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

Syllabus of M.Sc. (Marine Microbiology) Programme

The School of Earth, Ocean and Atmospheric Sciences (SEOAS) offers a two-year full time M.Sc. Marine Microbiology programme, w.e.f. the academic year 2020-21. This Programme was initiated in June 2012, under the award of UGC sponsored 'Innovative Programme for teaching and research in interdisciplinary and emerging areas'.

The Programme is meant for students to pursue higher studies in Marine Microbiology. Being a 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 Programme equips students for higher research leading to the Ph.D. Degree in India or in International Universities overseas, or for employment in Research Institutes, in teaching, and in Industry, the students finding speedy employment.

Prerequisites: B. Sc. Microbiology

Course Structure of M.Sc. Marine Microbiology

Core papers: 32 Credits

Optional Papers: 32 Credits

Code	Title of paper	L-T-P hrs/week	Credits
Semester I - Core Papers			
MMC 101	Microbial Biochemistry	3-0-0	3
MMC 102	Microbial Biochemistry – Practical	0-0-2	1
MMC 103	Fundamentals of Oceanography	3-0-0	3
MMC 104	Fundamentals of Oceanography – Practical	0-0-2	1
MMC105	Microbial Taxonomy and Systematics	3-0-0	3
MMC 106	Microbial Taxonomy and Systematics – Practical	0-0-2	1
MMC 107	Mathematics and Statistics in Biology	3-0-0	3
MMC108	Mathematics and Statistics in Biology -Practical	0-0-2	1
			Total = 16
Semester II - Core Papers			
MMC 201	Techniques and Instrumentation in Microbiology	3-0-0	3
MMC 202	Techniques and Instrumentation in Microbiology - Practical	0-0-2	1
MMC 203	Industrial Microbiology	3-0-0	3
MMC 204	Industrial Microbiology – Practical	0-0-2	1
MMC 205	Microbial Genetics and Gene Regulation	3-0-0	3
MMC 206	Microbial Genetics and Gene Regulation - Practical	0-0-2	1
MMC 207	Microbial Ecology	3-0-0	3
MMC 208	Microbial Ecology – Practical	0-0-2	1
			Total = 16
Semester III - Optional Papers			
MMO 301	Marine Virology	3-0-0	3
MMO 302	Marine Zooplankton Ecology and Microbial Interactions	3-0-0	3
MMO 303	Marine Zooplankton – Practical	0-0-2	1
MMO 304	Archaea	3-0-0	3
MMO 305	Archaea – Practical	0-0-2	1
MMO 306	Genetic Engineering	3-0-0	3
MMO 307	Genetic Engineering – Practical	0-0-2	1
MMO 308	Marine Mycology	3-0-0	3
MMO 309	Marine Mycology – Practical	0-0-2	1
MMO 310	Marine Pollution and Monitoring	3-0-0	3
MMO 311	Marine Pollution and Monitoring – Practical	0-0-2	1
MMO 312	Analytical Techniques in Phytoplankton Studies	0-0-2	1
MMO 313	Marine Extremophilic Microorganisms: Culturing and Characterization	0-0-2	1
MMO 314	Analysis of Microbial Pathogens in the Marine Environment	0-0-2	1

MMO 315	Microbial Remediation – Practical	0-0-2	1
MMO 316	Marine Microbial Screening for Secondary Metabolites	0-0-2	1
MMO 317	Microbiological Analysis in Fisheries	0-0-2	1
MMO 318	Microbial Oceanographic Methods	0-0-2	1
MMO 319	Field Trip/Study Tour – Practical	0-0-2	1
MMO 320	Training in an Institute/ Industry/ University	0-0-2	1
			Total = 16
Semester IV - Optional Papers			
MMO 401	Polar Microbiology	3-0-0	3
MMO 402	Deep Sea Microbiology	4-0-0	4
MMO 403	Coral Microbiology	3-0-0	3
MMO 404	Bioinformatics Databases	2-0-0	2
MMO 405	Marine Phytoplankton	2-0-0	2
MMO 406	Marine Extremophilic Microorganisms	3-0-0	3
MMO 407	Marine Microbial Prospecting and Technology	3-0-0	3
MMO 408	Marine Environment and Public Health	3-0-0	3
MMO 409	Marine Microbial Remediation	2-0-0	2
MMO 410	Ocean Observations and Techniques	3-0-0	3
MMO 411	Fishery Microbiology	3-0-0	3
MMD 412	Dissertation	0-0-8	8
			Total = 16

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 101
Title of the Course: MICROBIAL BIOCHEMISTRY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	The student should be familiar with the different biomolecules and their metabolism.	
Objective:	This course deals with the characteristics, properties and biological significance of the biomolecules of life. In depth knowledge of the energetics and regulation of different metabolic processes in microorganisms.	
Content:		
1	**Biological Molecules**	**12 L**
1.1	**Proteins**	
	Amino acids: features and properties.	
	Protein: structure, principles of separation and purification, molecular weight determination; sequencing and synthesis. Enzymes: activity, inhibition, mechanism of action	
1.2	**Carbohydrates**	
	Monosaccharides: types, characteristics and properties.	
	Disaccharides, oligosaccharides, polysaccharides – biological significance.	
1.3	**Lipids**	
	Fatty acids: saturated and unsaturated, structure and properties.	
	Lipids: biological significance; lipid composition of microorganisms.	
2	**Overview of Carbohydrate, Amino acid, Nucleotide and Lipid metabolic pathways**	**14 L**
2.1	**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.	
2.2	**Lipid Metabolism**	
	Anabolism: Biosynthesis of fatty acids: saturated and unsaturated, triglycerides, phospholipids,	
2.3	**Amino Acid and Nucleotide Biosynthesis**	
	Amino acid biosynthetic pathways and their regulation.	
	Purine and pyrimidine nucleotides, Deoxyribonucleotides: biosynthesis and regulation. Biosynthesis of nucleotide coenzymes	
3	**Mechanisms involved in Photosynthesis, Chemosynthesis and Osmoregulation**	**10 L**
3.1	**Photosynthetic Metabolism**	

	Organisms and photosynthetic pigments, fundamental processes in Photosynthesis. Photosynthetic electron transport and photophosphorylation	
3.2	**Chemosynthesis**	
	Organisms, substrates, bioenergetics of metabolism.	
3.3	**Osmoregulation**	
	Salt-in-cytoplasm mechanism, Organic-Osmolyte mechanism, Proton-motive force, Osmolyte transporters, Osmosensing.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Lehninger, A., Cox, M. and Nelson, D. L., Principles of Biochemistry, W. H. Freeman & Company.	
	Moat, A. G., Foster, J. W. and Spector, M. P., Microbial Physiology, A. John Wiley & Sons Inc. Publication.	
	Voet, D., Voet, J. G. and Pratt, C. W., Principles of Biochemistry, John Wiley and Sons Inc.	
	Murray, R. K., Bender, D. A., Botham, K. M., Kennelly, P. J., Rodwell, V. W. and Weil, P. A., Harper's Illustrated Biochemistry, The McGraw-Hill Companies, Inc.	
	Bull, A. T. and Meadow, P., Companion to Microbiology, Longman Group Limited, New York	
	Plummer, D. T., An Introduction to Practical Biochemistry, Tata McGraw Hill Publishing Company	
	H. J. Kunte, Osmoregulation in Bacteria: Compatible Solute Accumulation and Osmosensing. Environ. Chem. 2006, 3, 94–99. doi:10.1071/EN06016	
Learning outcomes	1. Apply the knowledge to understand the microbial physiology and to identify the microorganisms. 2. Understand the regulation of the biochemical pathway and possible process modifications for improved control over microorganisms for microbial product synthesis.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 102
Title of the Course: MICROBIAL BIOCHEMISTRY - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites:	It is required 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:		
I	**Microbial Biochemistry (MMC 102)**	**24 H**
1.	Standard curve for carbohydrates.	
2.	Standard curve for protein.	
3.	Enzyme assay.	
4.	Precipitation of protein from solution by salting out.	
5.	Dialysis.	
6.	Specific activity, fold purification, percentage yield of enzyme.	
7.	Molecular weight determination by SDS-PAGE.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Plummer, D. T., An Introduction to Practical Biochemistry, Tata McGraw Hill Publishing Company	
	Murray, R. K., Bender, D. A., Botham, K. M., Kennelly, P. J., Rodwell, V. W. and Weil, P. A., Harper's Illustrated Biochemistry, The McGraw-Hill Companies, Inc.	
Learning Outcomes	Skilful handling and estimating biomolecules and other metabolic products of microorganisms	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 103
Title of the Course: FUNDAMENTALS OF OCEANOGRAPHY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites:	Basic understanding of the marine environments.	
Objective:	Introduce the students to the dynamic nature of the marine environment.	
Content:		
1	**Introduction to Physical Oceanography**	**12 L**
1.1	Physical properties of the sea - temperature, salinity, pressure, density. Mixed layer depth. Ocean circulation- wind driven and thermohaline circulation. Eddies and gyres. Coriolis effect. Upwelling. Ekman transport. Currents. Water mass. Waves, tides and tsunamis. Sound in the ocean, energy from oceans.	
1.2	Atmospheric circulation, albedo, land-sea breeze, tropical cyclone, Indian monsoon, ITCZ, heat flux, ENSO - El Nino, La Nina, Southern Oscillation, Indian Ocean Dipole	
2	**Introduction to Chemical and Geological Oceanography**	**12 L**
2.1	Chemical properties of seawater. Elemental composition of seawater. Salinity and chlorinity. Residence time. Dissolved gases. Nutrients. Carbonate system. pH and alkalinity. Calcium carbonate precipitation and dissolution. Carbonate compensation depth and lysocline. Radioactivity.	
2.2	Geological time scale. Origin of the oceans. Ocean basins. Plate tectonics and seafloor spreading. Ocean floor morphology. Marine minerals and sediments types.	
3	**Introduction to Biological Oceanography**	**12 L**
	Habitat - estuaries, mangroves, salt marshes, rocky and intertidal, coral reefs, seagrass, coastal and open ocean, hydrothermal vents and cold seeps. Marine zonation. Pelagic and benthic communities. Marine photosynthesis. Phytoplankton and primary production. Gross and net productivity. New and regenerated productivity, f-ratio. Pigments. Redfield ratio. Measurement and control of secondary production. Benthic-pelagic coupling. Bioturbation. Bioluminescence. Exclusive economic zone.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	The Ocean: Their Physics, Chemistry and Biology, 1962 - Sverdrup, H.U., Johnson, M.W. and Flemming, R.H., Asia Publ. House, New Delhi.	
	Descriptive Physical Oceanography: An Introduction, 1989 - Pickard, G.B. and Emery, W.J., Pergamon press, U.K	

	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y	
	Meller, C. B., Wheeler, P. A., Biological Oceanography, WileyBlackwell Publishers.	
	Oceanography (5th ed), 1990 Grant Gross, M., Englewood Cliffs, N.J. Prentice Hall.	
	Introductory Oceanography (5th ed), 1988 Thurman, H.V., Columbus Mercill Publ. Co, Ohio.	
Learning outcomes	Provides brief knowledge on how marine physics, chemistry, biology and geology are interrelated. Understanding of how different physicochemical processes govern life in the ocean.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 104
Title of the Course: FUNDAMENTALS OF OCEANOGRAPHY - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites:	Basic understanding of the unique properties of water.	
Objective:	To study physicochemical and biological parameters of seawater.	
Content:		**24 H**
1.	Estimation of seawater salinity by titration method.	
2.	Determination of dissolved O_2 of seawater using Winkler's method.	
3.	Determination of pH of seawater by potentiometric/spectrophotometric method.	
4.	Determination of nitrate, phosphate, silicate by spectrophotometric method.	
5.	Determination of chlorophylls and phaeo-pigments by spectrophotometric method.	
Pedology:	Laboratory experiments/ Field trips	
References/ Readings	Grasshoff, K., Ehrhardt, M. and Kremling, K., (1999). Methods of Seawater Analysis, Verlag Chem., Weinheim.	
	Ewing, G. W.; (1981) Instrumental Methods of Chemical Analysis. McGraw-Hill, New York.	
	Parsons, T. R., Maita, Y. and Lalli, C. M.; (1984). A Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, Oxford.	
	Strickland, J.D.H, and Parsons T.R., (1972). A practical handbook of seawater analysis, Fisheries Board of Canada bulletin.	
Learning outcomes	Students will know to carry out field surveys and analyse the physicochemical and biological parameters of the marine system.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 105
Title of the Course: MICROBIAL TAXONOMY AND SYSTEMATICS
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites:	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:		
1.		
1.1	**Microbial taxonomy and systematics** Concepts of taxonomy (characterization, classification and nomenclature) and systematics; classification of microorganisms, three domain, six-kingdom, 8-kingdom systems.	**2 L**
1.2	**Phenotypic characters** - Morphology, Biochemical tests (e.g. API, BIOLOG), Bacteriophage typing, Serotyping.	**4 L**
1.3	**Chemotaxonomic markers** - Cell wall components, lipid composition, cellular fatty acid (FAME analysis), isoprenoid quinones, protein profiles (e.g. MALDI-TOF).	**6 L**
1.4	**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.	**8 L**
1.5	Concepts of species, numerical taxonomy and polyphasic taxonomy.	**4 L**
2.	Salient features of phylum, class and orders with representative examples of the following – Archaea, Eubacteria (bacteria, cyanobacteria, actinomycetes), Mycota, Protista (algae, protozoa, diatoms); and viruses.	**12 L**
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Sneath, A. H. P., Mair, S. N. and Sharpe, E. M., Bergey's Manual of Systematic Bacteriology Vol. 2. Williams & Wilkins Bacteriology Symposium, Series No 2, Academic Press, London/New York.	
	Goodfellow, M., Mordarski, M. and Williams, S. T., The biology of the actinomycetes, Academic Press.	

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

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 106
Title of the Course: MICROBIAL TAXONOMY AND SYSTEMATICS - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites:	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:		**24 H**
1.	Morphological, physiological and biochemical characterization of bacteria.	
2.	Chemotaxonomic analysis of cell wall.	
3.	Characterization of actinomycetes (*Streptomyces* sp.).	
4.	Characterization of yeast (*Saccharomyces cerevisiae*, *Schizosaccharomyces pombe*).	
5.	Characterization of cyanobacteria.	
Pedagogy:	Experiments in the laboratory, data collection and processing.	
References/ Readings	Sneath, A. H. P., Mair, S. N. and Sharpe, E. M., Bergey's Manual of Systematic Bacteriology Vol. 2. Williams & Wilkins Bacteriology Symposium, Series No 2, Academic Press, London/New York.	
	Goodfellow, M., Mordarski, M. and Williams, S. T., The biology of the actinomycetes, Academic Press.	
	Goodfellow, M. and Minnikin, D. E., Chemical Methods in Bacterial Systematics, The Society for Applied Bacteriology. Technical Series No. 20, Academic Press.	
	Barlow, A., The prokaryotes: A Handbook on the Biology of Bacteria: Ecophysiology, Isolation, Identification, Applications, Volume 1, Springer-Verlag.	
	Kurtzman, C. P., Fell, J. W. and Boekhout, T., The Yeasts - A Taxonomic Study, Elsevier.	
	Prescott, L. M., Harley, J. P. and Klein, D.A., Microbiology. McGraw Hill, New York.	
	Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Vol. 18 & 19, Academic Press.	
	Reddy, C. A., Methods for General and Molecular Microbiology, ASM Press.	
Learning outcomes	1. Application of techniques to characterize different groups of microorganisms.	

Program: M.Sc. Marine Microbiology
Course Code: MMC 107
Title of the Course: MATHEMATICS AND STATISTICS IN BIOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites:	Basic ability to handle numbers and calculation.	
Objective:	The paper develops concepts about types of data observed in biological experiments, its handling and processing. It 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:		
1	**Functions and analysis**	**10 L**
1.1	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.	05 L
1.2	Fitting linear models to data, The Basic linear least squares method, Fitting the exponential model by linear least squares. 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.	05 L
2	**Data collection and representation**	**05 L**
2.1	**Characteristics of biological data:** Variables and constants, derived variables (ratio, index, rates), types of measurements of biological data (interval scale, ratio scale, ordinal scale, nominal scale, discrete and continuous data).	02 L
2.2	**Data handling:** Population and samples, random samples, parameter and statistics, accuracy and precision, accuracy in observations, Tabulation and frequency distribution, relative frequency distribution, cumulative frequency distribution. **Graphical representation:** types of graphs, preparation and their applications.	03 L
3	**Statistical analysis**	**21 L**
3.1	**Measures of central tendency:** characteristics of ideal measure, Arithmetic mean – simple, weighted, combined, and corrected mean, limitations of arithmetic mean; Median – calculation for raw data, for grouped data, for continuous series, limitations of median; Mode – computation of mode for individual series, by	04 L

	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.	
3.2	**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	03 L
3.3	**Probability**: Probability, Combinatorial Techniques, Elementary Genetics	02 L
3.4	**Theoretical Distribution**: Binomial, Poisson, Normal Distributions.	02 L
3.5	**Hypothesis Testing** – parameter and statistics, sampling theory, sampling and non-sampling error, estimation theory, confidence limits, testing of hypothesis, test of significance; Students' T-test, t-distribution, computation, paired t-test.	03 L
3.6	Chi-square test, F-test and ANOVA.	04 L
3.7	**Non-parametric tests**: Wilcoxon Signed Rank test, Mann-Whitney 'U'test, Kruskal-Wallis 'H' test	02 L
3.8	**Introduction to Bioinformatics**	01 L
Pedagogy:	**Lectures/tutorials/assignments/self-study/Moodle/Videos**	
References/ Readings:	Kothari, C. R., Quantitative Techniques, Vikas Publishing House.	
	Arora, P. N. and Malhan, P. K., Biostatistics, Himalaya Publishing House.	
	Danilina, N.I., Computational Mathematics, Mir Publishers.	
	Surya, R. K., Biostatistics, Himalaya Publishing House.	
	Edelstein-Keshet, L., Differential Calculus for the Life Sciences, The University of British Columbia, Open Book	
Learning outcomes	Able to collect, handle, process and present the Biological Data. Apply the principles of statistics on biological experiments.	

Program: M.Sc. Marine Microbiology
Course Code: MMC 108
Title of the Course: MATHEMATICS AND STATISTICS IN BIOLOGY - PRACTICAL
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites:	Basic ability to handle numbers and calculation.	
Objective:	Handling and processing of biological data for statistical analysis.	
Content:		**24 H**
1.	Excel spreadsheet and data analysis.	
2.	Linear equation analysis (regression analysis).	
3.	Normal distribution.	
4.	Hypothesis testing.	
5.	Working with Grapher and Surfer	
Pedagogy:	Data processing, computations	
References/ Readings:	Kothari, C. R., Quantitative Techniques, Vikas Publishing House.	
	Arora, P. N. and Malhan, P. K., Biostatistics, Himalaya Publishing House.	
	Danilina, N.I., Computational Mathematics, Mir Publishers.	
	Surya, R. K., Biostatistics, Himalaya Publishing House.	
	Edelstein-Keshet, L., Differential Calculus for the Life Sciences, The University of British Columbia, Open Book	
Learning Outcomes:	Ability to process data and statistical interpretation of microbiology-related experiments.	

Program: M.Sc. Marine Microbiology
Course Code: MMC 201
Title of the Course: TECHNIQUES AND INSTRUMENTATION IN MICROBIOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

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

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

Program: M.Sc. Marine Microbiology
Course Code: MMC 202
Title of the Course: TECHNIQUES AND INSTRUMENTATION IN MICROBIOLOGY - PRACTICAL
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	The student should be familiar with the concepts in basic chemistry and should be able to use basic instruments in Microbiology.	
Objective	This course develops the skills for techniques and instrumentation in microbiology.	
Content:		**24 H**
1.	Microscopy – compound, phase contrast – of bacterial cells.	
2.	Density gradient separation of microbial cells.	
3.	Cell disruption of pigmented bacteria/yeast by sonicator, efficacy of sonication and pigment profiling using UV-visible spectrophotometer.	
4.	Polyacrylamide gel electrophoresis (PAGE), Zymogram.	
5.	Molecular exclusion chromatography.	
Pedagogy:	**Experiments in the laboratory**	
References/ Readings:	Wilson, K. and Walker, J., Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press, N.Y., USA.	
	Cooper, T. G., The Tools of Biochemistry, Wiley India Pvt. Ltd.	
	Goswami, C., Paintal, A. and Narain, R., Handbook of Bioinstrumentation, Wisdom Press, New Delhi.	
	Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Volume 5, Part B, Academic Press.	
	Colowick, S. P. and Kaplan, N. O., Methods in Enzymology, Vol. VI, Academic Press, N.Y.	
	Parakhia, M. V., Tomar, R. S., Patel, S. and Golakiya, B. A., Molecular Biology and Biotechnology: Microbial Methods, New India, Pitampura.	
	Sambrook, J., Fritsch, E. F. and Maniatis, T., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, USA.	
	Jayaraman, J., Laboratory Manual in Biochemistry, John Wiley & Sons Limited, Australia.	
Learning outcomes	Ability to use techniques and instruments for carrying out microbiological research work or in the industries.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 203
Title of the Course: INDUSTRIAL MICROBIOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	Basic knowledge about the types of microbes and their products of industrial relevance. Knowledge of microbial biochemistry, physiology, genetics and statistics.	
Objective:	Development of concepts in the processes, instruments, management, quality, etc. being used in the industries to produce the products using marine microorganisms.	
Content:		
1.	**Upstream Processing**	**12 L**
1.1	Industrial strains, Fermentation media, Asepsis and sterilisation	
1.2	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	
1.3	Solid substrate fermentation (SSF): Principles and application with examples – penicillin, amylase; Immobilized enzymes and cell systems.	
2.	**Process control and Downstream processing**	**12 L**
2.1	Fermentation monitor and control: speed, temperature, gas, pH, Dissolved oxygen, foam, redox, air flow, weight, pressure, biomass; On-line and off-line analysis	
2.2	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).	
2.3	Formulation, packaging; QC/QA; IPR	
3.	**Applications in industry**	**12 L**
3.1	Industrially important marine microorganisms; Microbiological techniques in marine food industry – canning, freezing, drying	
3.2	Industrial production and application – enzymes (Proteases, Lipases, amylase, pectinase), carotenoids, eps, bioplastics, biopolymers – xanthan, pigments, Antibiotics-erythromycin, steroids, SCP, biofuels	

3.3	Entrepreneurship	
Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/Videos	
References/ Readings	Demain, A. L., Davies, J. E. and Atlas, R. M. Manual of Industrial Microbiology and Biotechnology, ASM Press.	
	Flickinger, M. C. and Drew S. W., The Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis and Bioseparation, Volumes 1 - 5, John Wiley Publisher.	
	Stanbury, P. F., Whitaker, A. and Hall, S.J., Principles of Fermentation Technology, Butterworth-Heinemann Publishers.	
	Arad S. M. (1999). Polysaccharides from red microalgae. In Cohen Z (Ed) Chemicals from Microalgae, Taylor and Francis, London, pp 282-292.	
	Borowitzka M. A. (1995) Microalgae as sources of pharmaceuticals and other biologically active compounds. Journal of Applied Phycology 7, 3-15.	
	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.	
	Melis A. and Happe T. (2001). Hydrogen production. Green algae as a source of energy. Plant Physiology 127, 740-748	
Learning Outcomes	1. Apply the principle of management and controls on the microbial processes in industrial settings. 2. Apply the principles of physiological understanding in improvement of the industrial processes. 3. Study the industrial processes for production of metabolites from marine microoorganisms	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 204
Title of the Course: INDUSTRIAL MICROBIOLOGY - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Knowledge of basic microbiology techniques	
Objective:	This course develops the skills for techniques and instrumentation in industrial microbiology.	
Content	**Industrial Microbiology**	**24 H**
1.	Exopolysaccharide production using marine microbial isolates	
2.	Rheology of substrate solutions.	
3.	Designing of fermentor – stirred tank reactor	
4.	Culturing spirulina (*Arthrospira platensis*)	
Pedagogy:	Experiments in the laboratory, data collection and processing.	
References/ Readings	Flickinger, M. C. and Drew S. W., The Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis and Bioseparation, Volumes 1 - 5, John Wiley Publisher.	
	Stanbury, P. F., Whitaker, A. and Hall, S.J., Principles of Fermentation Technology, Butterworth-Heinemann Publishers.	
	Arad S. M. (1999). Polysaccharides from red microalgae. In Cohen Z (Ed) Chemicals from Microalgae, Taylor and Francis, London, pp 282-292.	
	https://www.justspirulina.org/spirulina-growing-requirements	
	Habib, M.A.B.; Parvin, M.; Huntington, T.C.; Hasan, M.R. 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. 2008. 33p.	
Learning Outcomes	Able to handle the instruments for carrying out microbiological research work or in the industries.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 205
Title of the Course: MICROBIAL GENETICS AND GENE REGULATION
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	It is required 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:		**Lectures**
1	**Chromosomes, Genomes and it's evolution**	**6 L**
1.1	Fundamental functions of DNA. Chromosomal DNA and its packaging in the chromatin fibre. Chromatin structure, structural features (Telomere, Centromere and Repetitive sequences) of chromosomes and their functions. Gene duplication and mutations. Genomic islands.	
1.2	Structural chromosomal aberrations and their significance: Deletion, duplication, inversion, translocation. Aneuploidy and polyploidy.	
2	**DNA Damage, DNA Repair and Recombination**	**18 L**
2.1	Types of DNA damage (spontaneous and induced DNA damage). Mutagenesis, mutation and mutants: Somatic and germinal mutation, spontaneous and induced mutations, site specific using PCR/ cassette mutagenesis, and random mutagenesis. Types of mutation: silent mutation, missense mutation, nonsense mutation, Read through mutation, frameshift- insertion and deletion mutation, translocation, Inversion, suppressor mutation. Mutagenic chemicals and radiations and their mechanism of action: Base analogues (5-Bromouracil and 2-amino purines), EMS, acridines, NTG, Hydroxylamine; mutagenic radiations- UV, X-rays and gamma rays. Ames test; Auxotrophy.	
2.2	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.	
2.3	Mechanisms of Genetic Recombination: General and site-specific recombination. Heteroduplex DNA formation (Homologous recombination). Synaptonemal Complex, Bacterial RecBCD system and its stimulation of chi sequences. Role of RecA protein, homologous recombination, Holliday junctions.	

3	**Genomic rearrangements, Gene structure and control of gene expression in Prokaryotes and Eukaryotes**	**12 L**
3.1	Mechanism of General and programmed DNA rearrangements, Antigenic and phase variation in bacteria. Transposons: IS elements – Composite transposons (Tn3, Tn10), Ty, Copia and P type, Mechanism of transposition. Role of transposons in DNA rearrangements and microbial genome evolution	
3.2	An overview of Gene expression control, DNA binding motifs in gene regulatory proteins, genetic switches and their role in control of gene expression. Post-transcriptional controls-transcriptional attenuation, Riboswitches, Alternate splicing, RNA editing, RNA Interference.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Gardner, E. J., Simmons, M. J. and Snustad, D. P., Principles of Genetics, John Wiley & Sons.	
	Krebs J. E., Lewin B., Goldstein E. S. and Kilpatrick, S.T., LEWIS Genes XI, Jones and Bartlett Publishers.	
	Maloy, S. R., Cronan, J. E. and Freifelder, D., Microbial Genetics, Jones and Bartlett Publishers.	
	Streips, U. N. and Yasbin, R. E., Modern Microbial Genetics, John Wiley.	
	Peter, J. R., iGenetics: A Molecular Approach, Pearson Education.	
	Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K. and Walter, P., Molecular Biology of the Cell, Garland Science.	
	Watson, J. D., Molecular Biology of the Gene, Pearson/Benjamin Cummings.	
	Malacinski, G.M., Freifelder's Essentials of Molecular Biology, Narosa Book Distributors Private Limited.	
	Twyman, R. M. and Wisden, W., Advanced Molecular Biology: A Concise Reference, BIOS Scientific Publishers.	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.	
	Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier.	
Learning Outcomes	Understanding of gene structure, expression, mutagenesis and regulation of gene expression in both prokaryotes and eukaryotes for application in molecular research and its significance in microbial evolution.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 206
Title of the Course: MICROBIAL GENETICS AND GENE REGULATION - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Basic knowledge about nucleic acids and replication	
Objective:	This course provides hands-on experience with DNA extraction, purification and electrophoretic techniques.	
Content		
	Microbial Genetics and Gene Regulation	**24 H**
1.	Isolation of genomic DNA of bacterial cells, estimation of quantity and purity of DNA by spectrophotometry, and agarose gel electrophoresis.	
2.	Isolation of genomic DNA from environmental sample (sediment/ seawater).	
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.	
4.	UV mutagenesis and screening of pigment deficient mutants of *Serratia marcescens*.	
Pedagogy:	Experiments in the laboratory.	
References/ Readings	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.	
	Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier.	
Learning Outcomes	To learn techniques involved in genomic DNA isolation and PCR amplification for use in molecular research.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 207
Title of the Course: MICROBIAL ECOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	Basic understanding of the marine environment and microorganisms.	
Objective:	Introduce the students to the marine environment, biodiversity and their interaction. Impart knowledge on the effect of climate change on microbial ecology.	
Content:		
1	**Marine environment, biodiversity and its interaction**	**12 L**
1.1	Marine microbial diversity. Ecosystem and food webs. Energy flow and cycling. Interaction between biotic and abiotic factors.	
1.2	Marine microbiome- Diversity, evolution and function, mutualism, commensalism, parasitism, microbial symbiosis, microbiomes from plankton, fish, coral, sponge, deep-sea invertebrate, and animals. Stress response and adaptation. Marine probiotics, prebiotics and its application.	
1.3	Biogeochemical cycles – carbon, nitrogen, phosphorus, sulphur, iron and manganese	
1.4	Oxygen minimum zones (OMZs), anaerobic microbial metabolism, OMZs in the world oceans, anthropogenic impact	
2	**Microbes and Carbon Cycling**	**12 L**
2.1	Marine carbon reservoirs, ocean carbon cycle, carbon pump-solubility, carbonate, biological, microbial, microbial loop, role of picoplankton.	
2.2	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 global climate change, role of DOM in the ecosystem, chromophoric dissolved organic matter (CDOM), factors affecting CDOM and its role in the ecosystem. Carbon cycling in the anoxic environment and sediments.	
3	**Marine Ecosystem and Global Climate Change**	**12 L**
	Greenhouse gases. Warming potential. Changes in physical and biogeochemical properties: ocean acidification, global warming, deoxygenation. Causes, changing chemistry of the ocean. Physiological, population and community response in marine organisms. Impact on marine plankton, fishery, coral, humans. Changes in growth, distribution, energetics, food web, marine productivity, microbial loop, reproduction, survival, recruitment, prey-predator interaction. Thermal	

	limits and distribution of organisms. Climate change refugia and adaptation. Coastal and ocean species migration and change in the structure, Environmental and economic consequences. Multiple stressors and Synergistic effects.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Mitchell, R. and Kirchman, D. L., Microbial Ecology of the Oceans, Wiley- Blackwell Publishers.	
	Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco.	
	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y.	
	Elements of Marine ecology (4th ed) 1982 – Tait, R.V. and Dipper, F. Butterworth – Heinemann	
	Textbook of Marine Ecology, 1980 – Nair, N.B. &Thampy, D.M., Macmillan, 352 pp	
	Marine Biology, 1984, Thurman, H.V. and Webber, H.H., Harper Collins Publishers	
Learning outcomes	Students will understand the concept of the marine biodiversity and the factors governing them. Role of climate change in marine ecosystem.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMC 208
Title of the Course: MICROBIAL ECOLOGY - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Basic understanding of the unique features of marine environments and microorganisms.	
Objective	Enable the students to identify microbes and understand their role in the marine environment.	
Content		**24 H**
1.	Enumeration of plankton associated microbes.	
2.	Determination of particulate organic matter (carbon/ nitrogen/ phosphorus) from plankton/ seawater.	
3.	Determination of carbohydrates/proteins/lipids from plankton/ seawater/ sediments.	
4.	Estimation of CDOM from seawater by spectrophotometric method.	
5.	Determination of extracellular enzymes from plankton/ seawater/ sediments by MUF.	
6.	Determination of sulphide in seawater.	
Pedagogy:	Laboratory experiments/ Field trips	
References/ Readings	Parsons, T. R., Maita, Y. and Lalli, C. M.; (1984). A Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, Oxford.	
	Zoppini et al., (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.	
	Strickland, J.D.H, and Parsons T.R., (1972). A practical handbook of seawater analysis, Fisheries Board of Canada bulletin. (2nd edition).	
	Padini et al., (2014). Contrasting phytoplankton community structure and associated light absorption characteristics of the western Bay of Bengal. Ocean Dynamics. 64:89–101.	
Learning outcomes	Understanding the role of microbes in the marine ecosystem and how to estimate it.	

Program: M.Sc. Marine Microbiology
Course Code: MMO 301
Title of the Course: MARINE VIROLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	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:		
1.	**Virus Structure, Diversity and Assay**	**14 L**
1.1	Marine Viruses - Introduction	
1.2	Marine phages and their host: Archaea, bacteria and cyanobacteria, phytoplanktons, algae	
1.3	Marine viruses and their hosts: fish and shrimp; Giant marine virus	
1.4	Metagenomic approaches to study the diversity of marine viruses	
2.	**Multiplication and Assay of Phages and Viruses**	**08 L**
2.1	Bacteriophage life cycles - lysogenic (latent) and lytic (virulent)	
2.2	Viral multiplication	
2.3	One step growth profile.	
2.4	Assay: plaque assay (PA); most-probable number (MPN)	
3.	**Significance of viruses in marine ecosystem**	**14 L**
3.1	Movement of viruses between biomes	
3.2	Effect of viruses on ecology of the marine ecosystem: Role of viruses in microbial loop, viral shunt	
3.3	Marine viruses and global climate change	
3.4	Viral pathogens of marine aquatic organisms: Lymphocystis virus, Infectious pancreatic necrosis virus (IPNV), Nervous necrosis virus (NNV), Salmon Alphavirus (SAV), Infectious haematopoietic necrosis virus (IHNV)	
3.5	Viruses in shell-fish and shrimps, and health hazards: Norwalk virus and Hepatitis virus A.	
Pedagogy:	**Lectures/tutorials/assignments/self-study/Moodle/Videos**	
References/ Readings:	Sano, E., Carlson, S., Wegley, L., Rohwer, F. (2004**)** Movement of Viruses between Biomes**.** Applied and Environmental Microbiology, 70: 5842–5846.	

	Breitbart, M., Thompson, L. R., Suttle, C. A., Sullivan, M. B. (2007) Exploring the Vast Diversity of Marine Viruses. Oceanography, 20: 135-139.	
	Rohwer, F., Thurber, R. V. (2009) Viruses manipulate the marine environment. Nature, 459: 207-212.	
	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.	
	Crane, M., Hyatt, A. (2011) Viruses of Fish: An Overview of Significant Pathogens. Viruses, 3: 2025–2046.	
	Woo, P. T. K. and Bruno, D. W., Fish Diseases and Disorders. Vol 3: Viral, Bacterial and Fungal Infections. CABI Publishing.	
	Bosch, A., Le Guyader, S.F. (2010) Viruses in Shellfish and Food, Environmental Virology 2: 115-116.	
	Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S., Microbiology, Harper and Row Publishers.	
	Microbiology and Immunology – Online, Department of Pathology, Microbiology and Immunology, University of South Carolina School of Medicine.	
Learning outcomes	Explain the role of viruses in marine environment,, the effect of viruses on global climate change. Apply the knowledge of viral diseases in aquaculture, various techniques of studying them in research.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 302
Title of the Course: MARINE ZOOPLANKTON ECOLOGY AND MICROBIAL INTERACTIONS
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	Knowledge of marine ecology with respect to different marine organisms found in seawater, metabolic diversity, various biological phenomena occurring in marine environment.	
Objectives	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		
1	**Introduction to Zooplankton and Associated Microbial Communities**	**12 L**
1.1	Classification based on size, ecology, as per depth distribution, length of planktonic life; Distribution; Spatial Temporal variation, Seasonal changes in zooplankton abundance, Encounter rate, Reynold's number, particle-tracking velocimetry, microscale turbulence, changes in vertical distribution, migration	
1.2	Diversity and biomass size spectra: Sampling, Instruments, Laser optical plankton counter, ZooScan, ZooCAM; diversity indices	
1.3	Feeding mechanism: Passive ambush feeding, Active ambush feeding, Feeding-current feeding (Direct interception, Filter feeding, Scanning currents, Hovering versus cruising), Cruise feeding (small prey, marine snow) Detection of possible modes of selective feeding, Calculation of feed rates, Intraguild predation; impact of zooplankton food selectivity on plankton dynamics and nutrient cycling	
1.4	Zooplankton associated microbial communities – prokaryotes, eukaryotes; aerobes, anaerobes	
1.5	Zooplankton monitoring projects, Continuous plankton recorder surveys, The Scientific Committee on Oceanic Research (SCOR), Global Ocean Observing System (GOOS), JGOFS, Global Alliance of CPR Surveys (GACS), Global Ocean Ecosystem Dynamics (GLOBEC), Integrated Marine Biosphere Research (IMBeR), Ocean Biogeographic Information System (OBIS)	
2	**Systematics, Genomics and Molecular Detection**	**12 L**
2.1	Systematics and morphology of the major groups such as copepods, rotifers, chaetognaths, euphausids, mysids, ostracods, tintinnids, cnidarians; Growth, Reproduction and development lifecycles; Protists (Mastigophora, Sarcodina, Ciliophora)	
2.2	Population genomics of marine zooplankton: Genomic resources, Mitogenomes, Transcriptomic resources, Genomic basis of adaptation, Metagenetics & metabarcoding, Case studies (*Calanus finmarchicus*,	

	Acartia tonsa, *Euphasia superba*, *Spadella cephaloptera*); Molecular detection, Sandwich hybridization assay, Zooplankton diversity analysis through single-gene sequencing of community 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	
3	**Ecological Significance of Zooplankton and Trophic Interactions**	**12 L**
3.1	Zooplankton indicators of water quality: in bays, in brackish coastal waters (Rotifer trophic state indices); Zooplankton toxicity test methods for marine water quality evaluations; Effect of water quality on structure of zooplankton assemblages – anthropogenic pressure	
3.2	Elemental stoichiometry of zooplankton, implications in nutrient cycling; microzooplankton stoichiometry plasticity	
3.3	Association between Vibrios and zooplankton Bacterial bioluminescence as a lure for marine zooplankton	
3.4	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, Implications of climate change	
3.5	Zooplankton grazing as an important source of mortality for harmful algal bloom species; zooplankton as toxin vectors or toxin sink; Relevance of marine chemical ecology to zooplankton	
3.6	Impact of climatic change on zooplankton: microzooplankton grazing rates due to changes in heterotrophic bacteria, zooplankton population dynamics influencing the recruitment success of pelagic fish stocks	
Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/Videos	
Reading/ References:	Methods in Marine Zooplankton Ecology, 1984 Omori, W. and Ikeda, T. Wiley	
	Zooplankton Methodology Manual, 2000 Harris, R., Wiebe, P., Lenz, J., Skjoldal, H.R., Huntley, M. (Eds), ICES Academic Press, San Diego, pp. 68	
	Tropical Zooplankton, 1984 Dumont, H. The Hogue Dr. W. Junk Publishers	
	Atlas of Marine Zooplankton Straits of Magellan: Amphipods, Euphausids, Mysids, Ostracods, and Chaetognaths, 1997 Guglielmo, L. New York Springer-Verlag	
	Introduction to Marine Plankton, 2004 Mitra, A. Delhi Daya Publishing House	
	Plankton and Productivity in the Oceans: Zooplankton, 1980 Raymont, J.E.G., Burton, J.D., Dyer, K.R. (Eds), Pergamon Press	
	Marine Microbiology Ecology and Applications, 2011 Munn, C.B. New York: Garland Science	
	Marine Microbiology: Facets and Opportunities, 2004 Ramaiah, N. Dona Paula, Goa, National Institute of Oceanography.	
	How zooplankton feed: mechanisms, traits and trade-offs, 2011 Kiørboe, T. Biological Reviews 86: 311-339.	

	Ecological Stoichiometry of Ocean Plankton, 2018 Moreno, A.R., Martiny, A.C., Annual Review of Marine Science 10: 43-69.	
	Single cell genomics yields a wide diversity of small planktonic protists across major ocean ecosystems, 2019 Sieracki, M.E., Poulton, N.J., Jaillon, O., Wincker, P., de Vargas, C., Rubinat-Ripoll, L., Stepanauskas, R., Logares, R., Massana, R., Nature Scientific Reports 9: 6025.	
Learning Outcomes:	1. Explain the role of zooplankton in various oceanographic processes. 2. Apply the knowledge of different groups of zooplankton to study them in any marine pelagic environment. 3. Explain the application of modern genomics technology for their detection.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 303
Title of the Course: MARINE ZOOPLANKTON - PRACTICAL
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Knowledge of marine ecology is a prerequisite.	
Objectives	To get practical knowledge of handling the sampling, microscopy and molecular identification of zooplankton.	
Content:		**24 H**
1.	Sampling of marine zooplankton	
2.	Identification of marine zooplankton up to different groups or order.	
3.	Methods of biomass estimation.	
4.	Grazing studies (dilution plot).	
5.	DNA extraction from zooplankton specimens for PCR.	
Pedagogy:	Field visit, laboratory experiments	
Reading/ References:	Methods in Marine Zooplankton Ecology, 1984 Omori, W. and Ikeda, T. Wiley	
	Zooplankton Methodology Manual, 2000 - Harris, R., Wiebe, P., Lenz, J., Skjoldal, H.R., Huntley, M. (Eds), ICES Academic Press, San Diego, pp. 68	
	Atlas of Marine Zooplankton Straits of Magellan: Amphipods, Euphausids, Mysids, Ostracods, and Chaetognaths, 1997 Guglielmo, L. New York Springer-Verlag	
Learning outcomes:	Practical knowledge of sampling, and identification of marine zooplankton and DNA isolation from the specimens for molecular identification.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 304
Title of the Course: ARCHAEA
Number of Credits: 3
Effective from Academic Year: 2020-21

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

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

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 305
Title of the Course: ARCHAEA- Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	It is required that students have basic knowledge of 3 domains of life and basic microbiology techniques.	
Objective:	This course develops concepts in sampling and isolation of archaea from different econiches. Also identification of archaea and study of archaeal pigments.	
Content:		
1.	Isolation and culturing of archaea	**24 H**
2.	Identification of archaeal isolates	
2.1	Biochemical tests for archaea	
2.2	Extraction of archaeal pigment and characterization using UV-Vis spectroscopy	
2.3	Screening for archaeal enzymes	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y.	
	Boone, D. R. and Castenholz, R. W., Bergey's Manual of Systematic Bacteriology: The Archaea and The Deeply Branching and Phototrophic Bacteria, Springer Science and Business Media.	
	Corcelli, A. and Lobasso, S., (2006) Characterization of Lipids of Halophilic Archaea. Methods in Microbiology, 35: 585-613.	
	Rothe, O. and Thomm, M., (2000) A simplified method for the cultivation of extreme anaerobic archaea based on the use of sodium sulfite as reducing agent, Extremophiles. 4: 247-252.	
Learning outcomes	1. Sampling from different Econiches of Archaea 2. Skill development for Isolation, culturing of Archaea and identification of archaea. 3. Bioprospecting of bioactive molecules from archaea.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 306
Title of the Course: GENETIC ENGINEERING
Number of Credits: 3

Prerequisites	Knowledge of bacterial and animal genetics, basic molecular and microbiology is a prerequisite.	
Objective:	This course aims to introduce the fundamental tools and techniques required for molecular cloning, with emphasis on DNA editing to protein expression in wide variety of hosts. Applications of genetic engineering in agriculture, therapeutics and industry will be covered.	
Content:		
1.	**Introduction to genetic engineering and tools involved in genetic manipulation**	**12 L**
1.1	**Introduction to genetic engineering**	
1.2	**Tools and techniques involved in genetic manipulation I**	
A.	DNA modifying enzymes: restriction endonucleases, exonucleases, DNA ligases (T4 DNA Ligase and *E.coli* DNA ligase), Terminal DNA transferase, DNA Polymerases (Taq, Amplitaq, vent, Exo-vent, Pfu, T4 etc), Reverse transcriptase, T4 polynucleotide kinases, Alkaline phosphatase, S-1 Nuclease, Mung bean nuclease, RNases.	
B.	Gene cloning systems/Hosts: Gene cloning in *E. coli* and other organisms such as *Bacillus subtilis*, *Saccharomyces cerevisiae* and other microbial eukaryotes. Retroviruses and retroposons , Genomic organization T4, Lambda Phage, TMV, SV40, Petite mutants of yeast, F plasmids and their use in genetic analysis R plasmids antibiotic resistance, Ti plasmid, 2μ plasmid	
C.	Sequencing Vectors: pUC 19 and M-13 Phage vector.	
2.	**Tools and techniques involved in genetic manipulation II**	**12 L**
A.	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.	
B.	Cloning vectors: plasmid (pUC19, pBR 322), λ phage based vectors, cosmid vectors, Phasmid vectors, shuttle vectors, High capacity Cloning vectors (BAC and YACs).	
C.	Construction of cDNA molecule and its transfer to appropriate host (bacteria/yeast/plant cell/animal cell) using a suitable technique: transformation, electroporation, transfection, gene gun.	
D.	Other Recombinant DNA techniques: Use of radioactive and non-radioactive nucleotides for DNA probe preparation and detection of hybrids, Gel retardation assay, Restriction mapping, RFLP, PCR, RT-PCR, Real time PCR, Microarray, DNA sequencing using Sanger's Dideoxy chain termination method and automated sequencer; Illumina sequencing; chromosome walking.	
3		**12 L**
3.1	**Application of genetic engineering in DNA diagnostics**	

A.	Screening of Genetic diseases using DNA probes (DNA diagnostics).	
B.	Application of recombinant DNA technology in solving parental dispute and criminal cases (DNA finger printing).	
3.2	**Application of genetic engineering production of recombinant drugs, vaccines and hormones**	
A.	Production of recombinant proteins and drugs (insulin, tissue plasminogen activator, erythropoietin, human growth hormones, Antibodies (including bispecific antibodies), vaccines, interferons, DNA vaccines: merits and demerits, Edible vaccines- merits and demerits.	
B.	Genetic manipulation to increase recombinant protein stability and secretion using signal sequences.	
3.3	**Genetic engineering of microbes for production of enzymes, biomolecules and fermentation products.**	
A.	Genetic manipulation of microbes to over-produce industrially valuable enzymes.	
B.	Production of microbial SCPs.	
3.4	**Genetic engineering of microbes for bioremediation and biomonitoring of toxic environmental pollutants, Biohydrometallurgy**	
A.	Microbial bioremediation of xenobiotics by recombinant microbes.	
B.	Bioremediation of toxic heavy metals and organometals by recombinant microbes.	
C.	Biohydrometallurgy using recombinant microbes for recovery of precious metals.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Old, R. W. and Primrose, S. B., Principles of Gene Manipulation: An introduction to Genetic Engineering, University of California Press.	
	Glick, B. R., Pasternak, J. J. and Patten, C. L., Molecular Biotechnology: Principles and Applications of Recombinant DNA, ASM Press.	
	Williamson, R., Genetic Engineering, Volumes 4-7, Academic Press.	
	Glover, D. M., Gene cloning: The Mechanics of DNA Manipulation, Springer-Science+Business Media, B. V	
	Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.	
Learning Outcomes	1. Understanding of tools and techniques involved in molecular cloning. 2. Overall understanding about the importance of GMOs, GMPs and other engineered products in science and industry.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 307
Title of the Course: GENETIC ENGINEERING - Practical
Number of Credits: 1

Prerequisites	Theoretical understanding of chromosomal DNA, plasmid DNA, selection media and preparatory microbiology is needed.	
Objective:	To have a hand on experience on plasmid DNA isolation, modification and insertion; basically a DNA cut-copy-paste technology that forms the basis of any genetic engineering wet lab.	
Content:		**24 H**
1.	Plasmid extraction	
2.	Restriction mapping of bacterial plasmid and agarose gel analysis.	
3.	Preparation of competent cells and transformation of *E. coli* host with plasmid DNA using heat shock method and electroporator; confirmation of positive transformants.	
4.	Assessment of DNA ligation activity of T4 DNA ligase.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.	
Learning Outcomes	1. A practical understanding of how the DNA modifying enzymes work. 2. Hand-on experience with plasmid and bacterial host	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 308
Title of the Course: MARINE MYCOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	The student should be familiar with the structural morphology of the fungus and their existence in the surrounding environment.	
Objective:	This course deals with detailed classification and identification of fungi, fungal ecology in marine and extreme habitats, fungal genetics and applications of fungal enzymes and various primary and secondary metabolites.	
Content:		
1.	**Fungal diversity and distribution**	**14 L**
1.1	**Fungi: Phylogeny and detailed classification**	
	Econiches of Marine Fungi: Polyhaline Coastal Environment (salt marsh, mangrove, estuarine and Oceans); Hypersaline environment (solar salterns, Salt Lake, Dead Sea); Deep Sea (Hydrothermal vents).	
1.2	**Extremophilic Fungi**	
	Halophiles, Xerophiles, Oligotrophs, Barophiles, Psychrophiles, Thermophiles.	
1.3	**Techniques to study marine and extremophilic fungi**	
	Sample collection and isolation procedures;	
	Identification - Morphotyping; Secondary metabolites; Molecular finger printing: FAME, Karyotyping, Gene sequencing.	
2.	**Physiology and Genetics**	**12 L**
2.1	**Growth and development**	
	Growth cycle. Fungal hormones- attractants, morphogenesis and differentiation. Secondary metabolites: pigments, mycotoxins.	
2.2	**Fungal genetics**	
	Cross over and tetrad analysis, gene conversion, mating type switching; Deuteromycotina: parasexuality, cytoplasmic inheritance.	
	Fungal associations: Saprophytes, parasites and symbionts on higher forms of marine life.	
3.	**Threats and Applications**	**10 L**
3.1	**Mycoses**	
	Diseases of fish, bivalves and corals	
3.2	**Bioprospecting and bioremediation**	
	Industrially important enzymes. Secondary metabolites: Natural products – nutraceuticals, antimicrobials, antitumour agents, pigments. Biodegradation and bioremediation.	
Pedagogy:	Lectures/tutorials/assignments/self-study	

References/ Readings	Alexopoulus, C. J., Mims, C. W. and Blackwell, M., Introductory Mycology, John Wiley & Sons.	
	Mehrotra, R. S. and Aneja K. R., An Introduction to Mycology. Wiley Eastern Limited.	
	Deacon, J. W., Introduction to Modern Mycology, Volume 7 of Basic Microbiology, Blackwell Scientific Publications.	
	Kendrick, B., The Fifth Kingdom, Focus Publishers.	
	Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S., Microbiology, Harper and Row.	
	Onions, A. H. S., Allsop, D. and Eggins H. O. W., Smith's Introduction to Industrial Mycology, Edward Arnold, London.	
	Domsch, K. H., Gams, W., and Anderson, T-H., Compendium of Soil Fungi, Eching, IHW-Verlag.	
	Borse, B. D., Bhat, J. D., Borse, K. N., Tuwar, N. S. and Pawar, N. S., Marine Fungi of India (Monograph), Broadway Publishing House.	
	Raghukumar, C., Biology of Marine Fungi, Springer Publishers.	
	Seshagiri Raghukumar, Fungi in Coastal and Oceanic Marine Ecosystems, Springer Publishers. Doi: 10.1007/978-3-319-54304-8	
Learning outcomes	Apply the knowledge in fungal taxonomy, bioremediation and bioprospecting of secondary metabolites and industrially important fungal enzymes.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 309
Title of the Course: MARINE MYCOLOGY - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	The student should know to cultivate the fungal cultures.	
Objective:	The course deals with sampling techniques for marine samples to isolate fungi and identify them	
Content:		**24 H**
1.	Study of representative fungal cultures: (a) Colony and (b) Morphological characteristics.	
2.	Isolation and identification of fungi from marine ecosystem	
3.	Biosorption of metal using marine fungal isolate.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Alexopoulus, C. J., Mims, C. W. and Blackwell, M., Introductory Mycology, John Wiley & Sons.	
	Mehrotra, R. S. and Aneja K. R., An Introduction to Mycology. Wiley Eastern Limited.	
	Deacon, J. W., Introduction to Modern Mycology, Volume 7 of Basic Microbiology, Blackwell Scientific Publications.	
	Kendrick, B., The Fifth Kingdom, Focus Publishers.	
	Borse, B. D., Bhat, J. D., Borse, K. N., Tuwar, N. S. and Pawar, N. S., Marine Fungi of India (Monograph), Broadway Publishing House.	
Learning outcomes	Apply the knowledge in fungal taxonomy, bioremediation and bioprospecting of secondary metabolites and industrially important fungal enzymes.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 310
Title of the Course: MARINE POLLUTION AND MONITORING
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	Basic knowledge about marine environment and pollution.	
Objective	Introduce the students to various marine pollutants, its impact on marine ecosystems and humans and how to monitor it.	
Content		
1.	**Sources and pathways of pollution**	**12 L**
1.1	Marine environment, pollutants, toxicity, point and non-point sources of pollution.	
1.2	Oil spills, tarballs, polyaromatic hydrocarbons. Domestic sewage. Agricultural waste. Nutrients. Industrial and thermal power plants. Pesticides and persistent organic pollutants. Pharmaceuticals and personal care products. Antibiotics. Metals, metalloids and organo metals, Radioactive waste. Deep-sea mining. Ocean dumping.	
1.3	Marine Debris- sources, constituents, derelict of fishing gears, plastics/microplastics, garbage patch in the oceans.	
1.4	Acoustic pollution- sources and conservation of marine ecosystem	
2.	**Threat to marine ecosystem, biodiversity, community structure and humans**	**12 L**
2.1	Eutrophication. Anaerobiosis. Biofouling and bioinvasion. Biocorrosion. Bioaccumulation and biomagnification. Case studies.	
2.2	Impact on estuarine, mangroves, coastal and open ocean, coral reefs.	
	Effect of pollution on life cycle and health of phytoplankton, zooplankton, fish, shellfish, corals reefs, humans. Harmful algal blooms, red tides.	
	Effect of marine pollutants on productivity and sustainability of marine econiche.	
	Effect of marine pollution on humans: Minamata, itai itai diseases, neurological disorders, reproductive disorder, carcinogenesis and teratogenic effects.	
3.	**Pollution Monitoring and Regulation**	**12 L**
3.1	Ocean health index, maritime laws, law of the sea and exclusive economic zone. Green chemistry.	
3.2	Biomonitoring and bioremediation, microbial degradation, bio-attenuation, bioaugmentation bioindicators, role of foraminifera as a bioindicator, biotracers, biosensors, biomarker, genetically engineered organisms, quorum sensing, cleanups.	

3.3	Genomics in marine monitoring: Environmental DNA. DNA barcoding and metabarcoding. Metagenomics. Microarrays. RT-PCR. Short nucleotide polymorphisms. Transcriptomics.	
3.4	Remote sensing in pollution monitoring. Marine conservation, Marine protected areas, Marine parks and sanctuaries. Marine environment-related legislation in the world and in India. Marine pollution monitoring programs. Marine environmental impact assessment. Wastewater treatment plants: primary, secondary and tertiary treatment.	
Pedagogy:	Lectures/tutorials/assignments/case studies/self-study	
References/ Readings	Satyanarayana, T., Johri, B. and Anil, T., Microorganisms in Environmental Management, Springer Publishers	
	Judith, S.W., Marine Pollution: What Everyone Needs To Know. Oxford University Press.	
	King, R. B., Sheldon, J. K. and Long, G. M. (1997) Practical Environmental Bioremediation: The Field Guide, Lewis Publishers.	
	Kennish, M. J. (1996) Practical Handbook of Estuarine and Marine Pollution. CRC Press, Francis and Taylor.	
	Naik, M. and Dubey, S. K. (2017). Marine Pollution and Microbial Remediation, Springer Publications	
	Prince, R. C., Bioremediation of Marine Oil Spills. In: Handbook of Hydrocarbon and Lipid Microbiology, Springer Publishers.	
Learning Outcomes	Knowledge on how marine pollutants can affect marine organisms and humans.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 311
Title of the Course: MARINE POLLUTION AND MONITORING - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Basic knowledge about marine environment and pollution.	
Objective	Estimate the pollutants from the marine environment	
Content		**24 H**
1.	Impact of lead/selenium/arsenic/chromium on the marine microbes.	
2.	Impact of naphthalene/anthracene on the marine microbes.	
3.	Determination of biochemical and chemical oxygen demand.	
4.	Size classification of marine debris/plastic.	
Pedology	Laboratory experiments/ Field trips	
References/ Readings	Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim.	
	Instrumental Methods of Chemical Analysis, 1981 – Ewing, G. W.; McGraw-Hill, New York.	
	Parsons, T. R., Maita, Y. and Lalli, C. M.; (1984). A Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, Oxford.	
	Strickland, J.D.H, and Parsons T.R., (1972). A practical handbook of seawater analysis, Fisheries Board of Canada bulletin. (2nd edition).	
Learning outcomes	Hands-on training to identify whether any marine ecosystem/organisms are polluted and measure it	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 312
Title of the Course: ANALYTICAL TECHNIQUES IN PHYTOPLANKTON STUDIES
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Knowledge of marine ecology is a prerequisite.	
Objective:	To get a practical knowledge of handling the sampling, isolation and purification process of phytoplankton. The course will enable the students to identify phytoplankton and learn the bioprospecting of marine phytoplankton	
Content		**24 H**
1.	Sampling and collection of phytoplankton.	
2.	Estimation of phytoplankton biomass.	
3.	Identification of phytoplankton.	
4.	Culturing of phytoplankton (f/2, K medium).	
5.	Extraction and bioactivity (bioprospecting).	
Pedagogy:	**On site sampling and laboratory experiments**	
Reading/ References	Sournia, A., UNESCO Monographs on Oceanographic Methodology, Vol. 6, Phytoplankton Manual, UNESCO Publishing, Paris.	
	Tomas, C.R. (Ed.) 1996. - Identifying Marine Diatoms and Dinoflagellates. Academic Press, Inc., N. York, 598 pp.	
	Tomas, Carmelo, R. 1997. Identifying Marine Phytoplankton. Academic Press	
Learning outcomes	Practical knowledge of sampling, isolation, identification of marine phytoplankton and bioprospecting for its commercial secondary metabolites	

Programme: M.Sc. (Marine Microbiology)

Course Code: MMO 313

Title of the Course: MARINE EXTREMOPHILIC MICROORGANISMS: CULTURING AND CHARACTERIZATION

Number of Credits: 1

Effective from Academic Year: 2020-21

Prerequisites	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:		**24 H**
1.	Technique for isolation of psychrophiles/halophiles/oligotrophs/anaerobes/organic solvent-tolerant bacteria.	
2.	Effect of varying salt concentrations on growth of halophiles/halotolerant microbes.	
3.	Growth of bacterial isolates at varying nutrient levels.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Brock, T. D., Thermophilic Microorganisms and Life at High Temperatures, Springer, New York.	
	Horikoshi, K. and Grant, W. D., Extremophiles – Microbial Life in Extreme Environments, Wiley, New York.	
	Rainey, F. A., Oren, A. (2006) Extremophile microorganisms and the methods to handle them. Methods in Microbiology, 35:1-25.	
	Satyanarayana, T., Raghukumar, C., Shivaji, S. (2005) Extremophilic microbes: diversity and perspectives. Current Science, 89(1): 78-90.	
	Ventosa, A., Nieto, J. J., Oren, A. (1998) Biology of moderately halophilic aerobic bacteria. Microbiology and Molecular Biology Reviews, 62: 504-544.	
Learning Outcomes	Skills in isolation and characterization of different groups of extremophiles.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 314
Title of the Course: ANALYSIS OF MICROBIAL PATHOGENS IN THE MARINE ENVIRONMENT
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	It is required that students have basic knowledge about marine environment, climate change, pollutants in marine environment and basic microbiology techniques.	
Objective:	This course develops concepts in protocols/ strategies for characterization of pathogenic organisms from the marine environment and for determining the efficacy of sanitizers used in aquaculture.	
Content:		**24 H**
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.	
2.	Characterization of pathogenic isolates - determination of salinity tolerance and antibiotic resistance.	
3.	Testing the efficacy of aquaculture sanitizer (phenol).	
Pedagogy:	Experiments in the laboratory	
References/ Readings	1.Hester, R. E., Harrison, R. M., Marine Pollution and Human Health, Vol. 33, Issues in Environmental Science and Technology, Royal Society of Chemistry. 2.Belkin, S. and Colwell, R. R., Oceans and Health: Pathogens in Marine Environment. Springer Publishers. 3.Noga E. J., Fish Disease: Diagnosis and Treatment, Wiley-Blackwell Publishers. 4.Rheinheimer, G., Aquatic Microbiology, John Wiley Publishers. 5.Clark, R. B., Frid, C., Attrill, M., Marine Pollution, Oxford University Press. 6.Wedemeyer, G. A., Meyer, F. P. and Smith, L., Environmental Stress and Fish Diseases, TFH Publications, Neptune, New Jersey. 7.Buller, N. B. and Plumb, J. A., Bacteria from Fish and Other Aquatic Animals: A Practical Identification Manual, CABI Publishing.	
Learning Outcomes	1) Students will learn to quantify and characterize bacterial pathogens and compare against relevant standard guidelines. 2) They will be able to formulate effective strategies for monitoring aquaculture systems.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 315
Title of the Course: MICROBIAL REMEDIATION - PRACTICAL
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	It is required that students have basic knowledge about marine environment, marine pollutants, and xenobiotics. Basic microbiology techniques.	
Objective:	This course develops concepts in application of marine microorganisms in pollution abatement and sustainable development.	
Content:		**24 H**
1.	Use of hydrocarbon-degrading marine bacteria to test degradation of sodium benzoate.	
2.	Isolation of biosurfactant-producing microorganisms.	
3.	Isolation of selenite/tellurite resistant marine-derived bacteria for application in bioremediation.	
4.	Use of bacterial/fungal isolates for decolourization of dyes.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Satyanarayana, T., Johri, B. and Anil, T., Microorganisms in Environmental Management, Springer Publishers. Prince, R. C., Bioremediation of Marine Oil Spills. In: Handbook of Hydrocarbon and Lipid Microbiology, Springer Publishers. Judith, S.W., Marine Pollution: What Everyone Needs To Know. Oxford University Press. Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y. King, R. B., Sheldon, J. K. and Long, G. M. (1997) Practical Environmental Bioremediation: The Field Guide, Lewis Publishers. Kennish, M. J. (1996) Practical Handbook of Estuarine and Marine Pollution. CRC Press, Francis and Taylor. Naik, M. and Dubey, S. K., Marine Pollution and Microbial Remediation, Springer Publications.	
Learning Outcomes	1) Students will learn to apply different bioremediation approaches using marine microorganisms to deal with pollutants and xenobiotics.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 316
Title of the Course: MARINE MICROBIAL SCREENING FOR SECONDARY METABOLITES
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	It is necessary that students should have a working knowledge of the techniques used for sampling and analysis of marine samples.	
Objective:	The course develops the techniques involved in processing of marine samples for bioprospecting.	
Content:		
1.	Sampling, isolation and screening for marine microbes from marine waters/sediments, marine organisms (bivalves/seaweeds/squid) for:	**24 H**
1.1	Pigments	
1.2	Antibiotics	
1.3	Plant growth hormones	
1.4	Siderophores	
Pedagogy:	Experiments in the laboratory	
References/ Readings	Kennish, M. J., Practical Handbook of Estuarine and Marine Pollution, CRC Press.	
	Goldman, E. and Green, L. H., Practical Handbook of Microbiology, CRC Press.	
	Kennish, M. J., Practical Handbook of Marine Science, CRC Press.	
	Chaney, R. C., Sampling and Preparation of Marine Sediments, Foundation Engineering Handbook, Springer Publishers.	
	Wolton, A. G., Methods For Sampling and Analysis of Marine Sediments and Dredged Material, Volume 1, Ocean Dumping Report, Department of Fisheries and the Environment.	
	Bull, A. T., Microbial Diversity and Bioprospecting. ASM Press.	
	Reddy, S. M., Charya, M. A. S. and Girisham, S., Microbial Diversity: Exploration and Bioprospecting, Scientific Publishers.	
	Thomas, T. R., Kavlekar, D. P., Lokabharathi, P. A. (2010) Marine drugs from sponge-microbe association : a review. Marine Drugs, 8: 1417-1468.	
	Borkar, S., Bioprospects of Coastal Eubacteria, Springer Publishers.	
Learning outcomes	Skills in designing and conducting experiments in the marine environment for bioprospecting purposes.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 317
Title of the Course: MICROBIOLOGICAL ANALYSIS IN FISHERIES - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Knowledge of fishes, and microbial diversity.	
Objective:	Provides hands-on experience in the fish anatomy and its associated microbial flora, including human pathogens.	
Content:		**24 H**
1.	Sampling techniques for microbiological investigation of moribund fish.	
2.	Methods for examination and analyzing fish for health certification/diagnosis of disease condition, techniques for sample collection and processing for bacteriological agents	
3.	Isolation and identification of various human bacterial pathogens from fish samples (*Enterobacteriaceae* and *Vibrio*).	
Pedagogy:	Experiments in the laboratory.	
References/ Readings	Woo, P. and Bruno, D. Fish Diseases and Disorders, Vol 3: Viral, Bacterial and Fungal Infections, CABI Publishers.	
	Noga, E. C., Fish Disease: Diagnosis and Treatment. Wiley-Blackwell Publishers.	
	Leatherland, J. F. and Wook, P. K. T., Fish Diseases and Disorders, CABI Publishers.	
Learning outcomes	Apply the tools and techniques of microbiology to specifically assess the microbiological quality of fishes in terms of associated disease or as carrier for human pathogens.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 318
Title of the Course: MICROBIAL OCEANOGRAPHIC METHODS - Practical
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Basic understanding of the marine environments.	
Objective	Enable the students to identify microbes and understand their role in the marine environment.	
Content		**24 H**
1.	Use of fluorochromes for enumeration of bacteria from the marine environment using epifluorescence microscopy.	
2.	Enumeration of live and dead marine microbes using microscopy	
3.	Microscopic observation of cellular components using fluorochromes	
4.	Estimation of primary productivity using light and dark method.	
5.	Determination of dissolved organic carbon from seawater.	
6.	Determination of hydrolytic enzymes from plankton/seawater/sediments	
Pedagogy:	Laboratory experiments/ Field trips	
References/ Readings	Colin Munn (2011). Marine Microbiology Ecology & Applications. Taylor Francis Group.	
	A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M.; Pergamon Press, Oxford.	
	A practical handbook of seawater analysis, 1972 - Strickland, J.D.H, and Parsons, T.R., Fisheries Board of Canada bulletin. (2nd edition).	
	Jeffrey, S.W and Vesk, M., Introduction to Marine Phytoplankton and Their Pigment Signatures. In: Phytoplankton Pigments in Oceanography. UNESCO Publishing, Paris.	
Learning Outcomes	Knowledge on how to study microbes in the ocean using different sampling strategies, techniques and instrumentation.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 319
Title of the Course: FIELD TRIP/ STUDY TOUR
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Knowledge about microbiology-related institutes and industries in Goa.	
Objective:	To provide knowledge about the on-going research in various national research institutes, and the functioning of marine microbiology/oceanography related industries and industrial processes.	
Content:		**24 H**
1.	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].	
2.	Visit to industries	
3.	Report writing based on the visits	
4.	Presentation and group discussion based on the visits	
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.	
References/ Readings	As suggested by the demonstrator to the participating students.	
Learning Outcomes	Exposure to research being carried out in the field of marine microbiology/oceanography in research institutes and industries using/or related to the applications of microbial principles.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 320
Title of the Course: TRAINING IN AN INSTITUTE/INDUSTRY/UNIVERSITY
Number of Credits: 1
Effective from Academic Year: 2020-21

Prerequisites	Knowledge about the basic techniques in microbiology.	
Objective:	To provide hands-on experience in the application of microbiological techniques in research institutes/industries/universities. To experience the workings of microbiology-related departments in commercial industries.	
Content:		**24 H**
	The student shall be required to 1. Undertake training for a minimum period of 10 working days or its equivalent. 2. Submit to the School of Earth, Ocean and Atmospheric Sciences (SEOAS), Goa University, a certificate of attendance signed by the Training Coordinator of the respective Institute/ Industry/University. 3. Submit to the SEOAS, a Report of the work undertaken. 4. Make a Presentation of the work carried out, to the Marine Microbiology faculty, for evaluation.	
Pedagogy:	Short-term internship (minimum 10 days) at an institute/industry/university	
References/ Readings	As suggested by the demonstrator to the participating students.	
Learning Outcomes	Apply the tools and techniques of microbiology to a range of situations.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 401
Title of the Course: POLAR MICROBIOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	An in-depth understanding of the concepts of marine microbiology is necessary.	
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:		
1.	Polar environments (Arctic region, Antarctic region and the Southern Ocean), polar econiches (dry valleys, ornithogenic soils, permafrost, cryoconites, sea ice, glaciers, lakes); microbial ecology, strategies to isolate and characterize polar microorganisms.	**12 L**
2.	Microbial diversity and factors influencing microorganisms in polar environments: Archaea – *Thaumarchaeota;* Bacteria – *Glaciecola psychrophila, Pseudoalteromonas haloplanktis, Marinomonas primoryensis*; *c*yanobacteria – *Oscillatoria*; fungi and yeast - *Glaciozyma psychrophila*, and diatoms - *Fragilariopsis cylindrus*; cellular, structural and physiological characteristics, community interactions and food webs, geochemical cycling. Biotechnological importance of polar microorganisms: psychroenzymes, anti-freeze proteins, novel antibiotics and other bioactive compounds.	**12 L**
3.	The effects of global warming and ocean acidification on polar ecosystems. Melting of glaciers, freshening of Arctic waters, intrusion of Atlantic waters into the Arctic region. 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.	**12 L**
Pedagogy:	Lectures/tutorials/assignments/self-study/case-studies	
References/ Readings	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.	
	Bej, A. K., Aislabie, J. and Atlas, R. M., Polar Microbiology: The ecology, biodiversity and bioremediation potential of microorganisms in extremely cold environments, CRC Press.	

	D'Amico, S., Collins, T., Marx, J. C., Feller, G., Gerday, C. (2006) Psychrophilic microorganisms: challenges for life, EMBO Reports, 7(4): 385-389.	
	Duarte, C. M., Impacts of global warming on polar ecosystems, Fundacion BBVA.	
	Margesin, R., Miteva, V. (2011) Diversity and ecology of psychrophilic microorganisms, Research in Microbiology, 162: 346-361. Miller, R. V. and Whyte, L. G., Polar Microbiology: Life in a Deep Freeze, ASM Press, Washington, DC.	
	Smetacek, V., Nicol, S. (2005) Polar ocean ecosystems in a changing world, Nature Insight Reviews, 437: 362-368.	
Learning Outcomes	1. Explain the uniqueness of the polar environment. 2. Apply the concepts learned to understand the sensitivity of polar environments to climate change.	

Program: M.Sc. Marine Microbiology
Course Code: MMO 402
Title of the Course: DEEP SEA MICROBIOLOGY
Number of Credits: 4
Effective from Academic Year: 2020-21

Prerequisites	It is required that students have a basic knowledge of marine environment- different coastal habitats, pelagic waters and also about some oceanographic processes such as tides, gyres, El Nino Southern Oscillation.	
Objective	This course develops concepts in microbiology of the various habitats in deep marine environment, their role in the ecology of that environment.	
Content:		
1.	**The deep sea environment** Basic and in-depth conceptualization of deep marine subsurface; dark ocean biosphere/aphotic pelagic ocean habitats beneath the ocean water column, such as marine sediments, oceanic crust, abyssopelagic/abyssal, hadal plains and hydrothermal vents. Types of deep sea habitats and resident microbiota: marine trenches, ridges, deep permafrost sediments, Antarctic Ocean and Southern Ocean deep environments; piezophilic/ barophilic microorganisms in the deep sea.	**12 L**
2.		**12 L**
2.1	**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.	
2.2	**Culturing of deep sea microbes** Introduction to anaerobic and pressure culture chambers/systems; techniques for isolation and culturing deep sea microorganisms under *in situ* and simulated deep sea conditions.	
3.	**Deep sea ecosystems:** Hydrothermal vents - Metals at hydrothermal vents, food webs, chemosynthesis, microbial communities – archaea, bacteria; and fungi; diversity of higher organisms including the tube worm *Riftia pachyptila*, sponges, corals; Cold seeps.	**12 L**
4.		**12 L**
4.1	**Marine deposits** Sapropel, carbonates, phosphorite, ancient halite, metallic nodules, marine basalts.	
4.2	**Biogeochemical cycling, enzymes and energetic** Nutrient cycling, oxidation of complex organic matter to carbon dioxide via Fe (III) oxide reduction or fermentation; *Nitrosopumilus maritimus*.	

Pedagogy:	**Lectures/tutorials/assignments/self-study/Moodle/Videos**	
References/ Readings:	Munn, C. Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y.	
	Jorgensen, B. B., Boetius, A. (2007) Feast and Famine: microbial life in the deep sea bed. Nature Reviews Microbiology, 5: 770-781.	
	Nakagawa, S., Takai, K. (2008) Deep-sea vent chemoautotrophs: diversity, biochemistry and ecological significance. FEMS Microbial Ecology, 68: 1-84.	
	Karl, D. M., The Microbiology of Deep-Sea Hydrothermal Vents, CRC Press.	
	Sharma, R. (2017) Deep-Sea Mining Resource Potential, Technical and Environmental Considerations. Springer International Publishing.	
	Kallmeyer, J., Wagner, D. (2012) Microbial Life of the Deep Biosphere. De Gruyter. eISBN: 9783110300130	
	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.	
	Seibold, E., Berger, W. (2017) The Sea Floor An Introduction to Marine Geology. 4th Edition. Springer International Publishing.	
Learning outcomes	1. Explain marine environment and various oceanographic processes, variation in microorganisms in different habitats, different marine deposits. 2. Explain microbial loop, biogeochemical cycling, biological carbon pump and its role in global climate change.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 403
Title of the Course: CORAL MICROBIOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	It is required 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:		
1.	**Introduction of Corals**	**12 L**
1.1	**Coral reef biology**	
	Types of corals, composition, ecology, structure- anatomy and physiology.	
	Types of coral reefs and their global distribution.	
1.2	**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.	
1.3	**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	
2.	**Microbial interaction with coral communities**	**12 L**
2.1	**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	
2.2	**Coral and microbiome dynamics.**	
	Internal nutrient cycling, Adaptive bleaching hypothesis, Coral probiotic hypothesis, Rosenberg's hologenome hypothesis	
	Symbiotic associations: Algal-coral associations, bacterial symbiosis, Multi-partner symbiosis.	
3.	**Diagnosis and recovery of diseased/damaged corals**	**12 L**
3.1	**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).	
	Non-biotic stressors - thermal bleaching, ocean acidification. Growth anomalies.	
3.2	**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).	
Pedagogy:	Lectures/tutorials/assignments/self-study/case-studies	
References/ Readings	C. Sheppard, S. Davy, G. Pilling, N. Graham. 2018. The Biology of Coral Reefs, 2nd Edition. Oxford University Press. Doi: 10.1093/oso/9780198787341.001.0001	
	M. J. H. van Oppen, L. L. Blackal 2019. Coral microbiome dynamics, functions and design in a changing world. Nature Reviews Microbiology. Doi: 10.1038/ s41579-019-0223-4	
	M. J. H. van Oppen et al. 2015. Building coral reef resilience through assisted evolution. PNAS. Doi: 10.1073/pnas.1422301112	
	L.L. Richardson 1998. Coral diseases: what is really known? TREE vol. 13, no. 11.	
	C. D. Harvell et al. 2007. Coral disease, environmental drivers, and the balance between coral and microbial associates. Oceanography. Doi: 10.5670/oceanog.2007.91	
	Laurie J. Raymundo, Courtney S. Couch and C. Drew Harvell. Coral Disease Handbook Guidelines for Assessment, Monitoring & Management.	
	L. J. Chakravarti, M. J. H. van Oppen 2018. Experimental Evolution in Coral Photosymbionts as a Tool to Increase Thermal Tolerance. Frontiers in Marine Science. doi: 10.3389/fmars.2018.00227	
	T. D. Ainsworth et al. 2007. Coral Disease Diagnostics: What's between a Plague and a Band? Applied and Environmental Microbiology. doi:10.1128/AEM.02172-06	
	M. Contardi et al. 2020. Treatment of coral Wounds by combining an Antiseptic Bilayer film and an injectable Antioxidant Biopolymer. Scientific Reports. Doi:10.1038/s41598-020-57980-1	
Learning outcomes	1. The biology and biodiversity of corals 2. Thorough understanding of coral microbiome dynamics 3. Ecology of microbial infections and recovery of corals	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 404
Title of the Course: BIOINFORMATICS DATABASES
Number of Credits: 2
Effective from Academic Year: 2020-21

Prerequisites:	Knowledge of molecular taxonomy.	
Objectives:	This course will introduce students to various databases used for analysis of molecular data and evolution-related concepts under bioinformatics. This will provide students with theoretical knowledge of use of common computational tools and databases that facilitate investigation of molecular biology.	
Content:		
1	**Introduction to Bioinformatics data and databases**:	**6 L**
	Types of Biological data:- Genomic DNA, Complementary DNA, Recombinant DNA, Expressed sequence tags, Sequence Tagged Sites, Genomic survey sequences; Primary/Genomic Databases:- GenBank, EMBL, DDBJ; Composite Databases:-NRDB, OWL, UniProt; Bioinformatics Resources:- NCBI, EBI, ExPASy, RCSB. Multiple sequence alignment and phylogenetic tree building.	
2	**Genome Databases**:	**6 L**
	Viral genome database:-ICTVdb; Bacterial Genomes database:- Ensembl Bacteria, Microbial Genome Database-MBGD; Genome Browsers:- Ensembl, VEGA genome browser, NCBI-NCBI map viewer, KEGG, MIPS, UCSC Genome Browser; Eukaryotic genomes with special reference to model organisms:- Yeast (SGD) Phylogenetic database – eggnog, HOGENOM, OrthoDB.	
3	**Protein Sequence Databases**:	**4 L**
	Swiss-Prot, TrEMBL, UniProt, UniProtKB, UniParc, UniRef, UniMES; Sequence motifs Databases:- Prosite, ProDom, Pfam, InterPro, Gene Ontology; Polymorphism and mutation database- introduction to BioMuta, dbSNP- Database of short Genetic Variation	
4	**Structure and derived databases**:	**8 L**
	Primary structure databases:- PDB, NDB, MMDB; Secondary structure databases:-Structural Classification of Proteins – SCOP, Class Architecture Topology Homology –CATH, Families of Structurally Similar Proteins –FSSP, Catalytic Site Atlas –CSA;	

	Molecular functions / Enzymatic catalysis databases:- KEGG ENZYME database; Protein-Protein interaction database:- STRING, BioGRID, MINT; Chemical Structure database:- Pubchem, DrugBank, ChEMBL; Gene Expression database:- GEO, SAGE.	
Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/Videos	
Reading/ References:	Lesk, A.M., 2005, Introduction to bioinformatics, Oxford University Press	
	Jean-Michel, C., 2005, Bioinformatics: a beginner's guide, Wiley Dreamtech India	
	Shanmughavel, P., 2005, Principles of bioinformatics, Jaipur Pointer Publishers	
	Jeremy, J.R., 2004, Bioinformatics: an introduction, Springer India	
	Rastogi, C., 2004, Bioinformatics: concepts, skills & applications, New Delhi CBS Publishers	
	Mount, D., 2000, Bioinformatics: sequence and genome analysis, New York Cold Spring Harbor Laboratory Press	
	Baxevanis, A., 2001, Bioinformatics: a practical guide t the analysis of genes and proteins, New York John Wiley & Sons	
	Srinivas, V.R., 2005, Bioinformatics: a modern approach, New Delhi Prentice Hall of India	
	Ignacimuthu, S., 2008, Basic Bioinformatics, New Delhi Narosa Publishing House	
	Khan, I.A., 2005, Elementary Bioinformatics, Hyderabad Pharma Book Syndicate	
Learning Outcomes:	Describe properties of important bioinformatics databases. Apply the knowledge to perform text- and sequence-based searches. Apply the knowledge to perform multiple sequence alignment. Use bioinformatics tools in research.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 405
Title of the Course: MARINE PHYTOPLANKTON
Number of Credits: 2
Effective from Academic Year: 2020-21

Prerequisites	Knowledge of marine ecology	
Objective:	This course will introduce students to the biology of marine photosynthetic phytoplankton, identifying and classifying phytoplankton from marine and estuarine habitats and recognizing its role in ocean biogeochemical cycles, harmful algal blooms, commercial products derived from phytoplankton and climate change effects on phytoplankton.	
Content		
1.	**Phytoplankton evolution, diversity and ecology**	**12 L**
1.1	**Evolution of phytoplankton**	
	Introduction to phytoplankton. Energy and elemental requirements for life, Chloroplasts and endosymbiosis, Phytoplankton evolution through geological time	
1.2	**Phytoplankton classification and diversity**	
	Major organelles and structural variations, morphological adaptations, Division of phytoplankton based on size, Phytoplankton groups (marine diatoms, dinoflagellates, microflagellates), Prokaryotic algae (cyanobacteria), Chlorophytes, Heterokontophytes (emphasis on diatoms), Prymnesiophytes, Dinophytes, Cryptophytes, Raphidophytes, Rhodophytes, Distribution and abundance of phytoplankton, Measuring diversity and remote sensing,	
1.3	**Phytoplankton nutrition, physiology and ecological significance**	
	Biogeographic zones of distribution, Nutrient requirements (N,P,Si), Margalef mandala, Photoautotrophic production, Light acclimation and adaptation, adaptation to other physical and biological factors, Grazing defences (morphological features-colony formation, silica shell; changes in life-cycle/behaviour – escape response; physiological – bioluminescence, toxin/ infochemical production), Marine food webs, Marine primary productivity, Role in biogeochemical cycles, (Biological carbon pump, Microbial loops), Phytoplankton and zooplankton interaction, Phytoplankton-bacteria interactions	
2.	**Phytoplankton genomics, commercial value, phytoplankton blooms**	**12 L**
2.1	**Phytoplankton genomics**	
	Genetic diversity, Whole-genome sequences and transcriptomics, Environmental genomics (the meta-omics),	

	Genetic manipulations of phytoplankton, Barcoding and other tools, Transgenic phytoplankton and its applications	
2.2	**Applications of Phytoplankton**	
	CO_2 sequestation in climate change, DMS production, Biofuels and other commercial products made from algae; Aquaculture, secondary metabolites	
2.3	**Phytoplankton blooms and climate change**	
	Ocean fertilization, Climate change effects on phytoplankton, Harmful algal blooms and toxin production, characterisation and causes of bloom formation - Red tides, Spring bloom, occurrences (some examples), solutions for bloom occurrence	
Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/Videos	
Reading/ References	Falkowski, PG and Knoll, AG (Editors). Evolution of Primary Producers in the Sea, Elsevier Academic Press (2007).	
	Kumar S.V., Misquitta R.W., Reddy V.S., Rao B.J. and Rajam M.V. (2004). Genetic transformation of the green alga *Chlamydomonas reinhardtii* by *Agrobacterium tumefaciens*. Plant Science (Shannon, Ireland) 166, 731-738.	
	Lewin K.W.J.C. 1962. Physiology and Biochemistry of Algae.	
	Margalef, R. (1978). Life-forms of phytoplankton as survival alternatives in an unstable environment. Oceanol. Acta, 1(4): 439-509.	
	Parsons, T.R., M. Takahashi and B. Hargrave (II Ed.), 1977. Biological Oceanography Processes. Pergamon Press Oxford.	
	Phillips J.D.H Quantitative aquatic biological indicators, 1980 -. Applied Science Publishers.	
	Raymont, J.E.G., Plankton and productivity in the oceans (Vol. 1 & 2), 1983 –Pergamon Press.	
Learning outcomes	1) The biology and biodiversity of marine phytoplankton 2) The role phytoplankton play in the biological carbon pump as well as in the cycles of other important elements 3) Ecology of harmful algal bloom formation and toxin production 4) Commercial products derived from algae including biofuels 5) The predicted effects of climate change on phytoplankton abundance and distributions	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 406
Title of the Course: MARINE EXTREMOPHILIC MICROORGANISMS
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	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:		
1.	Concept of extremophiles versus conventional microbial forms and archaea.	**1 L**
2.	Extreme marine econiches: marine trenches and ridges, submarine vents, deep sea basins and Antarctic sea ice and lakes.	**2 L**
3.	Key Molecular components, Unique Physiological features, Adaptation strategies, significance in biogeochemical cycles of the following:	
3.1	Anaerobes: *Anaerobranca horikoshi*, *Methanobacterium thermoautotrophicu*s. Barophiles/ Peizophiles: *Colwellia, Photobacterium*.	**7 L**
3.2	Cryophiles/Psychrophiles and Thermophiles: *Polaromonas*, *Shewanella*, *Desulphovibrio, Bacillus infernus*, *Aquifex, Geobacillus*, *Rhodothermus.*	**8 L**
3.3	Oligotrophs, Osmophiles, Halophiles and Xerophiles: *Caulobacter, Pelagibacter; Rhodotorula*; *Marinococcus*, *Wallemia.*	**6 L**
3.4	Alkaliphiles, Acidophiles: *Ferroplasma, Rhodotorula.*	**4 L**
3.5	Radiophiles, Metallophiles & Xenobiotic utilizers: *Deinococcus, Geobacter, Pseudomonas.*	**6 L**
3.6	Biotechnological potential of extremophiles.	**2 L**
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Brock, T. D., Thermophilic Microorganisms and Life at High Temperatures, Springer, New York.	
	Horikoshi, K. and Grant, W. D., Extremophiles – Microbial Life in Extreme Environments, Wiley, New York.	
	Rainey, F. A., Oren, A. (2006) Extremophile microorganisms and the methods to handle them. Methods in Microbiology, 35:1-25.	
	Satyanarayana, T., Raghukumar, C., Shivaji, S. (2005) Extremophilic microbes: diversity and perspectives. Current Science, 89(1): 78-90.	

	Ventosa, A., Nieto, J. J., Oren, A. (1998) Biology of moderately halophilic aerobic bacteria. Microbiology and Molecular Biology Reviews, 62: 504-544.	
Learning Outcomes	Apply the concepts learned to understand the occurrence and ecology of marine extremophiles.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 407
Title of the Course: MARINE MICROBIAL PROSPECTING AND TECHNOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	It is necessary that students should have a working knowledge of the relevance of marine environments as a source of bio-active compounds.	
Objective:	The course explores the role of the marine environment as a source of novel compounds having various potential applications in biotechnology, the range of strategies employed to detect and study them, and the regulatory frameworks that are in place to regulate their usage. Relevant case studies are discussed to understand these concepts.	
Content:		
1.	**Bioprospecting: C**oncept of exploiting marine microbial resource and their cellular components from marine environment and marine invertebrates.	**12 L**
2.	**Sampling and search strategies for novel targets under:** enzymes, therapeutics, antimicrobials and biofuels.	
3.	**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, FAO International Treaty (2001-2004), Bonn Declaration on Access and Benefit-sharing (ABS).	
4	**Conventional and high throughput screening strategy:**	**12 L**
4.1A	**Conventional:** Plating, Enrichment, Extinction culturing; Micro manipulations, Optical tweezers, Microautoradiography.	
4.1B	**Novel:** Function based screens (proteomics and metabolomics), Sequence based screens (genomics), substrate induced gene expression screens (SIGEX) catabolic gene expression screens. Metagenomics, Microarrays, Combinatory chemistry, combinatory biosynthesis and biochemistry assays. Data bases, Natural product libraries.	
4.2	**Deposition of microbes and biomolecules:**	
	Culture collection/ Repository, deposition of sequences of nucleic acids, proteins and structures of biomolecules.	
5.	**Case studies on marine products and process development using microbes:** archaea, cyanobacteria and proteobacteria; microbial products; MEOR and such others.	**12 L**
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Kennish, M. J., Practical Handbook of Estuarine and Marine Pollution, CRC Press.	

	Goldman, E. and Green, L. H., Practical Handbook of Microbiology, CRC Press.	
	Kennish, M. J., Practical Handbook of Marine Science, CRC Press.	
	Chaney, R. C., Sampling and Preparation of Marine Sediments, Foundation Engineering Handbook, Springer Publishers.	
	Wolton, A. G., Methods For Sampling and Analysis of Marine Sediments and Dredged Material, Volume 1, Ocean Dumping Report, Department of Fisheries and the Environment.	
	Bull, A. T., Microbial Diversity and Bioprospecting. ASM Press.	
	Reddy, S. M., Charya, M. A. S. and Girisham, S., Microbial Diversity: Exploration and Bioprospecting, Scientific Publishers.	
	Thomas, T. R., Kavlekar, D. P., Lokabharathi, P. A. (2010) Marine drugs from sponge-microbe association : a review. Marine Drugs, 8: 1417-1468.	
	Borkar, S., Bioprospects of Coastal Eubacteria, Springer Publishers.	
Learning outcomes	1. Apply the knowledge gained to designing and understanding bioprospecting studies 2. Explain the legal frameworks in place for the regulation of trade linked to marine bioprospecting.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 408
Title of the Course: MARINE ENVIRONMENT AND PUBLIC HEALTH
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	It is required that students have basic knowledge about marine environments, climate change, pollutants in marine environment.	
Objective:	This course develops the concepts of 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:		
1.		**12 L**
1.1	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 (outline); Understanding marine ecosystem and human health with DPSIR model.	
1.2	Overview of marine and coastal pollution; effects on the biota and environment. Water pollution - microbial changes induced by inorganic and organic pollutants, industrial effluents and domestic sewage. Effects on aquaculture systems and fisheries. Challenges for monitoring and control of pollution and overfishing; Standards for various types of water.	
2.		**12 L**
2.1	Biological indicators and indices of water quality; Microbial indicator systems – Fecal Indicator Bacteria (FIB), uses and limitation of FIB, development of ideal indicator systems (*Clostridium*, *Cryptosporidium, adenoviruses*, *Bacteroides,* Coliphages) – status, uses and limitation. Sanitation in aquaculture systems.	
2.2	Human pathogens - autochthonous and allochthonous pathogens, pathogen distribution; bacterial pathogens and diseases transmitted through marine and coastal water, faecal contamination, *Vibrio*, Wound sepsis, entero-viruses. Disease monitoring and surveillance.	
2.3	Algal blooms and environmental microflora, their effect on fish production and human health, mechanical, chemical and biological control of algal blooms, microbial toxins.	
3.		**12 L**

3.1	Bioinvasion; transport of pathogens through ballast water - impact, monitoring, rules and regulations, quarantine, certification and import risk analysis.	
3.2	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.	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	1.Hester, R. E., Harrison, R. M., Marine Pollution and Human Health, Vol. 33, Issues in Environmental Science and Technology, Royal Society of Chemistry. 2.Belkin, S. and Colwell, R. R., Oceans and Health: Pathogens in Marine Environment. Springer Publishers. 3.Noga E. J., Fish Disease: Diagnosis and Treatment, Wiley-Blackwell Publishers. 4.Rheinheimer, G., Aquatic Microbiology, John Wiley Publishers. 5.Clark, R. B., Frid, C., Attrill, M., Marine Pollution, Oxford University Press. 6.Wedemeyer, G. A., Meyer, F. P. and Smith, L., Environmental Stress and Fish Diseases, TFH Publications, Neptune, New Jersey. 7.Buller, N. B. and Plumb, J. A., Bacteria from Fish and Other Aquatic Animals: A Practical Identification Manual, CABI Publishing.	
Learning Outcomes	1) Understand the linkage between marine pollutants, climate change and their effects on marine biota and humans; the role of Ballast water in spreading diseases globally; and management strategies to deal with the same. 2) Applying long-term strategies in public health management and understanding the advances in disease control in the marine environment.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 409
Title of the Course: MARINE MICROBIAL REMEDIATION
Number of Credits: 2
Effective from Academic Year: 2020-21

Prerequisites	It is required that students have basic knowledge about marine environment, marine pollutants and xenobiotics.	
Objective:	This course develops the concept of using marine microorganisms as a tool for remediation of diverse pollutants.	
Content:		
1.	Concept of bioremediation, various bioremediation strategies including bio-augmentation, bio-stimulation, co-metabolism, use of microbial consortia and genetically-modified microorganisms.	**2 L**
2.	Bioremediation of metals mediated by marine microbes: Heavy metal resistant microbes from coastal waters, solar salterns, marine sediments hydrothermal vent and marine microbes associated with bivalves and sponges. Marine bacteria/fungi/archaea which can be harnessed for bioremediation technologies e.g. Efflux mechanism, intracellular bioaccumulation, extracellular sequestration and surface biosorption, bioprecipitation, biotransformation and redox reaction, volatilization.	**5 L**
	Bioremediation of hydrocarbons in marine environments, oil spill/ tar ball management. Biodegradation – reactions, enzymes and pathways. Biosurfactants (bioemulsifier), co-metabolism, bio-augmentation, bio-stimulation.	**5 L**
3.	Biodegradation of Complex Polysaccharide (CP)-containing algal waste by marine microorganisms: description and characteristics of algal waste, CP-degrading enzymes – agarase, alginate lyase, carragenase, cellulase, and their role in degradation of algal waste.	**3 L**
4.	Biodegradation of seafood waste by bacteria: description and characteristics of seafood waste, biodegradation of seafood waste by microorganisms – calcium carbonate-solubilizing bacteria, phosphate-solubilizing bacteria; the role of chitinase and protease enzymes in seafood waste degradation, use of microbial consortia, application of seafood waste for ethanol production. Case studies with fish, prawn and crab waste.	**5 L**
5.	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. Case studies with metals.	**4 L**
Pedagogy:	Lectures/tutorials/assignments/self-study	

References/ Readings	Satyanarayana, T., Johri, B. and Anil, T., Microorganisms in Environmental Management, Springer Publishers. Prince, R. C., Bioremediation of Marine Oil Spills. In: Handbook of Hydrocarbon and Lipid Microbiology, Springer Publishers. Judith, S.W., Marine Pollution: What Everyone Needs To Know. Oxford University Press. Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y. King, R. B., Sheldon, J. K. and Long, G. M. (1997) Practical Environmental Bioremediation: The Field Guide, Lewis Publishers. Kennish, M. J. (1996) Practical Handbook of Estuarine and Marine Pollution. CRC Press, Francis and Taylor. Naik, M. and Dubey, S. K., Marine Pollution and Microbial Remediation, Springer Publications. Advances in Biological Sciences Research, Meena, S.N., Naik, M.M. (eds.), Elsevier.	
Learning Outcomes	1) Application of marine microorganisms towards pollution abatement.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 410
Title of the Course: OCEAN OBSERVATIONS AND TECHNIQUES
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	Basic understanding of the marine environments.	
Objective	Introduce the students to analytical techniques and instrumentations used for oceanographic and remote sensing studies.	
Content		
1.	**Platforms and instruments used in Oceanography**	**12 L**
1.1	Marine environment domains, observation strategies, *in situ* observation, Lagrangian and Eulerian measurements, remote sensing. Indian oceanographic research vessels and their facilities.	
1.2	Platform and Instruments: Gliders, Argo, floats, Mooring and moored profilers, buoy, Acoustic Doppler Current Profiler, XBT, Radar, Current Meters, Radars, Marine Magnetometer, Echo Sounder, SONAR, Hydrophone and Geophone, Multibeam bathymetry. Underwater robots and vehicles, Submersible Incubation Device, Camera Systems. Animal tagging, bio-telemetry, bio-logging.	
1.3	Samplers: Conductivity-Temperature-Depth (CTD) sensors, Rosette sampler. Bongo paired Zooplankton Net, BIOMAPER, Video Plankton Recorder, Zooplankton Sampler, Acoustic Recording Package, Multiple Plankton Net. Grab sampler, Gravity corer, Box corer, Piston corer, Hydraulically damped gravity corer.	
2.	**Techniques in Microbial Oceanography**	**12 L**
2.1	Traditional methods. Use of microscopy for enumeration of microbes. Microbial staining. Preservation methods. Tools to study marine microbial diversity: flow cytometry, FlowCAM. Methods to estimate primary production. Phytoplankton pigments by fluorometry, spectrophotometry, HPLC. *In vivo* fluorescence - Fluorescence induction and relaxation and Fast Repetition Rate fluorometer. Respiration measurements of planktons. Tracer technique- 13C and 15N. Isotope labelled substrate uptake. Enzymatic assays.	
2.2	Respiration measurements of plankton. Respiratory quotient to estimate carbon-flux. Community level physiological profiling (CLPP). Fluorometric assessment of enzymatic activity using 4-Methylumbelliferyl (MUF) substrate. Confocal laser scanning microscopy for study of biofilms. Changes in redox potentials using fluorescent stain.	
2.3	Carbon measurement methods: CHNS elemental analyzer. Total inorganic carbon by Coulometer. Dissolved organic carbon using high temperature combustion method. Sediment traps	

	(Moored arrays/drifting traps). ^{234}Thorium as a tracer for POC export estimates.	
2.4	Genomic and metagenomics approach. Environmental DNA. Molecular probes	
3	**Marine Bio-optics and Remote Sensing**	**12 L**
3.1	Marine bio-optics. Electromagnetic radiation. Photosynthetically active radiation. Optically active components. Photosynthetically active radiation (PAR). Optical properties. Ocean color. Chromophoric dissolved organic matter (CDOM). Bio-optical instruments. Fundamentals of remote sensing. Polar-orbiting and geosynchronous satellites. Spatial, temporal and spectral resolution. Satellite sensors.	
3.2	Applications and societal benefits: Primary productivity, sea surface temperature, salinity, wind speed and direction, Ocean currents, ocean-atmosphere heat exchange, bloom dynamics, biogeochemical cycles, assessment of carbon reservoirs and fluxes, potential fishing zones, pelagic and migratory fish, species conservation (e.g. whales, turtles), coastal eutrophication and pollution, Environmental Impact Assessment (EIA), natural and man-made hazards, ocean color and climate change.	
Pedagogy:	Lectures/tutorials/assignments/self-study/case-studies	
References/ Readings	Schiller, Andreas, Brassington, Gary B. (2011). Operational Oceanography in the 21st Century. Springer	
	Jeffrey, S.W and Vesk, M., Introduction to Marine Phytoplankton and Their Pigment Signatures. In: Phytoplankton Pigments in Oceanography. UNESCO Publishing, Paris.	
	Martin S. (2004). An Introduction to ocean remote sensing. Cambridge University Press	
	Venkatesan et al (2018). Observing the oceans in real time. Springer	
	Parsons, T. R., Maita, Y. and Lalli, C. M.; (1984). A Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, Oxford.	
	Strickland, J.D.H, and Parsons T.R., (1972). A practical handbook of seawater analysis, Fisheries Board of Canada bulletin. (2nd edition).	
	Colin Munn (2011). Marine Microbiology Ecology & Applications. Taylor Francis Group.	
Learning Outcomes	Knowledge on different instruments and techniques used to study oceanography and microbes in the ocean.	

Programme: M.Sc. (Marine Microbiology)
Course Code: MMO 411
Title of the Course: FISHERY MICROBIOLOGY
Number of Credits: 3
Effective from Academic Year: 2020-21

Prerequisites	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:		
1.	**Introduction to Indian Fisheries**	**15 L**
1.1	Type of fishes, shellfishes and other coastal aquatic and marine living resources present in Indian Ocean, Arabian Sea and Bay of Bengal, concept of aquaculture and marine culture of fishes. Use of Probiotics in aquaculture. Concept of blue economy.	
1.2	Microbiology of Raw fish and processed fish. Adverse effects of microbial spoilage and PHFL on blue economy. Various methods for processing of fishes; Biopreservation, food processing, fermentation and aquaculture; effect of heat, chilling, freezing and chemical preservatives on bacteria, yeasts and fungi associated with fishes.	
1.3	Quality control and regulations for microbial quality of fishes, shellfish and marine living resources used for food and drugs.	
2.	**Microbes associated with fish and shellfish**	**10 L**
2.1	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:	
2.2	*Flavobacterium, Edwardsiella, Vibrio, Aeromonas, Renibacterium, Yersinia, Mycobacterium.*	
2.3	Viral infections of finfish.	
3	**Marine toxins and Human bacterial pathogens**	**11 L**
3.1	Human bacterial pathogens associated with fishes and their products - *Clostridium perfringens, Listeria spp., Plesiomonas, Vibrio cholerae, Vibrio parahaemolyticus, Vibrio vulnificus* and common *Enterobacteriaceae.*	
3.2	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/tutorials/assignments/self-study/case-studies	

References/ Readings	Fernandes, R., Microbiology Handbook: Fish and Seafood, RSC Publishing	
	Woo, P. and Bruno, D. Fish Diseases and Disorders, Vol 3: Viral, Bacterial and Fungal Infections, CABI Publishers.	
	Roberts, R. J., Fish Pathology, Wiley-Blackwell Publishers.	
	Hoole, D., Buck, D., Burgess, P. and Welby, I., Diseases of Carps and Other Cyprinid Fishes, Wiley-Blackwell Publishers.	
	Sindermann, C. J., Principle Diseases of Marine Fish and Shellfish, Gulf Professional Publishing.	
	Noga, E. C., Fish Disease: Diagnosis and Treatment. Wiley-Blackwell Publishers.	
	Leatherland, J. F. and Wook, P. K. T., Fish Diseases and Disorders, CABI Publishers.	
Learning outcomes	1. 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	