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(Accredited by NAAC)

GU/Acad –PG/BoS -NEP/2023/78/3 Date:24.05.2023

Ref: GU/Acad –PG/BoS -NEP/2022/339/13 dated 18.08.22

CIRCULAR

In supersession to the above referred Circular, the updated approved Syllabus with revised Course Codes of the **Master of Sciences in Microbiology** Programme is enclosed.

The Dean/ Vice-Deans of the School of Biological Sciences and Biotechnology/ Principals of Affiliated Colleges offering the **Master of Sciences in Microbiology** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2023.05.24 15:54:22 +05'30'

(Ashwin Lawande)
Assistant Registrar – Academic-PG

To,

1. The Dean, School of Biological Sciences and Biotechnology, Goa University.
2. The Vice-Deans, School of Biological Sciences and Biotechnology, Goa University.
3. The Principals of Affiliated Colleges offering the Master in Sciences in Microbiology Programme.

Copy to:

1. The Chairperson, Board of Studies in Microbiology.
2. The Programme Director, M.Sc. Microbiology, Goa University.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar, PG Examinations, Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

Goa University
P.O. Goa University, Taleigao Plateau, Goa 403 206, India

Syllabus of M.Sc. (Microbiology) Programme

The Programme is meant for students of B.Sc. (Microbiology) to pursue higher studies in Microbiology. It serves to impart advanced training to the students in the field of Microbiology with focus on microbial diversity, bioprospecting and applications of microbes for obtaining various biologically significant metabolites and in bioremediation of polluted environments. Students undergo hands-on training with state-of-the art technologies and are trained so as to develop an aptitude for independent research. The Programme equips students for higher research leading to the Ph.D. Degree in India or in International Universities overseas, or for employment in Research Institutes, in teaching, and in Industry.

Prerequisites: B. Sc. (Microbiology)

Program specific outcomes:

1. Understanding the concepts of microbiology along with the distribution, morphology, physiology and genetics of microorganisms.
2. Learning about the roles and application of microorganisms in diverse fields.
3. Demonstrating the skills in aseptic handling of microorganisms and their processes.
4. Applying good laboratory and good manufacturing practices in microbial processes and products in industries.
5. Identifying ethical issues related to intellectual property rights, biosafety and biohazards.
6. Competence in identifying real world problems and finding innovative solutions by microbiological research leading to entrepreneurship and employment.

CORE COURSES				
CODE	**COURSE**	**CREDIT(S)**		**Contact Hours**
		Theory	**Practical**	
	Semester I			
MIC-500	Microbial Biochemistry [T]	3	-	45
MIC-501	Microbial Biochemistry [P]	-	1	30
MIC-502	Microbial Genetics [T]	3	-	45
MIC-503	Microbial Genetics [P]	-	1	30
MIC-504	Techniques and Instrumentation in Microbiology [T]	3	-	45
MIC-505	Techniques and Instrumentation in Microbiology [P]	-	1	30
MIC-506	Biostatistics [T]	3	-	45
MIC-507	Biostatistics [P]	-	1	30
	Semester II			
MIC-508	Microbial Taxonomy and Systematics [T]	3	-	45
MIC-509	Microbial Taxonomy and Systematics [P]	-	1	30
MIC-510	Industrial Microbiology [T]	3	-	45
MIC-511	Industrial Microbiology [P]	-	1	30
MIC-512	Molecular Biology [T]	3	-	45
MIC-513	Molecular Biology [P]	-	1	30
MIC-514	Archaea – Ecology, Physiology, Biochemistry, and Genetics [T]	3	-	45
MIC-515	Archaea – Ecology, Physiology, Biochemistry, and Genetics [P]	-	1	30

Discipline Specific Elective Courses (DSE)				
CODE	**COURSE**	**CREDIT(S)**		**Contact Hours**
		Theory	**Practical**	
	Semester I			
MIC-521	Environmental Microbiology and Bioremediation [T]	3	-	45
MIC-522	Environmental Microbiology and Bioremediation [P]	-	1	30
MIC-523	Immunology [T]	3	-	45
MIC-524	Immunology [P]	-	1	30
	Semester II			
MIC-525	Agriculture Microbiology [T]	3	-	45
MIC-526	Agriculture Microbiology [P]	-	1	30
MIC-527	Mycology [T]	3	-	45
MIC-528	Mycology [P]	-	1	30

Research Specific Elective courses (RSE)				
CODE	**COURSE**	**CREDIT(S)**		**Contact Hours**
		Theory	**Practical**	
	Semester III			
MIC-600	Research Methodology and Advanced Biostatistics	4	-	60
MIC-601	Microbial Technology [T]	3	-	45
MIC-602	Microbial Technology [P]	-	1	30
MIC-603	Extremophilic Microorganisms [T]	3	-	45
MIC-604	Extremophilic Microorganisms [P]	-	1	30
MIC-605	Aquatic Virology [T]	2	-	30
MIC-606	Introduction to Bioinformatics [T]	2	-	30
	Semester IV			
MIC-607	Marine Microbial Interactions [T]	3	-	45
MIC-608	Marine Microbial Interactions [P]	-	1	30
MIC-609	Medical Virology [T]	3	-	45
MIC-610	Medical Virology [P]	-	1	30

CODE	**COURSE**	**CREDIT(S)**		**Contact Hours**
	Generic Elective courses (GE)	**Theory**	**Practical**	
	Semester III			
MIC-621	Microbial Bioprospecting [T]	4	-	60
MIC-622	Pharmaceutical Microbiology [T]	4	-	60
MIC-623	Genetic Engineering [T]	3	-	45
MIC-624	Genetic Engineering [P]	-	1	30
MIC-625	Food Microbiology [T]	3	-	45
MIC-626	Food Microbiology [P]	-	1	30
MIC-627	Medical Microbiology and Epidemiology [T]	3	-	45
MIC-628	Medical Microbiology and Epidemiology [P]	-	1	30
MIC-629	Marine Microbiology [T]	3	-	45
MIC-630	Marine Microbiology [P]	-	1	30

MIC-631	Entrepreneurship in Microbiology	4	-	60
MIC-632	Field Trip to industries/institutions in Goa	-	1	30
MIC-633	Field Trip to industries/institutions across India	-	1	30
MIC-634	Field Trip to coastal ecosystems and allied industries	-	1	30

	Semester IV			
MIC-651	Discipline Specific Dissertation	-	16	-
MIC-652	Discipline Specific Internship in Industry/Institution	-	2	60

Under Discipline Specific Elective / Generic Elective Course / Research Specific Elective Course theory course is a prerequisite for respective practical course.

Semester I

Core Courses

Title of the Course: MICROBIAL BIOCHEMISTRY [T]

Course Code: MIC-500
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	The student should be familiar with the different biomolecules and their metabolism.	
Objective:	This course deals with the characteristics, properties and biological significance of the biomolecules of life. In depth knowledge of the energetics and regulation of different metabolic processes in microorganisms.	
Content:		
1.	**Biological Molecules**	**(15)**
1.1	**Protein**	**8**
A.	Amino acids: features and properties.	
B.	Protein: structure, principles of separation and purification, molecular weight determination; sequencing and chemical synthesis.	
C.	Enzymes: activity, inhibition, mechanism of action; regulatory – allosteric and covalently modulated enzymes and their significance in metabolism.	
1.2	**Carbohydrate**	**4**
A.	Monosaccharides: types, characteristics and properties.	
B.	Disaccharides, oligosaccharides, polysaccharides – biological significance.	
1.3	**Lipid**	**3**
A.	Fatty acids: saturated and unsaturated, structure and properties.	
B.	Lipids: classification, structure (phospholipids, sphingolipids), properties; biological significance; lipid composition of microorganisms.	
2.	**Bioenergetics and Carbohydrate Metabolism**	**(15)**
2.2	**Bioenergetics**	**3**
	Thermodynamics, exergonic and endergonic reactions, redox potential, high energy compounds, ATP structure and significance.	
2.3	**Oxidative Phosphorylation**	**3**
	Redox enzymes, aerobic electron transport and oxidative phosphorylation, Proton Motive Force	
2.1	**Carbohydrate metabolism**	**9**
A.	Carbohydrates: Central pathways of metabolism – regulatory mechanisms, bioenergetics and significance – EMP, TCA cycle (glucose aerobic and anaerobic metabolism, malate metabolism), Homolactic	

	and Heterolactic acids pathway, Glyoxylate cycle. Utilization of sugars such as lactose, galactose, maltose and of polysaccharides such as starch, glycogen, cellulose, pectin.	
B.	Gluconeogenesis from TCA intermediates / amino acids / acetyl-CoA; biosynthesis of polysaccharides (Peptidoglycan, starch and glycogen) and sugar inter-conversions.	
3.	**Lipids, Amino Acids, Nucleotides and other Metabolic Paths**	**(15)**
3.1	**Lipid Metabolism**	**4**
A.	Catabolism: Oxidation of fatty acids and the bioenergetics involved.	
B.	Anabolism: Biosynthesis of fatty acids: saturated and unsaturated, triglycerides, phospholipids, sterol.	
3.2	**Amino Acid and Nucleotide Biosynthesis**	**4**
A.	Amino acid biosynthetic pathways and their regulation.	
B.	Purine and pyrimidine nucleotides, Deoxyribo nucleotides: biosynthesis and regulation.	
C.	Biosynthesis of nucleotide coenzymes.	
3.3	**Photosynthetic Metabolism**	**3**
A.	Microorganisms and photosynthetic pigments, fundamental processes in Photosynthesis.	
B.	Photosynthetic electron transport; Oxygenic and anoxygenic Photosynthesis; photophosphorylation.	
3.4	**Bioenergetics of Chemolithotrophic microorganisms**	2
3.5	**Antimetabolites of Microbial Origin**	2
	Structure, biosynthesis, types and mechanism of action	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Berg, J.M., Tymoczko, J.L., Gatto, G.J. and Stryer, L. Biochemistry. W. H. Freeman & Company. (2018)	
	Bull, A. T. and Meadow, P., Companion to Microbiology, Longman Group Limited, New York. (1978)	
	Jayaraman, J., Laboratory Manual in Biochemistry, John Wiley & Sons, Limited, Australia. (1981)	
	Lehninger, A., Cox, M. and Nelson, D. L., Principles of Biochemistry, W. H. Freeman & Company. (2021)	
	Moat, A. G., Foster, J. W. and Spector, M. P., Microbial Physiology, A. John Wiley & Sons Inc. Publication. (2003)	
	Murray, R. K., Bender, D. A., Botham, K. M., Kennelly, P. J., Rodwell, V. W. and Weil, P. A., Harper's Illustrated Biochemistry, The McGraw-Hill Companies, Inc. (2018)	
	Plummer, D. T., An Introduction to Practical Biochemistry, Tata McGraw Hill Publishing Company. (2001)	
	Sadasivam, S., Manickam, A., Biochemical Methods, New Age International (P) Limited. (2007)	

	Voet, D., Voet, J. G. and Pratt, C. W., Principles of Biochemistry, John Wiley and Sons Inc. (2018)	
Course Outcomes	● Apply the principles of biochemical processes to microbial physiology. ● Demonstrate the regulation of the biochemical pathway. ● Discriminate metabolic processes applicable to various biomolecules of the microbial origin. ● Explore microorganisms for their microbial products.	

Title of the Course: MICROBIAL BIOCHEMISTRY [P]

Course Code: MIC-501

Number of Credits: 1, Practical

Contact hours: 30

Effective from Academic Year: 2022-23

Prerequisites	The student should be familiar with the different biomolecules and their metabolism.	
Objective:	This course deals with the characteristics, properties and biological significance of the biomolecules of life. In depth knowledge of the energetics and regulation of different metabolic processes in microorganisms.	
Content:		**(30)**
1.	Standard curve for reducing sugar, total sugar and polysaccharide (starch).	
2.	Standard curve for protein (Folin Ciocalteau method).	
3.	Enzyme assay (Amylase), determination of *Km* and *Vmax*.	
4.	Precipitation of protein from solution by salting out and dialysis	
5.	Size exclusion (Gel filtration) chromatography.	
6.	Specific activity, fold purification, percentage yield of enzyme.	
7.	Molecular weight determination by SDS-PAGE.	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Berg, J.M., Tymoczko, J.L., Gatto, G.J. and Stryer, L. Biochemistry. W. H. Freeman & Company. (2018)	
	Bull, A. T. and Meadow, P., Companion to Microbiology, Longman Group Limited, New York. (1978)	
	Jayaraman, J., Laboratory Manual in Biochemistry, John Wiley & Sons, Limited, Australia. (1981)	
	Lehninger, A., Cox, M. and Nelson, D. L., Principles of Biochemistry, W. H. Freeman & Company. (2021)	
	Moat, A. G., Foster, J. W. and Spector, M. P., Microbial Physiology, A. John Wiley & Sons Inc. Publication. (2003)	
	Murray, R. K., Bender, D. A., Botham, K. M., Kennelly, P. J., Rodwell, V. W. and Weil, P. A., Harper's Illustrated Biochemistry, The McGraw-Hill Companies, Inc. (2018)	
	Plummer, D. T., An Introduction to Practical Biochemistry, Tata McGraw Hill Publishing Company. (2001)	
	Sadasivam, S., Manickam, A., Biochemical Methods, New Age International (P) Limited. (2007)	
	Voet, D., Voet, J. G. and Pratt, C. W., Principles of Biochemistry, John Wiley and Sons Inc. (2018)	
Course Outcomes	● Estimation of various biomolecules. ● Separate various biomolecules. ● Discriminate metabolic processes applicable to various biomolecules of the microbial origin.	

	● Explore microorganisms for their microbial products.	

Title of the Course: MICROBIAL GENETICS [T]

Course Code: MIC-502
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students have basic knowledge of Mendelian genetics, structure of DNA and RNA, Prokaryotic and eukaryotic genome organisation, mutation concept, basic knowledge about replication, transcription.	
Objective:	This course develops concept of Classical Mendelian genetics and deviation from Mendelian principles, Microbial genome organization (Prokaryotic and Eukaryotic), Viral Genetics, Mutagenesis and Bacterial plasmids. Understanding the concepts of replication, transcription and their regulation in prokaryotes and microbial eukaryotes.	
Content:		
1.	**Microbial genome organization, gene regulation and genetic transfer**	**(15)**
1.1	Classical Mendelian genetics; deviation from Mendelian principles; Origin of mitochondria and plastids – Endosymbiotic theory, DNA in Mitochondria and plastids, Mitochondrial and plastid genes inherited by Non-Mendelian mechanism; Introduction to epigenetic inheritance.	**4**
1.2	Prokaryotic & Eukaryotic genome size & structure, exceptions in prokaryotic genome (linear chromosome in *Borrelia burgdorferi*); Introduction to synthetic genome (*Mycoplasma genitalium*), pseudogenes and their significance, C-value paradox, polyploidy in prokaryotes. Prokaryotic and Eukaryotic replication, transcription and regulation. Structure of Prokaryotic genes (lac and trp operon) and Eukaryotic Genes (interrupted Genes, intron splicing mechanisms). Microbial gene transfer (Conjugation, transformation, transduction).	**8**
1.3	Genomic organization, replication and regulation of Lytic and Lysogenic Phages - T4 and Lambda Phage	**3**
2.	**Genomic Rearrangements and Mutagenesis**	**(15)**
2.1	Mechanism of General and programmed DNA rearrangements, Antigenic and phase variation in bacteria. Transposons: IS elements – Composite transposons (Tn3, Tn10), Ty, Copia and P type, Mechanism of transposition. Role of transposons in DNA rearrangements, microbial genome evolution and drug resistance. Deletion, duplication, inversion, translocation. Integrons and Genomic islands - pathogenicity islands.	**6**

2.2	**Mutagenesis, mutation and mutants**: Somatic and germinal mutation, spontaneous and induced mutations, site directed mutagenesis using PCR and cassette mutagenesis, and random mutagenesis. Tautomeric shift, transition, transversion; Concept of clustered regularly interspaced short palindromic repeats (CRISPR) - Cas9. **DNA Damage:** Thymine dimer, apyrimidinic site and apurinic site, cross linking, deamination of base, base mismatch. **Types of mutations:** silent mutation, missense mutation, nonsense mutation, Read through mutation, frameshift- insertion and deletion mutation, suppressor mutation, leaky mutation. **Mutagenic chemicals and radiations and their mechanism of action**: Base analogues (5-Bromouracil and 2-amino purines), alkylating agents (EMS, NTG), Intercalating agents (acridines, Acriflavins), Hydroxylamine; mutagenic radiations- UV, X-rays and gamma rays. Ames test; Auxotrophy. Importance of mutations.	**9**
3.	**Fungal Genetics**: Yeast - *Saccharomyces cerevisiae/ Schizosaccharomyces pombe* and *Neurospora* genomes as model genetic systems; Chromosome replication, 2µ plasmid, Yeast Artificial Chromosomes (YAC), tetrad analysis, genetic compatibility and non-compatibility genes, heterokaryosis, Parasexuality, Petite mutants of yeast, Killer yeast.	**(07)**
4.	**Bacterial plasmids**: Types of plasmids, F plasmids and their use in genetic analysis-F^+/Hfr cells/ F'cells, Col plasmids, R plasmids-plasmids with genes encoding metal resistance and antibiotic resistance - efflux pump/MDR bacteria, degradative plasmids, Ti plasmid. Replication in plasmids. Concept of copy number (Col Plasmid) and compatibility; Bacterial plasmids as research tools.	**(08)**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K. and Walter, P., Molecular Biology of the Cell, Garland Science. (2014)	
	Birnboim, H.C. and Doly, J., (1979) A rapid alkaline extraction procedure for screening recombinant plasmid DNA. Nucleic Acid Research, 7: 1513-1523.	
	Dale, J.W. and Park, S.F., Molecular Genetics of Bacteria, John Wiley (2010).	
	Freifelder, D. Molecular biology, a comprehensive introduction to prokaryotes and eukaryotes. JANE'S PUBLISHING INC., BOSTON, MA(USA). (1983).	
	Gardner, E.J., Simmons, M.J. and Snustad, D.P., Principles of Genetics, John Wiley & Sons. (2006).	
	Green, M. R. and Sambrook, J., Molecular Cloning: A laboratory	

	manual, Cold Spring Harbour Laboratory Press, New York. (2014).	
	Holmes, D.S. and Quigley, M., A rapid boiling method for the preparation of bacterial plasmids. Anal Biochem., 114(1): 193-197. (1981)	
	Krebs J.E., Lewin B., Goldstein E.S. and Kilpatrick, S.T., LEWIS Genes XI, Jones and Bartlett Publishers. (2014).	
	Maloy, S. R., Cronan, J. E. and Freifelder, D., Microbial Genetics, Jones and Bartlett Publishers.	
	Peter, J. R., *i*Genetics: A Molecular Approach, Pearson Education. (2016).	
	Sambrook, J., Fritsch, E. F. and Maniatis, T., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York. (1989).	
	Streips, U.N. and Yasbin, R.E., Modern Microbial Genetics, John Wiley. (2004).	
	Snyder, L., Peters, J. E., Henkin, T. M. and Champness, W., Molecular Genetics of Bacteria, ASM Press. (2013)	
	Trun, N. and Trempy, J., Fundamental Bacterial Genetics, John Wiley & Sons. (2003)	
	Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine, M., Losick, R. Molecular Biology of the Gene, Pearson/Benjamin Cummings. (2007).	
Course Outcomes	● Construct the relation between genetic constituents with phenotypic characteristics. ● Explains principles of prokaryotic and eukaryotic genetics, and viral genetics. ● Apply mutagenesis, mutation and mutants for the development of strains. ● Categorize the bacterial and eukaryotic plasmids and mobile elements.	

Title of the Course: MICROBIAL GENETICS [P]

Course Code: MIC-503
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	Students should have basic knowledge of DNA and RNA structure and Prokaryotic and eukaryotic genome.	
Objective:	To learn the basic principles and techniques of microbial genetics.	
Content:		**(30)**
1.	Isolation of genomic DNA from bacteria.	
2.	Isolation of plasmid DNA from bacterial cells by Alkaline Lysis method.	
3.	Spectrophotometric quantification and determination of purity of bacterial plasmid and genomic DNA.	
4.	Agarose gel electrophoresis, visualization and documentation of plasmid and genomic DNA using Gel Doc system.	
5.	UV mutagenesis and screening of pigment deficient mutants of *Serratia marcescens*.	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K. and Walter, P., Molecular Biology of the Cell, Garland Science. (2014)	
	Birnboim, H.C. and Doly, J., (1979) A rapid alkaline extraction procedure for screening recombinant plasmid DNA. Nucleic Acid Research, 7: 1513-1523.	
	Dale, J.W. and Park, S.F., Molecular Genetics of Bacteria, John Wiley (2010).	
	Freifelder, D. Molecular biology, a comprehensive introduction to prokaryotes and eukaryotes. JANE'S PUBLISHING INC., BOSTON, MA(USA). (1983).	
	Gardner, E.J., Simmons, M.J. and Snustad, D.P., Principles of Genetics, John Wiley & Sons. (2006).	
	Green, M. R. and Sambrook, J., Molecular Cloning: A laboratory manual, Cold Spring Harbour Laboratory Press, New York. (2014).	
	Holmes, D.S. and Quigley, M., A rapid boiling method for the preparation of bacterial plasmids. Anal Biochem., 114(1): 193-197. (1981)	
	Krebs J.E., Lewin B., Goldstein E.S. and Kilpatrick, S.T., LEWIS Genes XI, Jones and Bartlett Publishers. (2014).	
	Maloy, S. R., Cronan, J. E. and Freifelder, D., Microbial Genetics, Jones and Bartlett Publishers.	
	Peter, J. R., *i*Genetics: A Molecular Approach, Pearson Education. (2016).	
	Sambrook, J., Fritsch, E. F. and Maniatis, T., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York. (1989).	

	Streips, U.N. and Yasbin, R.E., Modern Microbial Genetics, John Wiley. (2004).	
	Snyder, L., Peters, J. E., Henkin, T. M. and Champness, W., Molecular Genetics of Bacteria, ASM Press. (2013)	
	Trun, N. and Trempy, J., Fundamental Bacterial Genetics, John Wiley & Sons. (2003)	
	Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine, M., Losick, R. Molecular Biology of the Gene, Pearson/Benjamin Cummings. (2007).	
Course Outcomes	● Isolate genomic and plasmid DNA ● Estimate genomic and plasmid DNA ● Separate genomic and plasmid DNA ● Perform mutagenesis for the development of strains.	

Title of the Course: TECHNIQUES AND INSTRUMENTATION IN MICROBIOLOGY [T]

Course Code: MIC-504

Number of Credits: 3, Theory

Contact hours: 45

Effective from Academic Year: 2022-23

Prerequisites	The student should be familiar with the concepts in chemistry and Microbiology.	
Objective:	This course develops the concepts of methodology and instruments involved in studying the different components of microbial cells and their products.	
Content:		
1.		**(15)**
1.1	**Chromatographic techniques:**	**5**
	Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC), detectors, column/s matrix- Ion-exchange, affinity and molecular exclusion. (using examples for separation of microbial lipids, fatty acids, pigments, nucleic acids and proteins/enzymes).	
1.2	**Centrifugation:**	**5**
	Principles, methodology, application, types: low speed, high speed and Ultracentrifugation (preparative and analytical) Density gradient centrifugation; Differential centrifugation	
1.3	**Spectroscopy:**	**5**
	Atomic Absorption Spectrophotometry (AAS), UV-Visible, fluorimetry, Fourier transformation infra-red spectroscopy (FTIR), NMR, MS:MALDI-TOF.	
2.		**(15)**
2.1	**Microscopy:**	**5**
	Phase Contrast, Epifluorescence filter technique (DEFT), SEM, TEM, Confocal and AFM.	
2.2	**Radio-isotope and tracer techniques:**	**5**
	Isotope and types of isotopes, Radio-activity counters, Autoradiography, Radiorespirometry.	
2.3	**Cell and tissue culture techniques:**	**5**
	Biohazards and Biosafety cabinet; Primary and secondary/established cell lines, Monolayer and suspension cultures, Fluorescence activated cell sorting (FACS).	
3.		**(15)**
3.1	**Electrophoretic technique:**	**6**
	PAGE, IEF, Agarose gel electrophoresis, PFGE, DGGE, TGGE, Capillary electrophoresis, Single stranded conformation	

	polymorphism (SSCP), Electroporator, Micro-array technique.	
3.2	**Isolation of cell organelles:**	**6**
	Different methods of cell lysis/ breakage and isolation and purification of various cell organelles - Cell surface structures, cell envelopes, plasma membranes, peptidoglycan, Outer membrane, ribosomes, protoplasts, vesicles, spheroplast, DNA, RNA. Separation of ribosomal subunits of bacteria	
3.3	**Other Bio-Instrumentation Techniques:**	**3**
	X-ray diffraction, Oxygen analyser, Biosensors.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Arora MP.Biophysics, Himalaya Publishing House, New Delhi (2020)	
	Bajpai P.K. Biological Instrumentation & methodology, 2nd revised edition, S.Chand and Co. (2010)	
	Cooper, T. G., The Tools of Biochemistry, Wiley India Pvt. Ltd.	
	Colowick, S. P. and Kaplan, N. O., Methods in Enzymology, Vol. VI, Academic Press, N.Y. (2013)	
	Goswami, C., Paintal, A. and Narain, R., Handbook of Bioinstrumentation, Wisdom Press, New Delhi. (2011)	
	Jayaraman, J., Laboratory Manual in Biochemistry, John Wiley & Sons Limited, Australia. (2011)	
	Mahesh S. Biotechnology-3. Including Molecular Biology and Biophysics, New Age International Pvt. Ltd Publishers, New Delhi. (2018)	
	Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Volume 5, Part B, Academic Press. (1971)	
	Parakhia, M. V., Tomar, R. S., Patel, S. and Golakiya, B. A., Molecular Biology and Biotechnology: Microbial Methods, New India, Pitampura. (2010)	
	Sambrook, J., Fritsch, E. F. and Maniatis, T., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, USA. (2012)	
	Wilson, K. and Walker, J., Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press, N.Y., USA. (2018)	
Course Outcomes	◆ Describe the various techniques and instruments used in study of microoganisms, metabloites, etc. ◆ Interpret the observations collected using various techniques and instruments. ◆ Outline the procedures and techniques used in investigation of microorganisms, metabolite, etc ◆ Plan the strategies for analysis of microbial products.	

Title of the Course: TECHNIQUES AND INSTRUMENTATION IN MICROBIOLOGY [P]

Course Code: MIC-505

Number of Credits: 1, Practical

Contact hours: 30

Effective from Academic Year: 2022-23

Prerequisites	The student should be familiar with the concepts of biochemistry and Microbiology.	
Objective:	This course develops the concepts of various techniques, methodology and instruments involved in studying the microbial cells and their products.	
Content:		**(30)**
1.	Analysis of the microbial cell structure using Phase contrast Microscopy.	
2.	Counting of bacterial cells using epifluorescence microscopy.	
3.	Cell disruption by sonicator and efficacy of sonication.	
4.	Density gradient separation of microbial cells.	
5.	Extraction of microbial pigments and profiling using UV-Vis spectroscopy.	
6.	Silica gel based adsorption chromatography for separation of pigments	
7.	Native Polyacrylamide gel electrophoresis (PAGE) for protein separation and Zymogram (Amylase or Protease).	
8	Demonstration of HPLC, FT-IR, GC and spectral analysis.	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Arora MP.Biophysics, Himalaya Publishing House, New Delhi (2020)	
	Bajpai P.K. Biological Instrumentation & methodology, 2nd revised edition, S.Chand and Co. (2010)	
	Cooper, T. G., The Tools of Biochemistry, Wiley India Pvt. Ltd.	
	Colowick, S. P. and Kaplan, N. O., Methods in Enzymology, Vol. VI, Academic Press, N.Y. (2013)	
	Goswami, C., Paintal, A. and Narain, R., Handbook of Bioinstrumentation, Wisdom Press, New Delhi. (2011)	
	Jayaraman, J., Laboratory Manual in Biochemistry, John Wiley & Sons Limited, Australia. (2011)	
	Mahesh S. Biotechnology-3. Including Molecular Biology and Biophysics, New Age International Pvt. Ltd Publishers, New Delhi. (2018)	
	Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Volume 5, Part B, Academic Press. (1971)	
	Parakhia, M. V., Tomar, R. S., Patel, S. and Golakiya, B. A., Molecular Biology and Biotechnology: Microbial Methods, New India, Pitampura. (2010)	
	Sambrook, J., Fritsch, E. F. and Maniatis, T., Molecular Cloning: A	

	Laboratory Manual, Cold Spring Harbor Laboratory Press, USA. (2012)	
	Wilson, K. and Walker, J., Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press, N.Y., USA. (2018)	
Course Outcomes	◆ Analyse the microbial cell structures. ◆ Examine the microbial metabolites and biomolecules. ◆ Develop various methods for the processing of microbial cells and their products. ◆ Interpret the activities of biomolecules.	

Title of the Course: BIOSTATISTICS [T]

Course Code: MIC-506
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	Basic ability to handle numbers and calculation.	
Objective:	The paper develops concepts about types of data observed in biological experiments, its handling and processing. It develops concepts of hypothesis and formulation of experiments. It gives understanding of various statistical operations needed to carryout and process the biological data.	
Content:		
1.		**(15)**
1.1	**Characteristics of biological data:** Variables and constants, discrete and continuous variables, relationship and prediction, variables in biology (measurement, ranked, attributes), derived variables (ratio, index, rates), types of measurements of biological data (interval scale, ratio scale, ordinal scale, nominal scale, discrete and continuous data).	**4**
1.2	**Elementary theory of errors:** exact and approximate numbers, source and classification of errors, decimal notation and rounding off numbers, absolute and relative errors, valid significant digits, relationship between number of valid digit and error, the error of sum, difference, product, quotient, power and root, rules of calculating digits.	**5**
1.3	**Data handling:** Population and samples, random samples, parameter and statistics, accuracy and precision, accuracy in observations Tabulation and frequency distribution, relative frequency distribution, cumulative frequency distribution. **Graphical representation:** types of graphs, preparation and their applications.	**6**
2.		**(15)**
2.1	**Measures of central tendency:** characteristics of ideal measure, Arithmetic mean – simple, weighted, combined, and corrected mean, limitations of arithmetic mean; Median – calculation for raw data, for grouped data, for continuous series, limitations of median; Mode – computation of mode for individual series, by grouping method, in a continuous frequency distribution, limitations of modes; Relationship between mean, median and mode; mid-range, geometric mean,harmonic mean, partition value, quartiles, deciles, percentiles.	**5**
2.2	**Measure of dispersion:** variability, Range, mean deviation, coefficient of mean deviation, standard deviation (individual observations, grouped data, continuous series), variance, coefficient of variance, limitation.	**6**

	Skewness – definition, positive, negative, purpose, measure, relative measure, Karl Pearson's Coefficient, Bowley's Coefficient, Kelly's Measure, Moments.	
2.3	**Correlation analysis** – Correlation, covariance, correlation coefficient for ungrouped data, Pearson's Rank Correlation coefficient, scatter and dot diagram (graphical method). **Regression analysis -** Linear and exponential function **-** DNSA conversion by reducing sugar, survival/growth of bacteria, regression coefficients, properties, standard error of estimates, prediction, regression analysis for linearequation.	**4**
3.		**(15)**
3.1	Probability: Probability, Combinatorial Techniques, Elementary Genetics, Conditional Probability, Bayes' Rule, Statistical Independence, Binomial, Poisson, Normal Distributions.	**5**
3.2	Hypothesis Testing – parameter and statistics, sampling theory, sampling and non-sampling error, estimation theory, confidence limits testing of hypothesis, test of significance; Students' T-test, t-distribution, computation, paired t-test.	**6**
3.3	Chi-square test, F-test and ANOVA.	**4**
Pedagogy:	Lectures/tutorials/assignments/MOODLE/Videos	
References/ Readings	Arora, P. N. and Malhan, P. K., Biostatistics, Himalaya Publishing House. (2020)	
	Cochran, WG and Snedecor, GW Statistical Methods. Iowa State University Press. (1989)	
	Danilina, N.I., Dubrovskaya, N.S. Kvasha, O.P. and Smirnov, G.L., Computational Mathematics, Mir Publishers. (1988)	
	Kothari, C. R., Quantitative Techniques, Vikas Publishing House. (2013)	
	Surya, R. K., Biostatistics, Himalaya Publishing House. (2018)	
Course outcomes	◆ Collect and process the biological data. ◆ Classify and analyse the biological data. ◆ Choose the statistical tool for biological experiments. ◆ Develop the hypothesis and experimental plan.	

Title of the Course: BIOSTATISTICS [P]

Course Code: MIC-507
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	Basic ability to handle numbers and calculation.	
Objective:	The paper develops concepts about types of data observed in biological experiments, its handling and processing. It develops concepts of hypothesis and formulation of experiments. It gives understanding of various statistical operations needed to process the biological data.	
Content:		**(30)**
1.	Excel spreadsheet and data analysis	
2.	Linear equation analysis (regression analysis).	
3.	Normal distribution.	
4.	Hypothesis testing (T Test, Z test)	
5.	Application of other software (graphpad / systat) for statistical analysis	
Pedagogy:	Experiments in the laboratory, data collection and processing.	
References/ Readings	Arora, P. N. and Malhan, P. K., Biostatistics, Himalaya Publishing House. (2020)	
	Cochran, WG and Snedecor, GW Statistical Methods. Iowa State University Press. (1989)	
	Danilina, N.I., Dubrovskaya, N.S. Kvasha, O.P. and Smirnov, G.L., Computational Mathematics, Mir Publishers. (1988)	
	Kothari, C. R., Quantitative Techniques, Vikas Publishing House. (2013)	
	Surya, R. K., Biostatistics, Himalaya Publishing House. (2018)	
Course outcomes	◆ Collect and process the biological data. ◆ Classify and analyse the biological data. ◆ Choose the statistical tool for biological experiments. ◆ Develop the hypothesis and experimental plan.	

Semester II

Title of the Course: MICROBIAL TAXONOMY AND SYSTEMATICS [T]

Course Code: MIC-508

Number of Credits: 3, Theory

Contact hours: 45

Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students should have a basic understanding of binomial nomenclature, the basis of classification systems and be familiar with the distinguishing features of different groups of microorganisms.	
Objective:	To introduce the concepts, tools and techniques of taxonomy and systematics of the microbial world. To introduce the salient features of various microbial groups and their underlying diversity.	
Content:		
1.		**(30)**
1.1	**Microbial taxonomy and systematics** Concepts of taxonomy (characterization, classification and nomenclature) and systematics; binomial classification and taxonomic hierarchy of microorganisms, three domain, six-kingdom, 8-kingdom systems, Endosymbiotic theory.	**7**
1.2	**Phenotypic characters** - Morphology, Biochemical tests (e.g. API, BIOLOG), Bacteriophage typing, Serotyping.	**5**
1.3	**Chemotaxonomic markers** - Cell wall components, lipid composition, cellular fatty acid (FAME analysis), isoprenoid quinones, protein profiles (e.g. MALDI-TOF), cytochrome composition, polyamines.	**8**
1.4	**Nucleic acid based techniques** – T-RFLP, G+C content (T_m and HPLC); 16S rRNA / 18S rRNA / ITS gene sequencing; phylogenetic analysis; DNA-DNA hybridization; DNA barcoding.	**6**
1.5	Concepts of species, numerical taxonomy and polyphasic taxonomy.	**4**
2.	Salient features of phylum, class and orders with representative examples of the following – Archaea, Eubacteria (bacteria, cyanobacteria, actinomycetes), Mycota, Protista (algae, protozoa, diatoms); and viruses.	**(15)**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Barlow, A., The prokaryotes: A Handbook on the Biology of Bacteria: Ecophysiology, Isolation, Identification, Applications, Volume 1, Springer-Verlag. (1992)	
	Goodfellow, M. and Minnikin, D. E., Chemical Methods in Bacterial Systematics, The Society for Applied Bacteriology. Technical Series No. 20, Academic Press. (1985)	

	Goodfellow, M., Mordarski, M. and Williams, S. T., The biology of the actinomycetes, Academic Press. (1983)	
	Kurtzman, C. P., Fell, J. W. and Boekhout, T., The Yeasts - A Taxonomic Study, Elsevier. (2011)	
	Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Vol. 18 & 19, Academic Press. (1971)	
	Prescott, L. M., Harley, J. P. and Klein, D.A., Microbiology. McGraw Hill, New York. (2020)	
	Reddy, C. A., Methods for General and Molecular Microbiology, ASM Press. (2007)	
	Sneath, A. H. P., Mair, S. N. and Sharpe, E. M., Bergey's Manual of Systematic Bacteriology Vol. 2. Williams & Wilkins Bacteriology Symposium, Series No 2, Academic Press, London/New York. (2004)	
Course Outcomes	◆ Associate the standard rules of classification systems to categorize microorganisms. ◆ Discuss the dynamic and developing nature of the field of microbial taxonomy and systematics. ◆ Classify the microorganisms on the basis of their characters. ◆ Appraise the applications of taxonomic tools.	

Title of the Course: MICROBIAL TAXONOMY AND SYSTEMATICS [P]

Course Code: MIC-509
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students should have a basic understanding of binomial nomenclature, the basis of classification systems and be familiar with the distinguishing features of different groups of microorganisms.	
Objective:	To understand the tools and techniques of taxonomy and systematics of the microbial world.	
Content:		**(30)**
1.	Morphological, physiological and biochemical characterization of bacteria.	
2.	Chemotaxonomic analysis of cell wall amino acids.	
3.	Characterization of actinomycetes (*Streptomyces* sp.).	
4.	Characterization of yeast (*Saccharomyces cerevisiae*, *Schizosaccharomyces pombe*).	
5.	Characterization of cyanobacteria.	
6.	Phylogenetic analysis of bacterial 16S rRNA sequences – retrieval of sequences from standard databases, BLAST analysis, construction of phylogenetic tree using bioinformatics tools.	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Barlow, A., The prokaryotes: A Handbook on the Biology of Bacteria: Ecophysiology, Isolation, Identification, Applications, Volume 1, Springer-Verlag. (1992)	
	Goodfellow, M. and Minnikin, D. E., Chemical Methods in Bacterial Systematics, The Society for Applied Bacteriology. Technical Series No. 20, Academic Press. (1985)	
	Goodfellow, M., Mordarski, M. and Williams, S. T., The biology of the actinomycetes, Academic Press. (1983)	
	Kurtzman, C. P., Fell, J. W. and Boekhout, T., The Yeasts - A Taxonomic Study, Elsevier. (2011)	
	Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Vol. 18 & 19, Academic Press. (1971)	
	Prescott, L. M., Harley, J. P. and Klein, D.A., Microbiology. McGraw Hill, New York. (2020)	
	Reddy, C. A., Methods for General and Molecular Microbiology, ASM Press. (2007)	
	Sneath, A. H. P., Mair, S. N. and Sharpe, E. M., Bergey's Manual of Systematic Bacteriology Vol. 2. Williams & Wilkins Bacteriology Symposium, Series No 2, Academic Press, London/New York. (2004)	
Course Outcomes	◆ Associate the standard rules of classification systems to categorize microorganisms.	

	◆ Classify the microorganisms on the basis of their characters. ◆ Appraise the applications of taxonomic tools. ◆ Identify the microorganisms.	

Title of the Course: INDUSTRIAL MICROBIOLOGY [T]

Course Code: MIC-510
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	Basic knowledge about the types of microbes and their products of industrial relevance. Knowledge of microbial biochemistry, physiology, genetics and statistics.	
Objective:	To comprehend concepts of the processes, instruments, management and quality used in the industries to produce the products using microorganisms.	
Content:		
1.		**(15)**
1.1	History of Industrial Microbiology, fermentation processes, descriptive layout and components of fermentation process for extracellular and intracellular microbial products.	**4**
1.2	Microbial growth kinetics: Batch kinetics – Monod's model (single substrate), deviations from Monod's model, dual substrates – sequential utilization, multiple substrates – simultaneous utilization, substrate inhibition, product synthesis (primary and secondary metabolite), toxic inhibition, death constant.	**5**
1.3	Microbial growth kinetics: Fed-batch kinetics – fixed volume, variable volume and cyclic fed-batch, applications and examples of fed-batch systems. Continuous cultivation system – relationship between specific growth rate (μ) and dilution rate, multistage systems, feedback systems (internal and external feedback), applications and examples of continuous cultivation system; comparison between various cultivation systems.	**6**
2.		**(15)**
2.1	Optimization and modeling of fermentation process – single variable design, multivariate screening designs, critical factor analysis, optimization designs for two or more factor, singlet method; Metabolic and flux control analysis.	**4**
2.2	**Bioreactor design and operation:** classification of reactors; Ideal mixed v/s plug flow reactor; designing parameters for reactors (stirred tank reactor, airlift reactor, plug flow reactor), rheology of fermentation broth.	**6**
2.3	**Bioreactor design and operation:** gas-liquid mass transfer, heat transfer, analysis of dimension less parameters and their application (aeration number, power number and Reynold's	**5**

	number; Scale-up of bioprocesses: parameters used in scale-up and problems associated with scale-up.	
3.		**(15)**
3.1	**Solid substrate fermentation (SSF):** Principles and application; Comparison between SSF and Submerged Fermentation (SmF), Bioreactor for SSF. Problems in fermentation process and handling (foam, contamination, strain degeneration, etc), Immobilized enzymes and cell systems.	**4**
3.2	**Fermentation monitoring and control:** Common measurement and control systems (speed, temperature, gas, pH, Dissolved oxygen, foam, redox, air flow, weight, pressure, biomass), On-line and off-line analysis, Digital controllers, control algorithm, flow charting, incubation control, advanced fermentation control and computer-based automation of process.	**5**
3.3	**Industrial scale Down-stream processing and product recovery**: principle and general description of instrumentation, Recovery of particulates (cells and solid particles), recovery of intracellular products, primary isolation (extraction, sorption), precipitation, industrial processes for chromatography and fixed bed adsorption, membrane separations; Type Processes - Antibiotic (Penicillin including semi-synthetic), Ethanol.	**6**
Pedagogy:	Lectures/tutorials/assignments/Moodle/Videos	
References/ Readings	Atkinson, B. and Mavituna, F., Biochemical Engineering and Biotechnology Handbook, Stockton Press. (1991) Demain, A. L., Davies, J. E. and Atlas, R. M. Manual of Industrial Microbiology and Biotechnology, ASM Press. (1999) Flickinger, M. C. and Drew S. W., The Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis and Bioseparation, Volumes 1 - 5, John Wiley Publisher. (1999) Stanbury, P. F., Whitaker, A. and Hall, S.J., Principles of Fermentation Technology, Butterworth-Heinemann Publishers. (2016) Vogel, H. C. and Tadaro, C. M., Fermentation and Biochemical Engineering Handbook: Principles, Process Design and Equipment, William Andrew Publisher. (2014)	
Course Outcomes	◆ Discuss management and controls on the microbial processes in industrial settings. ◆ Develop microbial processes in research and industrial settings. ◆ Connect physiological principles in improvement of the industrial processes. ◆ Formulate the strategies for microbial product and process development.	

Title of the Course: INDUSTRIAL MICROBIOLOGY [P]

Course Code: MIC-511
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	Basic knowledge about the types of microbes and their products of industrial relevance. Knowledge of microbial biochemistry, physiology, genetics and statistics.	
Objective:	Development of concepts in the processes, instruments, management, quality, etc.being used in the industries to produce the products using microorganisms.	
Content:		(30)
1.	Designing of fermentor – stirred tank reactor.	
2.	Fermentation kinetics – growth of *E.coli/S.cerevisiae* and determination of μ_{max}, Ks, Yx/s, m.	
3.	Rheology of substrate solutions.	
4.	Immobilization of microbial cells using alginate.	
5.	Baker's yeast – ISI/BSI quality assurance.	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Atkinson, B. and Mavituna, F., Biochemical Engineering and Biotechnology Handbook, Stockton Press. (1991) Demain, A. L., Davies, J. E. and Atlas, R. M. Manual of Industrial Microbiology and Biotechnology, ASM Press. (1999) Flickinger, M. C. and Drew S. W., The Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis and Bioseparation, Volumes 1 - 5, John Wiley Publisher. (1999) Stanbury, P. F., Whitaker, A. and Hall, S.J., Principles of Fermentation Technology, Butterworth-Heinemann Publishers. (2016) Vogel, H. C. and Tadaro, C. M., Fermentation and Biochemical Engineering Handbook: Principles, Process Design and Equipment, William Andrew Publisher. (2014)	
Course Outcomes	◆ Discuss management and controls on the microbial processes in research and industrial settings. ◆ Develop microbial processes in research and industrial settings. ◆ Connect physiological principles with the industrial processes. ◆ Evaluate quality of microbial product and process.	

Title of the Course: MOLECULAR BIOLOGY [T]

Course Code: MIC-512
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that the students have a basic knowledge of DNA (structure and replication), transcription and protein synthesis	
Objective:	To enhance the comprehension of concepts in molecular biology.	
Content:		
1.	**Chromosome architecture and eukaryotic DNA replication**	**(15)**
1.1	**Nucleic acids, types of DNAs and DNA packaging**	**4**
A.	Structure of DNA and RNA.	
B.	Types of DNA (A-DNA, B-DNA, Z-DNA and triplex DNA) and their structural characteristics.	
C.	DNA packaging in bacteria (nucleoid) and viruses.	
1.2	**Chromosomes, genomes and their evolution**	**5**
A.	Fundamental functions of DNA.	
B.	Chromosomal DNA and its packaging in the chromatin fibre, chromatin organization.	
C.	Structural features (telomere, centromere and repetitive sequences) of chromosomes and their functions. Lampbrush and polytene chromosomes.	
D.	Evolution of genomes, paralogous and orthologous evolution of duplicated genes	
1.3	**DNA replication in eukaryotes**	**6**
	DNA replication in the context of the cell cycle; Structure and functions of eukaryotic DNA polymerases, functions of other enzymes (helicase, gyrase, topoisomerase, primase, ligase, telomerase); Steps involved in DNA replication; Similarities and differences between prokaryotic and eukaryotic DNA replication.	
2.	**DNA damage, repair and recombination**	**(15)**
2.1	**DNA damage and repair mechanisms**	**8**
A.	Types of DNA damage: spontaneous and induced DNA damage.	
B.	Mechanisms / pathways to remove damaged DNA: Excision repair, mismatch repair, recombination repair, SOS Repair, photoreactivation repair.	
2.2	**Mechanisms of genetic recombination**	**7**
A.	General and site-specific recombination.	
B.	Homologous recombination, Non-homologous end joining (NHEJ).	
C.	Synaptonemal complex, Bacterial RecBCD system and its stimulation of chi sequences.	
D.	Role of RecA / RAD51 in repair and recombination	

3.	**Gene expression and its regulation in prokaryotes and eukaryotes**	**(15)**
A.	The central dogma concept, DNA to RNA to protein	**1**
B.	The RNA world and the origin of life.	**2**
C.	An overview of gene expression control, DNA binding motifs in gene regulatory proteins, genetic switches and their role in the control of gene expression, combinatorial gene control.	**2**
D.	Structure and function of prokaryotic and eukaryotic RNA: Prokaryotic and eukaryotic mRNA, tRNA, rRNA and ribosomes, processing of eukaryotic hnRNA, snRNA.	**2**
E.	Post-transcriptional controls: Transcriptional attenuation, riboswitches, alternate splicing, RNA editing, RNA interference.	**3**
F.	Synthesis and processing of proteins: The genetic code, aminoacylation of tRNA, mechanism of protein synthesis, translational proof-reading, translational inhibitors.	**3**
G.	Protein folding, post-translational modifications of proteins, leader sequences, protein localization and secretion.	**2**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Alberts, B., Heald, R., Johnson, A., Morgan, D., Raff, M., Roberts, K., Peter Walter, P., Molecular Biology of the Cell. WW Norton & Co. (2022).	
	Darnell, J. E., Lodish, H. F. and Baltimore, D., Molecular Cell Biology, Scientific American Books, Spektrum Akademischer Verlag. (1990)	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier (1986).	
	Gardner, E. J., Simmons, M. J. and Snustad, D. P. Principles of Genetics, John Wiley & Sons (2006).	
	Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier (1994).	
	Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York (2014).	
	Krebs, J.E., Krebs J.E., Lewin B., Goldstein E.S. and Kilpatrick, S.T., LEWIS Genes XII, Jones and Bartlett Publishers (2018)	
	Malacinski, G.M., Freifelder's Essentials of Molecular Biology, Narosa Book Distributors Private Limited (2008).	
	Tamarin, R. H., Principles of Genetics, McGraw-Hill Higher Education (2017).	
	Twyman, R. M. and Wisden, W., Advanced Molecular Biology: A Concise Reference, Garland Science (1998).	
	Watson, J. D., Molecular Biology of the Gene, Pearson/Benjamin Cummings (2007).	
Course Outcomes	◆ Classify genome and gene structure. ◆ Summarize the regulation of gene expression in both prokaryotes and eukaryotes. ◆ Explain DNA damage and repair. ◆ Connect genomics to expressed proteins.	

Title of the Course: MOLECULAR BIOLOGY [P]

Course Code: MIC-513
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that the students have a basic knowledge of DNA (structure and replication), transcription and protein synthesis	
Objective:	This course develops concepts in molecular biology: DNA packaging, DNA damage and repair, gene structure, expression and regulation in both prokaryotes and eukaryotes	
Content:		**(30)**
1.	Isolation of genomic DNA of eukaryotic microorganisms, estimation of quantity and purity of DNA by spectrophotometry, and agarose gel electrophoresis.	
2.	Recovery of genomic DNA from agarose gel.	
3.	Extraction of mRNA / total RNA.	
4.	cDNA synthesis from mRNA.	
5.	PCR amplification of a specific gene using genomic DNA as a template and agarose gel analysis of PCR product to determine amplicon size.	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Alberts, B., Heald, R., Johnson, A., Morgan, D., Raff, M., Roberts, K., Peter Walter, P., Molecular Biology of the Cell. WW Norton & Co. (2022).	
	Darnell, J. E., Lodish, H. F. and Baltimore, D., Molecular Cell Biology, Scientific American Books, Spektrum Akademischer Verlag. (1990)	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier (1986).	
	Gardner, E. J., Simmons, M. J. and Snustad, D. P. Principles of Genetics, John Wiley & Sons (2006).	
	Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier (1994).	
	Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York (2014).	
	Krebs, J.E., Krebs J.E., Lewin B., Goldstein E.S. and Kilpatrick, S.T., LEWIS Genes XII, Jones and Bartlett Publishers (2018)	
	Malacinski, G.M., Freifelder's Essentials of Molecular Biology, Narosa Book Distributors Private Limited (2008).	
	Tamarin, R. H., Principles of Genetics, McGraw-Hill Higher Education (2017).	
	Twyman, R. M. and Wisden, W., Advanced Molecular Biology: A Concise Reference, Garland Science (1998).	
	Watson, J. D., Molecular Biology of the Gene, Pearson/Benjamin Cummings (2007).	
Course Outcomes	◆ Isolate genomic DNA and mRNA of eukaryotes. ◆ Construct cDNA. ◆ Compare gene and its expression. ◆ Evaluate amplified DNA product.	

Title of the Course: ARCHAEA - ECOLOGY, PHYSIOLOGY, BIOCHEMISTRY AND GENETICS [T]

Course Code: MIC-514

Number of Credits: 3, Theory

Contact hours: 45

Effective from Academic Year: 2022-23

Prerequisites	Basic knowledge of the three domains of life.	
Objective:	This course gives the understanding of the ecology, diversity, cell structure, physiology and genetics of Archaea.	
Content:		
1.	**Ecology, Taxonomy and Significance of the Domain Archaea**	**(15)**
1.1	**Evolution of the Domain Archaea:** Three domains of life – Archaea, Eubacteria and Eukarya. a) Carl Woese classification of archaea based on 16S rRNA analysis. b) Similarities and dissimilarities - archaea, eubacteria and eukaryotes. c) Uniqueness of archaea versus other extremophilic microorganisms.	**2**
1.2	**Ecology and Diversity of Archaea**	**3**
	a) Ecology and Global econiches: Deep Sea, Hydrothermal vent, Dead Sea, solar salterns, geothermal vents, solfataras, Antarctica, soda lake, alkaline hot springs, marshy land. b) Strategies to cultivate, preserve and maintain Thermophilic and Halophilic Archaea. c) Studies of unculturable archaea by metagenomics.	
1.3	**Archaeal Taxonomy**	**3**
	Nutrition, growth Characteristics and physiological versatility, Stress response of Major Archaeal Physiological Groups a) Phyla Euryarchaeota : (i) Methanogens (*Methanobacterium thermoautotrophicum*), (ii) Haloarchaea (*Halobacterium halobium*) and (iii) Thermophiles (*Thermoplasma acidophilum*); (iv) Psychrophilic archaea (*Methanogenium frigidum*) b) Phyla Crenarchaeota : (i) *Sulfolobus and* (ii) *Thermoproteus* c) Phyla Thaumarchaeota : Archaeal ammonia oxidizers d) Phyla Korarchaeota e) Phyla Thermoproteota : thermoacidophilic (*Sulfolobus acidocaldarius*), *Ignicoccus hospitalis* f) Phyla Nanoarchaeota: *Nanoarchaeum equitans*	
1.4	**Cell structure and architecture of Archaea:** a) Shape Arrangement and size : *Haloquadratum walsbyi* b) Comparison Between Archaeal and Bacterial Cells c) Cellular organization: cell morphotypes, cell envelopes –	**4**

	Envelopes; membrane lipids and cell wall, ribosomes, histones-nucleosomes appendages -pili, flagella, cannulae, hami. d) Novel bio-molecules: Glycerol diether moieties and macrocyclic lipid, enzymes, co-enzymes: methanopterin, formaldehyde activation factor, Component B, Coenzyme M, F420, F430, corrinoids.	
1.5	**Significance of Archaea** in Biotechnology and Biogeochemical cycling a) *Pyrococcus furiosus- Pfu* Polymerase in Molecular studies b) *Halobacterium salinarum* – Bacteriorhodopsin c) *Thermococcus gammatolerans* - To improve DNA repair and reduce cellular aging d) *Methanosarcina* – Methane production	**3**
2.	**Metabolism and Energetics of Archaea**	**(15)**
2.1	Modified anabolic pathways: a) Gluconeogenesis b) Lipid biosynthesis c) Methanogenesis: from CO_2 and methanol d) Acetoclastic reactions in *Methanosarcina* - H_2 dependent and H_2 independent; and *Methanothrix* e) Carbon dioxide reduction pathways: 3-hydroxypropionate pathway, and reverse Kreb cycle f) Bacterioruberin pathway	**5**
2.2	Modified catabolic pathways: a) EMP b) ED: Semiphosphorylative and Nonphosphorylative ED pathway c) Chemolithoautotrophy: S oxidation	**5**
2.3	Bioenergetics: ATP synthesis (i) respiration-driven : Anaerobic a) light-driven:bacteriorhodopsin b) chloride-driven: halorhodopsin c) cation-driven.	**5**
3.	**Genome of Archaea**	**(15)**
3.1	Size of genome, G + C content, archaeal histones (Sul7d, MC1), chaperonins and heat shock proteins in archaea, introns in archaea, archaeal RNA polymerases, reverse DNA gyrase.	**5**
3.2	DNA replication, transcription and translation in archaea. Plasmids, transposons and insertion elements, AT-rich-islands, Modifications in tRNA and rRNA structure. Novel 7S rRNA.	**5**
3.3	Gene organization in Archaea: Operons (*fdh, his and mcr*). DNA repair in archaea.	**5**
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Barker, D. M.,Archaea: Salt-lovers, Methane-makers, Thermophiles and Other Archaeans, Crabtree Publishing Company. (2010)	

	Blum, P., Archaea: New Models for Prokaryotic Biology, Academic Press. (2008)	
	Boone, D. R. and Castenholz, R. W., Bergey's Manual of Systematic Bacteriology: The Archaea and The Deeply Branching and Phototrophic Bacteria, Springer Science and Business Media. (2011)	
	Cavicchioli, R., Archaea: Molecular and Cellular Biology, ASM Press. (2007)	
	Corcelli, A. and Lobasso, S., Characterization of Lipids of Halophilic Archaea. Methods in Microbiology, 35: 585-613. (2006)	
	Garrett, R. A. and Hans-Peter, K., Archaea: Evolution, Physiology and Molecular Biology, John Wiley and Sons. (2008)	
	Howland, J. L., The Surprising Archaea: Discovering Another Domain of Life, Oxford University Press. (2000)	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y. (2011)	
	Rothe, O. and Thomm, M., A simplified method for the cultivation of extreme anaerobic archaea based on the use of sodium sulfite as reducing agent,Extremophiles. 4: 247-252. (2000)	
	Woese, C. R., Fox, G. E., Phylogenetic structure of the prokaryotic domain: the primary kingdoms. Proc Natl Acad Sci USA. 74: 5088–5090. (1977)	
Course Outcomes	● Describe the ecology, physiology and biochemistry of the domain Archaea. ● Integrate the metabolism and physiology of Archaea. ● Relate the Principle of Archaeal Genetics. ● Appraise the application of Archaea and archaeal bioactive compounds.	

Title of the Course: ARCHAEA - ECOLOGY, PHYSIOLOGY, BIOCHEMISTRY AND GENETICS [P]

Course Code: MIC-515

Number of Credits: 1, Practical

Contact hours: 30

Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students have basic knowledge of 3 domains of life and basic microbiology techniques.	
Objective:	To introduce the methods in sampling and isolation of archaea from different econiches; identification of archaea and study of archaeal bio-molecules.	
Content:		**(30)**
1.	Isolation and culturing of halophilic archaea.	
2.	Identification of the isolates	
2.1	Biochemical tests for characterization of the halophilic archaea.	
2.2	Extraction of archaeal pigment and characterization using UV-Vis spectroscopy.	
2.3	Cellular lipids - Extraction and chromatographic resolution of lipids.	
3.	Screening for hydrolytic enzymes.	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Barker, D. M.,Archaea: Salt-lovers, Methane-makers, Thermophiles and Other Archaeans, Crabtree Publishing Company. (2010)	
	Blum, P., Archaea: New Models for Prokaryotic Biology, Academic Press. (2008)	
	Boone, D. R. and Castenholz, R. W., Bergey's Manual of Systematic Bacteriology: The Archaea and The Deeply Branching and Phototrophic Bacteria, Springer Science and Business Media. (2011)	
	Cavicchioli, R., Archaea: Molecular and Cellular Biology, ASM Press. (2007)	
	Corcelli, A. and Lobasso, S., Characterization of Lipids of Halophilic Archaea. Methods in Microbiology, 35: 585-613. (2006)	
	Garrett, R. A. and Hans-Peter, K., Archaea: Evolution, Physiology and Molecular Biology, John Wiley and Sons. (2008)	
	Howland, J. L., The Surprising Archaea: Discovering Another Domain of Life, Oxford University Press. (2000)	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y. (2011)	
	Rothe, O. and Thomm, M., A simplified method for the cultivation of extreme anaerobic archaea based on the use of sodium sulfite as reducing agent,Extremophiles. 4: 247-252. (2000)	
	Woese, C. R., Fox, G. E., Phylogenetic structure of the prokaryotic domain: the primary kingdoms. Proc Natl Acad Sci USA. 74: 5088–5090. (1977)	
Course Outcomes	● Define the conditions for isolation and maintenance of Archaea. ● Classify the archaea using chemotaxonomy. ● Identify the archaeal isolates. ● Analyse the archaea for bioactive molecules.	

Semester I

Discipline Specific Elective Courses

Title of the Course: ENVIRONMENTAL MICROBIOLOGY AND BIOREMEDIATION [T]

Course Code: MIC-521

Number of Credits: 3, Theory

Contact hours: 45

Effective from Academic Year: 2022-23

Prerequisites	It is assumed that the students have a basic knowledge of ecosystem structure and environmental pollution.	
Objective:	To introduce the concepts of microbial diversity, community structure, role of microorganisms in biogeochemical cycles, sustainable development and bioremediation.	
Content:		
1.	**Microbial Ecology**	**(15)**
	Ecosystems: Concept of ecosystem, habitat, econiche. Components and functioning of ecosystem, Microbial interactions with biotic environment. Ecological pyramids, energy flow, food chain and food web. Concepts of microbial guild, *r* and *k* selection concept, role of microbes in ecological succession.	**4**
	Microbial diversity in ecosystem and Community structure: The expanse and estimates/measurement of microbial diversity- Rank-abundance curve (species richness and eveness), indices of diversity (Shannon index, simpson index, Gini-simpson index), Culture based microbial diversity, Newer high throughput approaches (extinction culture, diffusion chamber/ichip, gel micro droplet method, co-culture method, flow cytometry) for exploring microbial diversity from environmental samples. Culture independent molecular methods (DGGE, FISH, phylochips, metagenomic library) for understanding microbial community structure. Metabolic diversity of microbial communities in diverse environments (aquatic and terrestrial).	**8**
	Microbial biofilms in environment: Quorum sensing in bacteria; Nature and significance, Microbial mat.	**3**
2.	**Biogeochemical processes, Pollution and sustainable devvelopment**	**(15)**
	Biogeochemical cycles: Physiological, biochemical, microbiological aspects of carbon, nitrogen, phosphorous, sulphur, Fe and Mn cycles.	**7**
	Impacts of pollution on ecosystem and Concepts of sustainable development: Effect of marine pollutants on productivity and sustainability of aquatic and terrestrial econiche. Eutrophication, HABs, biomagnification. Ballast water and significance of invasive microorganisms. Climate change and occurrence of microbial diseases. Environment impact assessment (EIA) studies. Concept of sustainable development and application of	**8**

	microorganisms towards sustainable development; Microorganisms for clean energy.	
3.	**Biomonitoring and microbial bioremediation of pollutants.**	**(15)**
	Application of microorganisms for pollution Biomonitoring-biotracers and biosensors, microbes as Bioindicators.	**2**
	Bioremediation technologies: Microorganisms for bioremediation of oil spills (biodegradation, bioaugmentation, biostimulation, biosurfactants) heavy metals, xenobiotics (biotransformation, co-metabolism) and recalcitrant pesticides.	**5**
	Waste water treatment plants: Primary, secondary and tertiary treatment of waste water. Concept of microbial consortia and microbial biofilms in waste management and pollution abatement.	**4**
	Valorization of agro waste: Containing lignin, cellulose and pectin. Intimate coupling of photocatalysis and microbial biodegradation (ICPB) for advanced treatment of organic pollutants.	**4**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Cavicchioli, R., Ripple, W. J., Timmis, K. N., Azam, F et al.. Scientists' warning to humanity: microorganisms and climate change. Nature reviews microbiology, 17, 569- 586, (2019).	
	Kennish, M. J. Practical Handbook of Estuarine and Marine Pollution. CRC Press, Francis and Taylor (2017).	
	King, R. B., Sheldon, J. K., & Long, G. M. Practical Environmental Bioremediation: The Field Guide. CRC Press (1997).	
	Liu, W-T. and Jansson, J. K., Environmental Molecular Microbiology, Caister Academic Press (2010).	
	Medigan, M. T., Bender, K. S., Bukley, D. H., Sattley, W. M., & Stahl, D. A. Brock Biology of Microorganisms. Pearson (2017).	
	Mitchell, R. and Kirchman, D. L., Microbial Ecology of the Oceans, Wiley Publishers (2018).	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y (2020).	
	Murugesan, A. G. and Rajakumari, C., Environmental Science and Biotechnology: Theory and Techniques, MJP Publishers (2019).	
	Naik, M. and Dubey, S. K., Marine Pollution and Microbial Remediation, Springer Publications (2017).	
	Norris, J. R. and Ribbons, D.W., Methods in Microbiology, Vol. 18 & 19, Academic Press (2012).	
	Osborn, A. M. and Smith, C. J., Molecular Microbial Ecology, Taylor and Francis (2005).	
	Satyanarayana, T., Johri, B. and Anil, T., Microorganisms in Environmental Management, Springer Publishers (2012).	
	Scragg, A. H., Environmental Biotechnology, Longman Publishers. (199)	
	Sharma, P. D., Environmental Microbiology, Alpha Science International (2005).	
	Willey, J. M., Sherwood, L. M., & Woolverton, C.J. Prescott's	

	Microbiology. McGraw-hill Education (2016).	
Course Outcomes	● Demonstrate the role of microorganisms in biogeochemical cycling of nutrients. ● Apply the principles of bioremediation for sustainable development. ● Correlate the microbial diversity with community structures ● Compare the different econiches and their microbial diversity.	

Title of the Course: ENVIRONMENTAL MICROBIOLOGY AND BIOREMEDIATION [P]

Course Code: MIC-522

Number of Credits: 1, Practical

Contact hours: 30

Effective from Academic Year: 2022-23

Prerequisites	It is assumed that the students have a basic knowledge of environmental pollution and microbiology.	
Objective:	To familiarize with the techniques of waste water analysis, biodegradation of aromatic pollutants and bioremediation of metal/metalloid pollutants.	
Content:		**(30)**
1.	Analysis of water samples for COD, BOD and microbial load.	
2.	Isolation of hydrocarbon degrading microorganism (degradation of sodium benzoate/Naphthalene).	
3.	Isolation of biosurfactant producing microorganisms.	
4.	BATH assay for microbial adherence.	
5.	Isolation of selenite/tellurite resistant microorganisms for application in bioremediation.	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Cavicchioli, R., Ripple, W. J., Timmis, K. N., Azam, F et al.. Scientists' warning to humanity: microorganisms and climate change. Nature reviews microbiology, 17, 569- 586, (2019).	
	Kennish, M. J. Practical Handbook of Estuarine and Marine Pollution. CRC Press, Francis and Taylor (2017).	
	King, R. B., Sheldon, J. K., & Long, G. M. Practical Environmental Bioremediation: The Field Guide. CRC Press (1997).	
	Liu, W-T. and Jansson, J. K., Environmental Molecular Microbiology, Caister Academic Press (2010).	
	Medigan, M. T., Bender, K. S., Bukley, D. H., Sattley, W. M., & Stahl, D. A. Brock Biology of Microorganisms. Pearson (2017).	
	Mitchell, R. and Kirchman, D. L., Microbial Ecology of the Oceans, Wiley Publishers (2018).	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y (2020).	
	Murugesan, A. G. and Rajakumari, C., Environmental Science and Biotechnology: Theory and Techniques, MJP Publishers (2019).	
	Naik, M. and Dubey, S. K., Marine Pollution and Microbial Remediation, Springer Publications (2017).	
	Norris, J. R. and Ribbons, D.W., Methods in Microbiology, Vol. 18 & 19, Academic Press (2012).	
	Osborn, A. M. and Smith, C. J., Molecular Microbial Ecology, Taylor and Francis (2005).	
	Satyanarayana, T., Johri, B. and Anil, T., Microorganisms in Environmental Management, Springer Publishers (2012).	
	Scragg, A. H., Environmental Biotechnology, Longman Publishers. (199)	
	Sharma, P. D., Environmental Microbiology, Alpha Science	

	International (2005).	
	Willey, J. M., Sherwood, L. M., & Woolverton, C.J. Prescott's Microbiology. McGraw-hill Education (2016).	
Course Outcomes	● Evaluate quality of water for pollution. ● Isolate microorganisms with specialized bioremedial potential. ● Establish the microbial physiology for bioremedial applications. ● Demonstrate the role of microorganisms in pollution abatement.	

Title of the Course: IMMUNOLOGY [T]

Course Code: MIC-523
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	Basic knowledge on pathogens, serology, and general principles of immunology.	
Objective:	1. To understand the concepts and mechanisms in the functioning of immunological cells and their interactions. 2. To get acquainted with the regulations of molecule synthesis, signalling, immune responses and allied activities of immune system at the molecular level.	
Content:		
1.		**(15)**
1.1	**Phagocytosis** – Cell surface receptors/markers and their role, killing mechanisms; **NK cells** – Cell to cell recognition for normal and modified cells, receptors, initiation of apoptosis and killing of target cells, malfunctioning of NK cells; role of mast cells in immunity.	**4**
1.2	Classification and concepts of immunoglobulin domain, distribution of immunoglobulin domain, superfamily member, structure and function of TCR and BCR, diversity of antigen binding domain, concept of segmented gene, gene organization of Ig and TCR, rearrangement and generation of gene during differentiation and development of B and T Cells, expression of Ig and TCR Cistrons, class switch and regulation of expression, B and T Cell ontogeny.	**5**
1.3	Major Histocompatibility Cluster – Introduction to MHC I, II and III, structure and function of MHC I and II, distribution and recognition of MHC I and II, gene organisation and concept of polymorphism, expression and its regulation, processing of extracellular antigen by APC, presentation of intracellular antigen by nucleated cells, recognition of MHC I and II by TCR/CD3 complex; Members of MHC III and their roles (in brief).	**6**
2.		**(15)**
2.1	Immunocompetent T and B cells, recognition, signaling and activation of T cells by APC, control and regulation of activated T-Cells, B-cell activation – Type 1 thymus-independent antigen, Type 2 thymus-independent antigen, thymus dependent antigen, co-operation with T-cells and activation of resting B-cells, antigen processing by B-cells, stimulation by cross-linking surface Ig.	**5**
2.2	Cytokine as messengers, receptor for cytokine – gp130 subfamily,	**5**

	beta-c and gamma-c receptor subfamily, signal transduction and effects, network interactions; TH1 and TH2 responses; Cytokine mediated chronic inflammatory response; Killer T Cell and its regulation; effect of antigen dose and maturation of affinity of antibodies; role of memory cells.	
2.3	Antigen as major factor in control, feedback control of antibody production, T cell regulation – T-helper cells, T-cell suppression; Idiotypic networks, influence of genetic factors, immune regulation through hormone; T-cell tolerance.	**5**
3.		**(15)**
3.1	Concept of inflammation, complement fixation, defense against intracellular bacterial pathogen, immunity to viral infection, immunity to fungi, immunity to parasitic infections; Passively acquired immunity, vaccination – herd immunity, strategies, killed organisms as vaccines, live attenuated vaccines, subunit vaccine, epitope vaccines, vaccines in use and experimental vaccines, Adjuvant and new approaches in vaccine development.	**5**
3.2	**Immuno-techniques**: Antigen antibody interactions in solution, identification and measurement of antigen, epitope mapping, hybridoma technology and monoclonal antibody revolution, catalytic antibodies, engineering antibodies, antigen-antibody based affinity chromatography, isolation of leukocyte and subpopulations, localization of antigen *in cyto* and *in tissue*, assessment of functional activity, genetic engineering of experimental animal for immune response investigation. **Immuno-assays and their application**: ELISA, SRID RIA, Immuno-fluorescence, Western Blotting.	**5**
3.3	**Clinical immunology (Immunodeficiency)**: phagocytic cell defects, complement system deficiency, primary B-cell deficiency, primary T-cell deficiency, combined immunodeficiency, secondary immunodeficiency, comparison between SCID and AIDS, recognition of immunodeficiency.	**5**
Pedagogy:	Lectures/tutorials/assignments/Moodle/videos	
References/ Readings	Abbas, A. K., Lichtman, A. H., & Pillai, S. Cellular and molecular immunology. Elsevier Health Sciences. (2021) Bona, C. A. and Bonilla, F. A., Textbook of Immunology, Fine Arts Press (1996). Chakraborty, P. and Pal, N. K., Manual of Practical Microbiology and Parasitology, New Central Book Agency (P) Ltd, Delhi, India. (2004). Delves, P., Martin, S., Burton, D. and Roitt, I., Roitt's Essential Immunology. Wiley-Blackwell. (2017). Goldsby, R. A., Kindt, T.J. and Osborne, B.A., Kuby Immunology.	

	W.H. Freeman (2007) Murphy, K., Janeway's Immunobiology, Garland Science. (2007)	
Course Outcomes	● Explain the mechanisms of immunological responses. ● Demonstrate the role of cellular ontogeny and the gene rearrangement in complex immune system. ● Apply the principles of immunology for immunodiagnostics. ● Correlate the clinical symptoms with imunological diseases	

Title of the Course: IMMUNOLOGY [P]

Course Code: MIC-524
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	Basic knowledge of pathogens, haematology and principles of immunology.	
Objective:	Hands-on practice for various techniques used in immunology.	
Content:		**(30)**
1.	Haemagglutination: Blood grouping - ABO and Rh systems	
2.	Immunodiffusion slide technique	
3.	Agglutination tests for *Salmonella*-antigens	
4.	Complement fixation test	
5.	C-reactive protein determination	
6.	ELISA	
7.	Rapid tests – Malaria antigens Pv/Pf, IgM/IgG antibodies for Dengue, Hepatitis HBsAg	
8.	Rheumatoid Arthritis Factor determination	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Abbas, A. K., Lichtman, A. H., & Pillai, S. Cellular and molecular immunology. Elsevier Health Sciences. (2021) Bona, C. A. and Bonilla, F. A., Textbook of Immunology, Fine Arts Press (1996). Chakraborty, P. and Pal, N. K., Manual of Practical Microbiology and Parasitology, New Central Book Agency (P) Ltd, Delhi, India. (2004). Delves, P., Martin, S., Burton, D. and Roitt, I., Roitt's Essential Immunology. Wiley-Blackwell. (2017). Goldsby, R. A., Kindt, T.J. and Osborne, B.A., Kuby Immunology. W.H. Freeman (2007) Murphy, K., Janeway's Immunobiology, Garland Science. (2007)	
Course Outcomes	● Explain the principal of various immunodiagnostics. ● Demonstrate the techniques used in immuno-diagnosis. ● Perform the various immunological techniques for diagnosis of various diseases. ● Develop novel and rapid immunodiagnostics.	

Semester II

Title of the Course: AGRICULTURE MICROBIOLOGY [T]

Course Code: MIC-525
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that the students have knowledge about microorganisms and their diversity.	
Objective:	The course deal with the information about Inter-relationship of soil and microorganisms, different groups of beneficial microorganisms in agriculture, microbes as biofertilizer, plant pathogen and biocontrol agent.	
Content:		
1.	**Soil Microbiology**	**(15)**
1.1	**Microbial ecology:** Terrestrial Ecosystem, Pyramids and Econiches.	**3**
1.2	**Soil Biogeochemistry**	**6**
A.	Types of soil, soil Profile, Physico-Chemical (abiotic) and biotic characteristics.	
B.	Factors influencing microbial survival and establishment of inoculants.	
C.	Significance of microbial metabolism/enzymes on soil chemistry (nutrient cycling) & humus formation (humic and fulvic acids).	
1.3	**Plant and soil Microbiology:** Microbiology of the above and below ground parts of the plant (Phytosphere; Rhizosphere and Rhizoplane Microflora, phyllosphere, spermosphere)	**6**
2.	**Plant-Microbe interactions (beneficial)**	**(15)**
A.	Plant growth promoting bacteria as biofertilizers Direct Mechanisms: Nutrient acquisition (nitrogen fixation, phosphate, Zinc, Potassium mobilization, siderophores, plant growth promoting hormones-Auxins, ACC Deaminase) Indirect Mechanisms: ISR, disease suppression	**3**
B.	Mycorrhiza – Ectomycorrhiza, Endomycorrhiza, VAM structure & significance.	**2**
C.	Nitrogen Fixing Microbes – Free living nitrogen (*Azotobacter, Azospirillum*), associative (Cyanobacteria, *Anabaena azollae)* and symbiotic (*Frankia*, *Rhizobium)*	**2**
D.	Biochemistry and Genetics of Nitrogen fixation with reference to symbiotic and non symbiotic nitrogen fixers Significance of *nif* H, D, K, A, L, nod, nodulin and fix genes in the process of microbial nitrogen fixation.	**4**
E.	Manure and compost as a soil amendment.	**1**
G.	Microbial Pesticides-Biocontrol agents for agriculturally important crop plants-Development and their significance; Source Organisms: Bacteria-	**3**

	Bacillus thuringiensis, Bt based commercial products, other Bacilli producing pesticides; Fungi—*Beauveria bassiana*, *Metarhizium anisopliae*, *Trichoderma,* Viruses- Baculoviruses for insect pest control.	
3.	**Plant-Microbe interactions (Harmful)**	**(15)**
A.	Plant Pathogens and Genetic basis of pathogenesis, symptoms and plant defense response	**4**
	Causative agents, pathogenesis symptoms, control of common bacterial pathogens, fungal, algal, viral, nematodes.	
B.	Plant Defense Response	**5**
(i)	Phytoalexins and their induction.	
(ii)	Plant defense responses or mechanisms of control (anatomical changes and biochemical synthesis of toxins, alkaloids and other biocontrol molecules).	
C.	Other means of pathogen control.	**6**
(i)	Application of Viral proteins in controlling viral diseases.	
(ii)	Antisense RNA technology in disease control.	
(iii)	Mycoviruses acting against fungal plant pathogens.	
(iv)	Integrated pest management, post harvest management, agri-entrepreneurship development (steps for starting small industry)	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Agrios G.N. Plant Pathology. Academic Press, San Diego. (2004)	
	Alexander, M., Introduction to Soil Microbiology, Wiley. (1977)	
	Bilgrami K. S. Plant Microbe Interactions, Proceedings of Focal Theme Symposium, Indian Science Congress Association, Narendra Publishing House. (1987)	
	Carr, N. G. and Whitton, B. A., The Biology of Blue-green algae, University of California Press. (1973)	
	Dadarwal, K. R., Biotechnological Approaches in Soil microorganisms for sustainable crop production, Scientific Publishers. (1997)	
	Kumar, H. D., Modern Concepts of Microbiology, Vikas Publishing House Pvt. Ltd. (2004)	
	Madigan, M. T., Martinko, J. M., Bender, K. S., Buckley, D. H. and Stahl, D. A., Brock Biology of Microorganisms, Pearson Education Limited. (2017)	
	Mahanta, K. C., Fundamentals of Agricultural Microbiology, Oxford & IBH Publishers. (1969)	
	Somani, L.L., Biofertilizers in Indian Agriculture, Concept Publishing Company. (1987)	
	Subba Rao, N.S., Biofertilizers in Agriculture and Forestry, International Science Publishers. (2017)	
	Subba Rao, N. S., Advances in Agricultural Microbiology, Oxford & IBH Publishers. (1982)	
	Veeresh, G. K. and Rajagopal, D., Applied Soil Biology and Ecology, Oxford	

	& IBH Publishing Company Pvt. Limited. (1988)	
Course Outcomes	● Recognize soil chemistry and its significance. ● Correlate biochemical processes of microbes to ecology. ● Integrate role of microorganisms in plant growth promotion ● Formulate strategies for integrated control and management of diseases and pests.	

Title of the Course: AGRICULTURE MICROBIOLOGY [P]

Course Code: MIC-526
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that the student have knowledge about the soil properties and microbial interactions with plants.	
Objective:	Assessing the diverse parameters influencing the soil health. Studying the plant growth promoters and plant pathogens.	
Content:		**(30)**
1.	Isolation of plant growth promoting bacteria from rhizosphere and screening for phosphate/zinc solubilisation, IAA production, K mobilisation, siderophore activity and seedling vigour test.	
2.	Detection of microbial enzymes – amylase, phosphatase, lipase, protease, catalase, urease from various soils such as sandy soil and garden soil.	
3.	Isolation of microbial plant pathogen(s)-bacterial/fungal.	
4.	Preparation of biofertilizer using cyanobacteria	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Agrios G.N. Plant Pathology. Academic Press, San Diego. (2004)	
	Alexander, M., Introduction to Soil Microbiology, Wiley. (1977)	
	Bilgrami K. S. Plant Microbe Interactions, Proceedings of Focal Theme Symposium, Indian Science Congress Association, Narendra Publishing House. (1987)	
	Carr, N. G. and Whitton, B. A., The Biology of Blue-green algae, University of California Press. (1973)	
	Dadarwal, K. R., Biotechnological Approaches in Soil microorganisms for sustainable crop production, Scientific Publishers. (1997)	
	Kumar, H. D., Modern Concepts of Microbiology, Vikas Publishing House Pvt. Ltd. (2004)	
	Madigan, M. T., Martinko, J. M., Bender, K. S., Buckley, D. H. and Stahl, D. A., Brock Biology of Microorganisms, Pearson Education Limited. (2017)	
	Mahanta, K. C., Fundamentals of Agricultural Microbiology, Oxford & IBH Publishers. (1969)	
	Somani, L.L., Biofertilizers in Indian Agriculture, Concept Publishing Company. (1987)	
	Subba Rao, N.S., Biofertilizers in Agriculture and Forestry, International Science Publishers. (2017)	
	Subba Rao, N. S., Advances in Agricultural Microbiology, Oxford & IBH Publishers. (1982)	
	Veeresh, G. K. and Rajagopal, D., Applied Soil Biology and Ecology, Oxford & IBH Publishing Company Pvt. Limited. (1988)	
Course Outcomes	● Isolate microorganisms for plant growth promotion. ● Correlate biochemical processes of microbes to soil ecology. ● Formulate biofertilizers for agricultural applications. ● Classify microbial diseases of plants.	

Title of the Course: MYCOLOGY [T]

Course Code: MIC-527
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	The student should be familiar with basic microbiology.	
Objective:	This course deals with classification and identification offungi, fungal diversity, genetics and their applications.	
Content:		
1.	**Fungal diversity and distribution**	**(15)**
1.1	**Origin and phylogeny; classification**	5
1.2	**Fungi – Terrestrial and Aquatic**	5
A.	Terrestrial fungi; Aquatic Fungi: Fresh water fungi; Marine fungi: Coastal and Mangrove, Estuarine, Open Ocean, Polar regions.	
B.	Fungal diversity in Hypersaline waters – Thalassohaline and Athallasohaline: Solar salterns, Salt Lake, Dead Sea.	
1.3	**Extremophilic Fungi**	5
	Oligotrophs, Alkaliphiles, Acidophiles, Barophiles, Psychrophiles, Thermophiles, Halophiles, Osmophiles, Xerophiles.	
	Fungal adaptation to extreme environments.	
2.	**Physiology and Genetics**	**(15)**
2.1	**Physiology of fungi**	5
A.	Growth and development.	
B.	Fungal hormones- attractants, morphogenesis and differentiation.	
C.	Microbial interactions.	
D.	Secondary metabolites: antimicrobials, mycotoxin, pigments.	
2.2	**Fungal genetics**	5
	Neurospora and *Saccharomyces*: Life-cycle; Tetrad analysis, gene conversion; Deuteromycotina: parasexuality, cytoplasmic inheritance; Electrophoretic karyotyping.	
2.3	**Identification of fungi**	5
A.	Colonial and morphological characteristics, standard keys for identification of fungi.	
B.	Molecular finger printing.	
3.	**Pathogenesis - Antifungal Therapy**	**(08)**
3.1	**Pathogenesis**	5
A.	Mycoses - Systemic, sub-cutaneous, cutaneous and superficial, Opportunistic	
B.	Plant pathogens.	
3.2	**Antifungal Therapy**	3
	Drugs acting on cell membrane, protein synthesis inhibitors;fungicides.	
4.	**Applications**	**(07)**
A.	Industrially important enzymes.	

B.	Bioprospecting of secondary metabolites: Antimicrobials, antitumour agents, nutraceuticals, pigments,.	
C.	Biodegradation and bioremediation.	
D.	Biocontrol	
E.	Edible Mushrooms	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Alexopoulus, C.J., Mims, C.W. and Blackwell, M., Introductory Mycology, John Wiley & Sons (Asia) Pvt. Ltd. (2007)	
	Cooke, R. C. and Whipps, J. M., Ecophysiology of fungi, Blackwell Scientific Publications, Oxford. (1993)	
	Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S., Microbiology, Harper and Row. (1980)	
	Deacon, J. W., Introduction to Modern Mycology, Volume 7 of Basic Microbiology, Blackwell Scientific Publications. (2022)	
	Domsch, K. H., Gams, W. and Anderson, T-H., Compendium of Soil Fungi, IHW-Verlag. (2008)	
	Gilman, J. C. and Joseph, C., A Manual of Soil Fungi, Daya Books. (2015)	
	Kendrick, B., The Fifth Kingdom, Focus Publishers. (2017)	
	Mehrotra, R. S. and Aneja, K. R., An Introduction to Mycology, Wiley Eastern Limited. (2015)	
	Onions, A. H. S., Allsop, D. and Eggins, M. O. W., Smith's Introduction to Industrial Mycology, Edward Arnold, London. (2007)	
	Strickberger, M. W., Genetic, The MacMillan Company, New York. (2014).	
Course Outcomes	● Explain the distribution of fungi in different ecosystems. ● Identify the fungal isolates. ● Explore the fungal isolates for bioprospecting. ● Ctaegorise fungal diseases and its therapy.	

Title of the Course: MYCOLOGY[P]

Course Code: MIC-528
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Objective:	To familiarize with techniques related to fungal isolation, identification and application.	
Content:		**(30)**
1.	**Study and Identification of fungi:** Study of standard cultures and identification - Observation of colonial and morphological characteristics, Reference to identification keys	
2.	**Fungal Genetics:** Isolation of fungal DNA	
3.	**Application of fungi for bioremediation:** Fungal degradation of azo dye	
4.	Degradation of plant polymer by fungal enzyme (crude)	
5.	Mushroom cultivation	
Pedagogy:	Hands-on experiments in the laboratory, video, online data	
References/ Readings	Alexopoulus, C.J., Mims, C.W. and Blackwell, M., Introductory Mycology, John Wiley & Sons (Asia) Pvt. Ltd. (2007)	
	Cooke, R. C. and Whipps, J. M., Ecophysiology of fungi, Blackwell Scientific Publications, Oxford. (1993)	
	Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S., Microbiology, Harper and Row. (1980)	
	Deacon, J. W., Introduction to Modern Mycology, Volume 7 of Basic Microbiology, Blackwell Scientific Publications. (2022)	
	Domsch, K. H., Gams, W. and Anderson, T-H., Compendium of Soil Fungi, IHW-Verlag. (2008)	
	Gilman, J. C. and Joseph, C., A Manual of Soil Fungi, Daya Books. (2015)	
	Kendrick, B., The Fifth Kingdom, Focus Publishers. (2017)	
	Mehrotra, R. S. and Aneja, K. R., An Introduction to Mycology, Wiley Eastern Limited. (2015)	
	Onions, A. H. S., Allsop, D. and Eggins, M. O. W., Smith's Introduction to Industrial Mycology, Edward Arnold, London. (2007)	
	Strickberger, M. W., Genetic, The MacMillan Company, New York. (2014).	
Course Outcomes	● Identify the fungal isolates. ● Isolate DNA from fungi ● Demonstrate the fungal isolates for bioremedial potentials. ● Establish fungal cultures for food security.	

Semester III

Research Specific Elective Courses (RSE)

Title of the Course: Research Methodology and Advanced Biostatistics

Course Code: MIC-600

Number of Credits: 4

Contact hours: 60

Effective from Academic Year: 2022-2023

Prerequisites	Student should have knowledge about microbiology and bassic biostatistics.	
Objective:	● To understand the basic concepts and methodologies involved in research. ● To develop the understanding of various advanced biostatistical tools involved in data analysis and interpretation.	
Content:		
1	**Introduction to research methodology**	**(20)**
1.1	Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical, concept of applied and basic research process, criteria of good research	
1.2	Defining the problem, setting of working hypothesis, Defining the Aims and Objectives, Literature survey: sources of literature, gathering of literature, understanding the flow for literature review, identification of gap areas, Databases and Research Metrics: Indexing databases, citation databases, Web of Sciences, Scopus, Pubmed, *etc*, Impact factor of journals, Citation of bibliography, Work Plan – Time-bound Frame, GANTT chart, technical writing: Research manuscript writing, thesis writing	
1.3	Establishment of ethics in science and research; examples of unethical work done in past, Ethical use of animal subjects, human subjects, Stem cell ethics, plant use and transgenic crops	
1.4	Plagiarism in research: Scientific misconduct, Falsification, fabrication, misinterpretation of data. Anti-plagiarism tools like Ouriginal / iThenticate / Turnitin and other open source software tools	
1.5	Hazards: Types of Hazards: radioactive, chemical and biohazard, waste management and disposal. Safety in laboratory: first-aid, fire safety, biosafety in laboratory, Good Laboratory Practices	
2	**Advanced biostatistics**	**(40)**
2.1	**Curve fitting**- fitting of a second degree parabola, power curve, exponential curve	
2.2	**Multiple Regression Analysis**- Two-variable linear model, significance test for parameter estimates, goodness of fit, three variable linear model, coefficient and adjusted coefficient of multiple determination, test of overall significance of regression (F test), correlation coefficient- partial, zero order, first order, second order, Multiple correlation, generalized linear model, matrix	

	approach for analysis, Regression analysis for qualitative variable/s and role of dummy variable	
2.3	**Non-parametric tests** – Concept of non-parametric test, advantages, disadvantages, sign test for one sample and two samples, Wilcoxon signed rank test, Median test, Run test, Mann-Whitney 'U' test, Kruskal-Wallis 'H' test	
2.4	**ANOVA-Two way classification** with one observation and multiple observations per cell- concept, procedure and examples	
2.5	**Designs of experiment**- Use and reasons for Design of experiments, definitions, concepts and terminology, Principles of experimental designs – replication, randomization and controls, Completely randomized design (CRD), Randomized complete block design (RCBD), Repeated measures design (RMD) – Single factor repeated measure design (SFRMD), handling of missing observations in RCBD, Latin square design (LSD), 2^2 Factorial experiments, Yates' Method, Confounding in factorial design, partial confounding, advantages and disadvantages	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Alley, M, The Craft of Scientific Writing, Springer Science and Business Media. (1996)	
(Latest edition)	Biological Safety Cabinets And Other Primary Containment Devices, Laboratory safety manual, WHO, (2020)	
	Biosafety in Microbiological and Biomedical Laboratories, U.S. Department of Health and Human Services, (2020)	
	Cochran, WG and Snedecor, GW Statistical Methods. Iowa State University Press. (1989)	
	Cooray P.G. Guide to Scientific and Technical Writing, Hindagala. (1992)	
	Day R.A. How to write and publish a scientific paper, Part 274, Volume 994, Oryx Press. (1998)	
	Good C V, Scates, DE, Methods of Research, Appleton-Century-Crofts. (1954).	
	Haaland, P.D., *Experimental design in biotechnology*. CRC press. (2020)	
	Indian Statistical Institute (https://www.isical.ac.in/)	
	Kothari CR, Research Methodology Methods and Techniques, New Age International (2015)	
	Kumar, RC, Research Methodology. APH Publ Corporation, New Delhi.(2008)	
	Mourya, DT, Yadav, PD, Majumdar, TD, Chauhan, DS and Katoch, VM, Establishment of Biosafety Level-3 (BSL-3) laboratory: Important criteria to consider while designing, constructing, commissioning & operating the facility in Indian setting. *The Indian Journal of Medical Research*, *140*(2), p.171. (2014)	
	Rao, KS, Biostatistics for Health and Life sciences, Himalaya Publishing House. (2017)	
	Rao, PSSS & Richard, J, An introduction to biostatistics - A manual for	

	students in health sciences, Prentice-Hall of India pvt. Ltd., New Delhi (2004)	
Course Outcomes	● Sketch the procedures and methodologies for performing a research experiment. ● Predict the required experimental designs. ● Analyze the experimental data using various biostatistical tools. ● Create a scientific report/ manuscript/ thesis.	

Title of the Course: MICROBIAL TECHNOLOGY [T]

Course Code: MIC-601
Number of Credits: 3
Contact hours: 45
Effective from Academic Year: 2022-2023

Prerequisites	Students should have basic knowledge of different techniques and instruments, their principle and applications.	
Objective:	● The course develops an understanding on the potential of microorganisms in sustainable development. ● The course summarizes the microbial technologies for energy production. ● The course discuss microbial technologies in aquaclture and for human health. ● The course describe potential of genetically engineered microorganisms and nanobiotechnology.	
Content:		
1.	**Biotechnology and prospecting with microbes.**	**(06)**
	Advantages of using microbial technology over chemical and physical technology. Increasing relevance of microbiology in all biotechnologies. Ethics in the use of Genetically Engineered Microorganisms (GEMs). Commercialization of Microbial Biotechnology. Introduction and applications of Nanobiotechnology.	
2.	**Microbial technology in agriculture**	**(09)**
	Production of microbial biofertilizers, biopesticides, soil conditioners to enhance crop yields.	
3.	**Microbial technology in mining**	**(15)**
	Bioleaching, Biomining, Microbial Enhanced Oil Recovery (MEOR), Microbial technology in waste and pollution management in mining: Bioconversions, Bioremediation, Bio-sedimentation, Bio-beneficiation, Aquifer cleaning.	
4.	**Microbial technology for energy production**	**(07)**
	Microbial fuel cell; Biogas; Biodiesel; Microbial cell mass	
5.	**Microbial technology in Human health & aquaculture**	**(08)**
	Pigments, Nutraceuticals, Probiotics, Bio-actives, Bioplastics, Microbes as bio-weapons.	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Ahmad, I., Ahmad, F. and Pichtel, J. Microbes and Microbial Technology: Agriculture and Environmental Applications, Springer. (2011) Arora, R., Microbial Biotechnology: Energy and Environment, CABI Publishing. (2012) Bull, A. T., Microbial Diversity and Bioprospecting, American Society for Microbiology. (2006) Peppler, H.J., Microbial Technology: Microbial Processes, Academic Press. (1979)	

	Sukla, L. B., Pradhan, N., Panda, S. and Mishra, B. K. Environmental Microbial Biotechnology, Springer. (2015)	
Course Outcomes	● To understand the key potential of microorganism in environmental remediation. ● To appraise and evaluate the microbial products for their potential application. ● To apply the knowledge of various microorganisms in developing technology. ● To create a microbial technology towards achieving the sustainable development goals.	

Title of the Course: MICROBIAL TECHNOLOGY [P]

Course Code: MIC-602

Number of Credits: 1, PRACTICAL

Contact hours: 30

Effective from Academic Year: 2022-2023

Prerequisites	Students should have a basic knowledge of different techniques in instrumentation- their principle, working and applications.	
Objective:	● This course gives hands-on experience to connect microbial potential with technology to produce the product.	
Content:		**(30)**
1.	Determination of stability of microbial fertilizer.	
2.	Effect of microbes on sedimentation and clarification of water.	
3.	Screening of isolates for production of (a) Pigments as bioactives and (b) Probiotics: Isolation of LABs and their characterization- Morphology, lactose fermentation, Bile tolerance test.	
4.	Demonstration of Microbial Bioplastics.	
5.	Biosynthesis of nanoparticles	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Ahmad, I., Ahmad, F. and Pichtel, J. Microbes and Microbial Technology: Agriculture and Environmental Applications, Springer. (2011) Arora, R., Microbial Biotechnology: Energy and Environment, CABI Publishing. (2012) Bull, A. T., Microbial Diversity and Bioprospecting, American Society for Microbiology. (2006) Peppler, H.J., Microbial Technology: Microbial Processes, Academic Press. (1979) Sukla, L. B., Pradhan, N., Panda, S. and Mishra, B. K. Environmental Microbial Biotechnology, Springer. (2015)	
Course Outcomes	● To evaluate the procedures for formulation of biofertilizers and probiotics. ● To analyse the role of microorganisms in biremediation of contaminated water. ● To understand and analyse the role of microbial synthesis of bioplastics. ● To design and produce technologies for biosynthesis of nanoparticles using microorganisms.	

Title of the Course: EXTREMOPHILIC MICROORGANISMS [T]

Course Code: MIC-603
Number of Credits: 3
Contact hours: 45
Effective from Academic Year: 2022-2023

Prerequisites	The student should have knowledge of microorganisms and their diversity.	
Objective:	• To discuss about the extreme habitats, extremophilic microorganisms, their adaptations and biotechnological potentials.	
Content:		
1.		**(15)**
1.1	Concepts of extremophilic and polyextremophilic microorganisms	**1**
1.2	Extreme habitats and extreme microbial communities: deserts, ore deposits/ mining areas (Fe, Mn, Cu), Yellow stone national park, Ring of fire, deep biosphere (terrestrial and marine), hydrothermal vents, cold seeps, soda lake, Dead Sea, solar salterns, polar environments. Astrobiology / exobiology (Mars, Europa and asteroids). Conventional culture techniques, high throughput techniques for culturing and culture independent (metagenomics) approach to study extremophiles.	**10**
1.3	Significance of extremophiles in biogeochemical cycling, industry, pharma and bioremediation.	**4**
2	**Key molecular components, unique physiological features, adaptation strategies and enzymes of various extremophilic types:**	**(30)**
2.1	Anaerobes- oxygen toxicity and regulation in *Clostridium, Moorella thermoacetica,* Wood Ljungdahl pathway; barophiles / piezophiles- mechanism in barophily, *Photobacterium profundum, Shewanella*; cryophiles / psychrophiles - (cold shock proteins and regulation) *Polaromonas, Pseudomonas, Methanococcoides burtonii*; thermophiles & hyperthermophiles: heat shock proteins and regulation, *Aquifex, Tepidomonas, Rhodothermus, Pyrococcus*; metallophiles - *Geobacter*; stromatolites; microbial mat and biofilms.	**(15)**
2.2	Alkaliphiles / basophiles - *Alkalimonas, Nesterenconia*; acidophiles - *Picrophilus, Ferroplasma, Thiobacillus ferrooxidans*; halophiles - *Halomonas, Haloferax, Dunaliella salina, Hortaea werneckii*; osmophiles - osmophilic *Lactobacilli, Schizosaccharomyces pombe*; oligotrophs - *Pelagibacter, Caulobacter*; xerophiles - *Wallemia*; extreme cyanobacteria	**(15)**

	(*Phormidium; Synechococcus lividus, Mastigocladus laminosus*); radiophiles - *Deinococcus radiodurans*; xenobiotic degraders - *Pseudomonas*; endoliths - *Chroococcidiopsis, Halothece*	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Blum, P., Archaea: New models for prokaryotic biology. Academic press. (2008)	
	Brock, T. D. Thermophilic microorganisms and life at high temperatures. Springer. (2011)	
	Cavicchioli, R., Archaea: Molecular and cellular biology. ASM Press. (2007)	
	Durvasula, R.V., Subba Rao, D.B. Extremophiles from biology to biotechnology. CRC Press. (2018)	
	Gerday, C., Glansdorff, N., Physiology and biochemistry of extremophiles. ASM Press. (2007)	
	Horikoshi, K. and Grant, W.D. Extremophiles-microbial life in Extreme Environments, Wiley. New York. (1998)	
	Kannan, P., Ignacimuthu, S., Paulraj, MG.Buffering capacity and membrane H^+ conductance of protease producing facultative alkaliphilic bacterium *Bacillus flexus* from mangrove soil. Indian J of Biochemistry and Biophysics. 46:261-265. (2009)	
	Medigan, M.T., Bender, K. S., Bukley, D.H., Sattley, W. M., & Stahl, D.A. Brock biology of microorganisms. Pearson. (2019)	
	Munn, C. Marine microbiology: Ecology and applications. Garland Science, Taylor and Francis Group. (2011)	
	Rainey, F.A. and Oren, A. Extremophile microorganisms and the methods to handle them. In: Extremophiles, methods in microbiology. Elsevier. (2006)	
	Satyanarayana, T., Raghukumar, C., Shivaji, S. Extremophilic microbes: diversity and perspectives. Current Science, 89(1): 78-90. (2005)	
	Ventosa, A., Nieto, J.J. and Oren, A. Biology of moderately halophilic aerobic bacteria. Microbiology and molecular biology Reviews, 62, 504–544. (1998)	
	Willey, J.M., Sherwood, L.M., and Woolverton, C.J. Prescott's Microbiology. McGraw-hill education. (2019)	
Course Outcomes	● Identify and compare different groups of extremophiles. ● Analyse physiological features and adaptation strategies employed by different groups of extremophiles. ● Develop extremophilic microbially derived product for industrial applications. ● Apply high throughput techniques and culture independent approach to explore extremophiles from diverse econiches and their unique properties.	

Title of the Course: EXTREMOPHILIC MICROORGANISMS [P]

Course Code: MIC-604

Number of Credits: 1

Contact hours: 30

Effective from Academic Year: 2022-2023

Prerequisites	The student should be familiar with handling of microorganisms in the laboratory.	
Objective:	• To develop skills involved in handling extremophilic microorganisms. • To illustrate adaptations strategies of extremophilic microorganisms and their biotechnological potentials.	
Content:		**(30)**
1.	Isolation of halophiles, alkaliphiles, and anaerobes.	
2.	Tolerance of bacterial culture to temperature, pH and salinity.	
3.	Buffering capacity of alkaliphiles.	
4.	Study extremozymes and pigments from extremophilic microorganisms.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Blum, P., Archaea: New models for prokaryotic biology. Academic press. (2008)	
	Brock, T. D. Thermophilic microorganisms and life at high temperatures. Springer. (2011)	
	Cavicchioli, R., Archaea: Molecular and cellular biology. ASM Press. (2007)	
	Durvasula, R.V., Subba Rao, D.B. Extremophiles from biology to biotechnology. CRC Press. (2018)	
	Gerday, C., Glansdorff, N., Physiology and biochemistry of extremophiles. ASM Press. (2007)	
	Horikoshi, K. and Grant, W.D. Extremophiles-microbial life in Extreme Environments, Wiley. New York. (1998)	
	Kannan, P., Ignacimuthu, S., Paulraj, MG.Buffering capacity and membrane H^+ conductance of protease producing facultative alkaliphilic bacterium *Bacillus flexus* from mangrove soil. Indian J of Biochemistry and Biophysics. 46:261-265. (2009)	
	Medigan, M.T., Bender, K. S., Bukley, D.H., Sattley, W. M., & Stahl, D.A. Brock biology of microorganisms. Pearson. (2019)	
	Munn, C. Marine microbiology: Ecology and applications. Garland Science, Taylor and Francis Group. (2011)	
	Rainey, F.A. and Oren, A. Extremophile microorganisms and the methods to handle them. In: Extremophiles, methods in microbiology. Elsevier. (2006)	
	Satyanarayana, T., Raghukumar, C., Shivaji, S. Extremophilic microbes: diversity and perspectives. Current Science, 89(1): 78-90. (2005)	
	Ventosa, A., Nieto, J.J. and Oren, A. Biology of moderately halophilic aerobic bacteria. Microbiology and molecular biology	

	Reviews, 62, 504–544. (1998)	
	Willey, J.M., Sherwood, L.M., and Woolverton, C.J. Prescott's Microbiology. McGraw-hill education. (2019)	
Course Outcomes	● Identify the extremophilic microorganisms from different econiches. ● Select novel industrially useful biomolecules from extremophilic microorganisms. ● Analyse adaptation strategies of extremophiles in different physiological conditions. ● Produce various biomolecules from extremophiles and study their unique properties.	

Title of the Course: AQUATIC VIROLOGY [T]

Course Code: MIC-605
Number of Credits: 2
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students should have an understanding of basic concepts in microbiology and molecular biology.	
Objective:	Develops the concept of viruses as key determinants of aquatic ecology. It introduces the traditional, modern and emerging techniques used in the study of aquatic viruses.	
Content:		
1.	**Aquatic viruses and their significance**	**15**
	Introduction to viruses, their structure and classification	2
	Abundance and distribution of virioplankton in various aquatic environments	2
	Diversity of aquatic viruses in terms of morphology, life cycle and host range; giant viruses and virophages	3
	Viruses as agents of microbial mortality; effects of viral infection on microbial community composition; viruses as an active component of aquatic microbial communities	2
	The role of viruses in biogeochemical cycles and the aquatic food web; Aquatic viruses and climate change	2
	Horizontal gene transfer and evolutionary contributions of viruses.	2
	Aquatic viruses pathogenic to humans and animals of economic importance	2
2.	**Cultivation, enumeration and molecular studies of aquatic viruses**	**15**
	Methods for isolation of aquatic viruses – concentration and purification of viruses from water, cultivation and assay of microbial viruses in liquid and solid media	**4**
	Methods for enumeration and ultrastructural observation of viruses – epifluorescence microscopy, transmission electron microscopy, flow cytometry	**3**
	Molecular techniques for detection of aquatic viruses – PCR-amplification of marker genes such as *g20, psbA, polB*; whole genome sequencing of cultured isolates; metagenomics of viral communities from diverse aquatic ecosystems	**4**
	Significance of culture-based and culture-independent methods for studying aquatic viruses	**1**
	Novel approaches in aquatic virus research and detection: single virus genomics, viral cross-linking and solid-phase purification, optical trapping, integrated approaches	**3**
Pedagogy:	Lectures/tutorials/assignments	

References/ Readings	Abedon, S. (Ed.), *Bacteriophage Ecology: Population Growth, Evolution, and Impact of Bacterial Viruses* - Advances in Molecular and Cellular Microbiology, Cambridge: Cambridge University Press (2010). Adriaenssens, E. M., & Cowan, D. A. Using signature genes as tools to assess environmental viral ecology and diversity. *Applied and Environmental Microbiology*, 80(15), 4470-4480 (2014). Clokie, M.R.J., and Andrew M.K. *Bateriophages Methods and Protocols, Volume 1: Isolation, Characterization, and Interactions*. Springer International Publishing (2009). Hyman, P. & Abedon, S.T., *Viruses of Microorganisms*. Caister Academic Press (2018). Malmstrom, C., *Environmental Virology and Virus Ecology*. Elsevier Academic Press (2018). Moon, K., & Cho, J. C. Metaviromics coupled with phage-host identification to open the viral 'black box'. *Journal of Microbiology*, 59(3), 311-323 (2021). Weitz, J. S., & Wilhelm, S. W. Ocean viruses and their effects on microbial communities and biogeochemical cycles. *F1000 Biology Reports*, 4:17 (2012). Wilhelm, S.W., Weinbauer, M.G., & Suttle, C.A., *Manual of Aquatic Viral Ecology*. American Society of Limnology and Oceanography, USA (2010). Wommack, K. E., & Colwell, R. R. Virioplankton: viruses in aquatic ecosystems. *Microbiology and Molecular Biology Reviews*, 64(1), 69-114 (2000). Zhang, Q. Y., Ke, F., Gui, L., & Zhao, Z. Recent insights into aquatic viruses: Emerging and reemerging pathogens, molecular features, biological effects, and novel investigative approaches. *Water Biology and Security*, 100062 (2022). Zhang, R., Weinbauer, M. G., & Peduzzi, P. Aquatic viruses and climate change. *Current Issues in Molecular Biology*, 41(1), 357-380 (2021).	
Course outcome	● Summarize the roles of viruses in aquatic ecosystems. ● Apply the traditional and modern techniques to isolate and characterize aquatic viruses ● Integrate the knowledge of viruses into an existing framework of aquatic microbiology ● Frame relevant research objectives in the field of aquatic virology.	

Title of the Course: INTRODUCTION TO BIOINFORMATICS [T]

Course Code: MIC-606
Number of Credits: 2
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students should have an understanding of basic concepts in molecular biology.	
Objective:	Develops concepts of informatics analysis for biological data, such as nucleic acid and protein sequence data	
Content:		
1.		**(15)**
1.1	**Introduction to Bioinformatics, Sequencing and Databases**	**8**
	Introduction to bioinformatics, the necessity for computation in modern life sciences research	
	The central dogma of molecular biology (overview), Types of bioinformatics databases	
	DNA sequencing, RNA sequencing; Nucleotide sequence databases – GenBank, EMBL, DDBJ; Cloning vectors used in sequencing; primer designing	
	Protein sequencing – Edman degradation, mass spectrometry; Protein sequence databases – SwissProt, UniProt	
	Protein structural and functional databases – PDB, Pfam, GO, KEGG, Subsystems	
	Molecular docking – applications and tools – Autodock, DOCK	
1.2	**Sequence Alignment**	**7**
	Rationale: why does sequence alignment matter? Evolutionary basis of sequence alignment; Pairwise and multiple alignment	
	Scoring matrices – PAM, BLOSUM, optimal alignment methods, gap penalties	
	Dynamic programming algorithms – Smith-Waterman, Needleman-Wunsch, k-mer, k-tuple	
	FASTA; BLAST; understanding of BLAST parameters including statistical scores	
2.		**(15)**
2.1	**Multiple Sequence Alignment Methods**	**4**
	Progressive methods – ClustalW, Iterative methods – MUSCLE, Short-read alignment – Bowtie, Motif-based alignment – MEME	
	Use of BioEdit for nucleotide sequence editing and alignment	
2.2	**Phylogenetic tree building and evaluation**	**5**
	Introduction to phylogeny and applications of phylogenetic analysis	
	Methods for tree building – UPGMA, NJ, MP and ML	
	Generation of phylogenetic trees in MEGA	
2.3	**Principles of Whole Genome and Metagenome Analysis by Bioinformatics**	**6**
	Quality control, reference databases – NCBI nr, Kraken	
	Assembly – reference-based, *de novo*	

	Annotation – taxonomic annotation, functional annotation	
	Use of Unix / Linux-based operating systems for bioinformatics analysis of sequence data	
Pedagogy:	Lectures/tutorials/assignments/online hands-on	
References/ Readings (Latest editions)	Antao, T, Bioinformatics with Python Cookbook 2nd Edition (2018). Christensen, H, Introduction to Bioinformatics in Microbiology. Vol. 39 (2018). Lesk, AM, Introduction to Bioinformatics. Vol. 66. Oxford University Press (2019). Ramsden, J, Bioinformatics: An Introduction. Springer-Verlag London (2015). Note: Latest versions of software tools and databases should be used for instruction.	
Course Outcomes	● Explain the principles behind bioinformatics tools and techniques. ● Apply the principles in the analysis of biological sequence data. ● Compare the various methods for sequence alignment and phylogenetic analysis. ● Design an analysis pipeline for specific types of biological data.	

Semester IV

Title of the Course: MARINE MICROBIAL INTERACTIONS [T]

Course Code: MIC-607
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-2023

Prerequisites	Students must have a background about the basic concepts of Marine Microbiology, including properties of seawater, marine microorganisms.	
Objective:	• Students will learn advances in marine microbiology with special emphasis on the intricate associations between microorganisms and marine organisms, diseases of microbial origin in fish and invertebrates, and other beneficial and harmful aspects like bioremediation and HABs respectively.	
Content:		
1.	**Symbiotic associations**	**(15)**
1.1	Symbiosis of microalgae with animals, Symbiosis of chemoautotrophic prokaryotes with marine animals; Light organ symbiosis in fish and invertebrates; Microbial symbionts of sponges-significance and advantages; Symbiosis and mixotrophy in protists; Metabolic consortia and mutualism between prokaryotes.	
1.2	Ecological significance and advantages of various symbiotic associations - Bacterial, Algal, Sponges, Protists, Planktons. Applications of symbiotic associations.	
2.	**Microbial diseases of fish and invertebrates**	**(15)**
	Diseases of fish, bivalve mollusks, crustaceans, corals in fresh water/ sea water/ aqua culture: Bacterial – vibriosis, pasteurellosis, furunculosis, marine, bacterial kidney disease, mycobacteriosis, streptococcosis, black band disease, white plague, white pox, Juvenile Oyster Disease (JOD), bacterial shell disease, Coral Bleaching and methods of restoration; Symptoms and diagnosis; Control of the disease Viral – Infectious salmon anemia (ISA) virus, viral hemorrhagic septicemia virus (VHSV), lymphocystis virus, birnaviruses, viral nervous necrosis. Symptoms and possible diagnosis; Control of the disease Protistan – *Paramoeba perurans, Kudoa sp., Loma salmonae, Hematodinium* Symptoms, Diagnostic methods, Control of disease.	
	Human diseases- toxic dinoflagellates and diatoms Red tides, shell fish poisoning, ciguatera fish poisoning	
3.	**Marine microbes - Beneficial and harmful aspects**	**(15)**
	Beneficial aspects: Biodegradation and bioremediation of marine pollutants such as oil, persistent organics and plastics. Environmental monitoring using indicator microorganisms. Microbial enzymes and polymers; biomedical and health products.	

	Harmful aspects: Harmful Algal Blooms (HABs)- effect on biota. Biodeterioration, biofouling, bio-invasion – ballast waters. Environmental monitoring – Microbiology of fish and sea food products, microbial enzymes, Secondary products from fish waste, application of microbial enzymes	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim. (1999)	
	Gatesoupe, F. J., The use of probiotics in aquaculture, Aquaculture, 180: 147-165. (1999)	
	Maier, R., Pepper, I. and Gerba, C., Environmental Microbiology, Academic Press. (2008)	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y. (2003)	
	Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco, N.Y. (2005)	
	Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York. (1984)	
	Sharma, P. D., Environmental Microbiology, Alpha Science. (2005)	
	Sindermann, C. J., Principal Diseases of Marine Fish and Shellfish: Diseases of Marine Fish, Vol. 1, Gulf Professional Publishing. (1970)	
	Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa. (1972)	
	Toranzo, A. E., Magarinos, B. and Romalde, J. L., A review of the main bacterial fish diseases in mariculture systems, Aquaculture, 246(1): 37-61. (2005)	
	Intergovernmental Oceanographic Commission, Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. DOI: https://doi.org/10.25607/OBP-1409 Intergovernmental Oceanographic Commission Manuals and Guides : 29 -JGOFS Report; 19 (1994)	
Course Outcomes	● Different kinds of interactions of microbes and marine organisms ● Ecological significance of microbial associations ● Understanding the various microbial diseases of marine organisms ● Bioprospecting and applications of microbial associations.	

Title of the Course: MARINE MICROBIAL INTERACTIONS [P]

Course Code: MIC-608
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students must have a background about the basic concepts of Marine Microbiology, and the techniques involved for sampling and processing of water, sediment, flora and fauna from the marine environment.	
Objective:	This Course emphasizes the techniques used to study the interactions between microorganisms and marine organisms, and also screening of enzymes for degradation of litter.	
Content:		**(30)**
1.	Determining *E. coli* in shellfish –MPN/ EC-MUG medium.	
2.	Isolation of luminescent bacteria from fish/shellfish.	
3.	Assessment of the microbiological quality of marine water in aquaculture: – physicochemical parameters. – potential pathogens.	
4.	Screening of enzymes involved in deterioration of wood/litter in marine environments.	
5.	Examine the beneficial effect of microbial association- Macro algae - Bacteria Isolation and identification of marine algae associated bacteria Isolation and identification of Zooplankton associated bacteria Associated bacterial efficiency for chitin degradation	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim. (1999)	
	Gatesoupe, F. J., The use of probiotics in aquaculture, Aquaculture, 180: 147-165. (1999)	
	Maier, R., Pepper, I. and Gerba, C., Environmental Microbiology, Academic Press. (2008)	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y. (2003)	
	Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco, N.Y. (2005)	
	Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York. (1984)	
	Sharma, P. D., Environmental Microbiology, Alpha Science. (2005)	
	Sindermann, C. J., Principal Diseases of Marine Fish and Shellfish: Diseases of Marine Fish, Vol. 1, Gulf Professional Publishing. (1970)	
	Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa. (1972)	
	Toranzo, A. E., Magarinos, B. and Romalde, J. L., A review of the main	

	bacterial fish diseases in mariculture systems, Aquaculture, 246(1): 37-61. (2005)	
	Intergovernmental Oceanographic Commission, Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. DOI: https://doi.org/10.25607/OBP-1409 Intergovernmental Oceanographic Commission Manuals and Guides : 29 -JGOFS Report; 19 (1994)	
Course Outcomes	● To isolation of marine organisms associated bacteria ● To analyse the bacterial diseases of fish ● To evaluate the marine organism associated bacteria for beneficial biomolecules	

Title of the Course: MEDICAL VIROLOGY [T]

Course Code: MIC-609
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-2023

Prerequisites	The student should have a basic understanding of viruses.	
Objective:	● Develops concepts in structure, classification, cultivation, assay, pathogenesis and treatment of disease-causing viruses.	
Content:		
1.	**Viral Diversity and the Study of Viruses**	**(15)**
1.1	**Viruses**	**7**
	Structure, genomic diversity, classification according to Baltimore's system and the ICTV	
	Viral replication and interference	
1.2	**Methods to study and detect viruses**	**8**
	Ultrastructure visualization by electron microscopy	
	Cultivation *in vitro*, *in ovo* and *in vivo*	
	Monitoring of clinical manifestations of *in vivo* viral inoculation: fever, neurological symptoms, pruritis	
	Detection by cytological and histological techniques: plaque, pock, polykaryocytes, hemadsorption, cytopathogenicity, tumor formation.	
	Detection by quantitative and serological techniques: hemagglutination assay, virus neutralization, ELISA, immunofluorescence, immunohistochemistry	
	Detection by nucleic acid-based techniques: PCR, RT-PCR, nucleic acid hybridization, high-throughput sequencing	
2.	**Viral Diseases**	**(15)**
	Viral agents of disease: structure, mode of replication, symptoms, pathogenesis and diagnosis Family Picornaviridae: Polio virus Family Herpesviridae: Herpes simplex virus Family Coronaviridae: SARS-CoV-2 Family Hepadnaviridae: Hepatitis B virus Family Orthomyxoviridae: Influenza A virus Family Retroviridae: HIV	
3.	**Oncogenic and Emerging Viruses and Antiviral Combat**	**(15)**
3.1	Oncogenic viruses: Family Papovaviridae – Human papillomavirus 16 and 18, cervical cancer development Role of viral oncogenes in causing cancer, retroviral oncogenes such as growth factors, transcription regulators and kinases	**5**

	Role of the Human Genome Project in identification of viral oncogenes	
3.2	Emerging viral agents of disease, such as Ebola, Nipah and Zika viruses	**2**
3.3	Virus-host interactions: Host specific and nonspecific defense mechanisms; neutralizing antibodies; the role of interferon.	**4**
3.4	Viral vaccine development: Traditional vaccine preparations and modern molecular approaches (adenoviral vector-based vaccines, mRNA vaccines), vaccines against oncoviruses. Antiviral drugs: nucleoside analogs, entry inhibitors, viral enzyme inhibitors, immunotherapy, combination therapy	**4**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Cohen, A., *Medical Virology*, John Wiley & Sons, Incorporated (1975).	
	Davis, B.D., Dulbecco, R., Eisen, H.N. and Ginsberg, H.S., *Microbiology*, Harper and Row Publishers (1982).	
	De La Maza, L.M., Peterson, E.M., *Medical Virology*, Springer Science & Business Media (2013).	
	Dimmock, N.J., Easton, A.L. Leppard, K.N., *Introduction to Modern Virology*, Blackwell Publishing Ltd (2023).	
	Evans, B., *Perspectives in Medical Virology*, Volume 1, Elsevier (2007).	
	Flint, S. J., Racaniello, V. R., Rall, G. F., Hatziioannou, T., & Skalka, A. M., *Principles of Virology*, John Wiley & Sons (2020).	
	Harper, D.R., *Viruses: Biology, Applications, Control*, Garland Science (2011).	
	Payne, S., *Viruses: From Understanding to Investigation*, Elsevier (2022).	
	Ryu, W., *Molecular Virology of Human Pathogenic Viruses*, Elsevier (2016).	
	White, D.O., Fenner, F., *Medical Virology*, Gulf Professional Publishing (2016).	
	https://www.cdc.gov/ncird/dvd.html	
	https://www.who.int/southeastasia	
	https://viralzone.expasy.org	
Course Outcomes	● To explain morphology, mode of infection and multiplication of medically important viruses and their treatment. ● To apply traditional and modern techniques for the study and detection of viruses ● To analyze the roles of viral pathogen and host in the development of disease ● To devise strategies to combat emerging viral pathogens.	

Title of the Course: MEDICAL VIROLOGY [P]

Course Code: MIC-610
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students should have basic knowledge of viruses and microbiological techniques.	
Objective:	Develop skills in handling, detecting and identifying viruses of medical importance	
Content:		**(30)**
1.	Electron micrographs representative of all the Baltimore classes of viruses	
2.	Real-time PCR detection of RNA viruses	
3.	Rapid antigen / antibody detection test for: i) HIV (retrovirus) ii) SARS-CoV-2 (coronavirus) iii) Dengue (picornavirus) iv) Hepatitis B (hepadnavirus)	
4.	ELISA test for detection of any one virus	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Cohen, A., *Medical Virology*, John Wiley & Sons, Incorporated (1975).	
	Davis, B.D., Dulbecco, R., Eisen, H.N. and Ginsberg, H.S., *Microbiology*, Harper and Row Publishers (1982).	
	De La Maza, L.M., Peterson, E.M., *Medical Virology*, Springer Science & Business Media (2013).	
	Dimmock, N.J., Easton, A.L. Leppard, K.N., *Introduction to Modern Virology*, Blackwell Publishing Ltd (2023).	
	Evans, B., *Perspectives in Medical Virology*, Volume 1, Elsevier (2007).	
	Flint, S. J., Racaniello, V. R., Rall, G. F., Hatziioannou, T., & Skalka, A. M., *Principles of Virology*, John Wiley & Sons (2020).	
	Harper, D.R., *Viruses: Biology, Applications, Control*, Garland Science (2011).	
	Payne, S., *Viruses: From Understanding to Investigation*, Elsevier (2022).	
	Ryu, W., *Molecular Virology of Human Pathogenic Viruses*, Elsevier (2016).	
	White, D.O., Fenner, F., *Medical Virology*, Gulf Professional Publishing (2016).	
	https://www.cdc.gov/ncird/dvd.html	
	https://www.who.int/southeastasia	
	https://viralzone.expasy.org	
Course Outcomes	● Identify viruses of medical importance based on their structural characteristics. ● Distinguish between the morphologies and tropism of various pathogenic viruses. ● Acquire skills in laboratory handling of viral material ● Apply modern techniques for the detection of viruses	

Semester III

Generic Elective Courses (GE)

Title of the Course: MICROBIAL BIOPROSPECTING [T]

Course Code: MIC-621
Number of Credits: 4, Theory
Contact hours: 60

Prerequisites	It is assumed that students should have a basic understanding of biomolecules.	
Objective:	● To describe the concept of bioprospecting and applications of microbes for obtaining various biologically significant biomolecules. ● To discuss the applications of biomolecules derived from microorganisms in industries and medical field.	
Content:		
1.		**(20)**
1.1	Introduction to bioprospecting & bioactive molecules from microorganisms. Characteristics of econiches to obtain microorganisms with novel properties and microorganisms producing novel bioactive molecules: geothermal springs (*Thermus aquaticus*), hydrothermal vents (*Pyrococcus furiosus*), polar regions (*Methanogenium frigidum / Polaromonas*), mining areas (ectomycorrhizae & *Pseudomonas*), desert (*Chroococcidiopsis / Phormidium*); salt pans (*Halobacterium salinarum*); acidic (*Acidithiobacillus ferrooxidans*), alkaline (*Bacillus alcalophilus / Nesterenconia*), seaweed / sponge associated microbes. Cartagena protocol, Bonn declaration on access and benefit-sharing (ABS).	**12**
1.2	**Culture dependent bioprospecting:** enrichment procedures; plating on selective media. Function based screens (proteomics and metabolomics). **High throughput screening strategy:** extinction culture technique; culturomics; optical tweezers; FACS.	**8**
2.		**(22)**
2.1	**Culture independent bioprospecting:** Metagenomics (DGGE, phylochip analysis; metagenomic library-functional screening and sequence-based screening); metatranscriptomics (ISRT-FISH; MAR-FISH); metaproteomics; metabolomics; microbiome; microbial genome guided bioprospecting / genome mining (GALAXY platform). Substrate induced gene expression screens (SIGEX) - catabolic gene expression screens. Systematic evolution of ligands by exponential enrichment (SELEX); microarrays. Introduction to predictive functional analyses (Tax4Fun2, PICRUSt)	**15**
2.2	**Directed evolution for bioprospecting:** Metabolic pathway engineering; Assembly of designed oligonucleotides; site directed mutagenesis. Incorporation of metabolic pathway from eukaryotes and archaea into bacteria. Indigo production, ascorbic acid production. Artimisinin synthesis through synthetic biology.	**7**
3	**Bioactive and industrially important biomolecules: e**nzymes –	**(18)**

	extremozymes, food additives/ quality enhancers; pigments–food colorants, fabric dyes; biopolymers – biodegradable plastics: PHAs; EPS, biosurfactants and bioemulsifiers.; Pharmaceuticals-Antimicrobials, therapeutics, antitumour agents, drug carriers, quorum quenching molecules; nutraceuticals - PUFAs, β-carotenes, antioxidants; cosmeceuticals & medicine; probiotics - probiotic bacteria in aquaculture/human heath; microbial lectins - roles and applications; biofuel. Microbial natural product libraries/data bases.	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Barcelo, D, Analysis of Marine samples in search of bioactive compounds. Comprehensive analytical chemistry. Elsevier (2014). Bhaumik, DS, & Rawat, DS, Bioactive marine natural products. Springer (2005). Borkar, S, Bioprospects of coastal eubacteria. Springer Publishers (2015). Bramhachari, G, Biotechnology of Microbial enzymes: Production, biocatalysts and industrial applications. Academic Press (2023). Bull, AT, Microbial Diversity and Bioprospecting. ASM Press (2006). Colin, M, Marine microbiology: Ecology and applications. Garland science (2020). Du, G-H, Natural small molecules drugs from plants. Springer (2018). Gupta, VK, Sharma, GD, Tuohy, MG, Gaur, R, The handbook of Microbial bioresourses. CABI (2016). Hernandez-Ledesma, B, & Herrero, M, Bioactive compounds from marine foods, plant and animal sources. Wiley Blackwell (2013). Madigan, MT, Bender, KS, Buckley, DH, Sattley, WM, Stahl, DA, Brock biology of microorganisms. Pearson (2017). Medina-Framco, JL, New approaches for discovery of pharmacologically active natural Compounds. MDPI (2019). Meena, SM, & Naik, MM, Advances in Biological Science Research: a practical approach. Elsevier (2019) Naik, MM, & Dubey, SK, Marine pollution and Microbial remediation. Springer (2017). Paterson, R & Lima, N, Bioprospecting: Success, potential and constraints. Springer (2017). Ravi, I, Baunthiyal, M, & Saxena, J, Advances in Biotechnology. Springer (2014). Reddy, SM, Charya, MAS, & Girisham, S, Microbial diversity: Exploration and bioprospecting, Scientific Publishers (2012). Suleria, HAR & Barrow, C, Bioactive compounds from plant origin: Extraction, applications and potential health benefits. CRC press (2020). Thomas, TR, Kavlekar, DP, & Lokabharathi, PA, Marine drugs from sponge-microbe association: a review. Marine Drugs, 8: 1417-1468 (2010) Willey, JM, Sherwood, LM, & Woolverton, CJ, Prescott's Microbiology. McGrawHill Education (2016).	
Course out comes	• Analyse and produce novel bioactive molecules from microorganisms.	

	● Explore industrial potential of microorganisms from different econiches. ● Design directed evolution for bioprospecting of molecules with desire properties. ● Evaluate culture dependent and culture independent techniques for bioprospecting of microorganisms with unique properties from diverse econiches.	

Title of the Course: PHARMACEUTICAL MICROBIOLOGY [T]

Course Code: MIC-622
Number of Credits: 4, Theory
Contact hours: 60
Effective from Academic Year: 2022-23

Prerequisites:	Students should have basic knowledge of industrial microbiology, fermentation technology, maintenance and identification of cultures.	
Objectives:	● To understand the role and importance of microorganisms in pharmaceutical industries. ● To summarize the concept of aseptic handling and preparation of sterilized pharmaceuticals processing. ● To examine the quality maintenance and manufacturing of pharmaceutical formulations. ● To demonstrate microbiological standardization of pharmaceuticals.	
Content:		
1.	**Introduction to Pharmaceutical Microbiology**	**(20)**
1.1	**History of Pharmaceutical Microbiology:** Contributions of Louis Pasteur, Edward Jenner, Alexander Fleming, Joseph Lister, Paul Ehrlich, Selman Waksman Milestones and developments in pharmaceutical microbiology History of profession of Pharmacy in India in relation to pharmacy education.	**3**
1.2	**Organization structure and layout of a pharmaceutical Industry:** Organizational structure and different departments in pharmaceutical industries, Location and layout of a pharmaceutical plant, Features of a good layout. **Good Practices:** Good Manufacturing Practices (cGMP) and Good Microbiology Laboratory Practices in a pharmaceutical industry.	**5**
1.3	**Regulatory approvals for Pharmaceutical Industry Certification (Sections relevant to microbiology):** Central Drugs Standard Control Organization (CDSCO), USFDA, MHRA (Medicines and Healthcare Products Regulatory Agency), PGA (Pharmacy Guild of Australia), WHO, The pharmacy Act, Drugs and Cosmetics Act, FSSAI, The Food Safety and Standards Act. **Guidance Documents for a Pharmaceutical Industry:** Indian Pharmacopoeia, British Pharmacopoeia/ European Pharmacopoeia, US Pharmacopoeia, Japan Pharmacopoeia **Documentation and Data Integrity:** ALCOA Principle, and ALCOA Plus.	**5**

1.4	**Biosafety Levels in Pharmaceutical Industries:** Biosafety cabinets, Working of biosafety cabinets, Protective clothing, Specification for BSL1, BSL-2, BSL-3, and BSL-4, Importance of biosafety in manufacturing pharmaceutical products.	**4**
1.5	**Discarding biohazardous waste:** Methodology of Disinfection, Autoclaving and Incineration.	**3**
2.	**Microbiological Quality Control and Sterility Assurance**	**20**
2.1	Concepts of Qualification, Validation & Calibration of equipment and instruments in microbiology laboratory. **Classes and types of pharmaceutical products:** Sterile and non-sterile formulations. **Sampling practices:** General principles, sampling of raw material, intermediate, finished products, primary packaging material, water, compressed air, and nitrogen gas. **Environmental monitoring:** Utilities, settle plate technique, air sampling, surface monitoring, and monitoring of personal gear. **Testing of utilities:** compressed air, nitrogen.	**5**
2.2	**Microbiological methods for pharmaceutical analysis:** **Media**: Preparation, Growth promoting and inhibitory properties of media, Sample preparation. **Enumeration:** Standard plate count, Direct microscopic counts, membrane filtration technique, most probable number, turbidimetric methods, Bioburden Test. **Microbiological examination of non-sterile products:** Pour plate, Membrane Filtration, MPN, Tests for specific microorganisms - Total Aerobic Microbial Count (TAMC), Total Yeast and Mold Count (TYMC), Tests for *E. coli*, *Salmonella, Pseudomonas aeruginosa,* and *S. aureus*. **Sterility Testing:** Membrane Filtration and Direct Inoculation Method. **Rapid Microbiological Methods**: ATP bioluminescence, Impedance, and Chemiluminescence. **Antimicrobial Effectiveness Testing:** Bioassay	**5**
2.3	**Advanced Identification systems of Microorganisms:** Automated Microbiological Identification Systems (BBL crystal identification system, BioMerieux Vitek, and Biolog). **Culture maintenance:** Basic culture and preservation methods, Lyophilization, Cryopreservation.	**3**
2.4	**Endotoxins and Pyrogens:** LAL Assay. Principles of Gel Clot Method, chromogenic end-point method, Kinetic turbidimetric assay, and Kinetic chromogenic assay.	**4**

2.5	**Sterilization Methods:** Pharmaceutical products, Autoclave Validation. Manufacturing of aseptically filled and terminally sterilized products. **Testing of disinfectants:** Surface challenge test	**3**
3.	**Drug Development**	**(10)**
3.1	**Preclinical development:** Toxicity testing – acute, sub-acute and chronic toxicity	**2**
3.2	Clinical development: Clinical trials (I, II, III and IV), Ethics in pharmaceutical industries.	**2**
3.3	**Pharmacokinetics:** Absorption Distribution Metabolism Excretion (ADME) and Bioavailability studies	**2**
3.4	Role of FDA in drug development (INDA, NDA)	**2**
3.5	Carriers and delivery systems, targeted drug delivery, sustained release	**2**
4.	**Production and Applications of Microbially Derived Pharmaceutical Agents:**	**(10)**
4.1	**Vaccines:** AIDS/ Malaria/ Covid-19	**3**
4.2	**Antimicrobial:** Streptomycin (antibacterial), Atazanavir (antiviral), Artimisinin (antiprotozoal)	**4**
4.3	Pre-biotics or Pro-biotics	**3**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Anjaneyulu Y, & Marayya R, Quality Assurance & Quality Management in Pharmaceutical Industry, Pharma Book Syndicate. (2017) Baird R.M., Hodges N.A. & Denyer S.P. Handbook of Microbiological Quality Control in Pharmaceutical and Medical Devices, Taylor and Francis Inc. (2000) D'Souza J., Killedar S.G., Biotechnology and Fermentation Process, Nirali Prakashan. (2008) Hugo W.B. & Russel A.D., Pharmaceutical Microbiology, Blackwell Scientific publications, Oxford London. (2004) Jain N.K., Pharmaceutical Product Development, CBS Publication. (2007) Kokare C. Pharmaceutical Microbiology, Nirali Prakashan. (2016) Lachman L., Lieberman H.A., Kanig J.L., The Theory and Practice of Industrial Pharmacy, Varghese Publishing House. (1986) Loftus B.T. & Nash R.A., Pharmaceutical Process Validation, Drugs and Pharmaceutical Science Series, Volume 23, Marcel	

	Dekker Inc. (1984) Shargel L. & Andrew B.C., Applied Biopharmaceutics & Pharmacokinetics, McGraw Hill Education. (2016) Latest Pharmacopeias, Acts, and Guidelines (as listed in the syllabus) (2022)	
Course Outcomes	● Integrate and connect the importance of microbiology in pharmaceutical ● Apply the knowledge of good manufacturing practices. ● Appraise, evaluate and implement the rules and regulations pertaining to microbiological standards in industry. ● Develop microbially derived pharmaceutical product.	

Title of the Course: GENETIC ENGINEERING [T]

Course Code: MIC-623
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	Knowledge of bacterial and animal genetics, basic molecular biology and microbiology.	
Objective:	• Introduces the fundamental and state-of the-art tools and techniques required for molecular cloning and protein expression. • Elaborates the applications of genetic engineering in agriculture, therapeutics, industry and bioremediation.	
Content:		
1.	**Introduction to genetic engineering and tools involved in genetic manipulation**	**(20)**
1.1	**Introduction to genetic engineering**	**1**
1.2	**Tools and techniques involved in genetic manipulation**	
A.	DNA modifying enzymes: restriction endonucleases, exonucleases, DNA ligases (T4 DNA Ligase and *E. coli* DNA ligase), Terminal DNA transferase, DNA Polymerases (Taq, Amplitaq, Vent, Exo-vent, Pfu, T4 etc), Reverse transcriptase, T4 polynucleotide kinase, Alkaline phosphatase, S-1 Nuclease, Mung bean nuclease, RNases.	**3**
B.	Gene cloning systems/Hosts: Gene cloning in *E. coli*, *Bacillus subtilis*, *Saccharomyces cerevisiae* and other microbial eukaryotes	**2**
C.	Cloning vectors: Plasmids (Col plasmid, pUC19, pBR322 and their derivatives), λ phage based vectors, cosmid vectors, phasmid vectors, shuttle vectors, high capacity cloning vectors (BAC and YACs).	**3**
D.	Sequencing vectors: pUC 19 and M-13 phage vector.	**2**
E.	Manipulation of gene expression in Prokaryotes; Strong and regulatable promoters (lac, trp, tac, SV 40, T7, T3) for induction of gene expression; Prokaryotic expression vectors – pET, pGEX-2T and others; Fusion proteins; Genetic manipulation to increase recombinant protein stability and secretion	**2**
F.	Construction of recombinant DNA molecule and its transfer to appropriate host (bacteria/yeast/plant cell/animal cell) using suitable techniques: transformation, electroporation, transfection, gene gun.	**2**
G.	Gene cloning strategies: Cohesive end and blunt end cloning, universal TA cloning, shotgun cloning and directed cloning; genomic DNA cloning, reverse-transcriptase mediated synthesis of cDNA and cDNA cloning, screening of gene libraries for recombinant clones.	**2**

H.	Other recombinant DNA techniques: Use of radioactive and non-radioactive nucleotides for DNA probe preparation and detection of hybrids, gel retardation assay, restriction mapping, RFLP, PCR, real time PCR, microarray, DNA sequencing using Sanger's dideoxy chain termination method, capillary sequencing and next-generation sequencing; chromosome walking, hybrid release and hybrid arrest translation to screen clones, site directed mutagenesis.	**3**
2.	**Genetic Engineering in Biology, forensics and medicine**	**(10)**
A.	Screening of genetic diseases using DNA probes (DNA diagnostics)	**2**
B.	Production of recombinant proteins and drugs (insulin, tissue plasminogen activator, erythropoietin, human growth hormones, Antibodies (including bispecific antibodies), vaccines, interferons, DNA vaccines: merits and demerits; Edible vaccines: merits and demerits.	**6**
C.	Application of recombinant DNA technology in solving parental disputes and criminal cases (DNA fingerprinting).	**2**
3.	**Genetic Engineering in Agriculture**	**(05)**
A.	Development of transgenic crops resistant to insect pests, bacterial, fungal and viral pathogens.	
B.	Strategies to develop transgenic crops and horticulture plants using various tools of recombinant DNA technology: Development of Bt Brinjal, Golden Rice and *flavr savr* tomato.	
C.	Importance of *Agrobacterium tumefaciens* in genetic manipulation of plants (Role of Ti plasmids), Role of *Bacillus thuringiensis* (*Bt* genes) to develop insect/pest resistant crops.	
D.	CRISPR-Cas mediated gene editing for improvement of farm animals and crops	
4.	**Applications of Genetic Engineering in Industry**	**(05)**
A.	Genetic manipulation of microbes to over-produce industrially valuable enzymes.	
B.	Production of recombinant pharmaceuticals, nutraceuticals and other biomolecules.	
C.	Production of fermentation products using recombinant organisms.	
D.	Production of microbial SCPs.	
5.	**Genetic engineering of microbes for biomonitoring, bioremediation and biohydrometallurgy.**	**(05)**
	Genetic manipulation of microbes to develop biosensors for monitoring toxic organic and inorganic pollutants, bioremediation of xenobiotics, toxic heavy metals and organometals,	

	Biohydrometallurgy for recovery of precious metals	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	● Brown, T.A., Gene cloning and DNA Analysis: An Introduction, Blackwell Science (2020).	
	● Davis, L. G., Dibner, M. D. & Battey, J. F., Basic Methods in Molecular Biology, Elsevier (1994).	
	● Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier (2007).	
	● Glick, B.R., Pasternak, J.J. & Patten, C.L., Molecular Biotechnology: Principles and Applications of Recombinant DNA, ASM Press (2022).	
	● Glover, D. M., Gene cloning: The Mechanics of DNA Manipulation, Springer-Science+Business Media, B. V (2013).	
	● Green, M.R. & Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York (2012).	
	● Grinsted, J. & Bennett, P.M., Methods in Microbiology, Vol. 21, Plasmid Technology, Academic Press (1990).	
	● Old, R.W. and Primrose, S.B., Principles of Gene Manipulation: An introduction to Genetic Engineering, University of California Press (2014).	
	● Williamson, R., Genetic Engineering, Volumes 4-7, Academic Press (1997).	
Course Outcomes	● Apply tools and techniques involved in molecular cloning. ● Formulate strategies for effective protein expression in prokaryotic hosts. ● Evaluate the applications of genetic engineering techniques in medical and forensic fields ● Appraise the potential of GMOs in industry and bioremediation.	

Title of the Course: GENETIC ENGINEERING [P]

Course Code: MIC-624
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	Theoretical understanding of chromosomal DNA, plasmid DNA, selection media and preparatory microbiology.	
Objective:	• Hands-on experience of the workflow of a typical genetic engineering experiment.	
Content:		**(30)**
1.	Restriction mapping of bacterial plasmid.	
2.	Assessment of DNA ligation activity of T4 DNA ligase	
3.	Preparation of competent cells and transformation of *E. coli* host with plasmid DNA using heat shock method and electroporator; confirmation of positive transformants by blue-white screening.	
4.	Demonstration of insertional inactivation of marker gene.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	• Brown, T.A., Gene cloning and DNA Analysis: An Introduction, Blackwell Science (2020).	
	• Davis, L. G., Dibner, M. D. & Battey, J. F., Basic Methods in Molecular Biology, Elsevier (1994).	
	• Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier (2007).	
	• Glick, B.R., Pasternak, J.J. & Patten, C.L., Molecular Biotechnology: Principles and Applications of Recombinant DNA, ASM Press (2022).	
	• Glover, D. M., Gene cloning: The Mechanics of DNA Manipulation, Springer-Science+Business Media, B. V (2013).	
	• Green, M.R. & Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York (2012).	
	• Grinsted, J. & Bennett, P.M., Methods in Microbiology, Vol. 21, Plasmid Technology, Academic Press (1990).	
	• Old, R.W. and Primrose, S.B., Principles of Gene Manipulation: An introduction to Genetic Engineering, University of California Press (2014).	
	• Williamson, R., Genetic Engineering, Volumes 4-7, Academic Press (1997).	
Course Outcomes	• Apply the technique of restriction mapping; • Clone a desired gene in a prokaryotic system. • Interpret experimental results on the basis of gel profiles. • Design experiments for obtaining specific outcomes in gene cloning and expression.	

Title of the Course: FOOD MICROBIOLOGY [T]

Course Code: MIC-625
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students know the nutritional quality of food to microorganisms and presence and types of different microorganisms in the food.	
Objective:	• Student will understand the beneficial and harmful association of microorganisms with the food. • Student will learn prospective applications of the microorganisms in food industry. • Student will learn the different methods of controlling the type and number of microorganisms in the food as per requirement. • Student will gain the knowledge about the role of food regulatory bodies and measures of food safety and quality control.	
Content:		
1.	**Microbial Food Spoilage and Food Preservation**	**(15)**
A.	Predictive food microbiology - Types of foods and their spoilage.	**4**
B.	Factors affecting the growth and survival of microorganisms in foods: Intrinsic, Extrinsic.	**4**
C.	Preservation methods: Heat processing, low temperature storage, control of water activity, irradiation, high pressure processing, modified atmospheres, preservatives: chemicals, natural organic molecules (nisin).	**7**
2.	**Microbiology in Food Processes**	**(15)**
2.1	**Fermented and processed foods**	**11**
A.	Indian fermented foods.	
B.	Oriental mold modified foods.	
C.	Fermented meats and fish: - sausage, fish sauce.	
D.	Fermentations: wine, vinegar.	
2.2	**Genetically engineered microorganisms in the Food Industry**	**4**
A.	Concept, advancements, principles.	
B.	Role of genetically engineered microbes in the food industry.	
3.	**Food Safety and Quality Assurance**	**(15)**
3.1	**Food borne diseases**	**5**
	Bacterial, with emphasis on emerging pathogens such as *E. coli* EHEC O157:H7 and other strains; *L. monocytogenes*, *H. pylori*; Fungal, Algal, Viral, Prions and other non-bacterial forms.	
3.2	**Quality control and Validation**	**10**
A.	Microbiological examination of foods – sampling, culturing/analysis including newer methods such as PCR, magnetic separation.	

B.	Plant sanitation.	
C.	Hazard Analysis and Critical Control Point (HACCP) concept.	
D.	Food Safety Act and Trade Regulations.	
E.	Good Manufacturing Practice (GMP) and Quality Systems.	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Adams, M. R. and Moss, M. O., Food Microbiology, New Age International (P) Limited Publishers, New Delhi. (2008)	
	Bacteriological Analytical Manual (BAM), US FDA Administration, https://www.fda.gov/food/laboratory-methods-food/bacteriological-analytical-manual-bam (2023)	
	Da Silva, N., Taniwaki, M. H., Junqueira, V. C. A., Silveira, N. F. A., Nascimento, M. S. do. and Gomes, R. A. R., Microbiological Examination Methods of Food and Water: A Laboratory Manual, CRC Press, Taylor & Francis Group, U.K. (2018).	
	Department of Food and Public Distribution, Ministry of Consumer Affairs, Food & Public Distributin, GOI https://dfpd.gov.in/index.htm (2023).	
	Doyle, M. P. and Buchanan, R. L., Food Microbiology: Fundamentals and Frontiers, ASM Press. (2012)	
	Food Safety and Standards Authority of India, Ministry of Healthand Family Welfare, GOI https://fssai.gov.in/cms/food-safety-and-standards-act-2006.php#:~:text=The%20Food%20Safety%20and%20Standards,34%20OF%202006. (2023)	
	Frazier, W. C. and Westhoff, D. C., Food Microbiology, M. C. Graw-Hill Companies, Inc., New York. (2020)	
	Harrigan, W. F., Laboratory Methods in food Microbiology, CRC Press, Taylor & Francis Group. (2020)	
	Jay, MJ, Loessner, M.J. & Golden, D.A., Modern Food Microbiology, Springer Science + Business Media Inc., NY. (2006)	
	Ramesh, K. V., Food Microbiology, MJP Publishers, Chennai. (2019).	
Course Outcomes	• Describe the beneficial and harmful association of microorganisms with the food. • Appraise the prospective applications of the microorganisms in food industry. • Select the different methods of controlling the type and number of microorganisms in the food for its preservation. • Integrate the knowledge about the role of food regulatory bodies and measures of food safety, quality control and validation.	

Title of the Course: FOOD MICROBIOLOGY [P]

Course Code: MIC-626
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that the student should have knowledge about handling of microorganisms.	
Objective:	• Students will be assessing the microbiological quality of food. • Students will learn the role of microorganisms in food fermentations.	
Content:		**(30)**
1.	Determination of the D value in heat treatment of foods.	
2.	Fermentation: Production of wine, monitoring of sugar reduction and alcohol production.	
3.	Assessment of sanitary status of an eatery – Examination of microflora from table surface; utensils; drinking water.	
4.	Isolation of probiotic culture (*Lactobacillus*).	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Adams, M. R. and Moss, M. O., Food Microbiology, New Age International (P) Limited Publishers, New Delhi. (2008)	
	Bacteriological Analytical Manual (BAM), US FDA Administration, https://www.fda.gov/food/laboratory-methods-food/bacteriological-analytical-manual-bam (2023)	
	Da Silva, N., Taniwaki, M. H., Junqueira, V. C. A., Silveira, N. F. A., Nascimento, M. S. do. and Gomes, R. A. R., Microbiological Examination Methods of Food and Water: A Laboratory Manual, CRC Press, Taylor & Francis Group, U.K. (2018).	
	Department of Food and Public Distribution, Ministry of Consumer Affairs, Food & Public Distributin, GOI https://dfpd.gov.in/index.htm (2023).	
	Doyle, M. P. and Buchanan, R. L., Food Microbiology: Fundamentals and Frontiers, ASM Press. (2012)	
	Food Safety and Standards Authority of India, Ministry of Healthand Family Welfare, GOI https://fssai.gov.in/cms/food-safety-and-standards-act-2006.php#:~:text=The%20Food%20Safety%20and%20Standards,34%20OF%202006. (2023)	
	Frazier, W. C. and Westhoff, D. C., Food Microbiology, M. C. Graw-Hill Companies, Inc., New York. (2020)	
	Harrigan, W. F., Laboratory Methods in food Microbiology, CRC Press, Taylor & Francis Group. (2020)	
	Jay, MJ, Loessner, M.J. & Golden, D.A., Modern Food Microbiology, Springer Science + Business Media Inc., NY. (2006)	
	Ramesh, K. V., Food Microbiology, MJP Publishers, Chennai. (2019).	
Course Outcomes	• Analyse food samples produced in food industry. • Correlate the different methods of food treatments used to control the microorganisms with food preservation.	

	● Evaluate foods in terms of microbial quality for food safety and quality control. ● Develop the value added food products using beneficial microorganisms.	

Title of the Course: MEDICAL MICROBIOLOGY AND EPIDEMIOLOGY [T]

Course Code: MIC-627

Number of Credits: 3, Theory

Contact hours: 45

Effective from Academic Year: 2022-23

Prerequisites	Knowledge of microorganisms, pathogens and various infectious diseases.	
Objective:	● To understand the mechanism of pathogenesis leading to development of disease in the host. ● To relate the pathogen, host and environment in terms of its varied existence and interactions, leading to various epidemiological events.	
Content:		
1.		
1.1	Pathogenicity, virulence and virulence factor – historical perspective and definitions, course of infectious diseases, damage-response curve and classes of pathogen, growth of pathogen in host.	**(05)**
1.2	Pili, flagella, biofilm, quorum-sensing, iron scavenging, aggressins/impedins against host defence.	**(03)**
1.3	Host susceptibility, pre-disposing factor (nutritional, socio-economical, occupational, therapy, genetical), factors affecting immune systems; Receptors for pathogen – GalNacbeta1-4 gal moiety exposed on asialylated glycolipids, TLRs, regulation of host cell apoptosis; establishment of latent infection; TB, Streptococcal Pneumonia, Amoebic and Bacillary dysentery.	**(07)**
2.		
2.1	Exotoxins – Type III secretion system, AB – type toxins, examples (Tetanospasmin, diphtheria toxin, pertusis toxin), bifunctional toxins, cytotoxins and cytolysins. Endotoxin – structure, biosynthesis, assay, pathophysiological effects, excessive inflammatory response, endotoxin neutralizing compound, antagonists of LPS.	**(08)**
2.2	Diagnostics – Sample type and handling of samples, selective enrichment, classical methods (review) of culturing and identification of pathogens, staining methods for demonstration of pathogen in situ (direct staining, fluorescent antibody staining), Applications of Molecular diagnosis and Typing: LPS (chemotyping), phage, pyocin, antimicrobial, serotyping, Restriction mapping, RFLP, PFGE, PCR.	**(03)**
2.3	Cystic fibrosis, Spongiform encephalopathy.	**(04)**
3.		
3.1	Spatial, temporal and social distributions of communicable	**(09)**

	diseases, transmissibility of infections, cross-sectional studies, case-control studies, cohort studies, Models for Developing Epidemiological Theory, modeling tools, Rates and risks, Population dynamics, Epidemiological Statistics Relating Exposure and Disease, Simple Epidemic Processes, Vaccine effect measures, Multistage chronic diseases, Joint effects of multiple exposure variables.	
3.2	Community acquired infection, infections in immuno-compromised patients, Nosocomial infections, catheter associated infections, infections in patients with debilitating diseases, neo-natal infections; Vector borne diseases – vectors for transmission of infectious diseases, epidemiological cycles of vector borne diseases, control measures.	**(06)**
Pedagogy:	Lectures/tutorials/assignments/Moodle/videos/web resources	
References/ Readings	Centers for Disease Control and Prevention, Department of Health & Human Services, USA https://www.cdc.gov/ Chakraborty, P. and Pal, N.K., Manual of Practical Microbiology and Parasitology. New Central Book Agency, India. (2018) Chakraborty, P. Textbook of Medical Parasitology. New Central Book Agency, India (2016) Davis, B.D. et al., Microbiology. Harper and Row. (1972) Gillespie, S.H. and Hawkey, P.M., Principles and Practice of Clinical Bacteriology. Wiley. (2006) National Centre for Disease Control, Ministry of Health & Family welfare, GOI https://ncdc.gov.in/ Online Tuberculosis Information System (OTIS) Data, Centers for Disease Control and Prevention, Department of Health & Human Services, USA https://wonder.cdc.gov/tb.html Parija, SC, Textbook of Microbiology & Immunology. Elsevier Health Sciences. (2016) Rafi, MD, Textbook of biochemistry for Medical Students, Universities Press, India (2020) Riedel, S., Hobden, J.A. , Miller, S., Morse, S.A., Mietzner, T.A. et al. Jawetz, Melnick, & Adelberg's Medical Microbiology, McGraw-Hill Education. (2019). Struthers, J.K. and Westran, R.P., Clinical Bacteriology. CRC Press. (2003) Topley, W.W.C., Wilson, G.S., Parker, M.T., & Collier, L.H. , Topley and Wilson's Principles of Bacteriology, Virology and Immunity: v. 1-4, Hodder Arnold (1990) World Health organization, South-East Asia https://www.who.int/southeastasia	
Course Outcomes	● To identify the various virulence and pathogenicity factors of microbial pathogens. ● To correlate the various pathological events during the progression of an infectious disease. ● To apply the various diagnostics techniques involved in	

	identification of pathogenic agent. ● To categorize the strategies/methods required to combat the spread of pathogens under various circumstances.	

Title of the Course: MEDICAL MICROBIOLOGY AND EPIDEMIOLOGY [P]

Course Code: MIC-628

Number of Credits: 1, Practical

Contact hours: 30

Effective from Academic Year: 2022-23

Prerequisites	Ability to handle microorganisms in the laboratory.	
Objective:	● Student will learn in handling, characterization and identification of pathogens. ● Student will able to do analysis of epidemiological data.	
Content:		**(30)**
1.	Demonstration of malaria parasite in blood film.	
2.	Determination of sensitivity of bacteria to antibiotics (Disc method).	
3.	Enrichment, isolation and identification of Enteric pathogen.	
4.	Analysis of disease incidence using CDC/epidemiological data.	
Pedagogy:	Experiments in the laboratory, web resources	
References/ Readings	Centers for Disease Control and Prevention, Department of Health & Human Services, USA https://www.cdc.gov/ Chakraborty, P. and Pal, N.K., Manual of Practical Microbiology and Parasitology. New Central Book Agency, India. (2018) Chakraborty, P. Textbook of Medical Parasitology. New Central Book Agency, India (2016) Davis, B.D. et al., Microbiology. Harper and Row. (1972) Gillespie, S.H. and Hawkey, P.M., Principles and Practice of Clinical Bacteriology. Wiley. (2006) National Centre for Disease Control, Ministry of Health & Family welfare, GOI https://ncdc.gov.in/ Online Tuberculosis Information System (OTIS) Data, Centers for Disease Control and Prevention, Department of Health & Human Services, USA https://wonder.cdc.gov/tb.html Parija, SC, Textbook of Microbiology & Immunology. Elsevier Health Sciences. (2016) Rafi, MD, Textbook of biochemistry for Medical Students, Universities Press, India (2020) Riedel, S., Hobden, J.A. , Miller, S., Morse, S.A., Mietzner, T.A. et al. Jawetz, Melnick, & Adelberg's Medical Microbiology, McGraw-Hill Education. (2019). Struthers, J.K. and Westran, R.P., Clinical Bacteriology. CRC Press. (2003) Topley, W.W.C., Wilson, G.S., Parker, M.T., & Collier, L.H. , Topley and Wilson's Principles of Bacteriology, Virology and Immunity: v. 1-4, Hodder Arnold (1990) World Health organization, South-East Asia https://www.who.int/southeastasia	
Course Outcomes	● To identify and distinguish between various human pathogens. ● To apply the microbiology tools and techniques in specific need for clinical cases.	

	• To estimate the resistance of bacteria against commercially available antibiotics. • To apply the principles of statistics in processing of epidemiological data.	

Title of the Course: MARINE MICROBIOLOGY [T]

Course Code: MIC-629
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	Basic understanding of the unique properties of water, features of marine environments and microorganisms.	
Objective:	● Students will learn microbial diversity in context of various characteristics of marine and coastal environments. ● Students will understand specialized tools and techniques used in study of microorganisms present marine and coastal ecosystems.	
Content:		
1.		**(15)**
1.1	Introduction to oceanography: the world's oceans and seas and its demarcations, zonation of the water column with respect to depth and light. Impact of water column zonation on biology. Properties of seawater, physico-chemical factors in the marine environment such as temperature, density, nutrients, salinity, dissolved gases. Ocean phenomena: waves, tides, oceanic currents, Ekman transport and upwelling- its significance and impact on biology in coastal regions and open ocean, Coriolis effect, eddies, gyres, El Nino-Southern Oscillation (ENSO), and its significance.	**9**
1.2	Marine microbial habitats: water column, sediments, estuaries, mangroves, salt marshes, beach ecosystems, coral reefs, deep sea hydrothermal vents, cold seeps.	**6**
2.	**Marine Microorganisms**	**(15)**
2.1	Marine microbes – viruses, bacteria, fungi, phytoplankton, zooplankton: their growth, physiology and contribution to ocean processes. Modes of microbial growth: viable but non-culturable (VBNC) microorganisms, biofilms, microbial mats, epibiosis.	**5**
2.2	Physiology of marine microbes: metabolic diversity and energy-yielding processes: Microbial carbon pump, microbial loop; marine snow; phototrophy and primary productivity, aerobic respiration, anaerobic respiration (denitrification, sulphate reduction, methanogenesis); nitrification, annamox, sulphur oxidation, methanotrophy; fermentation. Carbon dioxide fixation in autotrophs; the role of microorganisms in biogeochemical cycling: carbon, nitrogen, phosphorous, sulphur, iron, manganese.	**5**
2.3	Role of microbes in climate change and global warming. Microbes - a tool of carbon sequestration.	**2**
2.4	Mesocosm- quantification of global warming impact- species	**3**

	composition and turnover, distribution of functional traits, ecological processes; Microcosm- Quantification of global warming on bacterial metabolic rates, productivity.	
3.	**Methods in marine microbiology**	**(15)**
3.1	Sampling equipment: water samplers such as CTD rosette- Niskin sampler, sediment samplers -different types of grabs such as Van Veen grabs, Shipek grabs, Eckman grab and different types of corers- Piston corer, box corer, gravity corer.	**5**
3.2	Analysis of primary productivity: the radiocarbon method; Analysis of bacterial productivity: the thymidine uptake method; Analysis of bacterial productivity: the thymidine uptake method; Measurement of respiration rates: light-dark bottle method	**5**
3.3	Tools to study marine microbial diversity: flow cytometry (bacteria, picoplankton, picoeukaryotes, viruses); molecular approaches such as metagenomics, community fingerprinting and Fluorescence *in situ* hybridization (FISH), Microsensor, Biosensors**.**	**5**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Belkin, S. and Colwell, R. R., Ocean & Health: Pathogens in the Marine Environment, Springer. (2005)	
	Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim. (1999)	
	Hunter-Cevera, J., Karl, D. and Buckley, M., Marine Microbial Diversity: the Key to Earth's Habitability, American Academy of Microbiology. (2005)	
	Intergovernmental Oceanographic Commission, Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. DOI: https://doi.org/10.25607/OBP-1409 Intergovernmental Oceanographic Commission Manuals and Guides : 29 -JGOFS Report; 19. (1994)	
	Meller, C. B., Wheeler, P. A., Biological Oceanography, Wiley-Blackwell Publishers. (2012)	
	Gasol, J.M. and Kirchman, D. L., Microbial Ecology of the Oceans, Wiley- Blackwell Publishers. (2018).	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y. (2003)	
	Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco. (2005)	
	Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York. (1984)	
	Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa. (1972)	
	Sournia, A., UNESCO Monographs on Oceanographic Methodology, Vol. 6, Phytoplankton Manual, UNESCO Publishing, Paris. (1978)	
	Tomas, C. R., Identifying Marine Phytoplankton, Academic Press, San	

	Diego, CA. (1996)	
Course Outcomes	● Integrate microbial diversity in context of various characteristics of marine and coastal environments ● Connect the microbes and their role in marine and coastal habitats. ● Categorize and select different methods and tools to study microorganisms in marine and coastal ecosystems. ● Illustrate the various biogeochemical cycles in context of microorganisms.	

Title of the Course: MARINE MICROBIOLOGY [P]

Course Code: MIC-630
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students should have a basic understanding of the unique physico-chemical characteristics of seawater and the different microbial groups in marine environments.	
Objective:	● Students will learn different methods of sampling and analysis of physico-chemical parameters of estuarine and coastal environments. ● Students will analyze the marine samples for isolation and enumeration of microorganisms. ● Students will understand the different biochemical processes in marine microorganisms.	
Content:		**(30)**
1.	Sampling methods for collection of water and sediment samples from estuarine and coastal environments.	
2.	Analysis of physico-chemical parameters of seawater- Temperature, Salinity, Dissolved Oxygen, pH, Suspended matter, Nutrients; Nitrate, Nitrite, Phosphate, Silicate.	
3.	Isolation and enumeration of microbes from estuarine and coastal environments - Microscopic count of water column bacteria, Total count (epifluorescence method-DAPI), Bacterial respiration, community respiration and net production	
4.	Assessment of salt requirement of marine isolates from different ecosystems.	
5.	Denitrification by marine bacterial isolates.	
6.	Study of biofilm formation by microorganisms.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Belkin, S. and Colwell, R. R., Ocean & Health: Pathogens in the Marine Environment, Springer. (2005)	
	Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim. (1999)	
	Hunter-Cevera, J., Karl, D. and Buckley, M., Marine Microbial Diversity: the Key to Earth's Habitability, American Academy of Microbiology. (2005)	
	Intergovernmental Oceanographic Commission, Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. DOI: https://doi.org/10.25607/OBP-1409 Intergovernmental Oceanographic Commission Manuals and Guides : 29 -JGOFS Report; 19. (1994)	
	Meller, C. B., Wheeler, P. A., Biological Oceanography, Wiley-Blackwell Publishers. (2012)	
	Gasol, J.M. and Kirchman, D. L., Microbial Ecology of the Oceans, Wiley- Blackwell Publishers. (2018).	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland	

	Science, Taylor and Francis, N.Y. (2003)	
	Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco. (2005)	
	Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York. (1984)	
	Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa. (1972)	
	Sournia, A., UNESCO Monographs on Oceanographic Methodology, Vol. 6, Phytoplankton Manual, UNESCO Publishing, Paris. (1978)	
	Tomas, C. R., Identifying Marine Phytoplankton, Academic Press, San Diego, CA. (1996)	
Course Outcomes	● Sampling and analysis of physico-chemical parameters of estuarine habitat ● Analyse samples from marine and coastal habitat for isolation and enumeration. ● Connect microorganisms with marine and coastal habitats. ● Asses metabolic rates in marine bacterial isolates.	

Title of the Course: ENTREPRENEURSHIP IN MICROBIOLOGY [T]

Course Code: MIC-631
Number of Credits: 4
Contact hours: 60
Effective from Academic Year: 2022-2023

Prerequisites	Basics of microbiology, microbial physiology and industrial microbiology	
Objective:	● Students will able to recognize and acquire skills for entrepreneurship in microbiology. ● Students will able to discuss the possibilities of developing wealth derived from application of microbiology. ● Students will able to state various schemes and opportunities in taking up entrepreneurship in microbiology as career growth.	
Content:		
1	Scope of entrepreneurship in microbiology, process of entrepreneurship, type and competencies of entrepreneur, self-assessment of abilities and skills for entrepreneurship in microbiology, advantages and disadvantages of entrepreneurship in microbiology, motivational stories and sharing of experience of entrepreneurs in microbiology.	4
2	Characteristics of industries based on Microbiology, Context of entrepreneurship in microbiology and comparison with entrepreneurship in other fields, Bioentrepreneurial opportunities - spotting problems and needs, online-tools for searching databases for problems and needs, opportunities for solutions using microbiology, creativity and developing innovative ideas. Identifying limitation of product, process and design in implementation. Innovative steps in developing product or process in microbiology, use of mind-maps, proof of concept, identifying market and business possibility.	7
3	Entrepreneurial planning: MSME - definition, type; Five basic forms of legal organization - sole proprietorship, partnership, joint stock companies; company - types and salient features of companies; story of start-up and company of microbiology, regulations associated for company based on microbiology, economics of microbiology based industry including taxes	6
4	Stages-Types of microbiological products/process - microorganisms as product, metabolites, proteins and small molecules from microorganisms, microorganism based processes, genetically modified microorganisms for product and process, scale-up of process, stability and shelf life, ethical issues, Technological Readiness Levels (TRL), Marketable Readiness levels (MRL) and Business Readiness Level (BRL); technology versus business model; stages and strategies for commercialization and market, role of bioincubators and Government support system, Business models - Research Intensive pharmaceutical companies (RIPCO), fully integrated drug discovery and development organization (FIDDO),	14

	No research-development only (NRDO), fully integrated pharmaceutical/ biopharmaceutical company (FIPCO/FIBCO), Fully integrated pharmaceutical network (FIPNET/VIPCO)	
5	Intellectual Property Rights - Patents, Trademarks, Copyrights, Industrial Designs, Geographical Indications and Traditional knowledge, Integrated Circuits, Plant Varieties & Farmers Rights, Trade Secrets; Acts associated with: patents, copyrights and trademarks. Non-disclosure agreements, overview of patent registration in India, National and International IPR laws pertaining to microorganisms and product/process thereof , Budapest treaty, National and International Repositories for Microorganisms, comparison of Indian and International patent laws, Description and requirement for Indian Patent, search and filing of patent, microbiology based examples of patents (product/process/design), Role and importance of trademarks and brand name, search of trademarks, example of trademarks in Microbiology, management of innovation and IPR, IP portfolio, selling and licensing of IPR - examples from product and technologies in microbiology	12
6	Financial and economics of microbiology based industry - consideration and approaches for managing capital, determining capital cost, cost of equity and risks, working capital, working capital cycle, operating cycle and cash cycle, working capital management, cash flow management, financial planning and budget, Financial statements, Case study	5
7	Regulatory requirement and management - Food Act, FSSAI, Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/Genetically Engineered Organisms or Cells 1989 (Rules, 1989) [first notified under the Environment (Protection) Act, 1986], Drugs and Cosmetic Act, Guidelines on Similar Biologics, Insecticides Act, Biofertilizers and Organic Fertilizers (Fertilizer (Control) Order), Solid Waste Management Act	8
8	Funding opportunities and management: Funding Opportunities for Startups - Bootstrap, crowdfunding, angel investment, venture capital, bank loans, business loans from microfinance provider, friends and family, government grants, Schemes of the Government for start-up in microbiology, Incentives for Startups, Special Royalty Tax for Patents.	4
Pedagogy:	Lectures/tutorials/assignments/Group-discussion	
References/ Readings	Amaresan, N, Dharumadurai, D, & Babalola, OO, Agricultural Microbiology Based Entrepreneurship, Making Money from Microbes, Microorganisms for Sustainability (MICRO, volume 39), Springer Nature Singapore Pte Ltd., (2022)	
	Amaresan, N, Dharumadurai, D, & Babalola, OO, Food Microbiology Based Entrepreneurship: Making Money From Microbes, Microorganisms for Sustainability (MICRO, volume XX), Springer Nature Singapore Pte Ltd. (2022)	
	Amaresan, N, Dharumadurai, D, & Cundell, DR, Industrial Microbiology Based Entrepreneurship, Making Money from	

	Microbes, Microorganisms for Sustainability (MICRO, volume 42), Springer Nature Singapore Pte Ltd. (2022)	
	Casida, LE, Industrial Microbiology, New Age International Limited, New Delhi (2016)	
	Central pollution Control Board, Ministry of Environment, forest and Climate Change, GOI, https://cpcb.nic.in/env-protection-act/	
	Cntral Drugs Standard Control Organization, DGHS, MHFW, GOI https://cdsco.gov.in/opencms/opencms/en/Acts-Rules/	
	Department of Biotechnology, Ministry of Science and Technology, GOI, https://dbtindia.gov.in/	
	El-Mansi, EMT, Bryce, CFA, Demain, AL and Allman, AR (Editors), Fermentation Microbiology and Biotechnology, Taylor & Francis, FL (2011)	
	Food Safety and Standards Authority of India, Ministry of Healthand Family Welfare, GOI https://fssai.gov.in/cms/food-safety-and-standards-act-2006.php#:~:text=The%20Food%20Safety%20and%20Standards,34%20OF%202006.	
	Genetic Engineering Appraisal Committee, Ministry of Environment, Forest & Climate Change, GOI, https://geacindia.gov.in/acts-and-rules.aspx	
	Malik, S.S. & Shukla, S.S. Bioentrepreneurship development, Biotech Consortium India Limited, New Delhi (2018)	
	Office of the Controller General of Patents, Design & Trade Marks, Department for Promotion of Industry and Internal Trade, Ministry of Commerece & Industry, MOI https://ipindia.gov.in/	
	Stanbury, PF, Whitaker, A & Hall, SJ. Principles of Fermentation Technology, Elsevier (2016)	
	United States Patent & Trademark Office, USA, https://www.uspto.gov/	
	World Intellectual Property Organization, Switzerland, https://www.wipo.int/portal/en/index.html	
	Various acts and rules listed in the content section.	
	Biochemical Engineering and Biotechnology.	
	Journal of Industrial Microbiology and Biotechnology.	
Course Outcomes	● Develop product and/or process based solution using microbiological concepts. ● Differentiate IPR potentials of microbial process and product. ● Connect with the funding and marketing opportunities available in bioentrepreneurship. ● Appraise the process for developing and manufacturing product using microorganisms or their produce. ● Formulate strategies for establishing a start-up.	

Title of the Course: Field Trip to industries/institutions in Goa

Course Code: MIC-632

Number of Credits: 1, Practical

Contact hours: 30

Effective from Academic Year: 2022-23

Prerequisites	The student should have knowledge of microbiology.	
Objective:	● To recognize various industries and institutions in Goa providing employment in the area of Microbiology. ● To understand the scope of microbiology and role of microbiologists in various institutions and industries in Goa.	
Content:		
1.	**Visit to National Research Institutes:** National Centre for Polar and Ocean Research [NCPOR] / Council of Scientific and Industrial Research-National Institute of Oceanography [CSIR-NIO] / Indian Council of Agricultural Research – Central Coastal Agricultural Research Institute (ICAR - CCARI) / Indian Council of Medical Research- National Institute of Malarial Research (ICMR-NIMR) / Goa Medical College / Birla Institute of Technology and Sciences (BITS) Pilani, Goa Campus / Don Bosco College of Agriculture.	**(15)**
2.	**Visits to Industries:** Pharmaceutical industry, Agricultural farming, Food and Beverage industry, Waste Management Plant, CIBA	**(15)**
3.	**Report writing**	
4.	**Presentation and group discussion**	
Pedagogy:	Field visits/Presentation	
References/ Readings	Reading material provided by the institutions/industries. Websites of the institutions/industries.	
Course Outcomes	● Appraise the different instruments used in industries and institutions for microbiological analysis and research. ● Connect with the recent advancements in Microbiology taking place in different industries and institutions. ● Choose between the career in industry or research in Goa. ● Categorize the various opportunities available in microbiological industries in Goa.	

Title of the Course: Field Trip to industries/institutions across India

Course Code: MIC-633

Number of Credits: 1, Practical

Contact hours: 30

Effective from Academic Year: 2022-23

Prerequisites	The student should have knowledge of microbiology.	
Objective:	● To recognize various industries and institutions in India providing employment in the area of Microbiology. ● To understand the scope of microbiology and role of microbiologists in various institutions and industries in India.	
Content:		**(30)**
1.	**Visit to Institutes/Industries:** National/State research institutes/ Universities/ Industries outside Goa will be identified and the study tour will be arranged for the students.	
2.	**Report writing**	
3.	**Presentation and group discussion**	
Pedagogy:	Field visits/Presentation	
References/ Readings	Reading material provided by the institutions/industries. Websites of the institutions/industries.	
Course Outcomes	● Appraise the different instruments used in industries and institutions for microbiological analysis and research. ● Connect with the recent advancements in Microbiology taking place in different industries and institutions. ● Choose between the career in industry or research in India. ● Categorize the various opportunities available in microbiological industries in India.	

Title of the Course: Field Trip to coastal ecosystems and allied industries

Course Code: MIC-634

Number of Credits: 1, Practical

Contact hours: 30

Effective from Academic Year: 2022-23

Prerequisites	The student should have knowledge of microbiology.	
Objective:	● To apply various techniques and instruments used for collection of samples from marine and coastal ecosystem. ● To understand the processing of marine and coastal samples.	
Content:		
1.	**Sample collection from coastal regions:** **a) Estuarine sampling** Collection of samples using various water samplers and sediment grabs; recording of lat-long (net GIS), temperature and salinity; samples for BOD, COD; maintenance and transfer of samples. Processing the samples for isolation of microorganisms **b) Intertidal regions** Sampling and culturing of microorganisms associated with marine flora and fauna.	**(22)**
3.	**Visit to marine industries:** Aquaculture / Marine farming / Seafood processing industry.	**(08)**
4.	**Report writing**	
5.	**Presentation and group discussion**	
Pedagogy:	Field visit/Laboratory analysis/Presentation	
References/ Readings	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y. (2020) Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York. (2009) Przeslawski, R., Berents, P., Clark, M., Edgar, G., Frid, C., Hughes, L., & Smith, J. Marine sampling field manual for grabs and box corers. *Field Manuals for Marine Sampling to Monitor Australian Waters*, 172-195. (2018) Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa. (2007). Suter, E. A., Scranton, M. I., Chow, S., Stinton, D., Medina Faull, L., & Taylor, G. T. Niskin bottle sample collection aliases microbial community composition and biogeochemical interpretation. *Limnology and Oceanography*, *62*(2), 606-617. (2017). Reading material provided by the industries. Websites of the industries.	
Course Outcomes	● To experiment with marine and coastal samples. ● To plan isolation of marine microorganisms. ● To analyse the marine microorganism for their potential applications. ● To categorize the various opportunities available in marine industries in Goa.	

Semester IV

Title of the Course: Internship in Industry/Institution

Course Code: MIC-652
Number of Credits: 2, Practical
Contact hours: 60
Effective from Academic Year: 2022-23

Prerequisites	The student should have knowledge of microbiology.	
Objective:	● To apply the use of instruments and techniques used in industries and institutions through hands-on training. ● To associate with recent trends in research/economic activities in institutes/industries.	
Content:		
1.	**Training in an Institute/Industry** The student shall be required to undertake training in Research Institute/Industry for a minimum period of 2 weeks or its equivalent and submit a certificate of attendance signed by the Training Coordinator of the respective Institute/ Industry. *Students may opt to undertake a summer training Course in an Institute/ Industry of their choice. A student shall be required to make the necessary inquiries to seek the possibility of doing such a training; faculty will be assigned to assist them in their preparations. An official letter will then be issued.*	**(60)**
2.	**Report writing**	
3.	**Presentation and group discussion**	
Pedagogy:	Hands-on-training/literature review	
References/ Readings	Reading material provided by the institution/industry Websites of the institutions/industries.	
Course Outcomes	● To evaluate the use of specialized instruments for application in microbiological analysis. ● To plan the experiments based on recent trends in microbiology. ● To appraise the future prospects in microbiological research and industry. ● To compile analysis reports.	