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)

Course Structure of M.Sc. Microbiology

Semester 1 – Core Papers				
Code	**Title of paper**	**Theory/ Practical**	**Credit**	**CH**
MIC 101	Microbial Biochemistry	Theory	3	36
MIC 102	Microbial Genetics	Theory	3	36
MIC 103	Microbial Taxonomy and Systematics	Theory	3	36
MIC 104	Biostatistics	Theory	3	36
MIC 105	Practical I	Practical	4	96
Semester 2 – Core Papers				
MIC 201	Techniques and Instrumentation in Microbiology	Theory	3	36
MIC 202	Industrial Microbiology	Theory	3	36
MIC 203	Molecular Biology	Theory	3	36
MIC 204	Mycology	Theory	3	36
MIC 205	Practical II	Practical	4	96
Semester 3 & 4 – Optional Papers				
MIO 101	Medical Virology	Theory	3	36
MIO 102	Archaea [T]	Theory	3	36
MIO 103	Archaea [P]	Practical	1	24
MIO 104	Marine Microbiology [T]	Theory	3	36
MIO 105	Marine Microbiology [P]	Practical	1	24
MIO 106	Environmental Microbiology and Bioremediation [T]	Theory	3	36
MIO 107	Environmental Microbiology and Bioremediation [P]	Practical	1	24
MIO 108	Genetic Engineering [T]	Theory	3	36
MIO 109	Genetic Engineering [P]	Practical	1	24
MIO 110	Immunology [T]	Theory	3	36
MIO 111	Immunology [P]	Practical	1	24
MIO 112	Extremophilic Microorganisms [T]	Theory	3	36
MIO 113	Extremophilic Microorganisms [P]	Practical	1	24
MIO 114	Research Methodology [T]	Theory	1	12
MIO 115	Research Methodology [P]	Practical	1	24
MIO 116	Microbial Technology [T]	Theory	3	36
MIO 117	Microbial Technology [P]	Practical	1	24
MIO 118	Food Microbiology [T]	Theory	3	36
MIO 119	Food Microbiology [P]	Practical	1	24
MIO 120	Agriculture Microbiology [T]	Theory	3	36
MIO 121	Agriculture Microbiology [P]	Practical	1	24
MIO 122	Medical Microbiology and Epidemiology [T]	Theory	3	36
MIO 123	Medical Microbiology and Epidemiology [P]	Practical	1	24
MIO 124	Marine Microbial Interactions [T]	Theory	3	36
MIO 125	Marine Microbial Interactions [P]	Practical	1	24
MIO 201	Field Trip/Study Tour [P]	Practical	1	24
MIO 202	Training in an Institute/ Industry/ University		1	
MID	Dissertation		8	

Under Optional Courses:

- The theory course is a prerequisite for any practical course.
- Students of Microbiology and Marine Microbiology Programmes shall be required to take both Theory and Practical Courses under a given Course Title.

Programme: M.Sc. (Microbiology)

Course Code: MIC 101

Title of the Course: MICROBIAL BIOCHEMISTRY

Number of Credits: 3

Effective from Academic Year: 2018-19

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**	**(12)**
1.1	**Proteins**	
	Amino acids: features and properties.	
	Protein: structure, principles of separation and purification, molecular weight determination; sequencing and synthesis.	
	Enzymes: activity, inhibition, mechanism of action; regulatory – allosteric and covalently modulated enzymes and their significance in metabolism.	
1.2	**Carbohydrates**	
	Monosaccharides: types, characteristics and properties.	
	Disaccharides, oligosaccharides, polysaccharides – biological significance.	
1.3	**Lipids**	
	Fatty acids: saturated and unsaturated, structure and properties.	
	Lipids: biological significance; lipid composition of microorganisms.	
2.	**Bioenergetics and Carbohydrate Metabolism**	**(12)**
2.1	**Bioenergetics**	
	Thermodynamics, exergonic and endergonic reactions, redox potential, high energy compounds, ATP structure and significance.	
2.2	**Oxidative Phosphorylation**	
	Redox enzymes, aerobic electron transport and oxidative phosphorylation.	
2.3	**Carbohydrate metabolism**	
A.	Carbohydrates: Central pathways of metabolism – regulatory mechanisms, bioenergetics and significance – EMP, TCA cycle (glucose aerobic and anaerobic metabolism, malate metabolism), Glyoxylate cycle.	
B.	Gluconeogenesis from TCA intermediates / amino acids / acetyl-CoA; biosynthesis of polysaccharides and sugar interconversions.	

3.	**Lipids, Amino Acids, Nucleotides and other Metabolic Paths**	**(12)**
3.1	**Lipid Metabolism**	
A.	Anabolism: Biosynthesis of fatty acids: saturated and unsaturated, triglycerides, phospholipids,	
3.2	**Amino Acid and Nucleotide Biosynthesis**	
A.	Amino acid biosynthetic pathways and their regulation.	
B.	Purine and pyrimidine nucleotides, Deoxyribonucleotides: biosynthesis and regulation.	
C.	Biosynthesis of nucleotide coenzymes.	
3.3	**Photosynthetic Metabolism**	
A.	Organisms and photosynthetic pigments, fundamental processes in Photosynthesis.	
B.	Photosynthetic electron transport and photophosphorylation.	
3.4	**Chemolithotrophy**	
	Organisms, substrates, bioenergetics of metabolism.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Lehninger, A., Cox, M. and Nelson, D. L., Principles of Biochemistry, W. H. Freeman & Company.	
	Moat, A. G., Foster, J. W. and Spector, M. P., Microbial Physiology, A. John Wiley & Sons Inc. Publication.	
	Bull, A. T. and Meadow, P., Companion to Microbiology, Longman Group Limited, New York.	
	Voet, D., Voet, J. G. and Pratt, C. W., Principles of Biochemistry, John Wiley and Sons Inc.	
	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.	
	Plummer, D. T., An Introduction to Practical Biochemistry, Tata McGraw Hill Publishing Company.	
	Sadasivam, S., Manickam, A., Biochemical Methods, New Age International (P) Limited.	
	Jayaraman, J., Laboratory Manual in Biochemistry, John Wiley & Sons, Limited, Australia.	
Learning Outcomes	1. Apply the knowledge to understand the microbial physiology and to identify the microorganisms. 2. Understand the regulation of the biochemical pathway and possible process modifications for improved control over microorganisms for microbial product synthesis.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 102

Title of the Course: MICROBIAL GENETICS

Number of Credits: 3

Effective from Academic Year: 2018-19

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 and translation.	
Objective:	This course develops concept of Classical Mendelian genetics and deviation from Mendelian principles, Microbial genome organization (Prokaryotic and Eukaryotic), Viral Genetics, Mutagenesis, Bacterial plasmids as research tools, transcription and translation in prokaryotes and eukaryotes and application of Microbial Genetics.	
Content:		
1.		
1.1	**Classical Mendelian genetics and deviation from Mendelian principles:** Origin of mitochondria and plastids – Endosymbiont theory, DNA in Mitochondria and plastids, Mitochondrial and plastid genes inherited by Non-Mendelian mechanism.	**(03)**
1.2	**Microbial genome organization:** 3 Domains of Life based on 16S rRNA and 18S rRNA; Prokaryotic and Eukaryotic; replication, transcription and regulation. Structure of Prokaryotic genes (lac and trp operon) and Eukaryotic Genes (interrupted Genes), Prokaryotic & Eukaryotic genome. Microbial gene transfer (Conjugation, transformation, transduction). **Structural chromosomal aberrations and their significance:** Deletion, duplication, inversion, translocation. Aneuploidy and polyploidy.	**(05)**
1.3	**Viral Genetics :** Genomic organization and Replication of viruses:- T4, Lambda Phage and its strategies - Lytic and Lysogenic cycles, TMV, SV40, Hepatitis B, HIV. Retroviruses and retroposons - introduction and genetic significance. Viroids and plant diseases, virusoids.	**(04)**
2.		
2.1	**Genomic (DNA) Rearrangements:** 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 and microbial genome evolution.	**(04)**

2.2	**Mutagenesis, mutation and mutants**: Somatic and germinal mutation, spontaneous and induced mutations, site specific using PCR/ cassette mutagenesis, and random mutagenesis. **DNA Damage:** Thymine dimer, apyrimidinic site and apurinic site, cross linking, deamination of base, base mismatch. **Types of mutation:** silent mutation, missense mutation, nonsense mutation, Read through mutation, frameshift- insertion and deletion mutation, translocation, Inversion, suppressor mutation. **Mutagenic chemicals and radiations and their mechanism of action**: Base analogues (5-Bromouracil and 2-amino purines), EMS, acridines, NTG, Hydroxylamine; mutagenic radiations- UV, X-rays and gamma rays. Ames test; Auxotrophy.	**(08)**
3.		
3.1	**Fungal Genetics**: Yeast - *Saccharomyces cerevisiae/ S. pombe* and *Neurospora* genomes as model genetic systems; Chromosome replication, yeast artificial chromosomes, tetrad analysis, genetic compatibility and non-compatibility genes, heterokaryosis, Parasexuality, Petite mutants of yeast, Killer yeast.	**(06)**
3.2	**Bacterial plasmids**: Types of plasmids, F plasmids and their use in genetic analysis-$F^{+,}$Hfr cells/ F'cells, colicin and col plasmids, R plasmids, metal resistance, and antibiotic resistance - efflux pump/MDR bacteria, Ti plasmid, 2µ plasmid. Replication in plasmids. Bacterial plasmids as research tools. Integrons and Genomic islands - pathogenicity islands.	**(06)**
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Gardner, E. J., Simmons, M. J. and Snustad, D. P., Principles of Genetics, John Wiley & Sons.	
	Krebs J. E., Lewin B., Goldstein E. S. and Kilpatrick, S.T., LEWIS Genes XI, Jones and Bartlett Publishers.	
	Maloy, S. R., Cronan, J. E. and Freifelder, D., Microbial Genetics, Jones and Bartlett Publishers.	
	Streips, U. N. and Yasbin, R. E., Modern Microbial Genetics, John Wiley.	
	Synder, L., Peters, J. E., Henkin, T. M. and Champness, W., Molecular Genetics of Bacteria, ASM Press.	
	Dale, J. W. and Park, S. F., Molecular Genetics of Bacteria, John Wiley	
	Trun, N. and Trempy, J., Fundamental Bacterial Genetics, John Wiley & Sons.	
	Peter, J. R., *i*Genetics: A Molecular Approach, Pearson Education.	
	Birnboim, H. C. and Doly, J., (1979) A rapid alkaline extraction procedure for screening recombinant plasmid DNA. Nucleic Acid Research, 7: 1513-1523.	
	Holmes, D. S. and Quigley, M., (1981) A rapid boiling method for the preparation of bacterial plasmids. Anal Biochem., 114(1): 193-197.	

	Sambrook, J., Fritsch, E. F. and Maniatis, T., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York.	
	Green, M. R. and Sambrook, J., Molecular Cloning: A laboratory manual, Cold Spring Harbour Laboratory Press, New York.	
Learning Outcomes	1) Explains principles/concept of Prokaryotic and Eukaryotic genetics, Viral Genetics and application in research. 2) Mutagenesis, Mutation and mutants and their significance in microbial evolution. 3) Application of bacterial and eukaryotic plasmids in research.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 103

Title of the Course: MICROBIAL TAXONOMY AND SYSTEMATICS

Number of Credits: 3

Effective from Academic Year: 2018-19

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:	This course introduces the development of taxonomy and systematics, the various characters used for this purpose, the rules governing the different taxonomy and classification systems and the salient features of the different microbial groups. It also focuses on the rapidly evolving nature of taxonomy and systematics.	
Content:		
1.		
1.1	**Microbial taxonomy and systematics** Concepts of taxonomy (characterization, classification and nomenclature) and systematics; classification of microorganisms, three domain, six-kingdom, 8-kingdom systems.	**(02)**
1.2	**Phenotypic characters** - Morphology, Biochemical tests (e.g. API, BIOLOG), Bacteriophage typing, Serotyping.	**(04)**
1.3	**Chemotaxonomic markers** - Cell wall components, lipid composition, cellular fatty acid (FAME analysis), isoprenoid quinones, protein profiles (e.g. MALDI-TOF).	**(06)**
1.4	**Nucleic acid based techniques** – Terminal Restriction Fragment Length Polymorphism (TRFLP); G+C content (T_m and HPLC); pyrosequencing; 16S rRNA gene sequencing; phylogenetic analysis; DNA-DNA hybridization.	**(08)**
1.5	Concepts of species, numerical taxonomy and polyphasic taxonomy.	**(04)**
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.	**(12)**
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	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.	

	Goodfellow, M., Mordarski, M. and Williams, S. T., The biology of the actinomycetes, Academic Press.	
	Goodfellow, M. and Minnikin, D. E., Chemical Methods in Bacterial Systematics, The Society for Applied Bacteriology. Technical Series No. 20, Academic Press.	
	Barlow, A., The prokaryotes: A Handbook on the Biology of Bacteria: Ecophysiology, Isolation, Identification, Applications, Volume 1, Springer-Verlag.	
	Kurtzman, C. P., Fell, J. W. and Boekhout, T., The Yeasts - A Taxonomic Study, Elsevier.	
	Prescott, L. M., Harley, J. P. and Klein, D.A., Microbiology. McGraw Hill, New York.	
	Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Vol. 18 & 19, Academic Press.	
	Reddy, C. A., Methods for General and Molecular Microbiology, ASM Press.	
Learning Outcomes	1. Apply knowledge of the standard rules of classification systems to categorize microorganisms. 2. Appreciate and explain the dynamic and ever developing nature of the field of microbial taxonomy and systematics.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 104

Title of the Course: BIOSTATISTICS

Number of Credits: 3

Effective from Academic Year: 2018-19

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.		
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). **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.	**(03)** **(04)**
1.2	**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.	**(05)**
2.		
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.	**(03)**
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. Skewness – definition, positive, negative, purpose, measure, relative	**(04)**

	measure, Karl Pearson's Coefficient, Bowley's Coefficient, Kelly's Measure, Moments.	
2.3	**Correlation analysis** – Correlation, covariance, correlation coefficient for ungrouped and grouped data, Pearson's Rank Correlation coefficient, scatter and dot diagram (graphical method). **Regression analysis -** Linear and exponential function - examples: DNSA conversion by reducing sugar, survival/growth of bacteria, regression coefficients, properties, standard error of estimates, prediction, regression analysis for linear equation.	**(05)**
3.		
3.1	Probability: Probability, Combinatorial Techniques, Elementary Genetics, Binomial, Poisson, Normal Distributions.	**(04)**
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.	**(04)**
3. 3	Chi-square test, F-test and ANOVA.	**(04)**
Pedagogy:	Lectures/tutorials/assignments/self-study/MOODLE/Videos	
References/ Readings	Kothari, C. R., Quantitative Techniques, Vikas Publishing House.	
	Arora, P. N. and Malhan, P. K., Biostatistics, Himalaya Publishing House.	
	Danilina, N.I., Computational Mathematics, Mir Publishers.	
	Surya, R. K., Biostatistics, Himalaya Publishing House.	
Learning outcomes	Able to collect, handle, process and present the Biological Data. Apply the principles of statistics on biological experiments.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 105

Title of the Course: Practical I

Number of Credits: 4

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have theoretical knowledge about various biomolecules; the different groups of microorganisms; ability to perform calculations	
Objective:	This course provides opportunities for hands-on experience with microbiological and biochemical concepts in laboratory setup along with handling and processing of such data for statistical analysis.	
Content:		
I	**Microbial Biochemistry**	**(24)**
1.	Standard curve for sugar.	
2.	Standard curve for protein.	
3.	Enzyme assay.	
4.	Precipitation of protein from solution by salting out.	
5.	Dialysis.	
6.	Specific activity, fold purification, percentage yield of enzyme.	
7.	Molecular weight determination by SDS-PAGE.	
II	**Microbial Genetics**	**(24)**
1.	Isolation of plasmid DNA from bacterial cells by Alkaline Lysis method (Birnboim and Doly, 1979).	
2.	Agarose gel electrophoresis, visualization and documentation of plasmid and genomic DNA using Gel Doc system.	
3.	Spectrophotometric quantification and purity of bacterial plasmid DNA.	
4.	UV mutagenesis and screening of pigment deficient mutants of *Serratia marcescens*.	
III	**Microbial Taxonomy and Systematics**	**(24)**
1.	Morphological, physiological and biochemical characterization of bacteria.	
2.	Chemotaxonomic analysis of cell wall.	
3.	Characterization of actinomycetes (*Streptomyces* sp.).	
4.	Characterization of yeast (*Saccharomyces cerevisiae*, *Schizosaccharomyces pombe*).	
5.	Characterization of cyanobacteria.	

IV	**Biostatistics**	**(24)**
1.	Excel spreadsheet and data analysis.	
2.	Linear equation analysis (regression analysis).	
3.	Normal distribution.	
4.	Hypothesis testing.	
Pedagogy:	Experiments in the laboratory, data collection and processing.	
References/ Readings	As given under respective Theory Courses MIC 101-T to MIC 104-T	
Learning Outcomes	1. Skillful handling and estimating biomolecules and other metabolic products of microorganisms 2. Learning Plasmid DNA isolation using Alkaline lysis method and agarose gel electrophoresis for application in microbial research. 3. Application of techniques to isolate and characterize different groups of microorganisms. 4. Ability to collect data, processing and statistical interpretation of microbiology-related experiments.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 201

Title of the Course: TECHNIQUES AND INSTRUMENTATION IN MICROBIOLOGY

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	The student should be familiar with the concepts in basic chemistry and should be able to use basic instruments in Microbiology.	
Objective:	This course develops the concepts of methodology involved in studying the different components of microbial cell and various techniques and instruments involved in product analysis.	
Content:		
1.		**(12)**
1.1	**Chromatographic techniques:**	
	GC, HPLC, detectors, column/s matrix- Ion-exchange, affinity and molecular exclusion. (using examples for separation of microbial lipids, pigments, nucleic acids and proteins/enzymes).	
1.2	**Centrifugation:**	
	Principles, methodology, application; Density gradient centrifugation; Ultracentrifugation (Separation of ribosomal subunits of bacteria).	
1.3	**Spectrophotometry:**	
	Atomic Absorption Spectrophotometry (AAS), UV-Visible, fluorimetry, Fourier transformation infra-red spectroscopy (FTIR), NMR, MS.	
2.		**(12)**
2.1	**Microscopy:**	
	Epifluorescence filter technique (DEFT), SEM, TEM, Confocal microscopy.	
2.2	**Radio-isotope and tracer techniques:**	
	Isotope and types of isotopes, Radio-activity counters, Autoradiography,	
2.3	**Cell and tissue culture techniques:**	
	Primary and secondary/established cell lines, Monolayer and suspension cultures, Fluorescence activated cell sorting (FACS), Biohazards and Biosafety cabinet.	
3.		**(12)**
3.1	**Electrophoretic technique:**	
	PAGE, IEF, , PFGE, DGGE, TGGE, Single stranded conformation polymorphism (SSCP), Electroporator, Micro-array technique.	
3.2	**Isolation of cell organelles:**	
	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, spheroplast.	

3.3	**Others:**	
	X-ray diffraction.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Wilson, K. and Walker, J., Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press, N.Y., USA.	
	Cooper, T. G., The Tools of Biochemistry, Wiley India Pvt. Ltd.	
	Goswami, C., Paintal, A. and Narain, R., Handbook of Bioinstrumentation, Wisdom Press, New Delhi.	
	Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Volume 5, Part B, Academic Press.	
	Colowick, S. P. and Kaplan, N. O., Methods in Enzymology, Vol. VI, Academic Press, N.Y.	
	Parakhia, M. V., Tomar, R. S., Patel, S. and Golakiya, B. A., Molecular Biology and Biotechnology: Microbial Methods, New India, Pitampura.	
	Sambrook, J., Fritsch, E. F. and Maniatis, T., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, USA.	
	Jayaraman, J., Laboratory Manual in Biochemistry, John Wiley & Sons Limited, Australia.	
Learning Outcomes	Ability to use techniques and instruments involved in the study of microorganisms and their products.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 202

Title of the Course: INDUSTRIAL MICROBIOLOGY

Number of Credits: 3

Effective from Academic Year: 2018-19

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:		
1.		
1.1	History of Industrial Microbiology, fermentation processes, descriptive layout and components of fermentation process for extracellular and intracellular microbial products.	**(05)**
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.	**(05)**
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, comparison between various cultivation systems.	**(04)**
2.		
2.1	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.	**(05)**
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 number; Scale-up of bioprocesses: parameters used in scale-up and problems associated with scale-up.	**(05)**
3.		
3.1	Solid substrate fermentation (SSF): Principles and application; Surface fermentation Comparison between SSF, Surface fermentation and SmF. Immobilized enzymes and cell systems.	**(03)**

3.2	Fermentation monitor 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.	**(04)**
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).	**(05)**
Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/Videos	
References/ Readings	1. Demain, A. L., Davies, J. E. and Atlas, R. M. Manual of Industrial Microbiology and Biotechnology, ASM Press. 2. Vogel, H. C. and Tadaro, C. M., Fermentation and Biochemical Engineering Handbook: Principles, Process Design and Equipment, William Andrew Publisher. 3. Atkinson, B. and Mavituna, F., Biochemical Engineering and Biotechnology Handbook, Stockton Press. 4. Flickinger, M. C. and Drew S. W., The Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis and Bioseparation, Volumes 1 - 5, John Wiley Publisher. 5. Stanbury, P. F., Whitaker, A. and Hall, S.J., Principles of Fermentation Technology, Butterworth-Heinemann Publishers.	
Learning Outcomes	1. Apply the principle of management and controls on the microbial processes in industrial settings. 2. Apply the principles of physiological understanding in improvement of the industrial processes.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 203

Title of the Course: MOLECULAR BIOLOGY

Number of Credits: 3

Effective from Academic Year: 2018-19

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:		
1.	**Genetic material, bonds, types of DNAs, DNA packaging and model organisms**	**(12)**
1.1	**Nucleic Acids, bonds, types of DNAs, DNA packaging and model organisms**	
A.	Structure of DNA and RNA.	
B.	Bondings and different types of DNA (B-DNA & Z-DNA).	
C.	DNA packaging in bacteria (Nucleoid) and viruses.	
D.	Yeast as a minimal model eukaryote.	
1.2	**Chromosomes, Genomes and it's evolution**	
A.	Fundamental functions of DNA.	
B.	Chromosomal DNA and its packaging in the chromatin fibre.	
C.	Chromatin structure, structural features (Telomere, Centromere and Repetitive sequences) of chromosomes and their functions.	
D.	Gene duplication and mutations.	
E.	**DNA Gels:** Agarose gel electrophoresis, RNA denaturing gels, Ethidium Bromide, SYBER GOLD SYBER GREEN II, DNA and RNA ladders, Tracking dyes Methylene blue, Xylene cynol	
2.	**DNA Damage, DNA Repair and Recombination**	**(12)**
2.1	**DNA damage elements/factors**	
A.	Types of DNA damage (spontaneous and induced DNA damage).	
B.	Mechanisms/pathways to remove damaged DNA: Excision repair, mismatch repair, recombination repair in *E. coli* and SOS Repair.	
C.	Role of *RecA* in DNA damage repair, Photoreactivation repair in *E. coli* involving photolyase.	
2.2	**Mechanisms of Genetic Recombination**	
A.	General and site specific recombination.	
B.	Heteroduplex DNA formation (Homologous recombination).	
C.	Synaptonemal Complex, Bacterial RecBCD system and its stimulation of chi sequences.	
D.	Role of RecA protein, homologous recombination, Holliday junctions.	

3.	**How cells read the Genome**	**(12)**
3.1	**From DNA to Proteins**	
A.	From DNA to RNA.	
B.	From RNA to Protein.	
C.	The RNA world and origin of life.	
3.2	**Gene structure and control of gene expression in Prokaryotes and Eukaryotes**	
A.	An overview of Gene expression control, DNA binding motifs in gene regulatory proteins, genetic switches and their role in control of gene expression.	
B.	Post-transcriptional controls-transcriptional attenuation, Riboswitches, Alternate splicing, RNA editing, RNA Interference.	
C.	Translation of mRNA in Prokaryotes and Eukaryotes.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K. and Walter, P., Molecular Biology of the Cell, Garland Science.	
	Darnell, J. E., Lodish, H. F. and Baltimore, D., Molecular Cell Biology, Scientific American Books, Spektrum Akademischer Verlag.	
	Watson, J. D., Molecular Biology of the Gene, Pearson/Benjamin Cummings.	
	Malacinski, G.M., Freifelder's Essentials of Molecular Biology, Narosa Book Distributors Private Limited.	
	Krebs J. E., Lewin, B., Goldstein, E. S. and Kilpatrick S.T., LEWIS Genes XI., Jones and Bartlett Publishers.	
	Gardner, E. J., Simmons, M. J. and Snustad, D. P. Principles of Genetics, John Wiley & Sons.	
	Tamarin, R. H., Principles of Genetics, McGraw-Hill Higher Education.	
	Twyman, R. M. and Wisden, W., Advanced Molecular Biology: A Concise Reference, BIOS Scientific Publishers.	
	Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York.	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.	
	Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier.	
Learning Outcomes	Understanding of gene structure, expression and regulation of gene expression in both prokaryotes and eukaryotes for application in molecular research.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 204

Title of the Course: MYCOLOGY

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	The student should be familiar with the structural morphology of the fungus and their existence in the surrounding environment.	
Objective:	This course deals with detailed classification and identification of fungi, fungal ecology in terrestrial, aquatic and extreme habitats, fungal genetics and applications of fungal enzymes and various primary and secondary metabolites.	
Content:		
1.	**Fungal diversity and distribution**	**(12)**
1.1	**Origin and phylogeny**; **classification**	
1.2	**Fungi – Terrestrial and Aquatic**	
A.	Terrestrial, Fresh water and Marine: Coastal – mangrove; Estuarine; Ocean	
B.	Hypersaline waters – Thalassohaline and Athallasohaline: Solar salterns, Salt Lake, Dead Sea.	
1.3	**Extremophilic Fungi**	
	Oligotrophs, Alkaliphiles, Acidophiles, Barophiles, Psychrophiles, Thermophiles, Halophiles, Osmophiles, Xerophiles.	
	Adaptation to extreme environments.	
2.	**Physiology and Genetics**	**(12)**
2.1	**Physiology of fungi**	
A.	Growth and development.	
B.	Fungal hormones- attractants, morphogenesis and differentiation.	
C.	Microbial interactions.	
D.	Secondary metabolites: antimicrobials, mycotoxin, pigments.	
2.2	**Fungal genetics**	
	Neurospora and *Saccharomyces*: Life-cycle; Tetrad analysis, gene conversion; Deuteromycotina: parasexuality, cytoplasmic inheritance; Electrophoretic karyotyping.	
2.3	**Identification of fungi**	
A.	Colonial and morphological characteristics.	
B.	Molecular finger printing.	
3.	**Pathogenesis - Antifungal Therapy**	**(04)**
3.1	**Pathogenesis**	
A. B.	Mycoses - Systemic, sub-cutaneous, cutaneous and superficial, opportunistic	

	Plant pathogens.	
3.2	**Antifungal Therapy**	
	Drugs acting on cell membrane, protein synthesis inhibitors; fungicides.	
4.	**Applications**	**(08)**
A.	Industrially important enzymes.	
B.	Bioprospecting of secondary metabolites: Antimicrobials, antitumour agents, nutraceuticals, pigments,.	
C.	Biodegradation and bioremediation.	
D.	Biocontrol.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Alexopoulus, C. J., Mims, C. W. and Blackwell, M., Introductory Mycology, John Wiley & Sons (Asia) Pvt. Ltd.	
	Mehrotra, R. S. and Aneja, K. R., An Introduction to Mycology, Wiley Eastern Limited.	
	Cooke, R. C. and Whipps, J. M., Ecophysiology of fungi, Blackwell Scientific Publications, Oxford.	
	Deacon, J. W., Introduction to Modern Mycology, Volume 7 of Basic Microbiology, Blackwell Scientific Publications.	
	Kendrick, B., The Fifth Kingdom, Focus Publishers.	
	Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S., Microbiology, Harper and Row.	
	Strickberger, M. W., Genetic, The MacMillan Company, New York.	
	Domsch, K. H., Gams, W. and Anderson, T-H., Compendium of Soil Fungi, IHW-Verlag.	
	Gilman, J. C. and Joseph, C., A Manual of Soil Fungi, Daya Books.	
	Onions, A. H. S., Allsop, D. and Eggins, M. O. W., Smith's Introduction to Industrial Mycology, Edward Arnold, London.	
Learning Outcomes	Apply the knowledge in fungal taxonomy, bioremediation and bioprospecting of secondary metabolites and industrially important fungal enzymes.	

Programme: M.Sc. (Microbiology)

Course Code: MIC 205

Title of the Course: Practical II

Number of Credits: 4

Effective from Academic Year: 2018-19

Prerequisites	Knowledge of basic microbiology techniques	
Objective:	This course develops the skills for techniques and instrumentation in microbiology, industrial microbiology, molecular biology, and mycology	
Content:		
I	**Techniques and Instrumentation in Microbiology**	**(24)**
1.	Microscopy – compound, phase contrast – of bacterial cells.	
2.	Density gradient separation of microbial cells.	
3.	Cell disruption of pigmented bacteria/yeast by sonicator, efficacy of sonication and pigment profiling using UV-visible spectrophotometer.	
4.	Polyacrylamide gel electrophoresis (PAGE), Zymogram.	
5.	Molecular exclusion chromatography.	
II	**Industrial Microbiology**	**(24)**
1.	Fermentation kinetics – growth of *E.coli/S.cerevisiae* and determination of μ_{max}, Ks, Yx/s, m.	
2.	Rheology of substrate solutions.	
3.	Designing of fermentor – stirred tank reactor.	
4.	Baker's yeast – FSSAI/ISI quality assurance – Counts of Yeast, Fungi, Bacteria, Spore, Coliforms, *E.coli, Salmonella, Shigella, Vibrio*; Dough raising capacity; Fermentation power; Moisture content; Ash content.	
III	**Molecular Biology**	**(24)**
1.	Isolation of genomic DNA of bacterial cells, estimation of quantity and purity of DNA by spectrophotometry, and agarose gel electrophoresis.	
2.	PCR amplification of a specific gene using genomic DNA as a template and agarose gel analysis of PCR product to determine amplicon size.	
IV	**Mycology**	**(24)**
1.	**Study and Identification of fungi**	
1.1	Study of standard cultures:	
A.	Colony characteristics	
B.	Morphological characteristics	
1.2	Isolation and identification of fungi.	
A.	Observation of colonial and morphological characteristics	

B.	Reference to identification keys	
2.	Application of fungi for bioremediation Fungal degradation of a plant polymer.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under respective Theory Courses MIC 201-T to MIC 204-T	
Learning Outcomes	1. Able to handle the instruments for carrying out microbiological research work or in the industries. 2. To learn techniques involved in genomic DNA isolation and PCR amplification for use in molecular research. 3. Handling fungal cultures and exploring them for better and newer prospects. 4. Apply principles of industrial microbiology for development and assessment of process and products.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 101

Title of the Course: MEDICAL VIROLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	The student should have basic understanding of viruses.	
Objective:	This course develops concepts in structure, classification, cultivation, assay and pathogenesis of disease-causing viruses.	
Content:		
1.	**Virus: Structure, Cultivation and Assay**	**(12)**
1.1	**Viruses**	
A.	Introduction.	
B.	Visualization by electron microscopy.	
C.	Structure: envelope, capsid, nucleic acid.	
D.	Defective viruses.	
E.	Classification.	
1.2	**Viral genome**	
	Genomic diversity - DNA or RNA, segmented or non-segmented.	
1.3	**Cultivation and assay of viruses**	
A.	Cultivation - *in vitro* using cell cultures: primary, secondary cultures, cell lines. - *in ovo* using chick/duck egg embryo. - *in vivo* using experimental animals	
B.	Viral multiplication and interference.	
C.	Assay by physical methods and by infectivity and cultivation methods Detection by plaque, pock, polykaryocytes, haemadsorption, immunofluorescence, cytopathogenicity, tumor formation.	
2.	**Viral Diseases**	**(12)**
2.1	**Viral agents of disease**: structure, mode of replication and pathogenesis Picornavirus: Enteroviruses (polio) and rhinoviruses (upper respiratory tract); Herpes group: Herpes simplex, Herpes zoster, Cytomegalovirus, Epstein Barr virus. Hepatitis (A, B, C, D, E); HIV; Orthomyxoviruses: Influenza. Paramyxoviruses: Mumps and Measles; Arboviruses: Togavirus - Rubella; Rhabdovirus: Rabies; Corona Virus: SARS. Emerging viral agents of disease.	
2.2	**Oncogenic viruses** DNA viruses: Papova and Adeno viruses, Herpes EBV and HCV. Retrovirus.	

3.	**Antiviral Combat**	**(12)**
3.1	**Virus-Host interactions**. Host specific and nonspecific defense mechanisms; neutralizing antibodies; interferon.	
3.2	Viral vaccine development and viral chemotherapy. Traditional vaccine preparations and newer methods - molecular approach	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S., Microbiology, Harper and Row Publishers.	
	Microbiology and Immunology - Online, Department of Pathology, Microbiology and Immunology, University of South Carolina School of Medicine.	
	White, D. O., Fenner, F., Medical Virology, Gulf Professional Publishing.	
	Cohen, A., Medical Virology, John Wiley & Sons, Incorporated.	
	Evans, B., Perspectives in Medical Virology, Volume 1, Elsevier.	
	De La Maza, L. M., Peterson, E. M., Springer Science & Business Media.	
Learning Outcomes	Explain morphology, mode of infection, multiplication of medically important viruses and their treatment.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 102

Title of the Course: ARCHAEA [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge of 3 domains of life, difference between prokaryotic cells, eukaryotic cells and archaea.	
Objective:	This course develops concept of Three domains of Life, Ecology, physiology and diversity of Archaea, cell structure and architecture of archaea, metabolism and energetics of archaea and Genetics of domain Archaea.	
Content:		
1.		**(12)**
1.1	**Significance of Archaea**: Biotechnology, Biogeochemical cycling, Evolutionary developments.	
1.2	**Ecology, physiology and diversity of Archaea** Global econiches: Deep Sea, Hydrothermal vent, Dead Sea, solar salterns, geothermal vents, solfataras, Antarctica, soda lake. Study of archaeal biodiversity; unculturable archaea by metagenomics. Archaeal culture retrieval methods, novel samplers. Preservation and maintainance of archaeal cultures. Nutrition, growth and growth kinetics and physiological versatility, Stress response of Methanogens (*Methanobacterium thermoautotrophicum)*; Halophiles (*H. salinarum)*; Thermophiles (*Thermoplasma acidophilum*); Thermoacidophiles (*Sulfolobus acidocaldarius)*; Psychrophilic archaea (*Methanogenium frigidum, Methanococcoides burtonii*); Methanotrophs.	
1.3	**Cell structure and architecture of Archaea:** Cellular organization: cell morphotypes, cell envelopes -archaeal membrane lipids and cell wall, appendages -pili, flagella, cannulae, hami. Novel bio-molecules: Glycerol diether moieties and macrocyclic lipid, novel enzymes, co-enzymes: methanopterin, formaldehyde activation factor, Component B, Coenzyme M, F420, F430, corrinoids.	
2.	**Metabolism and energetics of Archaea**	**(12)**
2.1	Modified anabolic pathways of carbohydrates and lipids; methanogenesis and acetoclastic reactions.	
2.2	Modified central metabolic pathways: EMP, ED, incomplete TCA; reverse Kreb cycle, carbon dioxide reduction pathways: reductive acetyl-CoA pathway, 3-hydroxypropionate pathway. Chemolithoautotrophy.	

2.3	Bioenergetics: ATP synthesis (i) respiration-driven (ii) light-driven, involving bacteriorhodopsin (iii) chloride-driven, involving halorhodopsin	
3.	**Genome of Archaea**	**(12)**
3.1	Size of genome, G + C content, associated proteins, archaeal histones and nucleosomes, introns in archaea, archaeal RNA polymerases, reverse DNA gyrase.	
3.2	Plasmids, transposons -IS elements. Modifications in tRNA and rRNA structure. Novel 7S rRNA. DNA replication, translation and transcription in archaea.	
3.3	Gene organization in Archaea: (i) *his* operon (ii) *bob* operon (iii) *mcr* operon.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Woese, C. R., Fox, G. E., (1977) Phylogenetic structure of the prokaryotic domain: the primary kingdoms. Proc Natl Acad Sci USA. 74: 5088–5090.	
	Blum, P., Archaea: New Models for Prokaryotic Biology, Academic Press.	
	Cavicchioli, R., Archaea**:** Molecular and Cellular Biology, ASM Press.	
	Garrett, R. A. and Hans-Peter, K., Archaea: Evolution, Physiology and Molecular Biology, John Wiley and Sons.	
	Howland, J. L., The Surprising Archaea: Discovering Another Domain of Life, Oxford University Press.	
	Barker, D. M., Archaea: Salt-lovers, Methane-makers, Thermophiles and Other Archaeans, Crabtree Publishing Company.	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y.	
	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.	
	Corcelli, A. and Lobasso, S., (2006) Characterization of Lipids of Halophilic Archaea. Methods in Microbiology, 35: 585-613.	
	Rothe, O. and Thomm, M., (2000) A simplified method for the cultivation of extreme anaerobic archaea based on the use of sodium sulfite as reducing agent, Extremophiles. 4: 247-252.	
Learning Outcomes	1) Explains concept of third domain of Life Archaea. 2)Explains Ecology, Physiology and Biochemistry of domain Archaea. 3)Principles of Archaeal Genetics and application. 4)Application of Archaea and archaeal bioactive compounds in Industry.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 103

Title of the Course: ARCHAEA [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have basic knowledge of 3 domains of life and basic microbiology techniques.	
Objective:	This course develops concepts in sampling and isolation of archaea from different econiches. Also identification of archaea and study of archaeal pigments.	
Content:		**(24)**
1.	Isolation and culturing of archaea.	
2.	Identification of isolate:	
2.1	Biochemical tests for archaea.	
2.2	Extraction of archaeal pigment and characterization using UV-Vis spectroscopy.	
3.	Screening for hydrolytic enzymes.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 102-T	
Learning Outcomes	1)Sampling from different Econiches of Archaea 2)Skill development for Isolation, culturing of Archaea and identification of archaea. 3) Bioprospecting of bioactive molecules from archaea.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 104

Title of the Course: MARINE MICROBIOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic understanding of the unique properties of water, features of marine environments and microorganisms.	
Objective:	This course focuses on the various characteristics of marine environments including the physico-chemical variables, climate events, microbial habitats, the different marine microorganisms found in seawater and their metabolic diversity, detection and enumeration methods.	
Content:		
1.		**(12)**
1.1	Introduction to oceanography: the world's oceans and seas, properties of seawater, physico-chemical factors in the marine environment such as temperature, density, nutrients, salinity, dissolved gases, waves, tides, oceanic currents, Ekman transport and upwelling; oceanic phenomena such as Coriolis effect, eddies, gyres, El Nino Southern Oscillation (ENSO).	
1.2	Marine microbial habitats: estuaries, mangroves, salt marshes, beach, coastal ecosystems and coral reefs.	
2.	**Marine microbes – bacteria, fungi, phytoplankton, zooplankton, viruses: their growth, physiology and contribution to ocean processes**	**(12)**
2.1	Modes of microbial growth: viable but non-culturable (VBNC) microorganisms, biofilms, microbial mats, epibiosis.	
2.2	Physiology of marine microbes: metabolic diversity, microbial loop; marine snow; fermentation, aerobic respiration, anaerobic respiration (denitrification, sulphate reduction, methanogenesis); nitrification, annamox, sulphur oxidation, methanotrophy; carbon dioxide fixation in autotrophs; the role of microorganisms in biogeochemical cycling: carbon, nitrogen, phosphorous, sulphur, iron.	
3.	**Methods in marine microbiology**	**(12)**
3.1	Sampling equipment: water samplers such as Niskin sampler, Hydro-Bios sampler, Rosette samplers; sediment samplers such as van Veen grabs and corers.	
3.2	Analysis of primary productivity: the radiocarbon method	
3.3	Analysis of bacterial productivity: the thymidine uptake method	
3.4	Measurement of respiration rates: light-dark bottle method	
3.5	Tools to study marine microbial diversity: flow cytometry, molecular approaches such as metagenomics and community fingerprinting.	

Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Belkin, S. and Colwell, R. R., Ocean & Health: Pathogens in the Marine Environment, Springer.	
	Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim.	
	Hunter-Cevera, J., Karl, D. and Buckley, M., Marine Microbial Diversity: the Key to Earth's Habitability, American Academy of Microbiology.	
	Meller, C. B., Wheeler, P. A., Biological Oceanography, Wiley-Blackwell Publishers.	
	Mitchell, R. and Kirchman, D. L., Microbial Ecology of the Oceans, Wiley- Blackwell Publishers.	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y.	
	Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco.	
	Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York.	
	Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa.	
	Sournia, A., UNESCO Monographs on Oceanographic Methodology, Vol. 6, Phytoplankton Manual, UNESCO Publishing, Paris.	
	Tomas, C. R., Identifying Marine Phytoplankton, Academic Press, San Diego, CA.	
Learning Outcomes	1. Explain the concept of marine environments and the factors governing them. 2. Apply the principles of marine microbiology to understand the biological phenomena occurring in marine environments.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 105

Title of the Course: MARINE MICROBIOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

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:	This Course focuses on techniques involved in analysis of various parameters of seawater and enzyme and biofilm studies from marine bacterial isolates.	
Content:		**(24)**
1.	Analysis of physico-chemical parameters of seawater.	
2.	Isolation and enumeration of microbes from coastal environments.	
3.	Assessment of salt requirement of marine isolates from different ecosystems.	
4.	Denitrification by marine bacterial isolates.	
5.	Study of biofilm formation by microorganisms.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 103-T	
Learning Outcomes	1. Skillful estimation of physico-chemical parameters of seawater. 2. Expertise in handling and characterizing marine bacterial isolates.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 106

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

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that the students have a basic knowledge of ecosystem structure and biogeochemical cycles (water, O,C,N,S,P)	
Objective:	This course develops concepts in Environmental Microbiology (microbial diversity, community structure and role of microorganisms in biogeochemical cycles, role of microorganisms in sustainable development and bioremediation of pollutants using microorganisms.	
Content:		
1.	**Microbial Ecology**	**(12)**
	Microbial community structure, evolution of communities Types of Ecosystems: components and functioning of ecosystem, concept of homeostasis, biotic and abiotic components in the environment and their interaction, characteristics and functions. Energy flow and material cycling. Food webs. Ecological succession. Ecological efficiency. Concepts of microcosms and econiches.	
	The expanse of microbial diversity, estimates of total number of species, measures and indices of diversity.	
2.	**Biogeochemical processes**	**(07)**
	Biogeochemical cycling of carbon, nitrogen, phosphorous, sulphur, Fe and Mn: physiological and biochemical aspects	
3.	**Concepts of sustainable and holistic development**	**(05)**
	Role of microorganisms in environment, Use of microorganisms towards sustainable development and specific pollution abatement programmes, need for environment impact assessment studies.	
4.	**Microbes on surface**	**(05)**
	Nature and significance, activity in surface films Biofilm kinetics and its application to waste water treatment	
5.	**Microbiological bioremediation**	**(07)**
	Bioremediation technologies. Overview of aerobic / anaerobic biodegradation and biotransformation of aliphatic, aromatic, xenobiotic and recalcitrant hydrocarbons. Methods of environmental monitoring and pollution control using nanotechnology.	
Pedagogy:	Lectures/tutorials/assignments/self-study	

References/ Readings	Scragg, A. H., Environmental Biotechnology, Longman Publishers.	
	Sharma, P. D., Environmental Microbiology, Alpha Science International.	
	Osborn, A. M. and Smith, C. J., Molecular Microbial Ecology, Taylor and Francis.	
	Liu, W-T. and Jansson, J. K., Environmental Molecular Microbiology, Caister Academic Press.	
	Norris, J. R. and Ribbons, D.W., Methods in Microbiology, Vol. 18 & 19, Academic Press	
	Murugesan, A. G. and Rajakumari, C., Environmental Science and Biotechnology: Theory and Techniques, MUP Publishers.	
Learning Outcomes	Understanding the significance of microorganisms in biogeochemical cycling of nutrients, sustainable development and bioremediation of pollutants for developing strategies of environmental conservation and remediation.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 107

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

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that the students have a basic knowledge of the environmental parameters for water analysis.	
Objective:	This course develops techniques in water analysis and biodegradation of aromatic pollutants.	
Content:		**(24)**
1	Analysis of water samples - Physico-chemical: pH, temperature, COD, BOD, and microbiological	
2	Studies on microbial adherence: BATH assay.	
3	Study of biodegradation of aromatic compounds using ortho / meta mode of ring cleavage	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 104-T	
Learning Outcomes	Learning techniques for water analysis and biodegradation of aromatic pollutants.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 108

Title of the Course: GENETIC ENGINEERING (T)

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Knowledge of bacterial and animal genetics, basic molecular and microbiology is a prerequisite.	
Objective:	This course aims to introduce the fundamental tools and techniques required for molecular cloning, with emphasis on DNA editing to protein expression in wide variety of hosts. Applications of genetic engineering in agriculture, therapeutics and industry will be covered.	
Content:		
1.	**Introduction to genetic engineering and tools involved in genetic manipulation**	**(16)**
1.1	**Introduction to genetic engineering**	
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 kinases, Alkaline phosphatase, S-1 Nuclease, Mung bean nuclease, RNases.	
B.	Gene cloning systems/Hosts: Gene cloning in *E. coli* and other organisms such as *Bacillus subtilis*, *Saccharomyces cerevisiae* and other microbial eukaryotes.	
C.	Cloning vectors: plasmid (pUC19, pBR 322), λ phage based vectors, cosmid vectors, Phasmid vectors, shuttle vectors, High capacity Cloning vectors (BAC and YACs).	
D.	Sequencing Vectors: pUC 19 and M-13 Phage vector.	
E.	Expression vectors: Prokaryotic (pET, pGEX-2T and others). Characteristics of expression vectors: strong bacterial and viral promoters (lac, trp, tac, SV 40, T7, T3) for induction of gene expression.	
F.	Construction of rDNA molecule and it's transfer to appropriate host (bacteria/yeast/plant cell/animal cell) using a suitable technique: transformation, electroporation, transfection, gene gun.	
G.	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, RT-PCR, Real time PCR, Microarray, DNA sequencing using Sanger's Dideoxy chain termination method and automated sequencer; chromosome walking, Hybrid release and hybrid arrest translation to screen clones, site directed mutagenesis.	

2.	**Application of Genetic Engineering in Biology, forensics and medicine**	**(10)**
2.1	**Application of genetic engineering in DNA diagnostics and production of recombinant drugs, vaccines and hormones**	
A.	Screening of Genetic diseases using DNA probes (DNA diagnostics).	
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.	
C.	Application of recombinant DNA technology in solving parental dispute and criminal cases (DNA finger printing).	
2.2		
A.	Manipulation of gene expression in Prokaryotes; , gene expression from strong and regulatable promoters, Developing fusion proteins and separation of cloned protein by protease induced cleavage.	
B.	Genetic manipulation to increase recombinant protein stability and secretion using signal sequences.	
3.	**Application of Genetic Engineering in Agriculture**	**(05)**
3.1		
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.	
4.	**Application of Genetic Engineering in Industry**	**(02)**
4.1	**Genetic engineering of microbes for production of enzymes, biomolecules and fermentation products.**	
A.	Genetic manipulation of microbes to over-produce industrially valuable enzymes.	
B.	Production of microbial SCPs.	
5.	**Application of Genetic engineering in Bioremediation, Biorecovery and Biomonitoring of xenobiotics, metals and organometals.**	**(03)**
5.1	**Genetic engineering of microbes for bioremediation and biomonitoring of toxic environmental pollutants, Biohydrometallurgy**	
A.	Microbial bioremediation of xenobiotics by recombinant microbes.	
B.	Bioremediation of toxic heavy metals and organometals by recombinant microbes.	
C.	Biohydrometallurgy using recombinant microbes for recovery of precious metals.	

Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Old, R. W. and Primrose, S. B., Principles of Gene Manipulation: An introduction to Genetic Engineering, University of California Press.	
	Glick, B. R., Pasternak, J. J. and Patten, C. L., Molecular Biotechnology: Principles and Applications of Recombinant DNA, ASM Press.	
	Williamson, R., Genetic Engineering, Volumes 4-7, Academic Press.	
	Glover, D. M., Gene cloning: The Mechanics of DNA Manipulation, Springer-Science+Business Media, B. V.	
	Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York.	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.	
	Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier.	
	Grinsted, J. and Bennett, P. M., Methods in Microbiology, Vol. 21, Plasmid Technology, Academic Press.	
Learning Outcomes	1. Understanding of tools and techniques involved in molecular cloning. 2. Overall understanding about the importance of GMOs, GMPs and other engineered products in science and industry.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 109

Title of the Course: GENETIC ENGINEERING [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Theoretical understanding of chromosomal DNA, plasmid DNA, selection media and preparatory microbiology is needed.	
Objective:	To have a hand on experience on plasmid DNA isolation, modification and insertion; basically a DNA cut-copy-paste technology that forms the basis of any genetic engineering wet lab.	
Content:		**(24)**
1.	Restriction mapping of bacterial plasmid and agarose gel analysis.	
2.	Preparation of competent cells and transformation of *E. coli* host with plasmid DNA using heat shock method and electroporator; confirmation of positive transformants.	
3.	Assessment of DNA ligation activity of T4 DNA ligase.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 105-T	
Learning Outcomes	1.A practical understanding of how the DNA modifying enzymes work. 2. Hand-on experience with plasmid and bacterial host.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 110

Title of the Course: IMMUNOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge on pathogens, serology, and general principles of immunology.	
Objective:	It is to develop concepts in role and the underlying mechanisms for the functioning of immunological cells and their interactions. The regulations of molecule synthesis, signalling, immune responses and allied activities of immune system at the molecular level.	
Content:		
1.		
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.	**(05)**
1.2	Concept of immunoglobulin domain, distribution of immunoglobulin domain, superfamily member, structure and function of TCR, diversity of antigen binding domain, concept of segmented gene, gene organisation of Ig and TCR, 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.	**(05)**
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).	**(05)**
2.		
2.1	Ontogeny of T- and B-cells, immunocompetent T and B cells, recognition, signalling 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.	**(05)**
2.2	Cytokine as messengers, receptor for cytokine – gp130 subfamily, 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.	**(05)**

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.	**(04)**
3.		
3.1	Concept of inflammation (self-revision), complement fixation (self-revision), defence against intracellular bacterial pathogen, immunity to viral infection, immunity to fungi, immunity to parasitic infections; Passively acquired immunity, vaccination.	**(03)**
3.2	Immuno-techniques: Antigen antibody interactions in solution (self revision), identification and measurement of antigen (self revision), epitope mapping, hybridoma technology and monoclonal antibody revolution, catalytic antibodies, engineering antibodies, antigen-antibody based affinity chromatography (revision if done in techniques), isolation of leukocyte and subpopulations, localization of antigen *in cyto* and *in tissue*.	**(04)**
Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/videos	
References/ Readings	1. Goldsby, R. A., Kindt, T. J. and Osborne, B. A., Kuby Immunology. W.H. Freeman 2. Bona, C. A. and Bonilla, F. A., Textbook of Immunology, Fine Arts Press 3. Janeway, C. A., Travers, P., Walport, M. and Shlomchik, M. J., Immunobiology, Garland Science. 4. Delves, P., Martin, S., Burton, D. and Roitt, I., Roitt's Essential Immunology. Wiley-Blackwell. 5. Chakraborty, P. and Pal, N. K., Manual of Practical Microbiology and Parasitology, New Central Book Agency (P) Ltd, Delhi, India. 6. Goldsby, R. A., Kindt, T. J. and Osborne, B. A., Kuby Immunology. W.H. Freeman 7. Bona, C. A. and Bonilla, F. A., Textbook of Immunology, Fine Arts Press 8. Janeway, C. A., Travers, P., Walport, M. and Shlomchik, M. J., Immunobiology, Garland Science. 9. Delves, P., Martin, S., Burton, D. and Roitt, I., Roitt's Essential Immunology. Wiley-Blackwell. 10. Chakraborty, P. and Pal, N. K., Manual of Practical Microbiology and Parasitology, New Central Book Agency (P) Ltd, Delhi, India.	
Learning Outcomes	1. Explains the mechanisms of immunological responses. 2. Apply the principles of cellular ontogeny and the gene rearrangement to understand the novel and complex immune system.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 111

Title of the Course: IMMUNOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge of pathogens, blood and principles of immunology.	
Objective:	Hands-on practice for various techniques used in immunology.	
Content:		**(24)**
1.	Haemagglutination for Blood grouping ABO and Rh system	
2.	Immunodiffusion slide technique	
3.	Agglutination tests for *Salmonella*-antigens	
4.	ELISA	
5.	Rapid tests – Malaria antigens Pv/Pf, IgM/IgG antibodies for Dengue, Hepatitis HBsAg	
6.	Rheumatoid Arthritis Factor determination	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 106-T	
Learning Outcomes	Apply techniques in immuno-diagnosis.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 112

Title of the Course: EXTREMOPHILIC MICROORGANISMS [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	The student should have knowledge of microorganisms and their diversity.	
Objective:	This course gives insights about the extreme habitats, extremophilic microorganisms, their adaptations and biotechnological potentials.	
Content:		
1.	Concept of extremophiles v/s conventional microbial forms	**(01)**
2.	Extreme habitats in universe, extreme communities in following econiches: deserts, rhizospheres, ore deposits/ mining areas (Fe, Mn, Cu), animal systems, deep biosphere (terrestrial and marine), hydrothermal vents.	**(02)**
3.	Significance in biogeochemical cycling, industry, pharma and degradation of xenobiotics	**(02)**
4.	Key Molecular components, Unique : physiological features, adaptation strategies and enzymes of various extremophilic types:	
A.	Anaerobes: oxygen toxicity and regulation in *Clostridium, Moorella thermoacetica*, Wood Ljungdahl pathway	**(12)**
B.	Barophiles/Peizophiles: mechanism in barophily, alpha proteobacteria	
C.	Cryophiles, Psychrophiles: (cold shock proteins and regulation) *Polaromonas*	
D.	Thermophiles: heat shock proteins, rho factors and regulation, *Aquifex, Tepidomonas, Rhodothermus*	
E.	Alkaliphiles/ basophiles: *Alkalimonas, Nesterenconia*	**(12)**
F.	Acidophiles: *Picrophilus, Ferroplasma*	
G.	Halophiles: *Halomonas*	
H.	Osmophiles: Osmophilic *Lactobacilli, Schizosaccharomyces pombe*	
I.	Oligotrophs: *Pelagibacter*	
J.	Xerophiles: *Wallemia*, extreme cyanobacteria	**(07)**
K.	Radiophiles: *Deinococcus radiodurans*	
L.	Metallophiles: *Geobacillus*	
M.	Xenobiotic users: *Pseudomonas*	
N.	Endoliths: *Chroococcidiopsis, Halothece*	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Brock, T. D., Thermophilic Microorganisms and Life at High Temperatures, Springer, New York.	

	Horikoshi, K. and Grant, W. D., Extremophiles-Microbial Life in Extreme Environments, Wiley, New York.	
	Ventosa, A., Nieto, J. J. and Oren, A. (1998) Biology of moderately halophilic aerobic bacteria. Microbiology and Molecular Biology Reviews, 62, 504–544.	
	Rainey, F. A. and Oren, A., Extremophile Microorganisms and The Methods to Handle Them. In: Extremophiles, Methods in Microbiology, Vol. 35, Elsevier, Amsterdam.	
Learning Outcomes	Apply the knowledge to study the extremophilic microorganisms and tap their unique properties for ecological and industrial applications.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 113

Title of the Course: EXTREMOPHILIC MICROORGANISMS [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	The student should be familiar with handling of microorganisms in the laboratory.	
Objective:	This course teaches various skills involved in handling extremophilic microorganisms.	
Content:		**(24)**
1.	Isolation of halophiles, alkaliphiles, and anaerobes.	
2.	Tolerance of bacterial culture to varying salt concentrations.	
3.	Buffering capacity of alkaliphiles.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 107-T	
Learning Outcomes	Develop expertise in isolation and culturing of microorganisms thriving in extreme environment, and exploring the extremophiles to discover particular novel and unique useful biocompounds.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 114

Title of the Course: RESEARCH METHODOLOGY [T]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basics of microbiology is necessary.	
Objective:	This course develops the concepts of research and covers all aspects ranging from biosafety in the laboratory, experimental protocol, presentation of data and viva voce.	
Content:		**(12)**
1.	Biosafety in laboratory	
2.	Ethics in research	
3.	Defining the problem	
4.	Literature survey	
5.	Defining the Aims and Objectives	
6.	Work Plan – Time-bound Frame	
7.	Research design	
8.	Experimental protocol	
9.	Presentation of data	
10.	Analysis and Conclusions	
11.	Presentations	
12.	Research manuscript writing	
13.	Thesis Writing	
14.	Viva Voce	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Kothari C. R., Research Methodology Methods and Techniques, New Age International.	
	Kumar, R. C., Research Methodology. APH Publ Corporation, New Delhi.	
	Good C. V., Scates, D. E., Methods of Research, Appleton-Century-Crofts.	
	Day R.A. How to write and publish a scientific paper, Part 274, Volume 994, Oryx Press.	
	Alley, M., The Craft of Scientific Writing, Springer Science and Business Media.	
	Cooray P.G. Guide to Scientific and Technical Writing.	
Learning Outcomes	Skills to design, conduct an experiment and successfully process and report the observations in the form of a scientific report/manuscript/thesis.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 115

Title of the Course: RESEARCH METHODOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basics of microbiology laboratory techniques is necessary.	
Objective:	This course develops the experimental approach, designing of experimental protocols, presentation of data and viva voce.	
Content:		**(24)**
1.	Literature survey on a given research area.	
2.	Designing an experiment with respect to a given objective.	
3.	Experimental work.	
4.	Presentation of data.	
5.	Technical writing.	
6.	Literature survey on a given research area.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 108-T	
Learning Outcomes	Skills to design an experiment and process the data acquired and successfully report the observations in the form of a scientific report/manuscript/thesis.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 116

Title of the Course: MICROBIAL TECHNOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic knowledge of different techniques in instrumentation- their principle and applications.	
Objective:	This course develops concepts in technologies used in agriculture, mining, energy production and human health with respect to microorganisms and genetically engineered microorganisms. Introduces concept of nanotechnology.	
Content:		
1.	**Biotechnology and prospecting with microbes.**	**(04)**
A.	Advantages of using microbial technology over chemical and physical technology.	
B.	Ethics in the use of GEMs.	
C.	Commercialization of Microbial Biotechnology.	
D.	Introduction to Nanotechnology.	
2.	**Microbial technology in agriculture**	**(08)**
	Production of microbial biofertilizers, biopesticides, soil conditioners to enhance crop yields.	
3.	**Microbial technology in mining**	**(12)**
A.	Bioleaching.	
B.	Biomining.	
C.	Recovery of oil. MEOR	
D.	Microbial technology in waste and pollution management in mining: Bioconversions, Bioremediation, Biosedimentation, Bio-beneficiation, Aquifer cleaning.	
4.	**Microbial technology for energy production**	**(07)**
A.	Microbial fuel cell.	
B.	Biogas.	
C.	Microbial cell mass.	
5.	**Microbial technology in Human health & aquaculture**	**(05)**
	Pigments, Nutraceuticals, Probiotics, Bioplastics, Microbes as bio-weapons.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	1. Arora, R., Microbial Biotechnology: Energy and Environment, CABI Publishing.	

	2. Ahmad, I., Ahmad, F. and Pichtel, J. Microbes and Microbial Technology: Agriculture and Environmental Applications, Springer. 3. Peppler, H.J., Microbial Technology: Microbial Processes, Academic Press. 4. Sukla, L. B., Pradhan, N., Panda, S. and Mishra, B. K. Environmental Microbial Biotechnology, Springer. 5. Bull, A. T., Microbial Diversity and Bioprospecting, American Society for Microbiology.	
Learning Outcomes	1. Apply the knowledge of various techniques in developing technology for sustainable development. 2. Explain commercialization of a technology.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 117

Title of the Course: MICROBIAL TECHNOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic knowledge of different techniques in instrumentation- their principle, working and applications.	
Objective:	This course gives hands-on experience in designing experiments for determining effectiveness of biofertilizers and probiotics.	
Content:		**(24)**
1.	Determination of stability of microbial fertilizer.	
2.	Effect of microbes on sedimentation and clarification of water.	
3.	Probiotics: Isolation of LABs and their characterization- Gram staining, spore staining, lactose fermentation, Bile tolerance test, adherence efficiency.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 109-T	
Learning Outcomes	1. Explain the procedures for formulation of biofertilizers as well as probiotics. 2. Explain the role of microorganisms in clarification of water.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 118

Title of the Course: FOOD MICROBIOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

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:	This course deals with the beneficial and harmful association of microorganisms with the food and prospective application of the microorganisms in food industry. Teaches the methods of controlling the type and number of microorganisms in the food as per requirement. Teaches about the role of food regulatory bodies and measures of food safety and quality control.	
Content:		
1.	**Microbial Food Spoilage and Food Preservation**	**(12)**
A.	Predictive food microbiology - Types of foods and their spoilage.	
B.	Factors affecting the growth and survival of microorganisms in foods: Intrinsic, Extrinsic.	
C.	Preservation methods: Heat processing, low temperature storage, control of water activity, irradiation, high pressure processing, modified atmospheres, preservatives: chemicals, natural organic molecules (nisin).	
2.	**Microbiology in Food Processes**	**(12)**
2.1	**Fermented and processed foods**	
A.	Indian fermented foods.	
B.	Oriental fermented foods.	
C.	Fermentations: wine	
2.2	**Genetically engineered microorganisms in the Food Industry**	
A.	Concept and role of genetically engineered microbes in the food industry.	
3.	**Food Safety and Quality Assurance**	**(12)**
3.1	**Food borne diseases**	
	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**	
A.	Microbiological examination of foods – sampling, culturing/analysis.	
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/self-study	
References/ Readings	Adams, M. R. and Moss, M. O., Food Microbiology, New Age International (P) Limited Publishers, New Delhi.	
	Frazier, W. C. and Westhoff, D. C., Food Microbiology, M. C. Graw-Hill Companies, Inc., New York.	
	Jay, M. J., Loessner, M. J. and Golden, D. A., Modern Food Microbiology, Springer Science + Business Media Inc., New York.	
	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.	
	Ramesh, K. V., Food Microbiology, MJP Publishers, Chennai.	
	Harrigan, W. F., Laboratory Methods in food Microbiology, CRC Press, Taylor & Francis Group.	
	Doyle, M. P. and Buchanan, R. L., Food Microbiology: Fundamentals and Frontiers, ASM Press.	
Learning Outcomes	Apply the knowledge about the food preservation, food fermentation, food safety, quality control and validation.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 119

Title of the Course: FOOD MICROBIOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that the student should have knowledge about handling of microorganisms.	
Objective:	Assessing the microbiological quality of food and role of microorganisms in food fermentations.	
Content:		**(24)**
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.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 110-T	
Learning Outcomes	Develop skills required to analyse food samples in food industry and different food agencies.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 120

Title of the Course: AGRICULTURE MICROBIOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that the students have knowledge about microorganisms and their diversity.	
Objective:	The course deals 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**	**(12)**
A.	Terrestrial Ecosystem, Pyramids and Econiches.	
B.	Types of Soil, soil Profile, Physico-Chemical Characteristics.	
C.	Suitability of soil for agriculture.	
D.	Soil Enzymes and significance.	
E.	Influence of microbial metabolism on soil chemistry & humus formation and its significance (humic and fulvic acids).	
F.	Factors influencing bacterial survival in soils: Biotic & Abiotic.	
G.	Establishment of microbial inoculant.	
H.	Rhizosphere and Rhizoplane Microflora.	
I.	Plant growth promoting Rhizobacteria, nitrogen fixation, phosphate mobilization and biocontrol of plant pathogens.	
2.	**Beneficiary Microorganisms to plants**	**(12)**
A.	Mycorrhiza – Ectomycorrhiza, Endomycorrhiza, VAM structure & significance.	
B.	Plant growth promoting hormones from microbes viz. bacteria and fungi & their significance.	
C.	Nitrogen-fixing microbes - Biochemistry and Genetics of free living and symbiotic nitrogen fixers viz. *Azotobacter vinelandii, Rhizobium*. Significance of *nif* H, D, K, A, L, nod, nodulin and *fix* genes in microbial nitrogen fixation.	
D.	Biofertilizers: An Overview.	
(i)	free living soil microbes fixing N_2 (*Azotobacter, Azospirillum*).	
(ii)	*Rhizobium/Azorhizobium,* in symbiotic association with leguminous plants.	
(iii)	Free living cyanobacteria- N*ostoc*.	
(iv)	Associative cyanobacteria (symbionts)-*Anabaena azollae*	
(v)	*Azolla* as Biofertilizer.	
(vi)	Compost as Biofertilizer.	

E.	Microbial Pesticides – (Biocontrol agents for agriculturally important crop plants) – Development and their significance; Source Organisms: Bacteria-*Bacillus thuringiensis*, Bt based commercial products, other Bacilli producing pesticides; Fungi—*Beauveria bassiana*, Viruses-Baculoviruses for insect pest control.	
3.		**(12)**
	Plant Pathogens (bacterial, fungal, viral, viroid).	
	Virulence in plant pathogens - biochemical and genetic basis of virulence, toxins as virulence factors	
	Plant defense responses - anatomical changes, phytoalexins, alkaloids and other biocontrol molecules	
	Pathogen control - viral proteins in controlling viral diseases, mycoviruses against fungal plant pathogens, RNA and antisense RNA technology in disease control	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Alexander, M., Introduction to Soil Microbiology, Wiley.	
	Dadarwal, K. R., Biotechnological Approaches in Soil microorganisms for sustainable crop production, Scientific Publishers.	
	Subba Rao, N. S., Advances in Agricultural Microbiology, Oxford & IBH Publishers.	
	Carr, N. G. and Whitton, B. A., The Biology of Blue-green algae, University of California Press.	
	Mahanta, K. C., Fundamentals of Agricultural Microbiology, Oxford & IBH Publishers.	
	Veeresh, G. K. and Rajagopal, D., Applied Soil Biology and Ecology, Oxford & IBH Publishing Company Pvt. Limited.	
	Somani, L. L., Biofertilizers in Indian Agriculture, Concept Publishing Company.	
	Subba Rao, N. S., Biofertilizers in Agriculture and Forestry, International Science Publishers.	
	Bilgrami K. S. (1987) Plant Microbe Interactions, Proceedings of Focal Theme Symposium, Indian Science Congress Association, Narendra Publishing House.	
	Madigan, M. T., Martinko, J. M., Bender, K. S., Buckley, D. H. and Stahl, D. A., Brock Biology of Microorganisms, Pearson Education Limited.	
	Kumar, H. D., Modern Concepts of Microbiology, Vikas Publishing House Pvt. Ltd.	
Learning Outcomes	1. Apply the knowledge of soil chemistry and significant biochemical processes of microbes to improve agricultural practices. 2. Apply the understanding about genetics of advantageous microorganisms to genetically modify and develop improved crops.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 121

Title of the Course: AGRICULTURE MICROBIOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

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:		**(24)**
1.	Isolation of plant growth promoters from soil showing phosphatase, urease and siderophore activity.	
2.	Morphological characterization of cyanobacteria, extraction and estimation of cyanobacterial pigments (chlorophyll a, carotenoids).	
3.	Isolation of microbial plant pathogen(s).	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 111-T	
Learning Outcomes	Apply the microorganisms to improve soil health, promote plant growth and eradicate the phytopathogens for flourishing agriculture and its yield.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 122

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

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Knowledge of microorganisms, pathogens and various infectious diseases.	
Objective:	Develops concepts in pathogenesis of various pathogens, its underlying mechanisms along with molecular interactions, leading to development of disease in the host. Develops principles of 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.	**(04)**
1.2	Pili, flagella, biofilm, quorum-sensing, iron scavenging, aggressins/impedins against host defence.	**(03)**
1.3	Host susceptibility, pre-disposing factor (nutritional, soci-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). Endotoxin – structure, biosynthesis, assay, pathophysiological effects, excessive inflammatory response, endotoxin neutralizing compound, antagonists of LPS.	**(06)**
2.2	Cystic fibrosis, Spongiform encephalopathy.	**(04)**
3.		
3.1	Spatial, temporal and social distributions of communicable 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.	**(07)**
3.2	Community acquired infection, infections in immunocompromised 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.	**(05)**

Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/videos/web resources	
References/ Readings	1. Davis, B.D. et al., Microbiology. Harper and Row. 2. Gillespie, S.H. and Hawkey, P.M., Principal and Practice of Clinical Bacteriology. Wiley. 3. Struthers, J.K. and Westran, R.P., Clinical Bacteriology. CRC Press. 4. Chakraborty, P. and Pal, N.K., Manual of Practical Microbiology and Parasitology. Calcutta New Central Book Agency.	
Learning Outcomes	1. Explain the various pathological events during the progression of an infectious disease. 2. Apply the principles of epidemiological sciences in studying the underlying mechanisms of spread of disease and controls required thereof to combat the spread of pathogens.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 123

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

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Ability to handle microorganisms in the laboratory.	
Objective:	Hands-on training in handling, characterization and identification of pathogens. Analysis of epidemiological data.	
Content:		**(24)**
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	As given under Theory Course MIO 112-T	
Learning Outcomes	1. Apply the general principles of microbiology tools and techniques in specific need for clinical cases. 2. Apply the principles of statistics in processing of epidemiological data.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 124

Title of the Course: MARINE MICROBIAL INTERACTIONS [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Students must have a background about the basic concepts of Marine Microbiology, including properties of seawater, marine microorganisms.	
Objective:	The focus of this Course is to advance the understanding of the students of 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**	**(12)**
	Symbiosis of microalgae with animals; Symbiosis of chemoautotrophic prokaryotes with animal; Light organ symbiosis in fish and invertebrates; Microbial symbionts of sponges; Symbiosis and mixotrophy in protists; Metabolic consortia and mutualism between prokaryotes.	
2.	**Microbial diseases of fish and invertebrates**	**(12)**
	Diseases of fish, bivalve mollusks, crustaceans, corals in fresh water/ sea water/ aqua culture: Bacterial – vibriosis, furunculosis, bacterial kidney disease, mycobacteriosis, streptococcosis, black band disease, white plague, white pox, Juvenile Oyster Disease (JOD). Viral – Infectious salmon anemia (ISA) virus, viral hemorrhagic septicemia virus (VHSV), lymphocystis virus, birnaviruses, viral nervous necrosis. Protistan – *Paramoeba perurans, Kudoa sp., Loma salmonae, Hematodinium* Diagnostic methods. Control of disease.	
3.	**Marine microbes - Beneficial and harmful**	**(12)**
	Beneficial aspects: Biodegradation and bioremediation of marine pollutants such as oil, persistent organics and plastics. Environmental monitoring using indicator microorganisms. Microbial enzymes and polymers. Harmful aspects: Harmful Algal Blooms (HABs). Biodeterioration, biofouling, bio-invasion – ballast waters.	

Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim.	
	Gatesoupe, F. J., (1999) The use of probiotics in aquaculture, Aquaculture, 180: 147-165.	
	Maier, R., Pepper, I. and Gerba, C., Environmental Microbiology, Academic Press.	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y.	
	Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco, N.Y.	
	Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York.	
	Sharma, P. D., Environmental Microbiology, Alpha Science.	
	Sindermann, C. J., Principal Diseases of Marine Fish and Shellfish: Diseases of Marine Fish, Vol. 1, Gulf Professional Publishing.	
	Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa.	
	Toranzo, A. E., Magarinos, B. and Romalde, J. L., (2005) A review of the main bacterial fish diseases in mariculture systems, Aquaculture, 246(1): 37-61.	
Learning Outcomes	Explain the mechanisms underlying marine microbial communities and how they impact the environment.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 125

Title of the Course: MARINE MICROBIAL INTERACTIONS [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

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:		**(24)**
1.	Determining *E. coli* in shellfish –MPN/ EC-MUG medium.	
2.	Isolation of luminescent bacteria from fish/shellfish.	
3.	Screening of enzymes involved in deterioration of wood/litter in marine environments.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 113-T	
Learning Outcomes	Expertise in isolation and characterization of marine bacteria associated with fish/shellfish and enzyme studies.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 201

Title of the Course: STUDY TOUR / FIELD TRIP [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Knowledge about microbiology-related institutes and industries in Goa.	
Objective:	To provide knowledge about the on-going research in various national research institutes and the functioning of microbiology - related industries and industrial processes.	
Content:		**(24)**
1.	**Visit to National Research Institutes:** National Centre for Antarctic and Ocean Research [NCAOR], National Institute of Oceanography [NIO] and ICAR – Central Coastal Agricultural Research Institute (ICAR - CCARI)	
2.	**Visits to Industries:**	
2.1.	Pharmaceutical industry	
2.2.	Agricultural farming	
2.3.	Food and beverage	
3.	**Report writing**	
4.	**Presentation and group discussion**	
Pedagogy:	Visits to research institutes/industries/universities, demonstration of equipment available with respective laboratories, interaction with personnel working in the field of microbiology in the respective institutes.	
References/ Readings	As suggested by the demonstrator to the participating students.	
Learning Outcomes	1. Exposure to the various research being carried out in the field of microbiology. 2. Exposure to the various activities being carried out in industries using/or related to the applications of microbial principles.	

Programme: M.Sc. (Microbiology)

Course Code: MIO 202

Title of the Course: TRAINING IN AN INSTITUTE/ INDUSTRY/ UNIVERSITY

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Knowledge about the basic techniques in microbiology.
Objective:	To provide hands-on experience in the application of microbiological techniques in research institutes/industries/universities. To experience the workings of microbiology-related departments in commercial industries.
Content:	
	The student shall be required to 1. Undertake training for a minimum period of 10 working days or its equivalent. 2. Submit to the Department of Microbiology, Goa University, a certificate of attendance signed by the Training Coordinator of the respective Institute/ Industry/University. 3. Submit to the Department a Report of the work undertaken. 4. Make a Presentation of the work carried out, to the Department Council for evaluation.
Pedagogy:	Short-term internship (minimum 10 days) at an institute/industry/university
References/ Readings	As suggested by the demonstrator to the participating students.
Learning Outcomes	Apply the tools and techniques of microbiology to a range of situations.

Programme: M.Sc. (Microbiology)

Course Code: MID

Title of the Course: DISSERTATION

Number of Credits: 8

Effective from Academic Year: 2018-19

Prerequisites	Laboratory training in microbiology.
Objective:	Develop the skills of preparing and conducting independent research.
Content:	
1.	Review of the state of research in a particular problem involving microorganisms, and development of hypothesis.
2.	Planning and conducting the experiments.
3.	Periodic analysis of data and preparation of report.
4.	Final preparation of project report as dissertation to be submitted as partial fulfilment of M.Sc. Programme.
Pedagogy:	Project carried out individually by each student throughout the academic year
References/ Readings	As required for the development of review and methodology.
Learning Outcomes	Ability to apply the tools and techniques of microbiology in conducting independent research.