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(Accredited by NAAC)

GU/Acad –PG/BoS -NEP/2023/79/2 Date:25.05.2023

Ref: GU/Acad –PG/BoS -NEP/2022/339/20 dated 19.08.2022

CIRCULAR

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

The Dean/ Vice-Deans of the School of Earth, Ocean and Atmospheric Sciences are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2023.05.25 17:04:17 +05'30'

(Ashwin Lawande)
Assistant Registrar – Academic-PG

To,

1. The Dean, School of Earth, Ocean and Atmospheric Sciences, Goa University.
2. The Vice-Deans, School of Earth, Ocean and Atmospheric Sciences, Goa University.

Copy to:

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

Goa University
Syllabus of M.Sc. (Marine Microbiology) Program

The School of Earth, Ocean and Atmospheric Sciences (SEOAS) offers a two-year full time M.Sc.. Marine Microbiology program. This Program was initiated in June 2012, under the award of UGC sponsored 'Innovative Program for teaching and research in interdisciplinary and emerging areas'.

The Program is meant for students to pursue higher studies in Marine Microbiology. Being an University in coastal state of India, Goa University provides a strategic advantage in learning microbiology of marine and coastal ecosystems. It serves to impart advanced training to students in the field of Marine Microbiology with focus on marine microbial diversity, bioprospecting and applications of marine microbes in the production of 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 Program 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, the students finding speedy employment.

Eligibility: B. Sc. Microbiology, B.Sc. Biotechnology

M. Sc. Marine Microbiology Structure and Syllabus (Semesters I - IV)

Code	Title of paper	Credits
Semester I		
MMI-500	Fundamentals of Oceanography	3
MMI-501	Fundamentals of Oceanography – Practical	1
MMI-502	Microbial Biochemistry	3
MMI-503	Microbial Biochemistry – Practical	1
MMI-504	Microbial Taxonomy and Systematics	3
MMI-505	Microbial Taxonomy and Systematics – Practical	1
MMI-506	Mathematics and Statistics in Biology	3
MMI-507	Mathematics and Statistics in Biology – Practical	1
Discipline Specific Elective Courses		
MMI-521	Marine Virology	3
MMI-522	Marine Virology – Practical	1
MMI-523	Estuarine Microbiology	3
MMI-524	Estuarine Microbiology – Practical	1
MMI-525	Fishery Microbiology	3
MMI-526	Fishery Microbiology – Practical	1
MMI-527	Marine Extremophilic Microorganisms	3
MMI-528	Marine Extremophilic Microorganisms – Practical	1
Core: 16 credits, Optional: 04 credits; Theory: 15 credits; Practical: 05 credits		**Total = 20**
Semester II		
MMI-508	Techniques and Instrumentation in Microbiology	3
MMI-509	Techniques and Instrumentation in Microbiology – Practical	1
MMI-510	Industrial Microbiology	3
MMI-511	Industrial Microbiology – Practical	1
MMI-512	Microbial Genetics and Gene Regulation	3
MMI-513	Microbial Genetics – Practical	1
MMI-514	Microbial Ecology	3
MMI-515	Microbial Ecology – Practical	1
Discipline Specific Elective Courses		
MMI-529	Diversity, Ecophysiology and Interactions of Marine Microorganisms	3
MMI-530	Coral Microbiology	3
MMI-531	Marine Zooplankton Ecology and Microbial Interactions	3
MMI-532	Marine Zooplankton – Practical	1
MMI-533	Field Trip/Study Tour – Practical	1
Core: 16 credits; Optional: 04 credits; Theory: 15 credits; Practical: 05 credits		**Total = 20**

Code	Title of paper	Credits
Semester III - Elective Papers		
Research Specific Elective Courses		
MMI-600	Phytoplankton Ecology and Genomics	3
MMI-601	Phytoplankton Ecology Practical	1
MMI-602	Marine Microbial Prospecting and Technology	3
MMI-603	Marine Microbial Prospecting and Technology Practical	1
MMI-604	Microbial Growth and Enzyme Kinetics	3
MMI-605	Microbial Growth and Enzyme Kinetics Practical	1
MMI-606	Genetic Engineering	3
MMI-607	Genetic Engineering Practical	1
		Total = 8
Generic Specific Elective Courses		
MMI-621	Archaea	3
MMI-622	Archaea Practical	1
MMI-623	Ecology and Applications of Marine Fungi	3
MMI-624	Ecology and Applications of Marine Fungi Practical	1
MMI-625	Marine Pollution and Monitoring	3
MMI-626	Marine Pollution and Monitoring Practical	1
MMI-627	Marine Environment and Public Health	3
MMI-628	Marine Environment and Public Health Practical	1
MMI-629	Polar Microbiology	3
MMI-630	Deep Sea Microbiology	3
MMI-631	Marine Microbial Toxins	1
MMI-632	Scientific Writing Skills Practical	1
		Total = 12
Semester IV - Elective Papers		
Research Specific Elective Courses		
MMI-608	Ocean Observations and Techniques	3
MMI-609	Ocean Observations and Techniques Practical	1
MMI-610	Microbial Remediation in Marine Ecosystems	2
MMI-611	Microbial Remediation in Marine Ecosystems Practical	1
MMI-612	Bioinformatics in Marine Microbiology	2
MMI-613	Bioinformatics in Marine Microbiology Practical	1
MMI-614	Nanotechnology	2
MMI-615	Nanotechnology Practical	1
MMI-616	Blue Economy	1
MMI-617	Probiotics and Prebiotics in Aquaculture	1
MMI-618	Marine Drug Development and Metabolism	1
MMI-651	Discipline Specific Dissertation	16
		Total = 20

Semester I

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-500
Title of the Course: Fundamentals of Oceanography
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic understanding of the marine environments.	
Objective:	To learn the basic concepts of the physics, chemistry, geology and biology of the marine environment.	
Content:	**Module I** Origin of oceans - physical properties of the sea: temperature, salinity, density - mixed layer depth - ocean circulation: wind-driven and thermohaline circulation - ocean currents - water mass - Coriolis effect - upwelling - Ekman transport - tides - atmospheric circulation - albedo - land-sea breeze - Indian monsoon - El Niño - La Niña - Southern Oscillation - Indian Ocean Dipole. **Module II** Geological time scale - plate tectonics and seafloor spreading - sediment types - elemental composition of seawater - salinity and chlorinity - residence time of elements - dissolved gases: CO_2 and O_2 - nutrients - carbonate system - pH and alkalinity - calcium carbonate precipitation and dissolution - carbonate compensation depth - lysocline. **Module III** Habitat: estuaries, mangroves, salt marshes, rocky and intertidal, coral reefs, seagrass, coastal and open ocean - marine zonation - pelagic and benthic communities - marine photosynthesis - phytoplankton and primary production - Redfield ratio - gross and net productivity - new and regenerated productivity - *f*-ratio – pigments - zooplankton and benthic production - measurement and control of secondary production - exclusive economic zone.	15 hrs 15 hrs 15 hrs
Pedagogy:	Lectures/ assignements/ self-study	
References/ Readings:	1. Sverdrup, H.U. Johnson, M.W. and Flemming, R.H. (1962). The ocean: their physics, chemistry	

	and general biology, - Prentice-Hall, New York. 2. Pickard, G.L. and Emery, W.J. (1990). Descriptive physical oceanography: an introduction. Pergamon Press, U.K. 3. Munn, C.B. (2019). Marine microbiology: ecology and applications. CRC Press, Florida. 4. Miller, C.B. and Wheeler, P.A. (2012). Biological oceanography, Wiley-Blackwell Publishers, Oxford. 5. Gross, M.G. (1990). Oceanography: a view of the Earth. Prentice-Hall, New York. 6. Thurman, H.V. (1988). Introductory oceanography. Merrill Publishing, Columbus Ohio.	
Course Outcomes:	1. Explain the physical properties of ocean waters and effects of winds, tide and current formation. 2. Understand the geological scale and explain the chemical composition of sea water. 3. Define and discuss the different marine habitats and marine productivity. 4. Compare and contrast between primary and secondary productivity, gross and net productivity.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-501
Title of the Course: Fundamentals of Oceanography – Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic understanding of the unique properties of water.	
Objective:	To study chemical and biological parameters of seawater.	
Content:	1. Estimation of seawater salinity by titration method (6 hrs; Ref 1). 2. Determination of dissolved O_2 of seawater using Winkler's method (6 hrs; Ref 1) 3. Determination of phosphate by spectrophotometric method (6 hrs; Ref 1). 4. Determination of nitrate and nitrite by spectrophotometric method (6 hrs; Ref 1). 5. Determination of chlorophyll *a* by spectrophotometric method. (6 hrs; Ref 2).	30 hrs
Pedagogy:	Laboratory experiments	
References/ Readings:	1. Grasshoff, K., Ehrhardt, M. and Kremling, K. (1999). Methods of seawater analysis. Verlag Chemie, Weinheim. 2. Parsons, T.R., Maita, Y. and Lalli, C.M. (1984). A manual of chemical and biological methods for seawater analysis. Pergamon Press, Oxford.	
Course Outcomes:	1. Determine the concentrations of various chemical parameters (salinity, dissolved oxygen, phosphates, nitrates and nitrites). 2. Analyse chlorophyll content using spectrophotometer.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-502
Title of the Course: Microbial Biochemistry
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	The student should be familiar with the different biomolecules and their metabolism.	
Objective:	To provide in depth knowledge about characteristics, properties and biological significance of the biomolecules of life and energetics and regulation of different metabolic processes in microorganisms.	
Content:	**Module I** Biological Molecules: 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. Carbohydrates – Monosaccharides, Disaccharides, oligosaccharides, polysaccharides: types, characteristics, properties and biological significance. Lipids - Fatty acids: saturated and unsaturated, structure and properties. Lipid composition of microorganisms and biological significance. **Module II** Metabolic pathways: Carbohydrate metabolism - Central pathways of metabolism – regulatory mechanisms, bioenergetics and significance – EMP, TCA cycle (glucose aerobic and anaerobic metabolism, malate metabolism), Glyoxylate cycle. Gluconeogenesis from TCA intermediates / amino acids / acetyl-CoA; biosynthesis of polysaccharides and sugar interconversions. Lipid Metabolism - Anabolism: Biosynthesis of fatty acids: saturated and unsaturated, triglycerides, phospholipids. Amino Acid and Nucleotide Biosynthesis - Amino acid biosynthetic pathways and their regulation. Purine and pyrimidine nucleotides, Deoxyribonucleotides: biosynthesis and regulation. Biosynthesis of nucleotide coenzymes. **Module III** Mechanisms involved in Photosynthesis and Chemosynthesis: Photosynthetic Metabolism - Organisms and photosynthetic pigments, fundamental processes in Photosynthesis. Photosynthetic electron	15 hrs 15 hrs

	transport and photophosphorylation. Alternative pathways for carbon fixation in autotrophs: Calvin Benson cycle, Reverse TCA, Hydroxypropionate pathway. Chemosynthesis - Organisms, substrates, bioenergetics of metabolism. Osmoregulation: Salt-in-cytoplasm mechanism, Organic-Osmolyte mechanism, Proton-motive force, Osmolyte transporters, Osmosensing.	15 hrs
Pedagogy:	Lectures/ assignments/ self-study	
References/ Readings:	1. Cox M.C., Freeman W.H., & Nelson D.L. (2004). Lehninger Principles of Biochemistry (4th edn), W. H. Freeman & Co. New York. 2. Foster J.W., & Spector M.P. (2002). Microbial Physiology (4th edn), A. John Wiley & Sons Inc. Publication. New York. 3. Voet D., Voet J.G. & Pratt C.W. (2012). Principles of Biochemistry (4th edn), John Wiley and Sons Inc. New York. 4. Murray R.K., Bender D.A., Botham K.M., Kennelly P.J., Rodwell V.W. & Weil P.A. (2018). Harper's Illustrated Biochemistry (31st edn), The McGraw-Hill Companies, Inc. NewYork. 5. Kunte H.J. (2006). Osmoregulation in Bacteria: Compatible Solute Accumulation and Osmosensing. Environ. Chem. 3 : 94–99. doi:10.1071/EN06016	
Course Outcomes:	1. Identify various biomolecules and their importance in microbial physiology. 2. Differentiate various metabolic pathways and study their bioenergetics. 3. Analyze the regulation of the biochemical pathways. 4. Discuss various carbon fixation pathways in marine microbes.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-503
Title of the Course: Microbial Biochemistry - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	It is assumed that students have theoretical knowledge about various biomolecules.	
Objective:	This course provides opportunities for hands-on experience with microbiological and biochemical concepts in laboratory setup.	
Content:	1. Standard curves for carbohydrates, proteins and lipids. (8hrs, refs. 1 and 2) 2. Enzyme assay. (4 hrs, refs. 1 and 2) 3. Precipitation of protein from solution by salting out. (6 hrs, refs. 1 and 2) 4. Dialysis. (6 hrs, refs. 1 and 2) 5. Specific activity, fold purification, percentage yield of enzyme. (6 hrs, refs. 1 and 2)	30 hrs
Pedagogy:	Experiments in the laboratory.	
References/ Readings:	1. Plummer M.U. & Plummer D.T. (2008). An Introduction to Practical Biochemistry (3rd edn), Tata McGraw Hill Publishing Company. New Delhi. 2. Murray R.K., Bender D.A., Botham K.M., Kennelly P.J., Rodwell V.W. & Weil P.A. (2018). Harper's Illustrated Biochemistry (31st edn), The McGraw-Hill Companies, Inc. NewYork.	
Course Outcomes:	1. Estimate the concentration of various biomolecules. 2. Measure and calculate enzyme activity, specific activity and fold change. 3. Assess the efficiency of protein purification by salting out and dialysis method. 4. Design and perform experimental work on extracellular enzymes.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-504
Title of the Course: Microbial Taxonomy and Systematics
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	It is required 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:	**Module I** Concepts of taxonomy (characterization, classification and nomenclature), systematics, species, numerical taxonomy and polyphasic taxonomy. Classification of microorganisms, development of classification systems starting from two kingdom to three domain, six-kingdom and 8-kingdom systems; endosymbiotic theory for the origin of eukaryotic organelles. Traditional characters used in classification systems; phenotypic characters - Morphology, Biochemical tests (API, BIOLOG), Bacteriophage typing, Serotyping. **Module II** Nucleic acid-based techniques and chemotaxonomic markers used in classification systems. Nucleic acid-based techniques: Terminal Restriction Fragment Length Polymorphism (TRFLP); G+C content (T_m and HPLC); pyrosequencing; 16S rRNA, 18S rRNA and ITS gene sequencing; phylogenetic analysis; DNA-DNA hybridization. Chemotaxonomic markers: Cell wall components, lipid composition, cellular fatty acid (FAME analysis), isoprenoid quinones, protein profiling using MALDI-ToF. **Module III** Salient features of phylum, class and orders with representative examples of the following: Archaea, Eubacteria - Bacteria, Cyanobacteria, Actinomycetes; Mycota; Protista - Algae, Protozoa, Diatoms; and viruses.	15 hrs 15 hrs 15 hrs

Pedagogy:	Lectures/ assignments/ self-study/ videos.	
References/ Readings:	1. Sneath, A. H. P., Mair, S. N. & Sharpe, E. M. (1984). Bergey's Manual of Systematic Bacteriology, Vol. 2, Williams & Wilkins, Academic Press, London/New York. 2. Mordarski, M., Williams, S.T. & Goodfellow, M. (1983). The Biology of the Actinomycetes. Academic Press, London/New York. 3. Goodfellow, M. & Minnikin, D. E. (1985). Chemical Methods in Bacterial Systematics, The Society for Applied Bacteriology. Technical Series No. 20, Academic Press, London/New York. 4. Barlow, A. (ed.) (1992). The Prokaryotes: A Handbook on the Biology of Bacteria: Ecophysiology, Isolation, Identification, Applications, Vol. 1, Springer-Verlag, Germany. 5. Kurtzman, C. P., Fell, J. W. & Boekhout, T. (2011). The Yeasts - A Taxonomic Study, Elsevier, Amsterdam. 6. Willey, J. M., Sherwood, L. M. & Woolverton, C. J. (2011). Prescott's Microbiology (10^{th} edn), McGraw Hill, New York. 7. Ribbons, D. W. & Norris, J. R. (1970). Methods in Microbiology, Vols. 18 & 19, Academic Press, London/New York.	
Course Outcomes:	1. Recognize the dynamic and developing nature of the field of microbial taxonomy and systematics. 2. Recall the concepts of taxonomy and systematics. 3. Apply knowledge of the standard rules of classification systems to categorize microorganisms. 4. Select appropriate nucleic acid-based techniques and chemotaxonomic markers for use in classification systems.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-505
Title of the Course: Microbial Taxonomy and Systematics - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	It is required that students should have a basic understanding of the different types of marine microorganisms and their diversity.	
Objective:	This course provides opportunities for hands-on experience with the microbiological and biochemical techniques used for characterization of different microbial groups.	
Content:	1. Morphological, physiological and biochemical characterization of bacteria. (15 hrs, Refs 1 and 4) 2. Characterization of actinomycetes (*Streptomyces* sp.). (4 hrs, Ref 2) 3. Characterization of yeast (*Saccharomyces cerevisiae/ Schizosaccharomyces pombe*). (5 hrs, Ref 3) 4. Characterization of cyanobacteria. (3 hrs, Ref 4) 5. Microscopy of protists (phytoplankton/zooplankton) from seawater/sediment samples. (3 hrs, Refs 5 and 6)	30 hrs
Pedagogy:	Experiments in the laboratory	
References/ Readings:	1. Sneath, A. H. P., Mair, S. N. & Sharpe, E. M. (1984). Bergey's Manual of Systematic Bacteriology, Vol. 2, Williams & Wilkins, Academic Press, London/New York. 2. Mordarski, M., Williams, S.T. & Goodfellow, M. (1983). The Biology of the Actinomycetes. Academic Press, London/New York. 3. Kurtzman, C. P., Fell, J. W. & Boekhout, T. (2011). The Yeasts - A Taxonomic Study, Elsevier, Amsterdam. 4. Barlow, A. (ed.) (1992). The Prokaryotes: A Handbook on the Biology of Bacteria: Ecophysiology, Isolation, Identification, Applications, Vol. 1, Springer-Verlag, Germany. 5. Tomas, C. R. (ed.) (1997). Identifying Marine Phytoplankton, Academic Press, London/New York. 6. Kasturirangan, L. R. (1963). A Key For The Identification Of The More Common Planktonic Copepoda Of Indian Coastal Waters. In: Panikkar, N. K. (ed.), Key For The Identification Of The More Common Planktonic Copepoda Of Indian Coastal Waters. Council of Scientific and Industrial Research, New Delhi.	

Course Outcomes:	1. Demonstrate and apply the use of microscopy in studies on different groups of microorganisms. 2. Discriminate and evaluate the different phenotypic techniques used to characterize microorganisms.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-506
Title of the Course: Mathematics and Statistics in Biology
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	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 covers many mathematical techniques that are useful in understanding and predicting the behaviour of biological systems. 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:	**Module I** Introduction to Calculus: Scaling parameters, Non-linear parameters; Rates of change and the derivative: Linearity rule, Product rule, Quotient rule, Chain rule; The Definite Integral: linearity rule, partition rule. Fitting linear models to data, The Basic linear least squares method, Fitting the exponential model by linear least squares; Bacterial growth, steps towards building a mathematical model, Basic models of population growth: exponential and logistic; Nutrient uptake the Michaelis-Menten model; Droop model for internal nutrient stores and Monod model for growth and external nutrient supply; Analysis of population dynamics – models of production, growth and multiple reacting species, aquatic ecosystem in estuary and ocean viz. Lotka-Volterra Model; Bioinformatics: introduction, databases, hypothesis-generating bioinformatics (pathways), applications – biodiversity, structure prediction **Module II** Characteristics of biological data: Variables and constants, discrete and continuous variables, 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 errors, absolute and relative errors; Data handling: Population and samples, random samples, parameter and statistics, accuracy and precision, accuracy in observations, Tabulation and frequency distribution,	15 hrs 15 hrs

	relative frequency distribution, cumulative frequency distribution; Graphical representation: types of graphs, preparation and their applications; 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. 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, Kurtosis, Moments. **Module III** Correlation analysis – Correlation, covariance, correlation coefficient for ungrouped and grouped data, Karl Pearson's Coefficient, Rank Correlation coefficient, scatter and dot diagram (graphical method); Regression analysis **–** simple and multiple, linear and non-linear; examples: DNSA conversion by reducing sugar, survival/growth of bacteria; Probability: Probability (Elementary Genetics), Combinatorial Techniques; Theoretical Distribution: Binomial, Poisson, Normal Distributions; Hypothesis Testing – parameter and statistics, sampling theory, sampling and non-sampling error, confidence limits, testing of hypothesis, test of significance; Students' T-test, Chi-square test, F-test and ANOVA; Non-parametric tests: Wilcoxon Signed Rank test, Mann-Whitney 'U'test, Kruskal-Wallis 'H' test.	15 hrs
Pedagogy:	Lectures/ assignments/ self-study/ Moodle/ Videos.	
References/ Readings:	1. Kothari, C.R. (2013). Quantitative Techniques, Vikas Publishing House, Noida. 2. Arora, P.N. and Malhan, P.K. (2012). Biostatistics, Himalaya Publishing House, New Delhi. 3. Surya, R.K. (2010). Biostatistics for Health and Life Sciences, Himalaya Publishing House, New Delhi. 4. Danilina, N.I. (1988). Computational Mathematics, Mir Publishers, Russia. 5. Edelstein-Keshet, L. (2017). Differential Calculus for	

	the Life Sciences, The University of British Columbia, Vancouver, Open Book.	
Course Outcomes:	1. Able to collect, handle, process and present the Biological Data. 2. Apply the principles of statistics on biological experiments. 3. Analyze and interpret biological data using various mathematical expressions and biostatistical tools. 4. Discuss bioinformatics tools for biodiversity analysis.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-507
Title of the Course: Mathematics and Statistics in Biology - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic ability to handle numbers and calculation.	
Objective:	Handling and processing of biological data for statistical analysis.	
Content:	1. Statistical analysis and its applications. (9 hrs, Ref 1-6) 2. Regression analysis (6 hrs, Ref 1-3) 3. Normal distribution (6 hrs, Ref 1-3) 4. Hypothesis testing (9 hrs, Ref 1-3)	30 hrs
Pedagogy:	Laboratory experiments/field studies	
References/ Readings:	1. Kothari, C.R. (2013). Quantitative Techniques, Vikas Publishing House, Noida. 2. Arora, P.N. and Malhan, P.K. (2012). Biostatistics, Himalaya Publishing House, New Delhi. 3. Surya, R.K. (2010). Biostatistics for Health and Life Sciences, Himalaya Publishing House, New Delhi. 4. Basic Tasks in Excel - https://support.microsoft.com/en-us/office/basic-tasks-in-excel-dc775dd1-fa52-430f-9c3c-d998d1735fca 5. Grapher User's Guide, 2020 – Golden Software, LLC USA, www.GoldenSoftware.com 6. Surfer 12 Full User's Guide, 2014 - Golden Software, LLC USA, www.GoldenSoftware.com	
Course Outcomes:	1. Process and analyse data using different statistical tools for its application in microbiology-related experiments. 2. Use simple regression analysis for examining data related to standard graphs. 3. Apply normal distribution analysis to appropriate scientific problems. 4. Analyse biological problems statistically by examining their hypotheses using appropriate tests.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-521
Title of the Course: Marine Virology
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	It is required that students have a basic knowledge of viruses- their structure, classification and also about marine environment- different habitats.	
Objective:	This course develops concepts about viruses in marine environment, different approaches to study them, their role and significance in marine environment, few diseases of fishes, shrimps, shell-fishes.	
Content:	**Module I** Virus Structure, Diversity and Assay: Marine Viruses – Introduction, nature, structure and classification; Marine phages and their host: Archaea, bacteria and cyanobacteria, phytoplankton, algae; Marine viruses and their hosts: fish and shrimp; Giant marine virus; Metagenomic approaches to study the diversity of marine viruses **Module II** Multiplication and Assay of Phages and Viruses: Bacteriophage life cycles - lysogenic (latent) and lytic (virulent); Viral multiplication; One step growth profile; Assay: plaque assay (PA); most-probable number (MPN); epifluorescence microscopy, flow cytometry, transmission electron microscopy **Module III** Significance of viruses in marine ecosystem: Movement of viruses between biomes; Effect of viruses on ecology of the marine ecosystem; Marine viruses and global climate change; Viral pathogens of fish: Lymphocystis virus, Infectious pancreatic necrosis virus (IPNV), Nervous necrosis virus (NNV), Salmon Alphavirus (SAV), Infectious haematopoietic necrosis virus (IHNV), Viral hemorrhagic septicemia virus (VHSV); Viruses in shell-fish and shrimps, and health hazards: White Spot Syndrome Virus (WSSV), Taura syndrome virus, Norwalk virus and Hepatitis virus A.	15 hrs 15 hrs 15 hrs
Pedagogy:	Lectures/ assignments/ self-study/ Moodle/ Videos.	
References/	1. Sano, E., Carlson, S., Wegley, L., Rohwer, F. (2004).	

Readings:	Movement of Viruses between Biomes**.** Applied and Environmental Microbiology, 70: 5842–5846. 2. Breitbart, M., Thompson, L. R., Suttle, C. A., Sullivan, M. B. (2007). Exploring the Vast Diversity of Marine Viruses. Oceanography, 20: 135-139. 3. Rohwer, F., Thurber, R. V. (2009). Viruses manipulate the marine environment. Nature, 459: 207-212. 4. Danovaro, R., Corinaldesi, C., Dell'Anno, A., Fuhrman, J.A., Middelburg, J.J., Noble, R.T., Suttle, C.A. (2011). Marine viruses and global climate change. FEMS Microbiology Reviews, 35: 993–1034. 5. Crane, M., Hyatt, A. (2011). Viruses of Fish: An Overview of Significant Pathogens. Viruses, 3: 2025–2046. 6. Woo, P. T. K. and Bruno, D. W. (2011). Fish Diseases and Disorders. Vol 3: Viral, Bacterial and Fungal Infections. CABI Publishing, England. 7. Bosch, A., Le Guyader, S.F. (2010). Viruses in Shellfish and Food, Environmental Virology 2: 115-116. 8. Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S. (1982). Microbiology, Harper and Row Publishers, N.Y. . 9. Coutinho, F.H., Gregoracci, G.B., Walter, J.M., Thompson, C.C., and Thompson, F.L. (2018). Metagenomics sheds light on the ecology of marine microbes and their viruses, Trends in Microbiology, 26: 955-965.	
Course Outcomes:	1. Compare viruses from marine environment infecting different hosts. 2. Discuss various instruments and/or techniques for characterization of bacteriophages isolated from marine environment and for direct enumeration of viruses from natural samples. 3. Evaluate significance of viruses to the marine environment and to global climate change. 4. Predict the effect of viral infection on different fishes and fisheries.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-522
Title of the Course: Marine Virology - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	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 skills for handling bacterial viruses.	
Content:	1. Isolation of marine bacteriophages by double agar layer method (3 hrs; Ref 1-3) 2. Purification of bacteriophages (3 hrs; Ref 1-3) 3. Phage growth curve and Titration of phage lysate (plaque assay) (12 hrs; Ref 1-3) 4. Phage structural protein profile (12 hrs; Ref 4)	30 hrs
Pedagogy:	Experiments in the laboratory	
References/ Readings:	1. Mahy, B.W.J. and Kangro, H.O. (1996). Virology Methods Manual, Academic Press, N.Y. 2. Goldstein, G., Wm. C. (1992). Introductory Experiments in Virology, Brown & Benchmark Publishers, Ohio. 3. Burleson, F.G., Chambers, T.M. and Wiedbrauk, D.L. (2014). Virology: A Laboratory Manual, Elsevier, Netherlands. 4. Wilson, K. and Walker, J. (2013). Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press, N.Y., USA.	
Course Outcomes:	1. Demonstrate working with marine samples for isolation of bacteriophages. 2. Discuss various techniques for bacteriophage characterization. 3. Identify the phases of phage growth curve. 4. Design work plan for bacteriophage work from environmental sample.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-523
Title of the Course: Estuarine Microbiology
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	Knowledge of ecosystem and marine environments	
Objective:	The course explores the estuarine ecosystem understanding the abiotic and biotic factors playing role in balancing the dynamic system.	
Content:	**Module I** Estuaries: Definition - Characteristics of estuaries - Origin of estuaries - Structure of an estuary - functions of estuary - Types of estuaries - Some typical estuarine habitats of India (Mandovi, Zuari, Godavari, Krishna, Cauvery) - Estuarine geomorphology - patterns of environmental variability - Physical environmental factors (temperature, light, currents, tides and waves) - Chemical environmental factors (oxygen, carbon dioxide and carbonates, salinity, pH, nutrients) - Classification of marine organisms and their characteristic features - variety and spatial patterns of diversity. **Module II** Estuarine microbial ecology – Microorganisms in estuarine water and sediments – Factors influencing estuarine microorganisms - Factors influencing estuarine microorganisms and their adaptations, Interactions with associated biota - Estuarine food webs - Factors affecting primary productivity - Trophic transfer, cascade effects and role of bacterial protoplasm, Biomagnification. **Module III** Role of mangroves, salt marshes and deltas in estuarine ecosystem functioning. Threats to estuarine ecosystems - Natural threats - Anthropogenic threats – Trace metal pollution and bioaccumulation, effluents and introduction of pathogenic bacteria, Conservation of estuaries -Effects on estuarine ecosystem.	15 hrs 15 hrs 15 hrs
Pedagogy:	Lectures/assignments/self-study/ visit to estuary	

References/ Readings:	1. Friedrich, H. (1969). Marine Biology. Sidgewick & Jackson, London. 2. Raymont, J.E.C. (1980). Plankton and productivity in the oceans, Volume 1. Phytoplankton. 2nd Edition. Pergamon, U.K. 3. Balakrishna Nair. N. and Thampy D.M. (1980). A text book of marine ecology. Macmillan, Delhi. 4. Broecker, W.S. (1974). Chemical oceanography. Harcourt, Brace, Jovanivich Inc., New York. 5. Sverdrup, H.V., Johnson, M.W., and Fleming, R.H. (1942). The oceans - their physics, chemistry and general biology. Prentice-Hall Inc., U.S. 6. Mitra A. and Zaman S. (2016) Basics of marine and estuarine ecology. Springer, India. 7. Day, J.W., Crump B.C., Kemp W.M., Yanez-Arancibia A. (2013). Estuarine ecology. Wiley-Blackwell Inc., Oxford.	
Course Outcomes:	1. Explain the types of estuaries and their physico-chemical characteristics. 2. Analyse the biodiversity of marine organisms and their distribution patterns. 3. Explain the composition of Microflora of estuarine ecosystem, elaborate on the factors affecting and evaluate their interaction with other biota. 4. Define Primary productivity and explain food webs in estuarine ecosystem. 5. Enlist the types of mangroves and describe their role in the estuarine ecosystem. 6. Compile the anthropogenic activities affecting estuaries and list the importance of conservation of estuaries.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-524
Title of the Course: Estuarine Microbiology - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	It is necessary that students should have working knowledge of the techniques used for sampling and analysis of marine samples.	
Objective:	The course develops the techniques involved in estuarine sample processing and analysis.	
Content:	1. Chemical characteristics of estuarine water sample – BOD (5 hrs, Refs.1 and 4) 2. Estimation of suspended load, Particulate Organic Carbon and Total Organic Carbon of estuarine water (8 hrs, Refs.1 and 4) 3. Qualitative estimation of plankton (phytoplankton and zooplankton) (6 hrs, Ref. 6) 4. Isolation of bacteria –Total Plate Count (5 hrs, Refs. 2 and 7) 5. Isolation of fungi – plating and wet mount (6 hrs, Ref. 5)	30 hrs
Pedagogy:	Experiments in the laboratory	
References/ Readings:	1. Kennish, M. J. (2017). Practical Handbook of Estuarine and Marine Pollution, CRC Press, Florida. 2. Green, L.H. and Goldman, E. (2015). Practical Handbook of Microbiology, 3rd Edition. CRC Press, Florida. 3. Kennish, M.J. (2019). Practical Handbook of Marine Science, CRC Press, Florida. 4. Chaney, R.C. (1991). Sampling and Preparation of Marine Sediments, In, Foundation Engineering Handbook, Springer Publishers, New York. 5. Bull, A.T. (2003). Microbial Diversity and Bioprospecting. ASM Press, Washington, U.S. 6. Reddy, S.M., Charya, M.A.S. and Girisham, S. (2012). Microbial Diversity: Exploration and Bioprospecting, Scientific Publishers, India. 7. Thomas, T.R., Kavlekar, D.P., Lokabharathi, P.A. (2010). Marine drugs from sponge-microbe association: a review. Marine Drugs, 8: 1417-1468.	
Course Outcomes:	1. Estimate BOD, POC, TOC of estuarine water and sediment samples. 2. Analysis of water samples for phytoplankton and zooplankton identification. 3. Microbial analysis of water and sediment samples.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-525
Title of the Course: Fishery Microbiology
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	Knowledge of microbial diversity.	
Objective:	Develop the knowledge of fishes, fisheries, aquaculture in India. Develop the concepts of various infectious diseases present in fishes and spread through fishes.	
Content:	**Module I** Introduction to Indian Fisheries: pelagic and benthic resources, exploitation, craft and gears used, oceanographic processes affecting capture fisheries. Blue economy, semi-intensive culture systems, use of Prebiotics and Probiotics, SPF and SPR. Microbiology of Raw fish and processed fish. Adverse effects of microbial spoilage and PHFL in blue economy. Fish processing methods: biopreservation, food processing, fermentation and aquaculture; effect of heat, chilling, freezing and chemical preservatives on bacteria, yeasts and fungi associated with fishes. Quality control and regulations for fishes, shellfish and marine living resources. **Module II** Microbes associated with fish and shellfish: Commensals and pathogens; Classification of diseases; Methods of disease prevention; Detailed study of bacteria pathogenic to finfish and shellfish with emphasis on morphology, epidemiology, pathogenesis, treatment and control: *Flavobacterium, Edwardsiella, Vibrio, Aeromonas, Renibacterium, Yersinia, Mycobacterium.* Viral infections: White Spot Syndrome Virus (WSSV), Monodon Baculo Virus (MBV), Yellow Head virus (YHV), Hepatopancreatic Parvo Virus (HPV), Infectious Hypodermal and Hematopoeitic Necrosis Virus (IHHNV), EUS. Ecto and endoparasitic infections. **Module III** Marine toxins and Human bacterial pathogens: Human bacterial pathogens associated with fishes and their products - *Clostridium perfringens, Listeria spp., Plesiomonas, Vibrio cholerae, Vibrio*	15 hrs 15 hrs 15 hrs

	parahaemolyticus, Vibrio vulnificus and common *Enterobacteriaceae.* Marine toxins – Paralytic Shellfish Poisoning (PSP) Toxins, Amnesic Shellfish Poisoning (ASP) Toxins, Diarrhetic Poisoning Toxins, Lipophilic Shellfish Toxins (LST), Neurotoxin Shellfish Poisoning (NSP) Toxins, Venerupin shellfish poisoning, Ciguatera toxins, tetradotoxins, Azaspiracids, Cyclic Imines and their origin.	
Pedagogy:	Lectures/ assignments/ self-study	
References/ Readings:	1. Fernandes R. (2009). Microbiology Handbook: Fish and Seafood. RSC Publishing. London. 2. Woo P. & Bruno D. (2011). Fish Diseases and Disorders, Vol 3: Viral, Bacterial and Fungal Infections (2nd edn) CABI Publishers. United Kingdom. 3. Roberts R. J. (2012). Fish Pathology (4^{th} edn). Wiley-Blackwell Publishers. New Jersey. 4. Hoole D., Buck D., Burgess P., & Welby I. (2011). Diseases of Carps and Other Cyprinid Fishes, Wiley-Blackwell Publishers. New Jersey. 5. Sindermann C.J. (1970). Principle Diseases of Marine Fish and Shellfish (1st edn). Academic Press of NewYork and London. 6. Noga E. C. (2010). Fish Disease: Diagnosis and Treatment (2^{nd} edn). Wiley-Blackwell Publishers. New Jersey. 7. Leatherland J. F. & Wook P. K. T. (2006). Fish Diseases and Disorders (2^{nd} edn) CABI Publishers. United Kingdom.	
Course Outcomes:	1. Garner knowledge of wide diversity of marine and coastal ecosystems in terms of fishes, shrimps, etc. 2. Apply the principles of microbiology to a range of interactions between microorganisms and fishes. 3. Compare various microbial infections in fishery resources and their implications. 4. Assess the influence of zoonotic infections on fish and human health.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-526
Title of the Course: Fishery Microbiology - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Knowledge of fishes, and microbial diversity.	
Objective:	Provides hands-on experience in the fish anatomy and its associated microbial flora, including human pathogens.	
Content:	1. Sampling techniques for microbiological investigation of moribund fish. (10 hrs, refs. 1 -3) 2. Methods for examination and analyzing fish for health certification/diagnosis of disease condition, techniques for sample collection and processing for bacteriological agents. (10 hrs, refs. 1 -3) 3. Isolation and identification of various human bacterial pathogens from fish samples (*Enterobacteriaceae* and *Vibrio*). (10 hrs, refs. 1 -3)	30 hrs
Pedagogy:	Experiments in the laboratory.	
References/ Readings:	1. Woo P. & Bruno D. (2011). Fish Diseases and Disorders, Vol 3: Viral, Bacterial and Fungal Infections (2nd edn) CABI Publishers. United Kingdom. 2. Noga E. C. (2010). Fish Disease: Diagnosis and Treatment (2^{nd} edn). Wiley-Blackwell Publishers. New Jersey. 3. Leatherland J. F. & Wook P. K. T. (2006) Fish Diseases and Disorders (2^{nd} edn) CABI Publishers. United Kingdom	
Course Outcomes:	1. Apply the tools and techniques of microbiology for isolation of fish microbiota. 2. Assess the microbiological quality of fishes in terms of associated disease or as carrier for human pathogens. 3. Analyze the symptoms and colony characteristics of isolates for the prediction of disease type. 4. Hypothesize the disease occurrence in local fish catch.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-527
Title of the Course: Marine Extremophilic Microorganisms
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic knowledge of extreme marine environments and their defining features is necessary.	
Objective:	This course develops concepts relating to the ability of organisms to thrive in extreme marine ecosystems, their adaptations and biotechnological potential.	
Content:	**Module I** Concept of extremophiles and conventional microbial forms. Extreme marine econiches: marine trenches and ridges, submarine vents, cold seeps, deep sea basins and polar sea ice, glaciers, cryoconite holes, lakes, polynyas. Biotechnological potential of extremophiles. **Module II** Description, physiological features, adaptation strategies, significance in biogeochemical cycles of different microbial groups from marine environments: anaerobes, barophiles/piezophiles, cryophiles/psychrophiles, thermophiles and hyperthermophiles. **Module III** Description, physiological features, adaptation strategies, significance in biogeochemical cycles of the following marine extremophiles: oligotrophs, osmophiles, halophiles, xerophiles, alkaliphiles, acidophiles, radiophiles, metallophiles and xenobiotic utilizers.	15 hrs 15 hrs 15 hrs
Pedagogy:	Lectures/ assignments/ self-study/ videos.	
References/ Readings:	1. Brock, T. D. (2012). Thermophilic Microorganisms and Life at High Temperatures, Springer, New York. 2. Morita, R. Y. (1999). Extremophiles: Microbial life in extreme environments, Bioscience, 49(3), 245-248. 3. Rainey, F. A. & Oren, A. (2006). Extremophile microorganisms and the methods to handle them. Methods in Microbiology, 35, 1-25. 4. Satyanarayana, T., Raghukumar, C. & Shivaji, S. (2005). Extremophilic microbes: diversity and	

	perspectives. Current Science, 89(1), 78-90. 5. Ventosa, A., Nieto, J. J. & Oren, A. (1998). Biology of moderately halophilic aerobic bacteria. Microbiology and Molecular Biology Reviews, 62, 504-544.	
Course Outcomes:	1. Discover and identify diverse types of extreme econiches in the marine environment. 2. Describe and differentiate between extremophiles and conventional microbial forms. 3. Extend their knowledge about the adaptation strategies and ecological significance of extremophilic microorganisms from the marine environment. 4. Assess the biotechnological potential of marine extremophilic microorganisms.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-528
Title of the Course: Marine Extremophilic Microorganisms – Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic knowledge of extreme marine environments and their defining features is necessary.	
Objective:	This course aims to widen the students' understanding of the techniques involved in sampling extreme marine environments and processing and characterization procedures, for different categories of extremophiles.	
Content:	1. Techniques for isolation of psychrophiles and anaerobes. (8 hrs, Refs 1 - 3) 2. Techniques for isolation of xenobiotic-degraders and organic solvent-tolerant bacteria. (7 hrs, Ref 4) 3. Effect of varying salt concentrations on growth of halophiles/halotolerant microbes. (8 hrs, Ref 5) 4. Growth of bacterial isolates at varying nutrient levels. (7 hrs, Ref 6)	30 hrs
Pedagogy:	Experiments in the laboratory	
References/ Readings:	1. Rainey, F. A. & Oren, A. (2006). Extremophile microorganisms and the methods to handle them. Methods in Microbiology, 35, 1-25. 2. Russell, N. J. (2006). Antarctic micro-organisms: coming in from the cold. Culture, 27(2), e989. 3. Uchino, Y. & Ken-Ichiro, S. (2011). A simple preparation of liquid media for the cultivation of strict anaerobes. Petroleum and Environmental Biotechnology, S3:001. doi:10.4172/2157-7463.S3-001. 4. Sardessai, Y. & Bhosle, S. (2002). Tolerance of bacteria to organic solvents. Research in Microbiology, 153, 263-268. 5. Ventosa, A., Nieto, J. J. & Oren, A. (1998). Biology of moderately halophilic aerobic bacteria. Microbiology and Molecular Biology Reviews, 62, 504-544. 6. Kéki, Z., Grébner, K., Bohus, V., Márialigeti, K., & Tóth, E. (2013). Application of special oligotrophic media for cultivation of bacterial communities originated from ultrapure water. Acta Microbiologica et Immunologica Hungarica, 60(3), 345-357.	
Course Outcomes:	1. Develop skills in isolation of different groups of extremophiles. 2. Design experiments to characterize different groups of extremophiles.	

Semester II
Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-508
Title of the Course: Techniques and Instrumentation in Microbiology
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	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:	**Module I** 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); Centrifugation: Principles, methodology, application; Density gradient centrifugation; Ultracentrifugation (Separation of ribosomal subunits of bacteria); Spectrophotometry: Atomic Absorption Spectrophotometry (AAS), UV-Visible, fluorimetry, Fourier transformation infra-red spectroscopy (FTIR), NMR, IRMS, ICP MS, MALDI-TOF. **Module II** Microscopy: Epifluorescence filter technique (DEFT), SEM, TEM, Confocal microscopy; Radio-isotope and tracer techniques: Isotope and types of isotopes, Radio-activity counters, Autoradiography, Radiorespirometry; Cell and tissue culture techniques: Primary and secondary/established cell lines, Monolayer and suspension cultures, Fluorescence activated cell sorting (FACS), Biohazards and Biosafety cabinet. **Module III** Electrophoretic technique: PAGE, IEF, PFGE, DGGE, TGGE, Capillary electrophoresis, Single stranded conformation polymorphism (SSCP), Electroporator, Micro-array technique; Isolation of cell organelles: Different methods of cell lysis/ breakage and isolation and purification of various cell components - Cell surface structures, cell envelopes, plasma membranes, peptidoglycan, Outer membrane,	15 hrs 15 hrs 15 hrs

	ribosomes, protoplasts, spheroplast, DNA, RNA; X-ray diffraction, Oxygen analyser.	
Pedagogy:	Lectures/ assignments/ self-study/ Moodle/ Videos.	
References/ Readings:	1. Wilson, K. and Walker, J. (2013). Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press, N.Y., USA. 2. Cooper, T. G. (2011). The Tools of Biochemistry, Wiley India Pvt. Ltd., Noida. 3. Goswami, C., Paintal, A. and Narain, R. (2011). Handbook of Bioinstrumentation, Wisdom Press, New Delhi. 4. Parakhia, M. V., Tomar, R. S., Patel, S. and Golakiya, B. A. (2010). Molecular Biology and Biotechnology: Microbial Methods, NIPA New Delhi, Pitampura. 5. Jayaraman, J. (2011). Laboratory Manual in Biochemistry, New Age International Publishers, New Delhi. 6. Norris, J. R. and Ribbons, D. W. (1971). Methods in Microbiology, Volume 5, Part B, Academic Press, N.Y. 7. Colowick, S. P. and Kaplan, N. O. (1963). Methods in Enzymology, Vol. VI, Academic Press, N.Y. 8. Sambrook, J., Fritsch, E. F. and Maniatis, T. (2014). Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, USA.	
Course Outcomes:	1. Describe the principle, working and applications of various techniques/instruments. 2. Interpret the technique/instrument necessary for metabolite analysis. 3. Identify proper Biosafety levels of the work proposed. 4. Apply the knowledge to utilise appropriate technique/instrument for any analysis.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-509
Title of the Course: Techniques and Instrumentation in Microbiology - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	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 skills for techniques and instrumentation in microbiology.	
Content:	1. Microscopy – compound, phase contrast – of bacterial, fungal cells (3 hrs; Ref 1) 2. Density gradient separation of mixed bacterial and/or yeast cells. (3 hrs; Ref 1) 3. Cell disruption of pigmented bacteria/yeast by sonicator, efficacy of sonication and pigment profiling using UV-visible spectrophotometer. (9 hrs; Ref 1-5) 4. Polyacrylamide gel electrophoresis (PAGE) (12 hrs; Ref 1-5) 5. Demonstration of molecular exclusion chromatography (3 hrs; Ref 5)	30 hrs
Pedagogy:	Experiments in the laboratory	
References/ Readings:	1. Wilson, K. and Walker, J. (2013). Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press, N.Y., USA. 2. Cooper, T. G. (2011). The Tools of Biochemistry, Wiley India Pvt. Ltd., Noida. 3. Goswami, C., Paintal, A. and Narain, R. (2011). Handbook of Bioinstrumentation, Wisdom Press, New Delhi. 4. Parakhia, M. V., Tomar, R. S., Patel, S. and Golakiya, B. A. (2010). Molecular Biology and Biotechnology: Microbial Methods, NIPA New Delhi, Pitampura. 5. Jayaraman, J. (2011). Laboratory Manual in Biochemistry, New Age International Publishers, New Delhi.	
Course Outcomes:	1. Demonstrate microbial cells~~,~~ under the microscope. 2. Analyse separation of microbes based on their cell densities. 3. Employ cell disruption technique and UV-visible spectrophotometry for intracellular pigment profiling. 4. Analyze proteins using polyacrylamide gel electrophoresis. 5. Learn separation of biomolecules using molecular exclusion chromatography.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-510
Title of the Course: Industrial Microbiology
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic knowledge about the types of microbes and their products of industrial relevance.	
Objective:	Understanding of concepts in the fermentation processes employed in the industries to produce the products using marine microorganisms.	
Content:	**Module I** Industrial strains, Fermentation media, Asepsis and sterilisation, growth kinetics - Bioreactor design and operation: classification of reactors; designing parameters for reactors (stirred tank reactor, airlift reactor, plug flow reactor) - rheology of fermentation broth - gas-liquid mass transfer, heat transfer, scale up - Solid substrate fermentation (SSF): Principles and application with examples (penicillin, amylase) - Immobilized enzymes and cell systems. **Module II** Fermentation monitor and control: speed, temperature, gas, pH, Dissolved oxygen, foam, redox, air flow, weight, pressure, biomass - On-line and off-line analysis - Layout and components of fermentation process for extracellular and intracellular microbial products - Recovery of biomass (cells and solid particles), cell disruption for recovery of intracellular products, primary isolation (extraction, sorption), precipitation, industrial processes for chromatography and fixed bed adsorption, membrane separations - drying, crystallisation, whole broth processing (Penicillin production) - Formulation, packaging - QC/QA; IPR. **Module III** Industrially important marine microorganisms - Microbiological techniques in marine food industry, canning, freezing, drying - Industrial production and application – enzymes (Proteases, Lipases, amylase, pectinase), carotenoids, EPS, bioplastics, biopolymers – xanthan, pigments, Antibiotics-erythromycin, steroids, SCP, biofuels – Entrepreneurship.	15 hrs 15 hrs 15 hrs

Pedagogy:	Lectures/ assignments/ self-study	
References/ Readings:	1. Demain, A.L., Davies, J.E. and Atlas, R.M. (2010). Manual of industrial microbiology and biotechnology. ASM Press, Washington, U.S. 2. Flickinger, M.C. and Drew S.W. (2002). The Encyclopedia of bioprocess technology: Fermentation, biocatalysis and bioseparation. Volumes 1 – 5. John Wiley Publisher, New Jersey. 3. Stanbury, P.F., Whitaker, A. and Hall S.J. (2016). Principles of fermentation technology. 3rd Edition. Butterworth-Heinemann Publishers, Oxford, U.K. 4. Arad, S.M. (1999). Polysaccharides from red microalgae. In, Chemicals from microalgae, Cohen, Z. (Ed.). Taylor and Francis, London. Pp. 282-292. 5. Borowitzka M.A. (1995). Microalgae as sources of pharmaceuticals and other biologically active compounds. Journal of Applied Phycology 7, 3-15. 6. Kopecky J., Schoefs B., Loest K., Stys D. and Pulz O. (2000). Microalgae as a source for secondary carotenoid production: a screening study. Archiv für Hydrobiologie Supplement 133, 153-168. 7. Melis A. and Happe T. (2001). Hydrogen production. Green algae as a source of energy. Plant Physiology 127, 740-748.	
Course Outcomes:	1. Define fermentation, differentiate between different types of fermentations. 2. Elaborate on the methods for strain improvement and mutant selection. 3. Discuss role of rheology, sterilisation parameters for media and types of media. 4. Explain the fermentation monitoring methods and their controls. 5. Compare and contrast the different methods for downstream processing of fermentation products. 6. Explain the production and application of marine microbial products.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-511
Title of the Course: Industrial Microbiology - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Knowledge of basic microbiology techniques.	
Objective:	This course develops the skills for techniques and instrumentation in industrial microbiology.	
Content:	1. Fermentor design – stirred tank reactor. (6 hrs, Ref. 1) 2. Rheology of substrate solutions using viscometer. (6 hrs, Ref.2) 3. Exopolysaccharide production using marine microbial isolate. (6 hrs, Ref.3) 4. Downstream processing for EPS. (6 hrs, Refs 1 and 2) 5. Culturing *Spirulina* (*Arthrospira platensis*). (6 hrs, Refs 4 and 5).	30 hrs
Pedagogy:	Experiments in the laboratory, data collection and processing.	
References/ Readings:	1. Flickinger, M.C. and Drew S.W. (2002). The Encyclopedia of bioprocess technology: fermentation, biocatalysis and bioseparation. Volumes 1 – 5. John Wiley Publisher, New Jersey. 2. Stanbury, P.F., Whitaker, A. and Hall, S.J. (2016). Principles of fermentation technology. 3rd Edition. Butterworth-Heinemann Publishers, Oxford, U.K. 3. Arad, S.M. (1999). Polysaccharides from red microalgae. In Chemicals from microalgae. Cohen Z (Ed). Taylor and Francis, London, pp 282-292. 4. https://www.justspirulina.org/spirulina-growing requirements 5. Habib, M.A.B., Parvin, M., Huntington, T.C., and Hasan, M.R. (2008). A review on culture, production and use of spirulina as food for humans and feeds for domestic animals and fish. FAO Fisheries and Aquaculture Circular. No. 1034. Rome, FAO.	
Course Outcomes:	1. Describe Fermentor design, draw and label different parts of stirred tank reactor. 2. Measure and calculate rheology of substrate solutions using viscometer. 3. Extract and quantitate the exopolysaccharide produced using marine microbial isolate.	

	4. Designing large scale fermentation process for culturing *Spirulina* and assessing its purity by microscopy.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-512
Title of the Course: Microbial Genetics and Gene Regulation
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	It is assumed that the students have a basic knowledge of DNA (structure and replication), Prokaryotic and eukaryotic genome organisation, mutation concept, basic knowledge transcription and translation.	
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:	**Module I** Chromosomes, Genomes and its evolution: Introduction to microbial genetics. DNA structure and its fundamental functions. Chromosomal DNA and its packaging in the chromatin fibre. Chromatin structure, structural features (Telomere, Centromere and Repetitive sequences) of chromosomes and their functions. Satellite DNA, Repetitive DNA. Histone modifications. Genomic islands. Structural chromosomal aberrations and their significance: Deletion, duplication, inversion, translocation. Aneuploidy and polyploidy. Gene duplication and mutations. **Module II** DNA Damage, DNA Repair and Recombination: Types of DNA damage (spontaneous and induced DNA damage). Mutagenesis: Somatic and germinal mutation, site specific using PCR/ cassette mutagenesis, and random mutagenesis. Types of mutation: silent, missense, nonsense, Read through, 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. Mechanisms/pathways to remove damaged DNA: Excision repair, mismatch repair, recombination repair in *E. coli* and SOS Repair. Role of RecA in DNA damage repair, Photoreactivation repair in E. coli involving photolyase. Mechanisms of Genetic Recombination:	15 hrs 15 hrs

	General and site-specific recombination. Heteroduplex DNA formation (Homologous recombination). Holliday junctions. Synaptonemal Complex, Bacterial RecBCD system and its stimulation of chi sequences. **Module III** Genomic rearrangements, Gene structure and control of gene expression in Prokaryotes and Eukaryotes: 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. An overview of Gene expression control, DNA binding motifs in gene regulatory proteins, genetic switches and their role in control of gene expression. Lac operon, tryptophan operon, post-transcriptional controls-transcriptional attenuation, Riboswitches, Alternate splicing, RNA editing, RNAi.	15 hrs
Pedagogy:	Lectures/ assignments/ self-study	
References/ Readings:	1. Gardner E.J., Simmons M.J. & Snustad D.P. (2015). Principles of Genetics (7th edn) John Wiley & Sons. NewYork. 2. Krebs J. E., Lewin B., Goldstein E. S. & Kilpatrick S.T. (2018). LEWIS Genes XII (1st edn) Jones and Bartlett Publishers. Burlington. 3. Maloy S.R., Cronan J.E. & Freifelder D. (1994). Microbial Genetics (2nd edn) Jones and Bartlett Publishers. Boston. 4. Streips U.N. & Yasbin R.E. (2002). Modern Microbial Genetics (2nd edn). John Wiley & Sons. NewYork. 5. Peter J.R. (2010). iGenetics: A Molecular Approach (3rd edn) Pearson Education. San Francisco. 6. Alberts B., Johnson A., Lewis J., Morgan D., Raff M., Roberts K.& Walter, P. (2015). Molecular Biology of the Cell (J. Wilson, & T. Hunt, Eds.) (6th edn). W.W. Norton & Company. NewYork. 7. Twyman R.M. (1998). Advance Molecular Biology: A Concise Reference (W. Wisden, Ed.) (1st ed.). Garland Science. London. 8. Davis L.G., Dibner M.D. & Battey J. F. (1986). Basic Methods in Molecular Biology, Elsevier. Netherlands.	

Course Outcomes:	1. Understand gene structure and mutations in prokaryotes and eukaryotes. 2. Compare positive and negative gene expression and regulation systems. 3. Differentiate various repair mechanisms of DNA damage. 4. Discuss the significance of mutagenesis in molecular research and microbial evolution.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-513
Title of the Course: Microbial Genetics - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic knowledge about nucleic acids and replication	
Objective:	This course provides hands-on experience with DNA extraction, purification and electrophoretic techniques.	
Content:	1. Isolation of genomic DNA of bacterial cells, estimation of quantity and purity of DNA by spectrophotometry, and agarose gel electrophoresis. (10 hrs, refs. 1 and 2) 2. Isolation of genomic DNA from environmental sample (sediment/water). (4 hrs, refs. 1 and 2) 3. PCR / RT-PCR amplification of a specific gene using genomic DNA as a template and agarose gel analysis of PCR product to determine amplicon size. (10 hrs, refs. 1 and 2) 4. UV mutagenesis and screening of pigment deficient mutants of *Serratia marcescens*. (6 hrs, refs. 1 and 2)	30 hrs
Pedagogy:	Experiments in the laboratory.	
References/ Readings:	1. Davis L.G., Dibner M.D. & Battey J. F. (1986). Basic Methods in Molecular Biology, Elsevier. Netherlands. 2. Kamlage B. (1996). Methods for General and Molecular Bacteriology. Edited by P. Gerhardt, R. G. E. Murray, W. A. Wood and N. R. Krieg. American Society for Microbiology, Washington, D.C.	
Course Outcomes:	1. Perform genomic/total DNA extraction and PCR amplification in molecular research. 2. Compare various DNA extraction protocols and interpret the importance of each step. 3. Determine of amplicon size. 4. Plan and perform mutagenesis to study induced genetic manipulation.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-514
Title of the Course: Microbial Ecology
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic understanding of the marine environment and microorganisms.	
Objective:	To learn the basic concepts of the marine environment, biodiversity and their interaction. Also, to understand the effect of climate change on microbial ecology.	
Content:	**Module I** Marine microbiome: diversity, evolution and function, microbial interaction: mutualism, commensalism, parasitism, microbial symbiosis - microbiomes from plankton, fish, coral, sponge, deep-sea invertebrates, and animals - biogeochemical cycles: carbon, nitrogen, phosphorus, sulphur, and iron - oxygen minimum zones (OMZs): anaerobic microbial metabolism, OMZs in the world oceans, anthropogenic impact. **Module II** Marine carbon reservoirs - ocean carbon cycle - carbon pump: solubility, carbonate, biological, microbial - microbial loop - role of picoplankton - production, transformations and fate of dissolved organic matter (DOM) - sources and composition of DOM - reactivity class of DOM - DOM release and microbial food webs - extracellular enzymes - DOM release and influence of climate change - chromophoric dissolved organic matter (CDOM) - factors affecting CDOM and its role in the ecosystem - carbon cycling in the anoxic environment and sediments. **Module III** Factors affecting microbial ecology: greenhouse gases - global warming, ocean acidification, deoxygenation, implications on biogeochemical processes. Impact on microbial ecology: Physiological, population and community response to climate change - impact on plankton, fishery, coral, humans - microbial growth patterns and its distribution, energetics, food web, marine productivity, microbial loop, reproduction, survival, recruitment, prey-predator interaction - multiple stressors and synergistic effects. Mitigation	15 hrs 15 hrs 15 hrs

	measures: Marine probiotics, prebiotics.	
Pedagogy:	Lectures/ assignments/ self-study	
References/ Readings:	1. Gasol, J.M. and Kirchman, D.L. (2018). Microbial ecology of the oceans. Wiley- Blackwell Publishers, Oxford. 2. Nybakken, J.W. and Bertness, M.D. (2004). Marine biology: an ecological approach. Benjamin-Cummings Pub Co., San Francisco. 3. Munn, C.B. (2019). Marine microbiology: ecology and applications. CRC Press, Florida. 4. Dipper, F. and Tait, R.V. (1998). Elements of marine ecology, Butterworth-Heinemann, Oxford, U.K. 5. Nair, N.B. and Thampy, D.M. (1980). A Textbook of marine ecology. Macmillan, Delhi. 6. Webber, H.H. and Thurman, H.V. (1984). Marine biology. HarperCollins Publishers, New York.	
Course Outcomes:	1. Explain marine microbiomes and associations with marine organisms. 2. Describe the microbial loop, food webs and interactions. 3. Discuss role of marine microbiomes in biogeochemical cycles and DOM transformations. 4. Predict the implications of various factors on microbial ecology.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-515
Title of the Course: Microbial Ecology – Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Basic understanding of marine environments and microorganisms.	
Objective:	This course deals with the isolation of microbes and determining the biochemical composition of seawater.	
Content:	1. Enumeration of plankton-associated microbes (12 hrs; Ref 1). 2. Determination of carbohydrates from seawater (6 hrs; Ref 2). 3. Determination of extracellular enzymes from seawater using a fluorogenic substrate (6 hrs; Ref 3). 4. Determination of dissolved organic carbon from seawater (6 hrs; Ref 4).	30 hrs
Pedagogy:	Laboratory experiments/field studies	
References/ Readings:	1. Arora M., Anil A.C., Delany J., Rajarajan N., Emami K., and Mesbahi E. (2012). Carbohydrate-degrading bacteria closely associated with *Tetraselmis indica*: influence on algal growth. Aquatic Biology, 15:61-71. 2. Dubois M., Gilles K., Hamilton J., Rebers P.A. and Smith, F. (1951). A colorimetric method for the determination of sugars. Nature, 168: 350-356. 3. Zoppini, A., Puddu A., Fazi, S., Rosati, M. and Sist, P. (2005). Extracellular enzyme activity and dynamics of bacterial community in mucilaginous aggregates of the northern Adriatic Sea. Science of the Total Environment, 353(1-3): 270-86. 4. Krishna M.S., Prasad V.R., Sarma V.V.S.S., Reddy N.P.C., Hemalatha K.P.J., and Y.V. (2015). Fluxes of dissolved organic carbon and nitrogen to the northern Indian Ocean from the Indian monsoonal rivers. Journal of Geophysical Research: Biogeosciences, 120:2067–2080.	
Course Outcomes:	1. Study extracellular enzymes from sea water. 2. Assess carbohydrate concentrations from sea water. 3. Estimate microbial count of plankton associates. 4. Determine DOC concentrations in sea water.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-529
Title of the Course: Diversity, Ecophysiology and Interactions of Marine Microorganisms
Number Of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	The student should have a basic understanding of the features of marine environments and microorganisms.	
Objective:	This course deals with the distribution and diversity of different microbial groups in the marine environment and focuses on their ecophysiological adaptations to the diverse niches in the marine environment, and their interactions within and across trophic levels.	
Content:	**Module I** Microbes in the marine environment; Characteristics of diverse microbial groups in the marine environment Prokaryotes (bacteria and archaea), fungi; phytoplankton: diatoms, dinoflagellates, haptophytes (coccolithophores, prymnesiophytes), prasinophytes; zooplankton (holoplankton, meroplankton): chaetognaths, cnidarians, molluscs, radiolarians, foraminiferans, crustaceans, larvaceans; protists: the 'Junk Drawer' Kingdom; multiple marine protistan lineages in seven supergroups of the eukaryotic tree of life.	15 hrs
	Module II Ecophysiology of Marine Microorganisms. Metabolic characteristics of marine microbes, requirement for sodium, synthesis of extracellular enzymes for utilization of complex macromolecules, strategies for acquisition of iron, metabolic changes in response to starvation, oligotrophy, copiotrophy, viable but non-culturable microorganisms. Metabolic diversity. Phototrophy, chemotrophy, thiotrophy, autotrophy, heterotrophy; photosynthesis, anaerobic anoxygenic photosynthesis, aerobic anoxygenic phototrophy; fermentation, aerobic respiration, anaerobic respiration (denitrification, sulphate reduction, methanogenesis); nitrification, annamox, sulphur oxidation, methanotrophy; carbon dioxide fixation in autotrophs.	15 hrs
	Module III Microbial interactions. The paradox of the plankton; interactions within and across trophic levels	15 hrs

	(allelopathic interactions); chemical ecology; signalling molecules, quorum sensing, AHLs, bacteriocins, peptides, nitric oxide, lipids. Symbiotic associations. The dynamic nature of symbiotic interactions; interactions between phytoplankton and bacteria; indirect chemical defence of microalgae; microbe-sponge interactions; mixotrophy, kleptoplastidy.	
Pedagogy:	Lectures/ assignments/ self-study/ videos	
References/ Readings:	1. Hunter-Cevera, J., Karl, D. & Buckley, M. (2005). Marine Microbial Diversity: the Key to Earth's Habitability, American Academy of Microbiology. Washington DC. 2. Munn, C. (2011). Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, New York. 3. Meller, C. B. & Wheeler, P. A. (2012). Biological Oceanography (2nd edn), Wiley Blackwell Publishers. 4. Gasol, J. M. & Kirchman, D. L. (2018). Microbial Ecology of the Oceans (3rd edn), Wiley Blackwell Publishers, New Jersey. 5. Nybakken, J. W. & Bertness, M. D. (2005). Marine Biology: an Ecological Approach (6th edn), Benjamin Cummings, San Francisco.	
Course Outcomes:	1. Identify and describe the diverse prokaryotic and eukaryotic microorganisms in the marine environment. 2. Examine the ecophysiology and metabolic characteristics of marine microorganisms. 3. Critically evaluate the interactions of marine microorganisms within and across trophic levels. 4. Summarize the pivotal role of marine microorganisms in ecosystem functioning in the marine environment.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-530
Title of the Course: Coral Microbiology
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	It is assumed that students have a basic knowledge of corals- their structure, classification and ecology.	
Objective:	This course focuses on the various characteristics of coral ecosystems including the physico-chemical variables, evolution, survival strategies and associated microbial diversity.	
Content:	**Module I** Introduction to Corals: Coral reef biology - Types of corals, composition, ecology, structure- anatomy and physiology. Types of coral reefs and their global distribution. Factors affecting coral reefs - Abiotic factors: pH, temperature, salinity, sedimentation, wave action, weather conditions, nutrient availability, pollution, aerial exposure, light. Biological factors: competitors, disease, predators, symbiotic relationships, nutrient flux. Natural and human disturbances to reefs and their impacts. Importance of coral reefs - Fisheries and marine products associated with coral reefs. Ecological importance of coral reefs. Cultivation and conservation of corals. Law and policy for conservation and management of corals in India **Module II** Microbial interaction with coral communities: Coral evolution and development - Subsidence theory, Glacial Control Theory, Stand Still Theory, Cycle of Erosion theory. Coral communities and trophic structure. Primary producers (zooxanthellae, turf algae, coralline algae, endolithic algae, phytoplankton, benthic diatoms), consumers, food webs, productivity in coral reefs. Coral and microbiome dynamics - Coral holobiont. Rosenberg's hologenome hypothesis, Adaptive bleaching hypothesis (ABH), Adaptive Dysbiosis hypothesis (ADH), Coral probiotic hypothesis, DDAMed Model, Influence of sponge loop on corals. Symbiotic associations: Algal-coral associations, bacterial symbiosis, Multi-partner symbiosis. Nutrient cycling. **Module III** Diagnosis and recovery of diseased/damaged corals:	15 hrs 15 hrs

	Microbial causative agents associated with coral diseases - Bacterial infections (Black band disease, Yellow band disease, White band disease, White plague, White patch disease, Lethal Orange Disease**,** bacterial bleaching); Fungal infections (Aspergillosis); Viral infections; Protozoic infections (Brown band disease, Skeletal eroding band). Coral disease spread assessment, treatment and recovery - Coral disease survey and monitoring protocols. Disease response plan. Outbreak management. Use of antibiotics and anti-oxidants for treating diseased corals. Phage therapy. Coral Restoration and Health Consortium (CRHC).	15 hrs
Pedagogy:	Lectures/ assignments/ self-study	
References/ Readings:	1. Sheppard C., Davy S., Pilling G. & Graham N. (2018). The Biology of Coral Reefs (2nd edn). Oxford University Press. USA. 2. Munn C.B. (2019). Marine Microbiology: Ecology and Applications, CRC Press. Florida. 3. Jones O.A. & Endean R. (1973). Biology and Geology of coral reefs (1st edn). Academic Press. Cambridge. 4. Van Oppen M. J. H. & Blackal L. L. (2019). Coral microbiome dynamics, functions and design in a changing world. Nature Reviews Microbiology. 17: 557–567. 5. Van Oppen M. J. H. et al. (2015). Building coral reef resilience through assisted evolution. PNAS. 112 (8): 2307-2313. 6. Chakravarti L. J., Van Oppen M. J. H. (2018). Experimental Evolution in Coral Photosymbionts as a Tool to Increase Thermal Tolerance. Frontiers in Marine Science. 5 :227. 7. Contardi M. et al. (2020) Treatment of coral Wounds by combining an Antiseptic Bilayer film and an injectable Antioxidant Biopolymer. Scientific Reports.10: 988.	
Course Outcomes:	1. Understand the biodiversity of corals and their interactions. 2. Describe coral ecosystem function and examine its economic implications. 3. Indicate the physico-chemical and biological factors influencing coral ecology. 4. Create awareness of the impact of anthropogenic activities on coral health.	

	5. Identify microbial infections in corals and understand their epidemiology. 6. Survey the conservation and management strategies of damaged corals and their recovery.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-531
Title of the Course: Marine Zooplankton Ecology and Microbial Interactions
Number of Credits: 03
Effective from AY : 2022 - 23

Prerequisites for the course:	Knowledge of marine ecology with respect to different marine organisms found in seawater, metabolic diversity, various biological phenomena occurring in marine environment.	
Objective:	This course will introduce students to the biology of marine zooplankton which are the free-floating microscopic animals in the sea. Students will gain a deeper insight into the role of zooplankton in marine ecology and ecosystem functioning. They will also learn about global programs related to ocean observations.	
Content:	**Module I** Introduction to Zooplankton and Associated Microbial Communities: Classification based on size, ecology, as per depth distribution, length of planktonic life; Spatio-Temporal variation, Seasonal changes; Zooplankton transport in fronts and clines; microscale turbulence, vertical and ontogenic migration; Diversity and biomass: Feeding mechanism: Passive ambush feeding, Active ambush feeding, Feeding-current feeding, Cruise feeding; Detection of possible modes of selective feeding, Calculation of feed rates, Intraguild predation; impact of zooplankton food selectivity on plankton dynamics and nutrient cycling; Zooplankton associated microbial communities – prokaryotes, eukaryotes; aerobes, anaerobes; Zooplankton monitoring projects, Continuous plankton recorder surveys. Sampling constraints and instrumentation. **Module II** Systematics, Genomics and Molecular Detection: Systematics and morphology of the major groups such as copepods, rotifers, chaetognaths, euphausids, mysids, ostracods, tintinnids, cnidarians; Growth, Reproduction and development lifecycles; Protists; Population genomics of marine zooplankton: Genomic resources, Mitogenomes, Transcriptomic resources, Genomic basis of adaptation, Metagenetics & metabarcoding, Molecular detection, Sandwich hybridization assay, Zooplankton diversity analysis through single-gene sequencing of community	15 hrs 15 hrs

	sample; Non-destructive genome skimming for aquatic copepods; Target Capture Sequencing for cross-species relevance; Single Cell Genomics approach for pico- and nano-sized protists. **Module III** Ecological Significance of Zooplankton and Trophic Interactions: Zooplankton indicators of water quality: in bays, in brackish coastal waters; Zooplankton toxicity test methods for marine water quality evaluations; Effect of water quality on structure of zooplankton assemblages – anthropogenic pressure; Elemental stoichiometry of zooplankton, implications in nutrient cycling; microzooplankton stoichiometry plasticity; Association between Vibrios and zooplankton, Bacterial bioluminescence as a lure for marine zooplankton; Studies on the Interrelationships of Zooplankton and Phytoplankton, Microcosm experiments for interactions between zooplankton, phytoplankton and microbial foodweb; Zooplankton impact on the trophic structure of phytoplankton, Zooplankton grazing; zooplankton as toxin vectors or toxin sink; Relevance of marine chemical ecology to zooplankton; zooplankton population dynamics influencing the recruitment success of pelagic fish stocks, Effect of microplastics and climate change on zooplankton.	15 hrs
Pedagogy:	Lectures/ assignments/ self-study/ Moodle/ Videos.	
References/ Readings:	1. Omori, W. and Ikeda, T. (1984). Methods in Marine Zooplankton Ecology, John Wiley & sons, N.Y. 2. Harris, R., Wiebe, P., Lenz, J., Skjoldal, H.R., Huntley, M. (2000). Zooplankton Methodology Manual, ICES Academic Press, San Diego. 3. Dumont, H. (1984). Tropical Zooplankton, The Hogue Dr. W. Junk Publishers, USA. 4. Guglielmo, L. and Ianora, A. (1997). Atlas of Marine Zooplankton Straits of Magellan: Amphipods, Euphausids, Mysids, Ostracods, and Chaetognaths, Springer-Verlag, Berlin, Heidelberg. 5. Mitra, A. (2004). Introduction to Marine Plankton, Daya Publishing House, New Delhi. 6. Raymont, J.E.G., Burton, J.D., Dyer, K.R. (1980). Plankton and Productivity in the Oceans: Zooplankton, Pergamon Press, Oxford, UK.	

	7. Munn, C.B. (2011). Marine Microbiology Ecology and Applications, Garland Science, New York. 8. Ramaiah, N. (2004). Marine Microbiology: Facets and Opportunities, National Institute of Oceanography, Dona Paula, Goa. 9. Kiørboe, T. (2011). How zooplankton feed: mechanisms, traits and trade-offs, Biological Reviews, 86: 311-339. 10. Moreno, A.R., Martiny, A.C. (2018). Ecological Stoichiometry of Ocean Plankton, Annual Review of Marine Science, 10: 43-69. 11. Sieracki, M.E., Poulton, N.J., Jaillon, O., Wincker, P., de Vargas, C., Rubinat-Ripoll, L., Stepanauskas, R., Logares, R., Massana, R. (2019). Single cell genomics yields a wide diversity of small planktonic protists across major ocean ecosystems, Nature Scientific Reports, 9: 6025.	
Course Outcomes:	1. Discuss characteristics of zooplankton and associated microbes. 2. Describe new techniques for detection of zooplankton specimens. 3. Compare new techniques for zooplankton community analysis. 4. Discover on-going research at global scale through monitoring projects. 5. Evaluate the significance of zooplankton in marine environment with respect to food web dynamics (trophic interactions, nutrient cycling, vectors of toxins/microbes).	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-532
Title of the Course: Marine Zooplankton - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Knowledge of marine ecology is a prerequisite.	
Objective:	To get practical knowledge of handling the sampling, microscopy and molecular identification of zooplankton.	
Content:	1. Sampling of marine zooplankton (6 hrs; Ref 1-2) 2. Identification of marine zooplankton up to different groups or order (6 hrs; Ref 1-3) 3. Methods of biomass estimation (3 hrs; Ref 1-3) 4. Grazing studies (dilution plot) (15 hrs; Ref 1-3)	30 hrs
Pedagogy:	Field visit, Experiments in the laboratory	
References/ Readings:	1. Omori, W. and Ikeda, T. (1984). Methods in Marine Zooplankton Ecology, John Wiley & sons, N.Y. 2. Harris, R., Wiebe, P., Lenz, J., Skjoldal, H.R., Huntley, M. (2000). Zooplankton Methodology Manual, ICES Academic Press, San Diego. 3. Guglielmo, L. and Ianora, A. (1997). Atlas of Marine Zooplankton Straits of Magellan: Amphipods, Euphausids, Mysids, Ostracods, and Chaetognaths, Springer-Verlag, Berlin, Heidelberg.	
Course Outcomes:	1. Use the knowledge to conduct collection and preservation of zooplankton specimens. 2. Analyse microscopically different zooplankton groups based on morphology. 3. Analyse the zooplankton community based on biomass and grazing behaviour.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-533
Title of the Course: Field Trip/ Study Tour - Practical
Number of Credits: 01
Effective from AY : 2022 - 23

Prerequisites for the course:	Knowledge about microbiology-related institutes and industries in Goa. Basic knowledge of estuarine and intertidal marine environments.	
Objective:	To provide knowledge about the on-going research in various national research institutes, and the functioning of microbiology related industries and industrial processes. To provide hands-on experience in collection of water and sediment samples from the marine environment.	
Content:	Visit to national research institutes: National Centre for Polar and Ocean Research [NCPOR], National Institute of Oceanography [NIO] and ICAR – Central Coastal Agricultural Research Institute [ICAR – CCARI]. Visit to industries. Demonstration of sampling in the marine environment using water samplers and sediment grabs. Report writing based on the visits. Presentation and group discussion based on the visits.	30 hrs
Pedagogy:	Visits to research institutes and industries. Demonstration of equipment available with respective laboratories, interaction with personnel working in the field of microbiology in the respective institutes. Field trip visits to estuarine environments aboard a trawler for collection of water and sediment samples.	
References/ Readings:	As suggested by the supervisor to the participating students.	
Course Outcomes:	1. Discover and examine the working of microbiology-related industries. 2. Appraise on ongoing/recent research activities carried out in the fields of marine microbiology and oceanography. 3. Formulate work plans for the collection of water and sediment samples from the marine environment.	

Semester III
Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-600
Title of the Course: Phytoplankton Ecology and Genomics
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Part I Courses.	
Objective:	The students will learn the biology of marine photosynthetic phytoplankton, identifying and classifying phytoplankton from marine and estuarine habitats and recognizing its role in ocean biogeochemical cycles.	
Content:	**Module I** Introduction to phytoplankton, evolution through geological time scale. Phytoplankton classification and diversity – major organelles and structural variations, morphological adaptations, division of phytoplankton based on size. Phytoplankton groups like diatoms, dinoflagellates, coccolithophores, microflagellates. Cyanobacteria, Chlorophytes, Heterokontophytes (emphasis on diatoms), Prymnesiophytes, Dinophytes, Cryptophytes, Raphidophytes, Rhodophytes. Phytoplankton distribution and its diversity indices. Phytoplankton biomass estimation, primary productivity. Phytoplankton enumeration techniques – FlowCAM and flow cytometry. **Module II** Biogeographic zones of distribution. Phytoplankton nutrition, nutrient requirements (N, P, Si), physiology and ecological significance. Photoautotrophic production, adaptations to physico-chemical and biological factors. Grazing defences (morphology, chemical defences, life cycle strategies, escape response). Marine food webs. Role in biogeochemical cycles. Biological pump, microbial loop. Phytoplankton and zooplankton interactions, phytoplankton-bacteria interactions. **Module III** Phytoplankton and environmental genomics. Genetic diversity and manipulation, barcoding and its applications. Applications of phytoplankton in CO_2 sequestration, DMS production, biofuels and other commercial products, as live feed in aquaculture, secondary metabolites. Harmful algal blooms and toxin production, characterisation and causes of bloom formation, red tides, prevention and control. HNLC areas and iron fertilization.	15 hrs. 15 hrs. 15 hrs.

Pedagogy:	Lectures/ assignments/self-study.	
References/Readings:	1. Falkowski, P. G., & Knoll, A. G. (Eds.) (2007). *Evolution of primary producers in the sea.* (First Edition), Amsterdam: Elsevier Academic Press. 2. Kumar, S. V., Misquitta, R. W., Reddy, V. S., Rao, B. J., & Rajam, M. V. (2004). Genetic transformation of the green alga *Chlamydomonas reinhardtii* by *Agrobacterium tumefaciens. Plant Science,* 166(3), 731–738. doi:10.1016/j.plantsci.2003.11.012 3. Lewin, R.A. (1962). *Physiology and biochemistry of algae.* (First Edition), Academic Press. 4. Margalef, R. (1978). Life-forms of phytoplankton as survival alternatives in an unstable environment. *Oceanologica Acta,* 1(4), 439–509. 5. Parsons, T. R., Takahashi, M., & Hargrave, B. (1977). *Biological oceanography processes.* (Second Edition), Oxford: Pergamon Press. 6. Phillips, J. D. H. (1980). *Quantitative aquatic biological indicators.* (Second Edition), Applied Science Publishers. 7. Raymont, J. E. G. (1983). *Plankton and productivity in the oceans.* Vol. 1 and 2. (Second Edition). Toronto: Pergamon Press.	
Course Outcomes:	1. Understand the ecological importance of phytoplankton. 2. Describe characteristic features of marine phytoplankton. 3. Identify and classify marine phytoplankton. 4. Correlate the biological factors affecting plankton biomass and adaptations observed. 5. Analyse the role of phytoplankton in DMS formation, CO_2 sequestering and biogeochemical cycles. 6. Indicate the harmful effects of blooms and red tides.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-601
Title of the Course: Phytoplankton Ecology Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Part I Courses.	
Objective:	To acquaint students about phytoplankton sampling and isolation. The course will enable the students to identify phytoplankton.	
Content:	**Module I** 1. Sampling and collection of phytoplankton (6 hrs, Ref. 1). 2. Estimation of phytoplankton biomass (6 hrs, Ref. 1). 3. Identification of phytoplankton (6 hrs, Ref. 2,3). 4. Culturing of phytoplankton (f/2, K medium) (6 hrs, Ref. 1). 5. The extinction-dilution method (6 hrs, Ref. 4).	30 hrs.
Pedagogy:	On-site sampling and laboratory experiments.	
References/Readings:	1. Sournia, A. (1978). UNESCO *Monographs on oceanographic methodology*, Vol. 6, Phytoplankton manual, UNESCO Publishing. 2. Tomas, C.R. (1996). *Identifying marine diatoms and dinoflagellates*. Academic Press. 3. Tomas, C.R. (1997). *Identifying marine phytoplankton*. Academic Press. 4. Throndsen, J. (1978). The dilution-culture method. In: Sournia, A. (Ed.). *UNESCO Monographs on oceanographic methodology.* Vol. 6, Phytoplankton manual. Paris: UNESCO Publishing.	
Course Outcomes:	1. Perform sampling methods for phytoplankton. 2. Perform isolation and identification of phytoplankton. 3. Develop culturing methods and estimate biomass of phytoplankton. 4. Assess purification of phytoplankton by extinction dilution method.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-602
Title of the Course: Marine Microbial Prospecting and Technology
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Part I Courses.	
Objective:	The course explores marine microbes as a potential source for isolation of novel compounds and the regulatory frameworks for their usage.	
Content:	**Module I** Bioprospecting: Concept of exploiting marine microbial resources. Microbes: free-living and associated with marine invertebrates, macroalgae, phytoplankton. Diversity of bio-active metabolites. Collection, sampling and analytical techniques for natural product isolation. Sampling and search strategies for novel targets under: enzymes, therapeutics, antimicrobials and biofuels. Legal framework for collection and conservation of marine niches and microbes. Convention on Biological Diversity, Rio (1992/1994). Bioethics and Biosafety. Quarantine regulations. Biopiracy. Cartegena & Montreal Protocols. FAO International Treaty (2001-2004), Bonn Declaration on Access and Benefit-Sharing. **Module II** Conventional and high throughput screening strategy. Conventional: Plating, enrichment, extinction culturing, micro manipulations, optical tweezers, microautoradiography. Novel: Proteomics and metabolomics, genomics; Substrate-Induced Gene Expression Screens (SIGEX), catabolic gene expression screens, metagenomics, microarrays, combinatory chemistry, combinatory biosynthesis and biochemistry assays. Databases, natural product libraries. **Module III** Deposition of microbes and biomolecules. Culture collection/ repository, deposition of sequences of nucleic acids, proteins and structures of biomolecules. Geo-indicators. Commercial development of marine natural products like chitosan, algal products, SCPs, β-carotene and vitamins. Case studies on marine products and process development using microbes: archaea, cyanobacteria and proteobacteria.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/assignments/self-study/case-studies.	
References/ Readings:	1. Borkar, S. (2015). *Bioprospects of coastal Eubacteria.* Springer Publishers.	

	2. Bull, A. T. (2003). *Microbial diversity and bioprospecting.* ASM Press. 3. Goldman, E., & Green, L. H. (2019). *Practical handbook of microbiology.* (Fourth Edition), CRC Press. 4. Kennish, M. J. (2019). *Practical handbook of estuarine and marine pollution.* CRC Press. 5. Kennish, M. J. (2022). *Practical Handbook of Marine Science.* (Fourth Edition), CRC Press. 6. Reddy, S. M., Charya, M. A. S., & Girisham, S. (2012). *Microbial diversity: Exploration and bioprospecting.* Scientific Publishers. 7. Thomas, T. R., Kavlekar, D. P., & Lokabharathi, P. A. (2010). Marine drugs from sponge-microbe association: a review. *Marine Drugs,* 8, 1417-1468.	
Course Outcomes:	1. Explain the concept of bioprospecting. 2. Identify and discuss analytical methods for isolation of natural products from the marine environment. 3. Interpret and summarize the regulatory frameworks governing bioprospecting. 4. Point out the commercial applications of natural products isolated from the marine environment.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-603
Title of the Course: Marine Microbial Prospecting and Technology Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Part I Courses.	
Objective:	The course develops the techniques involved in processing of marine samples for bioprospecting.	
Content:	**Module I** 1. Sampling, isolation and screening for marine microbes from marine waters/sediments, marine organisms (bivalves/ seaweeds/ squid) for the following natural products: 1.1 Pigments (6 hrs, Ref. 1). 1.2 Siderophores (6 hrs, Ref. 1). 1.3 Antimicrobials (8 hrs, Ref. 2-3). 1.4 Plant growth hormones (10 hrs, Ref. 4).	30 hrs.
Pedagogy:	Experiments in the laboratory.	
References/Readings:	1. Naik, M., & Dubey, S. K. (2017). *Marine pollution and microbial remediation,* Springer Publications. 2. Balouiri, M., Sadiki, M., & Ibnsouda, S. K. (2016). Methods for in vitro evaluating antimicrobial activity: A review. *Journal of Pharmaceutical Analysis,* 6(2), 71-79. 3. Schmidt, T. M. (2019). *Encyclopedia of microbiology.* Academic Press. 4. Patel, D., Patel, A., Vora, D., Menon, S., Vadakan, S., Acharya, D., & Goswami, D. (2018). A resourceful methodology to profile indolic auxins produced by rhizo-fungi using spectrophotometry and HPTLC. *3 Biotech,* 8(10), 1-13.	
Course Outcomes:	1. Demonstrate skills in sampling and isolation of marine microorganisms for bioprospecting studies. 2. Survey the marine environment and plan experiments for detection of molecules of commercial interest.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-604
Title of the Course: Microbial Growth and Enzyme Kinetics
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Part I Courses.	
Objective:	Development of concepts in microbial enzymology and the microbial processes used in industries to produce microbial products.	
Content:	**Module I** Microbial growth kinetics. Batch kinetics: Monod's model (single substrate), deviations from Monod's model, dual substrates, multiple substrates, substrate inhibition, product synthesis (primary and secondary metabolite), toxic inhibition, death constant. Fed-batch kinetics: fixed volume, variable volume and cyclic fed-batch, applications and examples. Continuous cultivation system: relationship between specific growth rate (μ) and dilution rate, comparison between various cultivation systems. **Module II** Enzyme kinetics: Michaelis - Menten Equation, Line-Weaver Burk plot for one substrate reactions, significance of V_{max} and K_m. Enzyme turnover: K_s and K_d, its measurement and significance, mechanism of enzyme degradation and reversible and irreversible inhibition: competitive, uncompetitive and non-competitive. **Module III** Enzyme catalysis mechanisms, identification of functional groups, factors affecting catalytic efficiency, proximity and orientation effects. Enzyme regulation: control of activity, availability of substrate and inhibitor or enhancer molecules, change in the covalent structure of enzyme. Regulatory enzymes: Allosteric (aspartate transcarbamylase) and covalently modulated enzymes (glycogen phosphorylase, glutamine synthetase); Mechanism of action and their significance in metabolism. Zymogens and isozymes. Multienzyme systems: disassociated system (catabolic enzymes), multienzyme complex (pyruvate dehydrogenase); membrane-bound system (electron carrying enzymes).	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ assignments/ self-study.	

References/ Readings:	1. Stanbury, P. F., Whitaker, A., & Hall, S. J. (2005). *Principles of fermentation technology*. (Third Edition), Butterworth-Heinemann Publishers. 2. Flickinger, M. C., & Drew S. W. (2002). The *encyclopedia of bioprocess technology: Fermentation, biocatalysis and bioseparation*, Vols. 1 - 5, New Jersey: John Wiley Publishers. 3. Atkinson, B., & Mavituna, F. (1992). *Biochemical engineering and biotechnology handbook*. (Second Edition), Stockton Press. 4. Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2008). *Principles of biochemistry*. (Fifth Edition), New York: Worth Publishers. 5. Dixon, M., & Webb, E. C. (2014). *Enzymes*. (Second Edition) Elsevier. 6. Price N. C., & Stevens, L. (2009). *Fundamentals of enzymology*. (Third Edition), Oxford University Press.	
Course Outcomes:	1. Differentiate microbial growth kinetics based on nutrient availability. 2. Discuss factors responsible for extracellular enzyme activity. 3. Analyse regulation of enzymes under different cellular environments.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-605
Title of the Course: Microbial Growth and Enzyme Kinetics Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Part I Courses.	
Objective:	To understand microbial growth and enzyme kinetics.	
Content:	**Module I** 1. Growth kinetics – bacterium/yeast and determination of µmax, Ks, Yx/s, m (15 hrs, Ref. 1-4). 2. Enzyme kinetics - Purification of enzyme: salting out, dialysis, gel filtration, assay of enzyme activity, rate of reaction, determination of specific activity, K_m, V_{max} (15 hrs, Ref. 1-2, 5-6).	30 hrs.
Pedagogy:	Laboratory experiments/ tutorials.	
References/ Readings:	1. Hegyi, G., Kardos, J., Kovács, M., Málnási-Csizmadia, A., Nyitray, L., Pál, G., Radnai, L., Reményi, A., & Venekei, I. (2013). *Introduction to practical biochemistry*. E-book. www.renderx.com 2. Plummer, M. U., & Plummer, D. T. (2008). *An introduction to practical biochemistry*. (Third Edition), New Delhi: Tata Mc Graw Hill Publishing Company. 3. Stanbury, P. F., Whitaker, A., & Hall, S. J. (2005). *Principles of fermentation technology*. (Third Edition). Butterworth-Heinemann Publishers. 4. Flickinger, M. C., & Drew, S. W. (2002). The *encyclopedia of bioprocess technology: Fermentation, biocatalysis and bioseparation*. Vols. 1 - 5, New Jersey: John Wiley Publishers. 5. Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2008). *Principles of biochemistry*. (Fifth Edition), New York: Worth Publishers. 6. Dixon, M., & Webb, E. C. (2014). *Enzymes*. (Second Edition), Elsevier.	
Course Outcomes:	1. Estimate microbial growth in different nutrient conditions. 2. Formulate experiment to calculate growth rate and enzyme activity under any given condition.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-606
Title of the Course: Genetic Engineering
Number of credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Part I Courses.	
Objective:	This course aims to introduce the tools and techniques in molecular cloning, DNA editing and protein expression in wide variety of hosts and their applications in genetic engineering.	
Content:	**Module I** Introduction to genetic engineering. Tools and techniques involved in genetic manipulation – I: restriction endonucleases, exonucleases, DNA ligases, terminal DNA transferase, DNA polymerases, reverse transcriptase, T4 polynucleotide kinases, alkaline phosphatase, S-1 nuclease, mung bean nuclease, RNases. Gene cloning systems/Hosts: Gene cloning in *E. coli* and other organisms such as *Bacillus subtilis*, *Saccharomyces cerevisiae*. Retroviruses and retroposons. **Module II** Tools and techniques involved in genetic manipulation – II: Expression vectors – Prokaryotic (pET, pGEX-2T). Characteristics of expression vectors – strong bacterial and viral promoters (lac, trp, tac, SV 40, T7, T3) for induction of gene expression. Cloning vectors – plasmid (pUC19, pBR 322), λ phage-based vectors (M-13, 2µ plasmid), cosmid vectors, phasmid vectors, shuttle vectors, high capacity cloning vectors (BAC and YACs), Ti plasmid. Construction of cDNA, cloning, its expression and techniques – transformation, electroporation, transfection, gene gun. Other recombinant DNA techniques – use of radioactive and non- radioactive nucleotides for DNA probe preparation and detection of hybrids, restriction mapping, RFLP, PCR, RT-PCR, Real time PCR. Microarray. DNA sequencing methods. Chromosome walking. CRISPR-Cas. **Module III** Application of genetic engineering in diagnostics, agriculture, medicine, pharmaceuticals, industries and allied areas. Genetically modified foods/crops, recombinant drugs, vaccines, interferons and hormones. Recombinant proteins and drugs, enzymes, biomolecules and fermentation products, bioremediation and	15 hrs. 15 hrs. 15 hrs.

	biomonitoring (biosensors) of toxic environmental pollutants. Ethics in genetic engineering.	
Pedagogy:	Lectures/assignments/self-study.	
References/Readings:	1. Old, R. W., & Primrose, S. B. (1980). *Principles of gene manipulation: An introduction to genetic engineering.* University of California Press. 2. Glick, B. R., Pasternak, J. J., & Patten, C. L. (1994). *Molecular biotechnology: Principles and applications of recombinant DNA*. ASM Press. 3. Brown, T. A. (2010). *Gene cloning & DNA analysis*. Wiley-Blackwell. 4. Glover, D. M. (1984*). Gene cloning: The mechanics of DNA manipulation.* Springer-Science+Business Media. 5. Green, M. R., & Sambrook, J. (2001). *Molecular cloning: A laboratory manual*. New York: Cold Spring Harbor Laboratory. 6. Davis, L. G., Dibner, M. D., & Battey, J. F. (1986). *Basic methods in molecular biology*. Elsevier.	
Course Outcomes:	1. Understand and analyze the techniques involved in gene manipulation and molecular cloning. 2. Recognize **t**he applications of genetic engineering in agriculture, medicine, pharmaceuticals and allied areas. 3. Understand and apply the knowledge of genetic engineering in developing industrially important microbial products. 4. Use the principles of genetic manipulations for addressing bioremediation and biomonitoring. 5. Practice the basis of ethics involved in genetic engineering.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-607
Title of the Course: Genetic Engineering Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Part I Courses.	
Objective:	To have a hand on experience on plasmid DNA isolation, restriction mapping, ligation and transformation.	
Content:	**Module I** 1. Plasmid extraction (6 hrs, Ref. 1). 2. Restriction mapping of bacterial plasmid (6 hrs, Ref. 1). 3. Assessment of DNA ligation activity of T4 DNA ligase (6 hrs, Ref. 1). 4. Preparation of competent cells and transformation of *E. coli* host with plasmid DNA using heat shock method/electroporator (6 hrs, Ref. 2). 5. Screening of positive transformants (6 hrs, Ref. 2).	30 hrs.
Pedagogy:	Experiments in the laboratory.	
References/Readings:	1. Green, M. R., & Sambrook, J. (2001). *Molecular cloning: A laboratory manual*. New York: Cold Spring Harbor Laboratory. 2. Davis, L. G., Dibner, M. D., & Battey, J. F. (1986). *Basic methods in molecular biology*. Elsevier.	
Course Outcomes:	1. Perform isolation of bacterial plasmid DNA by gel electrophoresis and Restriction mapping. 2. Assess the DNA ligation activity using enzymes. 3. Develop competent cells using heat shock/ electroporator. 4. Perform and analyze the transformation of *E. coli* host using a plasmid.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-621
Title of the Course: Archaea
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course develops concept of three domains of life, ecology, physiology, diversity, cell structure, metabolism, energetics and genetics of archaea.	
Content:	**Module I** Carl Woese's three domain classification of life, classification of archaea. Cellular organization of archaea. Ecology, physiology and diversity of Archaea. Nutrition, growth and growth kinetics and physiological versatility. Stress response of methanogenic, halophilic, thermophilic, thermoacidophilic, barophilic, alkaliphilic and psychrophilic archaea. Methanotrophs, methylotrophs. Global econiches: deep sea, hydrothermal vents, Dead Sea, solar salterns, geothermal vents, solfataras, Antarctica, soda lake. Study of archaeal diversity. Unculturable archaeal studies by metagenomics. Archaeal culture retrieval methods. Novel samplers. Preservation and maintenance of archaeal cultures. Significance of Archaea: biogeochemical cycling, biotechnology. **Module II** Metabolism and energetics of Archaea: modified anabolic pathways of carbohydrates and lipids, methanogenesis and acetoclastic reactions. Modified central metabolic pathways – EMP, ED, incomplete TCA, reverse Kreb cycle, carbon dioxide reduction pathways – reductive acetyl-CoA pathway, 3-hydroxypropionate pathway. Chemolithoautotrophy. Bioenergetics – ATP synthesis (i) respiration-driven; (ii) light-driven, involving bacteriorhodopsin; and (iii) chloride-driven, involving halorhodopsin. **Module III** Genome of Archaea: size of genome, G + C content, associated proteins, archaeal histones and nucleosomes, introns in archaea. Archaeal RNA polymerases, reverse DNA gyrase. Plasmids, transposons -IS elements. Modifications in tRNA and rRNA structure. Novel 7S rRNA. DNA replication, transcription and translation in archaea. Gene organization in Archaea: (i) *his* operon; (ii) *bob*	15 hrs. 15 hrs. 15 hrs.

	operon; and (iii) *mcr* operon.	
Pedagogy:	Lectures/assignments/self-study.	
References/Readings:	1. Woese, C. R., & Fox, G. E. (1977). Phylogenetic structure of the prokaryotic domain: the primary kingdoms. *Proceedings of the National Academy of Sciences USA*. 74, 5088–5090. 2. Cavicchioli, R. (2007). *Archaea: Molecular and cellular biology*. ASM Press. 3. Garrett, R. A., & Hans-Peter, K. (2007). *Archaea: Evolution, physiology and molecular biology.* John Wiley and Sons. 4. Munn, C. (2004). *Marine microbiology: Ecology and applications*. Garland Science, Taylor and Francis Group. 5. Boone, D. R., & Castenholz, R. W. (1984). *Bergey's manual of systematic bacteriology. Vol. I, The Archaea and the deeply branching and phototrophic bacteria*. Springer. 6. Corcelli, A., & Lobasso, S. (2006). Characterization of Lipids of Halophilic Archaea. *Methods in Microbiology*. 35, 585-613. 7. Rothe, O., & 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.	
Course Outcomes:	1. Classify and summarize the types of archaea. 2. Describe the ecological niches and culturability. 3. Draw the biochemical pathways and calculate its energetics. 4. Understand the genetic makeup of archaea and emphasize its uniqueness. 5. Explain the gene organisation and compare the operons in archaea.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-622
Title of the Course: Archaea Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course focuses on sampling, isolation and identification techniques of archaea from different econiches and the study of archaeal pigments.	
Content:	**Module I** 1. Isolation and culturing of archaea (6 hrs, Ref. 1). 2. Identification of archaeal isolates (6 hrs, Ref. 2). 3. Biochemical tests for archaea (6 hrs, Ref. 2). 4. Extraction of archaeal pigment and characterization using UV-Vis spectroscopy (6 hrs, Ref. 2). 5. Screening for archaeal enzymes (6 hrs, Ref. 3).	30 hrs.
Pedagogy:	Experiments in the laboratory.	
References/Readings:	1. Rothe, O., & 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. 2. Boone, D. R., & Castenholz, R. W. (1984). *Bergey's manual of systematic bacteriology. Vol. I, The Archaea and the deeply branching and phototrophic bacteria*. Springer. 3. Kumar, S., Karan, R., Kapoor, S., et al. (2012). Screening and isolation of halophilic bacteria producing industrially important enzymes. *Brazilian Journal of Microbiology*. 43(4),1595-603. doi: 10.1590/S1517-838220120004000044.	
Course Outcomes:	1. Analyse samples from different econiches for archaea. 2. Perform isolation, culturing and identification of archaea. 3. Carry out bioprospecting of bioactive molecules from archaea.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-623
Title of the Course: Ecology and Applications of Marine Fungi
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course deals with detailed classification and identification of fungi, fungal ecology in marine and extreme habitats, fungal genetics and applications of fungal enzymes and various primary and secondary metabolites.	
Content:	**Module I** Fungal diversity and distribution: Phylogeny and detailed classification of fungi. Econiches of marine fungi – polyhaline coastal environments (salt marshes, mangroves, estuaries, oceans); hypersaline environment (solar salterns, Salt Lake, Dead Sea); deep sea (hydrothermal vents). Extremophilic fungi – halophiles, xerophiles, oligotrophs, barophiles, psychrophiles, thermophiles. Techniques to study marine and extremophilic fungi **–** sample collection and isolation procedures, identification – morphotyping, secondary metabolites, molecular finger printing, FAME, karyotyping, gene sequencing. **Module II** Physiology and genetics: Growth cycle and development. Fungal hormones (attractants), morphogenesis and differentiation. Secondary metabolites – pigments, mycotoxins. Fungal genetics **– c**ross over and tetrad analysis, gene conversion, mating type switching. Deuteromycotina – parasexuality, cytoplasmic inheritance. Fungal associations – symbionts, saprophytes and parasites on higher forms of marine life. **Module III** Threats and applications: Mycoses – diseases of fish, bivalves and corals. Bioprospecting and bioremediation – industrially important enzymes, secondary metabolites, nutraceuticals, antimicrobials, antitumour agents, pigments. Biodegradation and bioremediation.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ assignments/ self-study.	
References/Readings:	1. Alexopoulus, C. J., Mims, C. W., & Blackwell, M. (2017). *Introductory mycology*. (Fourth Edition), New Delhi: John Wiley & Sons.	

	6. Mehrotra, R. S., & Aneja K. R., (1990). *An Introduction to Mycology*. New Delhi: Wiley Eastern Limited. 7. Deacon, J. W. (1984). *Introduction to modern mycology*. Oxford Blackwell Scientific Publications. 8. Moore, D. (2011). *21st Century guidebook to fungi*. New York: Cambridge University Press. 9. Moore, D., & Frazer, L. A. N. (2002). *Essential fungal genetics*. New York: Springer Publishers. 10. Onions, A. H. S., Allsop, D., & Eggins H. O. W., (1981). *Smith's introduction to industrial mycology*. London: Edward Arnold Publishers. 11. Domsch, K. H., Gams, W., & Anderson, T-H., (2007). *Compendium of soil fungi*. (Second Edition), Eching, IHW-Verlag. 12. Borse, B. D., Bhat, J. D., Borse, K. N., Tuwar, N. S., & Pawar, N. S. (2012). *Marine fungi of India (Monograph)*, Panaji: Broadway Publishing House. 13. Raghukumar, C. (2012). *Biology of marine fungi*. Springer Publishers, Berlin Heidelberg. 14. Raghukumar, S. (2017). *Fungi in coastal and oceanic marine ecosystems*. Switzerland : Springer Publishers. doi: 10.1007/978-3-319-54304-8. 15. Borkovich, K. A., & Ebbole, D. J., (2010). *Cellular and molecular biology of filamentous fungi*. Washington DC: ASM Press.	
Course Outcomes:	1. Discuss the distribution of fungi in the marine environment. 2. Demonstrate fungal growth and development using physiological and genetic studies. 3. Analyse various biotechnological applications of marine fungi. 4. Integrate new technologies in studying physiology, genetics and applications of marine fungi.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-624
Title of the Course: Ecology and Applications of Marine Fungi Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	The course deals with sampling techniques for marine samples, and isolation and identification of marine fungi.	
Content:	**Module I** 1. Study of fungal cultures: colony and morphological characteristics (6 hrs, Ref. 1-3). 2. Isolation and identification of fungi from marine ecosystem (16 hrs, Ref. 1-3). 3. Biosorption experiment using marine fungal isolates (8 hrs, Ref. 4-5).	30 hrs.
Pedagogy:	Laboratory experiments/ tutorials.	
References/ Readings:	1. Alexopoulus, C. J., Mims, C. W., & Blackwell, M. (2017). *Introductory mycology*. (Fourth Edition), New Delhi: John Wiley & Sons. 2. Mehrotra, R. S., & Aneja K. R., (1990). *An Introduction to Mycology*. New Delhi: Wiley Eastern Limited. 3. Borse, B. D., Bhat, J. D., Borse, K. N., Tuwar, N. S., & Pawar, N. S. (2012). *Marine fungi of India (Monograph)*, Panaji: Broadway Publishing House. 4. Dusengemungu, L., Kasali, G., Gwanama, C., & Ouma, K. O. (2020). Recent advances in biosorption of copper and cobalt by filamentous fungi, *Frontiers in Microbiology*, 11, 582016. 5. Lotlikar, N. P., Damare, S. R., Meena, R. M., Linsy, P., & Mascarenhas, B. (2018). Potential of marine-derived fungi to remove hexavalent chromium pollutant from culture broth. *Indian Journal of Microbiology*, 58(2), 182-192.	
Course Outcomes:	1. Compare various morphological features of fungal cultures for identification to genus level. 2. Analyse and apply techniques necessary for isolation of fungi from different marine samples. 3. Design experimental work with fungal cultures on plate as well as in broth. 4. Assess handling of sporulating and non-sporulating fungal cultures during laboratory studies.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-625
Title of the Course: Marine Pollution and Monitoring
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	Introduce the students to various marine pollutants, their impact on marine ecosystems and humans.	
Content:	**Module I** Marine environment, pollutants, toxicity, point and non-point sources of pollution. Oil spills, tarballs, polyaromatic hydrocarbons, domestic sewage, agricultural waste, industrial discharge, thermal power plant discharge, pesticides, persistent organic pollutants, pharmaceuticals, personal care products, antibiotics, metals, metalloids, organo metals, radioactive waste. Deep-sea mining, marine debris – sources, constituents, derelict fishing gear, plastics/ microplastics, garbage patches in the oceans. **Module II** Eutrophication, biofouling and bioinvasion, biocorrosion. Bioaccumulation and biomagnification. Impact of pollutants on estuarine, mangroves, coastal and open ocean, coral reefs, phytoplankton, zooplankton, fish, shellfish. Effect of marine pollutants on productivity and humans: harmful algal blooms, Minamata and itai itai diseases. **Module III** Ocean health index, biomonitoring and bioremediation, genomics in marine monitoring, biosensors, biotracers. Remote sensing in pollution monitoring, marine pollution monitoring programs, marine environmental impact assessment.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/assignments/case studies.	
References/Readings:	1. Satyanarayana, T., Johri, B., & Anil, T. (2012). *Microorganisms in environmental management.* Germany: Springer Dordrecht. 2. Judith, S.W. (2015). *Marine pollution: What everyone needs to know.* USA: Oxford University Press. 3. King, R. B., Sheldon, J. K., & Long, G. M. (2019). *Practical environmental bioremediation: The field guide.* Florida: CRC Press.	

	4. Kennish, M. J. (1997). *Practical handbook of estuarine and marine pollution.* CRC Press, Boca Raton. 5. Naik, M., & Dubey, S. K. (2017). *Marine pollution and microbial remediation.* India: Springer Publications. 6. Prince, R. C., & Atlas, R. M. (2016). Bioremediation of Marine Oil Spills. In: Steffan, R. (Eds.). *Consequences of microbial interactions with hydrocarbons, oils and lipids: biodegradation and bioremediation. Handbook of hydrocarbon and lipid microbiology,* Springer, Cham.	
Course Outcomes:	1. Elaborate on the marine pollutants and their toxicity levels. 2. Highlight the impact of pollution at different trophic levels. 3. Discuss the implications of biological pollution. 4. Point out the impact assessment and monitoring tools and methodologies.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-626
Title of the Course: Marine Pollution and Monitoring Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	Estimate the impact of pollutants from the marine microbes' environment	
Content:	**Module I** 1. Impact of lead/arsenic on marine microbes (6 hrs, Ref. 1). 2. Impact of naphthalene/anthracene on marine microbes (6 hrs, Ref. 1). 3. Determination of biochemical oxygen demand (6 hrs, Ref. 2). 4. Determination of chemical oxygen demand (6 hrs, Ref. 3). 5. Size classification of marine debris/plastic (6 hrs, Ref. 4).	30 hrs.
Pedogogy:	Laboratory experiments/ Field trips.	
References/Readings:	1. Cappuccino, J. G., & Sherman, N. (1998). *Microbiology: A laboratory manual.* California: Benjamin/Cummings Science Publishing. 2. Martin, D. F. (1972*). Marine chemistry (01).* London: Academic Press. 3. Rice, E. W., & Bridgewater, L. (2012). *Standard methods for the examination of water and wastewater analysis* (Second Edition), Washington DC: American Public Health Association. 4. Kroon, F. J., Motti, C. E., Jensen, L. H., & Berry, K. L. (2018). Classification of marine microdebris: A review and case study on fish from the Great Barrier Reef, Australia. *Science Reports,* 8(1), 1-15.	
Course Outcomes:	1. Assess the impact of toxic metals and compounds on marine microbes. 2. Determine the biological oxygen demand and chemical oxygen demand of polluted waters. 3. Perform size classification of marine debris/plastics.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-627
Title of the Course: Marine Environment and Public Health
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course deals with the effects of marine pollution and climate change on human health, the challenges for monitoring and control of pollution, long-term strategies in public health management; advances in disease control in the marine environment.	
Content:	**Module I** Environmental variables related to marine, coastal and aquatic ecosystems. Water quality and sediment characteristics. Climate change and impact on human health – migration of *Vibrio*, flooding of coastlines, influence of El Nino Southern Oscillation on cholera outbreaks. Disaster management. Understanding marine ecosystem and human health with DPSIR model. Overview of marine and coastal pollution and its effects on aquaculture systems and fisheries. Challenges for monitoring and control of pollution and overfishing. Standards for various types of water. **Module II** Biological indicators and indices of water quality. Microbial indicator systems – Fecal Indicator Bacteria, *Clostridium, Cryptosporidium, adenoviruses, Bacteroides,* coliphages. Sanitation in aquaculture systems. Human pathogens: its distribution, diseases transmitted through marine and coastal water, *Vibrio,* wound sepsis, entero-viruses. Disease monitoring and surveillance. Algal blooms: their effect on fish production and human health, microbial toxins, mechanical, chemical and biological control of algal blooms. **Module III** Bioinvasion, transport of pathogens through ballast water – impact, monitoring, rules and regulations. Quarantine, certification and import risk analysis. Application of health management protocols and biosecurity principles in aquaculture. Long-term strategies in health management. Advances in disease control and management. Principles of SPF/SPR. Biosecurity in aquaculture.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/assignments/self-study/case studies.	

References/ Readings:	1. Hester, R. E., & Harrison, R. M. (2011). *Marine pollution and human health, Vol. 33, Issues in environmental science and technology.* Royal Society of Chemistry. 2. Belkin, S., & Colwell, R. R. (2005). *Oceans and health: Pathogens in marine environment.* Springer Publishers. 3. Noga, E. J. (2010). Fish disease: Diagnosis and treatment. (Second Edition). Wiley-Blackwell Publishers. 4. Rheinheimer, G. (1985). *Aquatic microbiology.* (Third Edition). John Wiley Publishers. 5. Clark, R. B., Frid, C., & Attrill, M. (2001). *Marine pollution.* Oxford University Press. 6. Wedemeyer, G. A., Meyer, F. P., & Smith, L. (1976). *Environmental stress and fish diseases.* New Jersey: TFH Publications. 7. Buller, N. B., & Plumb, J. A. (2004). *Bacteria from fish and other aquatic animals: A practical identification manual.* CABI Publishing.	
Course Outcomes:	1. List the impacts of marine pollutants and climate change on marine biota and humans. 2. Break down the factors influencing the spread of diseases through the marine environment. 3. Prepare long-term strategies in public health management. 4. Critically evaluate the advances in disease control in the marine environment.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-628
Title of the Course: Marine Environment and Public Health Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course focuses on protocols/ strategies for characterization of pathogenic organisms from the marine environment and for determining the efficacy of sanitizers used in aquaculture.	
Content:	**Module I** 1. Detection of different indicator and pathogenic organisms from marine environments such as *S. aureus, E. coli, V. cholerae, Salmonella, Shigella* by conventional and rapid methods (12 hrs, Ref. 1-3). 2. Characterization of pathogenic isolates - determination of salinity tolerance and antibiotic resistance profiles (10 hrs, Ref. 4-6). 3. Testing the efficacy of aquaculture sanitizer (phenol) (08 hrs, Ref. 7).	30 hrs.
Pedagogy:	Experiments in the laboratory.	
References/ Readings:	1. Griffin, D. W., Lipp, E. K., McLaughlin, M. R., & Rose, J. B. (2001). Marine recreation and public health microbiology: Quest for the ideal indicator: This article addresses the historic, recent, and future directions in microbiological water quality indicator research. *BioScience,* 51(10), 817-825. 2. *Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: World Health Organization.* (2022). Licence: CC BY-NC-SA 3.0 IGO. 3. Liu, C., Shi, C., Li, M., Wang, M., Ma, C., & Wang, Z. (2019). Rapid and simple detection of viable foodborne pathogen *Staphylococcus aureus. Frontiers in Chemistry,* 7, 124. 4. Ventosa, A., Nieto, J. J., & Oren, A. (1998). Biology of moderately halophilic aerobic bacteria. *Microbiology and Molecular Biology Reviews,* 62(2), 504-544. 5. Balouiri, M., Sadiki, M., & Ibnsouda, S. K. (2016). Methods for in vitro evaluating antimicrobial activity: A review. *Journal of Pharmaceutical Analysis,* 6(2), 71-79. 6. Schmidt, T. M. (2019). Encyclopedia of microbiology. (Fourth Edition), Academic Press. 7. Rideal, S., & Ainslie Walker, J. T. (1903). Standardisation of disinfectants. *Journal of the Sanitary Institute,* 24(3), 424-	

	441.	
Course Outcomes:	1. Enumerate bacterial pathogens and compare their abundance against relevant standard guidelines. 2. Recommend effective strategies for monitoring aquaculture systems.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-629
Title of the Course: Polar Microbiology
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course highlights the unique characteristics of polar environments (the Arctic, Antarctic and the Southern Ocean), with emphasis on their microbial ecology, diversity, community interactions, and response to climate change.	
Content:	**Module I** Polar environments (Arctic, Antarctica, Southern Ocean), polar econiches (atmosphere, dry valleys, ornithogenic soils, permafrost, cryoconites, sea ice, glaciers, lakes). Microbial ecology. Strategies to isolate and characterize polar microorganisms. Biotechnological importance of polar microorganisms: psychroenzymes, anti-freeze proteins, novel antibiotics and other bioactive compounds.	15 hrs.
	Module II Microbial diversity and factors influencing microorganisms in polar environments: archaea – *Thaumarchaeota;* bacteria – *Glaciecola psychrophila, Pseudoalteromonas haloplanktis, Marinomonas primoryensis*; cyanobacteria – *Oscillatoria*; fungi and yeast – *Glaciozyma psychrophila*, and diatoms – *Fragilariopsis cylindrus*; cellular, structural and physiological characteristics, community interactions and food webs, biogeochemical cycling. Viruses in polar ecosystems.	15 hrs.
	Module III The polar environment as a vulnerable ecosystem. Impact of anthropogenic pollutants and climate change on microbial communities. Effects of greenhouse gases, ozone depletion, global warming and ocean acidification on polar ecosystems. Melting of glaciers, intrusion of Atlantic waters into the Arctic region. The introduction, transport and fate of pollutants in polar environments: oil spills, microplastics, heavy metals, Persistent Organic Pollutants (POPs) xenobiotic compounds, acid rain, radioactive isotopes. Effects of iron fertilization on productivity and carbon export in the High-Nutrient-Low-Chlorophyll (HNLC) regions of the Southern Ocean and its impact on the Antarctic region.	15 hrs.
Pedagogy:	Lectures/assignments/self-study/case studies.	

References/ Readings:	1. Bathmann, U. (2005). Ecological and biogeochemical response of Antarctic ecosystems to iron fertilization and implications on global carbon cycle. *Ocean and Polar Research,* 27(2), 231-235. 2. Bej, A. K., Aislabie, J., & Atlas, R. M. (2009). *Polar Microbiology: The ecology, biodiversity and bioremediation potential of microorganisms in extremely cold environments.* CRC Press. 3. D'Amico, S., Collins, T., Marx, J. C., Feller, G., & Gerday, C. (2006). Psychrophilic microorganisms: challenges for life. *EMBO Reports,* 7(4), 385-389. 4. Duarte, C. M. (2008). *Impacts of global warming on polar ecosystem.* Fundacion BBVA. 5. Margesin, R., & Miteva, V. (2011). Diversity and ecology of psychrophilic microorganisms. *Research in Microbiology,* 162, 346-361. 6. Miller, R. V., & Whyte, L. G. (2014). *Polar Microbiology: Life in a deep freeze.* Washington DC: ASM Press. 7. Smetacek, V., & Nicol, S. (2005). Polar ocean ecosystems in a changing world. *Nature Insight Reviews,* 437, 362-368.	
Course Outcomes:	1. Describe the uniqueness of the polar environment. 2. Estimate the microbial diversity in polar environments, and interpret their role in biogeochemical cycling. 3. Point out the role of polar environments as a source of metabolites of commercial interest. 4. Evaluate the sensitivity of polar environments to climate change and pollutants.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-630
Title of the Course: Deep Sea Microbiology
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course focuses on concepts in microbiology and ecology of the various habitats in deep marine environment.	
Content:	**Module I** The deep-sea environment. Basic and in-depth conceptualization of deep marine subsurface. Types of deep-sea habitats and resident microbiota, dark ocean biosphere/aphotic pelagic ocean habitats, trenches, ridges, habitats beneath the ocean water column, such as marine sediments, oceanic crust, abyssopelagic/abyssal, hadal plains, deep permafrost sediments. Antarctic Ocean and Southern Ocean deep environments. Marine deposits (sapropels, nodules). **Module II** Sampling equipment: deep sea sampling equipment, submersibles, remotely operated underwater vehicles. Techniques for collecting water and sediment samples, corers: gravity, piston and multiple corers (MUC), giant box corer (GBC); drilling techniques, MEBO sea floor drill rig. Culturing of deep sea microbes (piezophilic/ barophilic microorganisms). Introduction to anaerobic and pressure culture chambers/systems, techniques for isolation and culturing of deep sea microorganisms under *in situ* and simulated deep sea conditions. **Module III** Hydrothermal vents, metals at hydrothermal vents, food webs, chemosynthesis, microbial communities. Diversity of higher organisms including the tube worm *Riftia pachyptila,* sponges, corals. Cold seeps. Nutrient cycling.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/assignments.	
References/Readings:	1. Munn, C. (2011). *Marine microbiology: Ecology and applications*. (Second Edition), New York: Garland Science, Taylor and Francis Group. 2. Jorgensen, B. B., & Boetius, A. (2007). Feast and famine: microbial life in the deep sea bed. *Nature Reviews*	

	Microbiology. 5, 770-781. 3. Nakagawa, S., & Takai, K., (2008). Deep-sea vent chemoautotrophs: diversity, biochemistry and ecological significance. *FEMS Microbial Ecology*. 68, 1-84. 4. Karl, D. M. (1995). *The microbiology of deep-sea hydrothermal vents.* New York: CRC Press. 5. Sharma, R. (2017). *Deep-sea mining resource potential, technical and environmental considerations*. Switzerland: Springer International Publishing. 6. Kallmeyer, J., & Wagner, D. (2012). *Microbial life of the deep biosphere*. De Gruyter. eISBN: 9783110300130. 7. Orcutt, B. N., Sylvan, J. B., Knab, N. J., Edwards, K. J. (2011). Microbial ecology of the dark ocean above, at, and below the seafloor. *Microbiology and Molecular Biology Reviews*, 75, 361-422. 8. Seibold, E., & Berger, W. (2017). *The sea floor : An introduction to marine geology*. (Fourth Edition), Switzerland: Springer International Publishing.	
Course Outcomes:	1. Identify various deep-sea habitats. 2. Discuss ecological processes occurring in the deep sea. 3. Compare various procedures for sample collection and microbiome analysis. 4. Appraise new technologies for research in deep-sea habitats.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-631
Title of the Course: Marine Microbial Toxins
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course helps students to understand the production, fate and commercial aspects of marine microbial biotoxins.	
Content:	**Module I** Marine microbial toxins: cholera toxin, botulinum toxin, saxitoxins, okadaic acid, dinophysistoxins, pectenotoxins, yessotoxin, brevetoxin, karlotoxins, ciguatoxins, domoic acid, azaspiracids, spirolides; structural diversity, biosynthetic pathways, biological functions, mechanisms of action, ecological role, biomagnification and biotransformation across trophic levels. Factors affecting toxin production. Syndromes caused by microbial toxins. Analytical methods for the detection of microbial toxins: bioassays, Liquid Chromatography – Mass Spectrometry, High Performance Liquid Chromatography (HPLC). Toxins in pharmacology.	15 hrs.
Pedagogy:	Lectures/assignments/self-study/case-studies.	
References/Readings:	1. Waters, A. L., Hill, R. T., Place, A. R., & Hamann, M. T. (2010). The expanding role of marine microbes in pharmaceutical development. *Current Opinion in Biotechnology,* 21(6), 780-786. 2. Santi Delia, A., Caruso, G., Melcarne, L., Caruso, G., Parisi, S., & Laganà, P. (2015). Biological toxins from marine and freshwater microalgae. In: *Microbial toxins and related contamination in the food industry*. Springer, Cham. 3. Lelong, A., Hegaret, H., Soudant, P., & Bates, S. S. (2012). *Pseudo-nitzschia* (Bacillariophyceae) species, domoic acid and amnesic shellfish poisoning: revisiting previous paradigms. *Phycologia,* 51(2), 168-216. 4. McCallum, M. E., & Balskus, E. P. (2019). Enzymes that detoxify marine toxins. *Nature,* 570, 315-316. 5. Stonik, V. A., & Stonik, I. V. (2016). Toxins produced by marine microorganisms: A short review. In: Gopalakrishnakone, P. et al. (Eds.). *Marine and Freshwater Toxins, Toxinology.* DOI 10.1007/978-94-007-6419-4_2.	
Course Outcomes:	1. Examine the diversity of marine microbial toxins. 2. Distinguish between the mechanisms of different marine microbial toxins.	

	3. Choose appropriate analytical methods for measuring the concentration of toxins in the marine environment.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-632
Title of the Course: Scientific Writing Skills Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	To give a hands-on experience in various writing skill required for dissertation thesis preparation and presentation.	
Content:	**Module I** 1. Tabular and graphical representation of data (8 hrs, Ref. 1,2). 2. Paper and book publication (5 hrs, Ref. 1,2). 3. Proposal writing (5 hrs, Ref. 3). 4. Writing dissertation thesis (5 hrs, Ref. 4-5). 5. Poster and power point presentation (5 hrs, Ref. 6). 6. Check for plagiarism (2 hrs, Ref. 7).	30 hrs.
Pedagogy:	Projects and assignments in the laboratory.	
References/Readings:	1. https://www.youtube.com/watch?v=JVaKq-oJnFs 2. https://www.embibe.com/exams/basic-graphical-representation/ 3. https://slite.com/learn/how-to-write-project-proposal 4. Felix, M.S., & Smith, I. (2019). *A practical guide to dissertation and thesis writing.* Cambridge Scholars Publishing. 5. https://www.prospects.ac.uk/applying-for-university/university-life/7-steps-to-writing-a-dissertation 6. https://support.microsoft.com/en-us/office/create-a-presentation-in-powerpoint-422250f8-5721-4cea-92cc-202fa7b89617. 7. URKUND Plagiarism handbook – A guide for both teachers and students. https://www.urkund.com/ resources/knowledge-hub/ plagiarism-handbook/.	
Course Outcomes:	1. Represent data in tabular and graphical formats. 2. Write research proposals, dissertation thesis, paper and book publications. 3. Prepare poster and power-point presentations to represent findings. 4. Analyse data for plagiarism check.	

Semester IV
Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-608
Title of the Course: Ocean Observations and Techniques
Number of Credits: 03
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc.. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	Introduce the students to analytical techniques and instrumentations used for oceanographic and remote sensing studies.	
Content:	**Module 1** Indian oceanographic research vessels and their facilities. Platform and Instruments: gliders, Argo, floats, acoustic doppler current profiler, current meters, radar, seawater samplers, Conductivity-Temperature-Depth (CTD), XBT plankton net, grab and corer, echosounder, SONAR, underwater robots and vehicles. **Module II** Confocal laser scanning microscopy for study of biofilms. Changes in redox potentials. Carbon measurement methods: CHNS elemental analyzer, total inorganic carbon by a coulometer, dissolved organic carbon using high-temperature combustion method, sediment traps (moored arrays/drifting traps). ^{234}Thorium as a tracer for POC export estimates, respiration measurements of plankton, fluorometric assessment of enzymatic activity using 4-Methylumbelliferyl (MUF) substrate. Genomic and metagenomics approaches. **Module III** Marine bio-optics, electromagnetic radiation, Photosynthetically Active Radiation (PAR), optical properties of seawater, ocean color, Chromophoric Dissolved Organic Matter (CDOM), polar-orbiting and geosynchronous satellites, satellites and sensors. Applications of remote sensing and societal benefits: primary productivity, sea surface temperature, salinity, wind speed and direction, ocean currents, ocean-atmosphere heat exchange, bloom dynamics, assessment of carbon reservoirs and fluxes, potential fishing zones. Pelagic and migratory fish. Species conservation.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/assignments/self-study/case-studies.	
References/Readings:	1. Andreas, S., & Brassington, G. B. (2011).	

	Operational oceanography in the 21st century. Germany: Springer. 2. Jeffrey, S. W., & Vesk, M. (1997). Introduction to marine phytoplankton and their pigment signatures. In: *Phytoplankton pigments in oceanography.* Paris: UNESCO Publishing. 3. Martin, S. (2004). *An introduction to ocean remote sensing.* UK: Cambridge University Press. 4. Venkatesan, R., Tandon, A., D'Asaro, E.A., & Atmanand, M. A. (2018). *Observing the oceans in real time.* USA: Springer. 5. Munn, C. (2011). *Marine microbiology: Ecology & applications.* New York: Taylor Francis Group.	
Course Outcomes:	1. Understand ocean processes using instrumentation, sensors and observation techniques. 2. Learn various methods of deploying and recovering oceanographic sensors. 3. Analyse oceanographic data to interpret relationships between different parameters. 4. Evaluate the limitations and potential biases of different oceanographic data collection methods.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-609
Title of the Course: Ocean Observations and Techniques Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	Enable the students to identify microbes and understand their role in the marine environment.	
Content:	**Module I** 1. Estimation of primary productivity using light and dark methods (8 hrs, Ref. 1). 2. Use of fluorochromes for enumeration of bacteria from the marine environment using epifluorescence microscopy (8 hrs, Ref. 2). 3. Enumeration of live and dead marine microbes using microscopy (8 hrs, Ref. 2). 4. Microscopic observation of cell organelles using fluorochromes (6 hrs, Ref. 2).	30 hrs.
Pedagogy:	Laboratory experiments/ Field trips.	
References/Readings:	1. Selvaraj, G. S. D. (2005). Estimation of primary productivity (modified light and dark bottle oxygen method). In: *Mangrove ecosystems: A manual for the assessment of biodiversity.* 83, CMFRI Special Publication. 2. Cappuccino, J. G., & Sherman, N. (1998). *Microbiology: A laboratory manual.* California: Benjamin/Cummings Science Publishing.	
Course Outcomes:	1. Estimate primary productivity in aquatic systems. 2. Enumerate live/dead bacteria using epifluorescence technique from the marine environment.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-610
Title of the Course: Microbial Remediation in Marine Ecosystems
Number of Credits: 02
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	This course focuses on the use of using marine microorganisms as a tool for remediation of diverse pollutants.	
Content:	**Module I** Concept of bioremediation, various strategies (bio-augmentation, bio-stimulation, co-metabolism, use of microbial consortia and genetically-modified microorganisms). Bioremediation of metals mediated by marine microbes: heavy metal resistant bacteria/fungi/archaea. Metal resistance mechanisms (efflux mechanism, intracellular bioaccumulation, extracellular sequestration and surface biosorption, bioprecipitation, biotransformation and redox reaction, volatilization). Bioremediation of hydrocarbons in marine environments: oil spills/ tar ball management. Biodegradation – reactions, enzymes and pathways. Biosurfactants. **Module II** Biodegradation of Complex Polysaccharides (CPs) by marine microorganisms: algal waste, CP-degrading enzymes – agarase, alginate lyase, carragenase, cellulase, and their role in degradation. Biodegradation of seafood waste by microorganisms: seafood waste, calcium carbonate-solubilizing bacteria, phosphate-solubilizing bacteria; the role of chitinase and protease enzymes, use of microbial consortia, application of seafood waste for ethanol production. Bioremediation of xenobiotics and pollutants in hypersaline environments using Sulfate-Reducing Bacteria (SRB) and archaea: pollutants in hypersaline environments – metals, xenobiotics, remediation strategies involving SRB, application in remediation of industrial effluents.	15 hrs. 15 hrs.
Pedagogy:	Lectures/assignments.	
References/ Readings:	1. Satyanarayana, T., Johri, B., & Anil, T. (2012). *Microorganisms in environmental management.* Springer Publishers. 2. Prince, R. C., & Atlas, R. M. (2017). Bioremediation of	

	marine oil spills. In: *Handbook of hydrocarbon and lipid microbiology.* Springer Publishers. 3. Judith, S.W. (2015). *Marine pollution: What everyone needs to know.* Oxford University Press. 4. Munn, C. B. (2020). *Marine microbiology: Ecology and applications.* (Third Edition), New York: Garland Science, Taylor and Francis Group. 5. King, R. B., Sheldon, J. K., & Long, G. M. (1997). *Practical environmental bioremediation: the field guide,* Lewis Publishers. 6. Kennish, M. J. (1996). *Practical handbook of estuarine and marine pollution.* CRC Press, Francis and Taylor. 7. Naik, M., & Dubey, S. K. (2017). *Marine pollution and microbial remediation.* Springer Publications. 8. Meena, S. N., & Naik, M. M. (2019). *Advances in biological sciences research.* Elsevier Publications.	
Course Outcomes:	1. Describe the concept of microbial bioremediation and predict its use in abatement of pollution. 2. Apply various strategies for bioremediation of pollutants. 3. Recommend suitable bioremediation strategies for different categories of pollutants.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-611
Title of the Course: Microbial Remediation in Marine Ecosystems Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	This course focuses on application of marine microorganisms in pollution abatement.	
Content:	**Module I** 1. Use of hydrocarbon-degrading marine bacteria to test degradation of sodium benzoate (8 hrs, Ref 1-2). 2. Isolation of biosurfactant-producing microorganisms (8 hrs, Ref. 2). 3. Isolation of selenite/tellurite resistant marine-derived bacteria for application in bioremediation (6 hrs, Ref. 2). 4. Use of bacterial/fungal isolates for decolourization of dyes (8 hrs, Ref. 3).	30 hrs.
Pedagogy:	Experiments in the laboratory.	
References/Readings:	1. Zaveri, P., Iyer, A. R., Patel, R., & Munshi, N. S. (2021). Uncovering competitive and restorative effects of macro-and micronutrients on sodium benzoate biodegradation. *Frontiers in Microbiology,* 12, 634753. 2. Naik, M., & Dubey, S. K. (2017). *Marine pollution and microbial remediation.* Springer Publications. 3. Rani, B., Kumar, V., Singh, J., Bisht, S., Teotia, P., Sharma, S., & Kela, R. (2014). Bioremediation of dyes by fungi isolated from contaminated dye effluent sites for bio-usability. *Brazilian Journal of Microbiology,* 45, 1055-1063.	
Course Outcomes:	1. Compare different microbial bioremediation approaches to deal with pollutants and xenobiotics. 2. Design experiments to evaluate the efficacy of microbial remediation of pollutants and xenobiotics.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-612
Title of the Course: Bioinformatics in Marine Microbiology
Number of Credits: 02
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	To understand the basics of bioinformatics and learn to analyse phylogeny and metagenomics data for diversity studies.	
Content:	**Module I** Introduction to microbiome research. Data mining – DNA sequence assembly and annotation of genes. Types of User Interface (CUI, GUI). Biological Databases and search tools. Sequence alignment: Pairwise, Multiple. Similarity and homology of sequences. Orthologs, paralogs, analogs. Sequence alignment tools. Similarity and distance, similarity scores, weight matrices, Heuristic method, Hidden Markov Models. Gene annotation, phylogenetics: gene phylogeny versus species phylogeny. Sequence-based classification and identification, Operational Taxonomic Units, rooted and unrooted trees. Approaches in phylogenetic analysis – phenetic, cladistic, evolutionary systematic approach. Methods in tree construction – distance-based methods (UPGMA, NJ, ME), character-based methods (MP, ML). **Module II** Metagenomics: 16S rRNA amplicon sequencing for metagenomics or targeted metagenomics pipelines to analyse the raw data generated from next generation platforms. Quality check and filtering of sequences, pairing of reads, grouping of reads into OTUs or/and Amplicon Sequence Variants (ASVs). Databases for taxonomic identification. Alignment of OTUs, α-(within group) and β-diversity (between groups) comparison. Full Shotgun DNA metagenomics – de-multiplexing of raw reads, quality check, conversion to FASTQ format files, QIIME/QIIME2, clustering into OTUs, assigning taxonomy to the clusters, Prokka, metAMOS. Introduction to predictive functional analyses and tools for visualization.	15 hrs. 15 hrs.
Pedagogy:	Lectures/ assignments/ interactive learning.	
References/ Readings:	1. Lesk, A. M. (2005). *Introduction to bioinformatics.* Oxford University Press. 2. Jean-Michel, C. (2005). *Bioinformatics: a beginner's guide*. India: Wiley Dreamtech. 3. Shanmughavel, P. (2005). *Principles of bioinformatics*.	

	Jaipur: Pointer Publishers. 4. Jeremy, J. R., (2004). *Bioinformatics: an introduction*. India: Springer Publishers. 5. Rastogi, C. (2004). *Bioinformatics: concepts, skills & applications.* New Delhi: CBS Publishers. 6. Mount, D. (2000). *Bioinformatics: sequence and genome analysis*. New York: Cold Spring Harbor Laboratory Press. 7. Baxevanis, A. (2001). *Bioinformatics: a practical guide to the analysis of genes and proteins*. New York: John Wiley & Sons. 8. Srinivas, V.R. (2005). *Bioinformatics: a modern approach*. New Delhi: Prentice Hall of India. 9. Ignacimuthu, S. (2008). *Basic bioinformatics.* New Delhi: Narosa Publishing House. 10. Khan, I.A. (2005). *Elementary bioinformatics*. Hyderabad: Pharma Book Syndicate.	
Course Outcomes:	1. Identify various data mining procedures. 2. Apply appropriate models for bioinformatic analysis. 3. Create suitable phylogenetic tree for microbiome analysis. 4. Discuss the workflow for metagenomics analysis of environmental samples. 5. Choose various tools for diversity and functional analyses of environmental samples.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-613
Title of the Course: Bioinformatics in Marine Microbiology Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	To understand database search, sequence-based identification and phylogenetic tree construction for evolutionary studies.	
Content:	**Module I** 1. NCBI search tool, nBLAST (2 hrs, Ref. 1-6). 2. Downloading type sequences, creating FASTA files for alignment, sequence alignment (2 hrs, Ref. 1-6). 3. Construction of phylogenetic trees (4 hrs, Ref. 1-6). 4. Introduction to Galaxy workflow (10 hrs, Ref. 7-10). 5. QIIME2 workflow (12 hrs, Ref. 7-10).	30 hrs.
Pedagogy:	Experiments/ videos/ tutorials in the laboratory.	
References/Readings:	1. Lesk, A. M. (2005). *Introduction to bioinformatics.* Oxford University Press. 2. Jean-Michel, C. (2005). *Bioinformatics: a beginner's guide*. India: Wiley Dreamtech. 3. Jeremy, J. R., (2004). *Bioinformatics: an introduction*. India: Springer Publishers. 4. Mount, D. (2000). *Bioinformatics: sequence and genome analysis*. New York: Cold Spring Harbor Laboratory Press. 5. Baxevanis, A. (2001). *Bioinformatics: a practical guide to the analysis of genes and proteins*. New York: John Wiley & Sons. 6. Ignacimuthu, S. (2008). *Basic bioinformatics.* New Delhi: Narosa Publishing House. 7. Greenwald, W. W., Klitgord, N., Seguritan, V., Yooseph, S., Venter, J. C., Gamer, C., Nelson, K.E., & Li, W. (2017). Utilization of defined microbial communities enables effective evaluation of meta-genomic assemblies. *BMC Genomics*, 18, 296. 8. Sczyrba, A. *et al.* (2017). Critical assessment of metagenome interpretation – a benchmark of computational metagenomics software. *Nature Methods,* 14(11), 1063-1073. 9. Vollmers, J., Wiegand, S., & Kaaster, A-K. (2017). Comparing and evaluating metagenome assembly tools from a microbiologist's perspective – not only size matters! *PloS One*, 12 (1), e0169662.	

	10. Hiltemann, S. D., Boers, S. A., van der Spek, P. J., Jansen, R., Hays, J. P., & Stubbs, A. P. (2019). Galaxy mothur toolset (GmT): a user-friendly application for 16S rRNA gene sequencing analysis using mothur. *GigaScience*, 8, 1-5.	
Course Outcomes:	1. Design workflow for phylogenetic analysis of microbial cultures. 2. Discuss metagenomics workflow for environmental studies. 3. Apply open-source bioinformatics software for use in microbiome analysis. 4. Design a roadmap for analysis of high throughput sequence data.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-614
Title of the Course: Nanotechnology
Number of Credits: 02
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	To impart the knowledge of nanotechnology and the synthesis of nanoparticles from marine microorganisms.	
Content:	**Module I** Introduction to nanotechnology; overview of development of nanotechnology. Types of nanoparticles; natural and incidental nanoparticles. Cellular nanostructures: nanopores, biomolecular motors. Bio-inspired nanostructures: thin films, colloidal nanostructures, nanovesicles, nanospheres, nanocapsules. Properties and characterization. Nanomaterials in biotechnology – nanoparticles, quantum dots, nanotubes, nanowires. Applications of nanoparticles in drug delivery, bio-imaging and diagnosis. Concept: cantilevers as nano-biosensors for cancer screening. **Module II** Microbial synthesis of nanomaterials, methodology, mechanism and applications of nanomaterials synthesis mediated by bacteria, fungi and yeast. Advantages of microbial/biogenic nanomaterials synthesis methods. Antimicrobial activities/mechanisms of nanomaterials; concept of MIC, MBC. Toxicity studies.	15 hrs. 15 hrs.
Pedagogy:	Lectures/assignments.	
References/Readings:	1. Poole, C. P. Jr., & Qwens, F. J. (2003). *Introduction to nanotechnology*. Wiley. 2. Ehud, G. (2007). *Plenty of room for biology at the bottom: An introduction to bionanotechnology*. Imperial College Press. 3. Bharat, B. (2007). *Springer handbook of nanotechnology*. Springer Verlag. 5. Challa, S., Kumar, S. R., & Carola, J. H. (2006). *Nanofabrication towards biomedical application: Techniques, tools, application and impact*. John Wiley and Sons. 6. Malsch, N.H. (2005). *Biomedical nanotechnology*. Taylor and Francis, CRC Press. 7. Greco, R. S., Prinz, F. B., & Smith, R. L. (2004). *Nanoscale technology in biological systems*. CRC Press. 8. Tibbals, H. F. (2010). *Medical nanotechnology and nanomedicine.* CRC Press.	
Course	1. Define nanoparticles and explain its types.	

Outcomes:	2. Discuss the properties and applications of nanoparticles. 3. Indicate methodologies for bionanoparticle synthesis 4. Explain underlying principles of toxicity studies and inhibitory levels of nanoparticles as bioactive compounds.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-615
Title of the Course: Nanotechnology Practical
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	To impart the practical knowledge of nanoparticle synthesis from marine microorganisms.	
Content:	**Module I** 1. Isolation and enrichment of metal-tolerant microorganisms (4 hrs, Ref. 1-4). 2. Preparation of metal nanoparticles using marine bacteria/fungi/plankton (14 hrs, Ref. 2-5). 3. Characterisation of metal nanoparticles using spectroscopy (6 hrs, Ref. 2-5). 4. Biological activity of nanoparticles – antimicrobial assay (6 hrs, Ref. 6).	30 hrs.
Pedagogy:	Practicals in the laboratory.	
References/ Readings:	1. Naik, M., & Dubey, S. K. (2017). *Marine pollution and microbial remediation.* Springer Publications. 2. Poole, C. P. Jr., & Qwens, F. J. (2003). *Introduction to nanotechnology*. Wiley. 3. Kulkarni, S. K. (2015). *Nanotechnology: principles and practices*. (Third Edition), Springer. https://doi.org/10.1007/978-3-319-09171-6. 4. Niemeyer, C. M. & Mirkin, C. A. (2004). *Nanobiotechnology: Concepts, applications and perspectives*. Wiley VCH. 5. Vo-Dinh, T. (Ed.) (2017). *Nanotechnology in biology and medicine: Methods, devices and applications*. (Second Edition). CRC Press. https://doi.org/10.4324/9781315374581. 6. Bhagwat, S. S., Kulkarni, A. S., & Parulekar-Berde, C. (2015). Evaluation of antimicrobial activity of silver nanoparticles biosynthesized from *Penicillium* spp. *World Journal of Pharmaceutical Research.* 4 (12), 1256-1265.	
Course Outcomes:	1. Isolate metal-tolerant microorganisms. 2. Synthesize nanoparticles of different metals using marine microorganisms. 3. Design and execute nanoparticle characterisation using spectroscopy. 4. Demonstrate antimicrobial activity of nanoparticles.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-616
Title of the Course: Blue Economy
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	To create awareness of global and national stand on blue economy, its economic and ecological significance.	
Content:	**Module I** Introduction to blue economy: Rio +20 summit, definition, importance and implications. Framework for sustainable development. International legal framework for fisheries. Small Islands Development States (SIDS). Climate change impact. Indian Ocean Rim Association (IORA) Blue carbon hub (mangroves, tidal marshes, sea grasses). Blue economy: issues and opportunities. Indian's blue economy policy framework. National Fisheries Development Board (NFDB) schemes and blue revolution. Potential of blue economy in Indian Ocean: fish production, deep sea minerals and trade benefits.	15 hrs.
Pedagogy:	Lectures/ assignments/ self-study.	
References/ Readings:	1. Morgan, P. J., Huang, M. C., Voyer, M., Benzaken, D., & Watanabe, A. (2022). *Blue economy and blue finance toward sustainable development and ocean governance.* ISBN 978-4-89974-252-4. https://doi.org/10.56506/HDLZ1912. 2. Blue economy policy - https://incois.gov.in/documents/Blue_Economy_policy.pdf 3. Diez, S. M., Patil, P. G., Morton, J., Rodriguez, D. J., Vanzella, A., Robin, D., Maes, T., & Corbin, C. (2019). *Marine pollution in the Caribbean: Not a minute to waste.* Washington DC: World Bank Group. 4. http://documents.worldbank.org/curated/en/482391554225185720/pdf/Marine-Pollution-in-the-Caribbean-Not-a-Minute-to-Waste.pdf 5. NFDB Schemes & blue revolution – Inland fisheries schemes. National Fisheries Development Board. http://nfdb.gov.in.	
Course Outcomes:	1. Garner knowledge of blue economy and its significance. 2. Create awareness of legal frameworks for fisheries. 3. Formulate draft framework under India's blue economy policy. 4. Evaluate the potential of blue economy in India.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-617
Title of the Course: Probiotics and Prebiotics in Aquaculture
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	This course will introduce the concept of probiotics and prebiotics in aquaculture.	
Content:	**Module I** Introduction to probiotics and prebiotics. Role in fish culture – growth and health. Source and types of probiotics and prebiotics, their characteristics, administration, mechanisms of action, and beneficial applications in aquaculture.	15 hrs.
Pedagogy:	Lectures/assignments/self-study.	
References/Readings:	1. Subedi, B., & Shreshta, A. (2020). Probiotics in aquacuture. *International Journal of Forest, Animal and Fisheries Research*. 4, 52-60. 2. Austin, B., & Sharifuzzaman, S. M. (Editors.) (2022). *Probiotics in aquacuture.* (First Edition), Springer. 3. Hasan, K. N., & Banerjee, G. (2020). Recent studies on probiotics as beneficial mediator in aquaculture: a review. *The Journal of Basic and Applied Zoology*. 81, 53. 4. Sugula, T. (2020). Role of probiotics in aquaculture. *International Journal of Current Microbiology and Applied Science*. 9(10), 143-149.	
Course Outcomes:	1. Define pre and probiotics. 2. Describe the source and enlist the types of pre and probiotics. 3. State the characteristics and benefits of pre and probiotics. 4. Relate the administration methods and the mechanisms of action of pre and probiotics.	

Name of the Program: M.Sc. Marine Microbiology
Course Code: MMI-618
Title of the Course: Marine Drug Development and Metabolism
Number of Credits: 01
Effective from AY: 2022 - 23

Prerequisites for the course:	Students should have undergone M.Sc. Marine Microbiology/Marine Biotechnology Semester III Courses.	
Objective:	To introduce the concepts of clinical research for drug development, drug administration and metabolism.	
Content:	**Module I** Marine drug discovery and development. Comprehensive Marine Natural Product Database (CMNPD). docking studies. Preclinical and clinical research. FDA review. FDA post-market safety monitoring. Marine pharmacology: antibacterial, antiviral, anti-inflammatory, antiparasitic, neuroprotective, anticancer, analgesic, antimicrobial, anti-malarial and nutraceutical. Marine drugs in clinical phase trials. Approved drugs of marine origin (Cytarabine, Vidarabine). Routes of drug administration. Biotransformation and metabolism. Factors affecting biotransformation.	15 hrs.
Pedagogy:	Lectures/ assignments/ students' seminars/ interactive learning.	
References/ Readings:	1. Lyu, C., Chen, T., Qiang, B., Liu, N., Wang, H., Zhang, L., & Liu Z. (2021). CMNPD: a comprehensive marine natural products database towards facilitating drug discovery from the ocean. *Nucleic Acids Research*. 49, D509-D515. *doi: 10.1093/nar/gkaa763.* 2. Paradkar, A. R., & Bakliwal, S. R. (2006). *Biopharmaceutics and pharmacokinetics*. Pune: Nirali Prakashan. 3. Shargel, L., & Yu, A. B. C. (2015). *Applied biopharmaceutics & pharmacokinetics*. (Seventh Edition), New Delhi: Tata Mc Graw Hill Publishing Company. 4. Brahmankar, D. M., & Jaiswal, S. B. (2015). *Biopharmaceutics and pharmacokinetics – a treatise*. (Third Edition), Delhi: Vallabh Prakashan. 5. Schoenwald, R.D. (2009). *Pharmacokinetics in drug discovery and development*. CRC Press. Boca Raton. 6. Chakraborty, C., & Bhattacharyya, A. (2004). *Pharmacogenomics An approach to new drug development*. Delhi: Biotech Books. 7. Lodola, A., & Stadler, J. (2011). *Pharmaceutical toxicology in practice: a guide for non-clinical development*. New	

	Jersey: John Wiley & Sons. *8.* Differding, E. (2017). The drug discovery and development industry in India – two decades of proprietary small-molecule R&D. *ChemMedChem Reviews*. 12, 786-818. *doi:10.1002/cmdc.201700043.*	
Course Outcomes:	1. Describe the process of development of drug from a marine source. 2. Compare various biomolecules towards application in pharmacology. 3. Predict fate of any drug after administration in human body. 4. Apply the concept of drug development for planning bioprospecting studies.	