food
2. Microbial types associated with spoilage and biochemical changes
3. Preservation of foods: General principles & methods of food preservation
4. Physical methods: Low temperature, high temperature, osmotic dehydration, blanching, canning, dielectric heating, microwave processing, membrane technology, irradiation.
5. Chemical Methods: preservatives, salts, sugars, antioxidants and spices.

Module 4: Dairy technology **12 hrs**

6. Composition of Milk, types of microbes in milk

- Types of spoilage of milk and milk products
- Milk borne infections affecting human and milking animal.
- Preservation of milk and milk products
- Bioactive foods: prebiotics, probiotics and synbiotics

Module 5: List of Practicals **24 hrs**

- Detection and enumeration of various microbes in processed and unprocessed foods
- Efficiency of pasteurization and sterilization of milk by Phosphatase Test
- Preparation of Cheese, sauerkraut by microbial fermentation process
- Determination of common adulterants in different food sample
- Isolation of *Aspergillus flavus* and detection of aflatoxin from infected peanuts

- Determination of antioxidant activity of citric fruits
- Production and estimation of lactic acid
- Production of Yogurt

Text Books:

- Frazier W. C., Westhoff D. C., Vanitha N.M. (2017). Food Microbiology. 5th Edition Tata McGraw-Hill Publishing Company.
- Cappuccino, J. G. and Sherman, N., (2013) Microbiology: A Laboratory Manual.10th Edition Pearson Benjamin Cummings

Reference Books:

1. Pelczar, M.J., Chan, E.C.S. and N.R. Kreig (2001). Microbiology, 5th Edition. New Delhi: Tata Mc Graw Hill Publishing co. Ltd.
2. Presscott, M.J., Harley, J.P., Klein, D.A. Willey J., Sherwood L., Woolverton C. J. (2017). Microbiology, 10th Edition. New York: WCB Mc GrawHill publication.
3. Smith, S (2010) Food Biotechnology Practical Manual, Deakin University.
4. Jay, J.J., Loessener, M.J., Golden, D.A. (2005). Modern Food Microbiology: Springer publication.
5. Frazier William and Westhoff Denis (2008). Food Microbiology 4th Ed. Tata McGraw-Hill Education
6. Adams M. R. , Moss M. O. (2008) Food Microbiology 3rd Ed. Royal Society of Chemistry

Pedagogic tools:

- Chalk and Board
- Presentations
- Practical
- Videos
- Assignments
- Class activity

Suggested readings / e-resources:

- http://www.milkfacts.info/Milk Microbiology/Milk Microbiology Page

Suggested MOOCs

- https://swayam.gov.in/courses/5147-food-microbiology-and-food-safety
- http://ecoursesonline.iasri.res.in/course/view.php?id=107

Methods of assessing the course outcomes
Components of CIA: 50 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	First Two Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	First Four Modules	$2^{1/2}$hours	15 (Set for 50)	
	Practical CIA	All Practicals included in Module V	3 hours	15 (Set for 30)	15
B	Assignment			05	15
C	Class activity			10	
				Grand Total	**50**

Assignment	3. Concept mapping - 05
Class activity	• One-minute paper - 05

	• Spot Test - 05

Semester- IV									
Course Code	**Course**	**Hrs of Instruction / week**			**Exam Duration (Hrs)**	**Max Marks**			**Credit**
		Th	**Pr**	**Tu**		**CIA**	**SEE**	**Total**	
Part-I: Core									
19PMBCC401	**Core13**: Agricultural Microbiology	4	2	-	3	90	60	150	4+1
19PMBCC402	**Project / Internship/ Training**		18		3	200	100	300	9
Discipline Specific Elective – Core (Theory)									
19PMBDC401 / 19PMBDC402	**Discipline Specific Elective-** Pharmaceutical Microbiology /Advanced Molecular	4	2	-	2.5	50	50	100	4+1
Total		**30**						**550**	**19**
TOTAL OF ALL SEMESTERS								**2600**	**96**

Semester IV

18MMBCC401	Core 13: Agricultural Microbiology	4 + 2 hrs/wk	4 + 1 Credits

Course Description:

The course deals with soil, microorganisms and its interaction with plants. It explains fundamental concepts deals with plant growth promotion and disease control. The course appreciates the practical aspect of plant growth promoting microorganisms and isolation, identification and control of important plant pathogens.

Course Purpose:

The course makes the students understand the basics of soil with its interaction and applications. The course provides the student in depth knowledge on plant growth promotion. It also makes the students understand the behavior of plant after pathogen attack and preventive measures for it.

Course Outcomes: Upon completion of this course the learner will be able to		
CO NO.	**CO Statement**	**Blooms Taxonomy Level (K1 to K5)**
CO1	Show soil and its characteristics	**K3**
CO2	Choose microorganisms in soil as per their role in agriculture	**K3**
CO3	Produce biofertilizer and biopesticides	**K5**
CO4	Differentiate Plant Microbe interaction	**K4**
CO5	Summarize harmful interaction between plant and microbes	**K2**

Module 1: Microbes in Soil **12 hrs**

- Role of Microbes in soil

- Decomposition of organic matter by microorganisms
- Role of Microbes in evaluation and improvement of soil
- Rhizosphere Microorganisms : Phyllosphere, Spermosphere and Rhizoplane
- Factors affecting Rhizosphere Microorganisms

Module 2: Biofertilizer and Biopesticides **12 hrs**

1. Biofertilizer -types, production and quality control.
2. Cultivation and mass production of bioinoculants- Azotobacter, Rhizobium,
3. Phosphate solubilising microorganisms.
4. Carrier-based inoculants -production and applications.
5. Biopesticides –types and applications (*Bacillus thuringiensis, Trichoderma harzianum*)

Module 3: Harmful effect of microbes on plant **12 hrs**

- What is a disease and what causes disease,
- pathogenesis, pathogenesis in relation to environment,
- Recognition and entry of pathogens into host cells
- Alteration of host behavior by pathogen,
- Biochemical basis of plant diseases: Enzymes and toxins in plant diseases, phytoalexins

Module 4: Plant disease mechanism **12 hrs**

- Resistance Mechanism in Plants: Systemic Resistance
- Role of PR and cry Proteins in plant disease control
- Genetics of host-pathogen interactions, resistance genes
- Signaling Mechanisms of plant hormone
- Molecular mechanisms of disease diagnosis

Module 5: List of Practicals **24 hrs**

- Isolation of Siderophore producing microrganisms
- Permanent slide demonstration of VAM
- Isolation of symbiotic Nitrogen Fixation *(Rhizobium sp)*
- Isolation of asymbiotic Nitrogen Fixation *(Azotobacter sp)*
- Production and Quality control of biofertilizer (Azotobacter/ Rhizobium)
- Production and Quality control of Phosphate Solubilizing Microorganisms

- Interactions among soil microorganisms: Antagonistic study using *Trichoderma* sp
- Isolation and characterization of plant pathogen from plants. (Smut/ Rust/ Mildew)

Pedagogic tools:

- Chalk and Board
- Presentations
- Videos
- Assignments
- Class activity

Text Books:

1. Rangaswami, G., Mahadevan, A. (2004). Diseases of Crop plants in India: 2nd Edition PHI publication.
2. K.R. Aneja (2017) Experiments in Microbiology, Plant Pathology and Biotechnology, 2nd Edition New Age Publication.

Reference Books:

1. Purohit, S.S. (2007). Microbiology-Fundamentals and Applications, 6th Edition. New Delhi: Agrobios Publications.
2. Atlas, R.M., Bertha, R. (2002). Microbial Ecology, 4th Edition: Pearson Education India
3. Kowalchuk, G.A., de Bruijn, F., Head, I.M., Van der Zijpp, A.J., van Elsas, J.D. Molecular Microbial Ecology Manual
4. Prescott L.M, Harley J.P. And Klein D.A. (1996) Microbiology 2nd Edition Wm. C. Brown Publishers.
5. R. C. Dubey and D.K. Maheshwari (2002) Practical Microbiology, 2nd Edition,–S. Chand Publications.
6. Dickinson M. (2003). Molecular Plant Pathology, 1st edition, BIOS Scientific Publishers.
7. Alexander, M. (1991). Introduction to soil microbiology, 2nd edition. Krieger Pub Co.
8. W. F. Harrigan Margaret E. McCance (2014) Laboratory Methods in Microbiology, 1st Edition Academic Press.

9. Marylynn V. Yates, Cindy H. Nakatsu, Robert V. Miller, Suresh D. Pillai (2016) Manual of Environmental Microbiology, 4th Edition, American Society for Microbiology.
10. Dhananjaya P. Singh, Harikesh B. Singh, Ratna Prabha (2017) Plant-Microbe Interactions in Agro-Ecological Perspectives Volume 1: Fundamental Mechanisms, Methods and Functions, Springer.

Suggested readings / e-resources:

1. https://www.mooc-list.com/course/understanding-plants-part-i-what-plant-knows-coursera

Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through

Components of CIA: 90 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	Any 2 Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	All 4 Modules	3 hours	15 (Set for 60)	
	Practical CIA 1	75% of practical completion	3 hours	30 (Set for 60)	30
B	Assignment	-	-	20	40
C	Class activity	-	-	20	
Grand Total					90
Assignment		• Assignment 1 • Assignment 2			
Class activity		• Survey report/Map project/Model making/Illustration of steps involved in production of biofertilizer			

Suggested MOOCs

- https://www.agmoocs.in/course/integrated-disease-management

- https://www.agmoocs.in/course/integrated-pest-management-ipm

18MMBDC401	Discipline Specific Elective- Pharmaceutical Microbiology	4 + 2 hrs/wk	4 + 1 Credits

Course Description:

The course deals with role of microbiologist in pharmaceutical industry. The course enlightens the importance of regulatory authorities along with its working protocols and guidelines.

Course Purpose:

Students get acquainted with pharmaceutical technology, industrial requirement of microbial technology with standard operating procedures as per regulatory authorities Drug delivery system and drug resistance mechanism

Course Outcomes: Upon completion of this course the learner will be able to		
CO NO.	**CO Statement**	**Blooms Taxonomy Level (K1 to K5)**
CO1	Explain and differentiate role of different authorities in pharma industries	**K2, K4**
CO2	Play a role in different sectors of pharma industries	**K5**
CO3	Choose differentiate drug delivery systems	**K3**
CO4	Use different parameters for quality analysis	**K3**
CO5	Apply and analyze standard operating procedures for different pharmaceutical products	**K3,K4**

Module 1: Introduction to pharmaceutical industry **12 hrs**

1. Concept of Drugs, Medicine and Active Pharmaceutical Ingredients
2. Overview of key features of Pharmacopoeias in India and United States.
3. Role of Food and Drug Administration in India.
4. Quality Assessment of Water
5. Quality Assessment of Air: AHU

Module 2: Quality Control and Sterilization 12 hrs

6. Microbial contamination and spoilage of sterile pharmaceutical products
7. Type of HEPA
8. Types of Clean room: Class area
9. Types of biosafety cabinets
10. Sterilization: Introduction, significance, sensitivity of microorganisms, detailed methods for sterilization processes.

Module 3: Quality Analysis 12 hrs

11. Standard operating Protocol (SOP)
12. Raw Material QC and Finished Product QC
13. Endotoxin test methods -gel clot assay, turbidometeric assay and chromogenic methods.
14. Endotoxin activity –risk assessment in parenterals manufacture
15. Pyrogen test –depyrogenation methods.

Module 4: Quality Assurance 12 hrs

1. Current Good Manufacturing Practices (cGMP) in pharmaceutical industry
2. Good Laboratory Practices (GLP) in pharmaceutical industry.
16. Quality assurance and quality management in pharmaceuticals: ISO, WHO and US FDA certification.
17. Overview of NABL accreditation of testing labs
18. Calibration and validation of equipments: Concept of IQ, OQ and PQ.

Module 5: List of Practicals 24 hrs

- Sterility testing of pharmaceutical products (sterile injectables and tablets)
- Microscopic analysis of sterile injectables and tablets
- Bacterial Endotoxin Test of pharmaceutical products (Demonstartion)

- Microbial limit test (MLT) of water
- Quality assessment of pharmaceutical products with special reference to regulatory Affairs
- Quality check of HEPA filter using settle plate method
- Design of Standard operating procedures for vitamins assay
- Design of Standard operating procedures for assay of chemical disinfectants.

Text books:

- Stephen P. D., Norman A. H., Sean P. G., Brendan F. G. (2011) Hugo & Russell Pharmaceutical Microbiology 8th Ed. Wiley-Blackwell Publishing house
- Vyas S. P., Dixit V. (2007) Pharmaceutical Biotechnology, CBS Publishers & Distributors
- Mehra Prahlad Singh (2011) A Textbook of Pharmaceutical Microbiology, 1st edition I.K. International Publishing House Pvt. Ltd.

Reference books:

1. World Health Organization. (2010) Handbook: Good Laboratory Practice (GLP): quality practices for regulated non-clinical research and development. World Health Organization.
2. Selvakumar, R. (2010). Good Laboratory Practices. Indian Journal of Clinical Biochemistry. 25 (3): 221-224.
3. Weinberg, S. (2007). Good Laboratory Practice Regulations: CRC Press.
4. Sidney H.W. Murray M. Tuckerman, W., S.Hitchings IV. Mercel D.,(2007) Good Manufacturing Practices for Pharmaceuticals, Second Edition, NC New York
5. Sandle Tim (2015) Pharmaceutical Microbiology: Essentials for Quality Assurance and Quality Control. 1st Edition. Elsevier Publication

Suggested readings / e-resources:

1. https://www.mooc-list.com/course/essentials-good-pharmacy-practice-basics-futurelearn

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Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through

Components of CIA: 50 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	First Two Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	First Four Modules	$2^{1/2}$hours	15 (Set for 50)	
	Practical CIA	All Practicals included in Module V	3 hours	30 (Set for 60)	15
B	Assignment			05	15
C	Class activity			10	
				Grand Total	**50**

Assignment	4. Concept mapping - 05
Class activity	• One-minute paper - 05 • Spot Test - 05

18MMBDC402	Discipline Specific Elective-: Advanced Molecular Techniques	4 + 2 hrs/wk	4 + 1 Credits

Course Description:

The course deals with use and applications of various molecular techniques. The course covers up the steps involved in isolation, purification and characterization of biologically important molecules.

Course Purpose:

To enhance the skills of students in advanced molecular techniques such as PCR, Blotting, ELISA for better understanding and application of biomolecules in research and industries.

Course Outcomes: Upon completion of this course the learner will be able to

CO NO.	CO Statement	Blooms Taxonomy Level (K1 to K5)
CO1	Investigate DNA and Protein characteristics	K4
CO2	Compare and select various techniques used in isolation and purification	K2,K4
CO3	Plan sequential steps in genome analysis	K5
CO4	Evaluate various protein engineering steps	K4
CO5	Produce gene copies using PCR and analyze bimolecule by blotting studies	K4,K5

Module 1: Molecular Techniques for nucleic acids **12 hrs**

- Types of PCR: qPCR, RT PCR
- Hybridization: Southern and Northern; Subtractive Hybridization
- Fluorescence in situ Hybridization
- Microarray, SAGE
- Genomics, Metagenomics, Transcriptomics and Metatranscriptomics studies

Module 2: Molecular Techniques for Proteins, Metabolites and Cells **12 hrs**

- 2D Electrophoresis
- Western Blotting; Protein Sequencing
- ELISA
- Flow Cytometry

- Fluorescence Microscopy for localization studies

Module 3: Techniques for studying molecular interactions 12 hrs

- DNA-RNA interactions, DNA-Protein Interactions and RNA-Protein Interactions
- Gel mobility shift assay, Dnase I foot printing, Sl nuclease mapping,
- Chromatin immunoprecipitation (ChIP)
- Co-immunoprecipitation (CIP),Tandam affinity tags (TAT) and Phage display
- Fluorescent resonance energy transfer (FRET), Yeast-2-hybid and Yeast-3-hybid

Module 4: Advanced Molecular Techniques 12 hrs

- Spectroscopic techniques such as FT-IR
- Mass Spectrometry for analyzing proteins and metabolites
- Application of NMR in biological sciences
- Understanding protein structure by X-ray Diffraction
- Proteomics, Metaproteomics Metabolomics, Fluxomics & Systems Biology

Module 5: List of Practicals: 24 hrs

- To perform DNA finger printing using PCR (RAPD)
- To perform Southern Hybridization
- To perform Western Blotting
- To study Protein crystallization
- To analyze functional groups of a compound using FT-IR spectra.

Text Books:

- T.A. Brown. (2016) Gene cloning and DNA analysis.7th Edition Wiley-Blackwell Publishing Ltd.
- Hofmann A., Clokie S. (2018) Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology 8th Edition Cambridge University Press

Reference Books:

- Strauch M. A (2001) Protein–DNA Interaction: Techniques Used. John Wiley & Sons, Ltd.

- Dale J. W., Schantz M., Plant N. (2011) From genes to genomes.3rd Edition John Wiley & Sons, Ltd.
- Nicola King (2010) Methods in Molecular Biology Real Time PCR Protocols: Vol. No. 630, 2nd Edition Humana Publication
- Neus Visa and Antonio Jordán-Pla (2018) Methods in Molecular Biology Chromatin Immunoprecipitation Protocol: Vol. No. 1689 Humana Publication

Suggested readings / e-resources:

- https://www.futurelearn.com/courses/introduction-to-bacterial-genomics

Methods of Assessing the Course Outcomes:

The COs of the course will be assessed through

Components of CIA: 50 marks

Sr. No.	Component	Content	Duration (if any)	Marks	Sub Total
A	Test 1	First Two Modules	$1^{1/2}$ hours	05 (Set for 30)	20
	Test 2	First Four Modules	$2^{1/2}$hours	15 (Set for 50)	
	Practical CIA	All Practicals included in Module V	3 hours	30 (Set for 60)	15
B	Assignment			05	15
C	Class activity			10	
				Grand Total	**50**

Assignment	5. Case study - 05
Class activity	• One-minute paper - 05 • Spot Test - 05

Suggested MOOCs

- https://nptel.ac.in/noc/individual_course.php?id=noc17-ge04
- https://ocw.mit.edu/courses/health-sciences-and-technology/hst-508-quantitative-genomics

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