GOA UNIVERSITY
Taleigao Plateau, Goa 403 206

REVISED MINUTES

of the 5th Meeting of the Standing Committee of

X ACADEMIC COUNCIL

Day & Date

Tuesday, 14th February, 2023 & Thursday, 23rd February, 2023

Time

10.00 a.m.

Venue
Council Hall,
Administrative Block
Goa University

	the University as Dean, Shenoi Goembab School of languages & Literature during his tenure. **(Action: Assistant Registrar Academic-PG)**
D 3.17	**Minutes of the Board of Studies in Sanskrit meeting held on 28.10.2022.** The Standing Committee of the Academic Council approved the minutes of the Board of Studies in Sanskrit meeting held on 28.10.2022 with the following suggestions: 1. Number of hours for Course Code SATE -401, Discipline Specific Elective Course to be verified. 2. Titles of the Courses to be written in Devanagari and English language. **(Action: Assistant Registrar Academic-PG)**
D 3.18	**Minutes of the Board of Studies in Marine Microbiology meeting held on 21.10.2022.** The Standing Committee of the Academic Council approved the minutes of the Board of Studies in Marine Microbiology meeting held on 21.10.2022 with the following suggestions: 1. Tutorials/Lectures (L-T-P) mentioned under Structure to be deleted. 2. Prerequisite for the courses to be specified. 3. Prerequisite to be changed of the Course MMTE 501 Phytoplankton Ecology and Genomics. 4. Terminology Textbook/References to be changed to References/Readings. **(Action: Assistant Registrar Academic-PG)**
D 3.19	**Minutes of the Board of Studies in Marine Science meeting held on 27.10.2022.** The Standing Committee of the Academic Council approved the minutes of the Board of Studies in Marine Science meeting held on 27.10.2022 with the following suggestions: 1. Tutorials/Lectures (L-T-P) mentioned under Structure to be deleted. 2. Wherever only one module exists under content, heading 'Module I' to be deleted. 3. Titles and the syllabus of the Courses to be verified. 4. Python to be explored under Course Code MSTE 501. 5. The content of the Course Code MSTE – 530 to be revised. 6. MSTE – 525 Advanced Research Analysis Course, from Pedagogy Terminology 'faculty' to be deleted. **(Action: Assistant Registrar Academic-PG)**
D 3.20	**Minutes of the Board of Studies in Earth Science meeting held on 29.10.2022.** The Standing Committee of the Academic Council approved the minutes of the Board of Studies in Earth Science meeting held on 29.10.2022 with the following suggestions: 1. Tutorials/Lectures (L-T-P) mentioned under Structure to be deleted. 2. AGPE -508 Practical of Petroliferous Basins of India Programme to be conducted

Std. Com. X AC-5
14.02.2023

GOA UNIVERSITY
Taleigao Plateau, Goa 403 206

F I N A L A G E N D A

For the 5th Meeting of the Standing Committee of

X ACADEMIC COUNCIL

Day & Date

Tuesday, 14th February, 2023

Time

10.00 a.m.

Venue
Conference Hall
Administrative Block
Goa University

	Discipline Specific Optional Courses 1)SATE-401 –Darsana Sastra 2)SATE – 402- Vedanta Darsana **SEMESTER – II** **Discipline Specific Core Courses** 1)SATC –405 –Sanskrit Vyakarana 2)SATC -406- Paraskaragrhyasutra and Arthasatra 3)SATC-407 – Sahitya: Natyastra and Dhvanyaloka 4)SATC-408- Survey of Indian Astrology **Discipline Specific Optional Courses** 1)SATC-403 –Tarka evam Jnana Mimansa 2)SATE-404 – Buddha Darsana Date: 15.11.2022 Sd/- Place: School of Sanskrit, Philosophy and Indic Studies, Goa University Signature of the Chairman of BOS **Part G:** Remark of the Dean of faculty: The minutes are in order: Recommended for approval of Academic Council Date: 15.11.2022 Sd/- Place: School of Sanskrit, Philosophy and Indic Studies, Goa University Signature of the Dean, **(Back to Index)**
D 3.18	**Minutes of the Board of Studies in Marine Microbiology meeting held on 21.10.2022.** **Part A** i. Recommendations regarding courses of study in the subject or group of subjects at the undergraduate level: NIL ii. Recommendations regarding courses of study in the subject or group of subjects at the postgraduate level: **1. BOS members met on 21.10.2022 at 1030 hrs and took up the following agenda for discussion.** a. Approval of M.Sc. syllabus (Semester III and IV) as per OA35. **(Annexure I Refer page No. 679)** b. Approval of Ph.D. syllabus of Research Methodology course (04 credits) **(Annexure II Refer page No. 711)** **2. Members of the BOS deliberated on the above matter and approved the following:** (a) The program structure and syllabus in M.Sc. Marine Microbiology (Semester III and IV) was deliberated and few suggestions made by the Experts were incorporated and the same was approved.

(b) The syllabus for the Research Methodology course (04 credits) for Ph.D. in Marine Microbiology was placed and approved.

Part B

i. Scheme of Examinations at undergraduate level: Nil
ii. Panel of examiners for different examinations at the undergraduate level: Nil
iii. Scheme of Examinations at postgraduate level: Nil
iv. Panel of examiners for different examinations at post-graduate level: Nil

Part C

1. Recommendations regarding preparation and publication of selection of reading material in the subject or group of subjects and the names of the persons recommended for appointment to make the selection: Nil

Part D

i) Recommendations regarding general academic requirements in the Departments of University or affiliated colleges: Nil
ii) Recommendations of the Academic Audit Committee and status thereof: Nil

Part E

i) Recommendations of the text books for the course of study at undergraduate level: Nil
ii) Recommendations of the text books for the course of study at post graduate level: Nil

Part F

Important points for consideration/approval of Academic Council

i. The important points/recommendations of BoS that require consideration/approval of Academic Council (points to be highlighted) as mentioned below
   (a) The program structure and syllabus in M.Sc. Marine Microbiology (Semester III and IV) was deliberated and few suggestions made by the Experts were incorporated and the same was approved. This syllabus of M.Sc. Marine Microbiology (Semester III and IV) was revamped with introduction of ten new courses (22%) in view of the implementation of NEP guidelines by the University.
   (b) The syllabus of Research Methodology paper (04 credits) for Ph. D. in Marine Microbiology was placed and the suggestions made by the Experts were incorporated and approved.
ii. The declaration by the Chairperson that the minutes were readout by the Chairperson at the meeting itself.

Date: 21.10.2022
Place: Goa University Campus

Sd/-
Signature of the Chairperson

Part G. The Remarks of the Dean of the Faculty

i. The minutes are in order.
ii. The minutes may be placed before the Academic Council with remarks if any.
iii. May be recommended for approval of Academic Council.

	iv. Special remarks if any. Sd/- Signature of the Dean Date: 21.10.2022 Place: Goa University Campus **(Back to Index)**
D 3.19	**Minutes of the Board of Studies in Marine Science meeting held on 27.10.2022.** **Part A** i. Recommendations regarding courses of study in the subject or group of subjects at the undergraduate level: ii. Recommendations regarding courses of study in the subject or group of subjects at the postgraduate level: 1. **BOS members met on 27.10.2022 (Thursday) in School of Earth, Ocean and Atmospheric Sciences at 1030 hrs in room number CF 20 and discussed the following.** a. Approval of M.Sc. syllabus (Semester III and IV) as per OA35. b. Approval of Ph.D. syllabus of Research Methodology course (04 credits). c. Any other Business with the permission of the Chair. 2. **Members of the BOS deliberated on the above matter and approved the following:** **(a) The syllabus of M.Sc. Marine Sciences (Semester III and IV) was deliberated and few suggestions made by the Experts. The suggestions were incorporated and the same was approved attached as Annexure I (Refer page No. 713).** **(b) The syllabus of Research methodology paper (04 credits) for Ph. D. in Marine Sciences was discussed and approved attached as Annexure II (Refer page No. 746)** **Part B** i. Scheme of Examinations at undergraduate level: Nil ii. Panel of examiners for different examinations at the undergraduate level: Nil iii. Scheme of Examinations at postgraduate level: Nil iv. Panel of examiners for different examinations at post-graduate level: Nil **Part C** 1. Recommendations regarding preparation and publication of selection of reading material in the subject or group of subjects and the names of the persons recommended for appointment to make the selection: Nil **Part D** i) Recommendations regarding general academic requirements in the Departments of University or affiliated colleges: Nil ii) Recommendations of the Academic Audit Committee and status thereof: Nil **Part E**

D 3.18 Minutes of the Board of Studies in Marine Microbiology meeting held on 21.10.2022.

Annexure I

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

Syllabus of M.Sc. (Marine Microbiology) Programme (2022-23)

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

The Program 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 Program equips students for higher research leading to the Ph.D. degree in India or in International Universities overseas, or for employment in Research Institutes, in teaching, and in Industry, the students finding speedy employment.

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

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

Code	Title of paper	L-T-P hrs/week	Credits
Semester III - Elective Papers			
Research Specific Elective Courses			
MMTE-501	Phytoplankton Ecology and Genomics	3-0-0	3
MMPE-502	Phytoplankton Ecology Practical	0-0-2	1
MMTE-503	Marine Microbial Prospecting and Technology	3-0-0	3
MMPE-504	Marine Microbial Prospecting and Technology Practical	0-0-2	1
MMTE-505	Microbial Growth and Enzyme Kinetics	3-0-0	3
MMPE-506	Microbial Growth and Enzyme Kinetics Practical	0-0-2	1
MMTE-507	Genetic Engineering	3-0-0	3
MMPE-508	Genetic Engineering Practical	0-0-2	1
			Total = 8
Generic Specific Elective Courses			
MMTE-509	Archaea	3-0-0	3
MMPE-510	Archaea Practical	0-0-2	1
MMTE-511	Ecology and Applications of Marine Fungi	3-0-0	3
MMPE-512	Ecology and Applications of Marine Fungi Practical	0-0-2	1
MMTE-513	Marine Pollution and Monitoring	3-0-0	3
MMPE-514	Marine Pollution and Monitoring Practical	0-0-2	1
MMTE-515	Marine Environment and Public Health	3-0-0	3
MMPE-516	Marine Environment and Public Health Practical	0-0-2	1
MMTE-517	Polar Microbiology	3-0-0	3
MMTE-518	Deep Sea Microbiology	3-0-0	3
MMTE-519	Marine Microbial Toxins	1-0-0	1
MMPE-520	Scientific Writing Skills Practical	0-0-2	1
			Total = 12
Semester IV - Elective Papers			
Research Specific Elective Courses			
MMTE-521	Ocean Observations and Techniques	3-0-0	3
MMPE-522	Ocean Observations and Techniques Practical	0-0-2	1
MMTE-523	Microbial Remediation in Marine Ecosystems	2-0-0	2
MMPE-524	Microbial Remediation in Marine Ecosystems Practical	0-0-2	1
MMTE-525	Bioinformatics in Marine Microbiology	2-0-0	2
MMPE-526	Bioinformatics in Marine Microbiology Practical	0-0-2	1
MMTE-527	Nanotechnology	2-0-0	2
MMPE-528	Nanotechnology Practical	0-0-2	1
MMTE-529	Blue Economy	1-0-0	1
MMTE-530	Probiotics and Prebiotics in Aquaculture	1-0-0	1
MMTE-531	Marine Drug Development and Metabolism	1-0-0	1
MMDE-532	Discipline Specific Dissertation	0-0-4	16
			Total = 20

Course Code: MMTE-501
Title of the Course: Phytoplankton Ecology and Genomics
Number of Credits: 03

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Part I Courses.	
Objective:	The students will learn the biology of marine photosynthetic phytoplankton, identifying and classifying phytoplankton from marine and estuarine habitats and recognizing its role in ocean biogeochemical cycles.	
Content:	**Module I** Introduction to phytoplankton, evolution through geological time scale. Phytoplankton classification and diversity – major organelles and structural variations, morphological adaptations, division of phytoplankton based on size. Phytoplankton groups like diatoms, dinoflagellates, coccolithophores, microflagellates. Cyanobacteria, Chlorophytes, Heterokontophytes (emphasis on diatoms), Prymnesiophytes, Dinophytes, Cryptophytes, Raphidophytes, Rhodophytes. Phytoplankton distribution and its diversity indices. Phytoplankton biomass estimation, primary productivity. Phytoplankton enumeration techniques – FlowCAM and flow cytometry. **Module II** Biogeographic zones of distribution. Phytoplankton nutrition, nutrient requirements (N, P, Si), physiology and ecological significance. Photoautotrophic production, adaptations to physico-chemical and biological factors. Grazing defences (morphology, chemical defences, life cycle strategies, escape response). Marine food webs. Role in biogeochemical cycles. Biological pump, microbial loop. Phytoplankton and zooplankton interactions, phytoplankton-bacteria interactions. **Module III** Phytoplankton and environmental genomics. Genetic diversity and manipulation, barcoding and its applications. Applications of phytoplankton in CO_2 sequestration, DMS production, biofuels and other commercial products, as live feed in aquaculture, secondary metabolites. Harmful algal blooms and toxin production, characterisation and causes of bloom formation, red tides, prevention and control. HNLC areas and iron fertilization.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/tutorials/assignments/self-study.	
References/ Readings:	1. Falkowski, P. G., & Knoll, A. G. (Eds.) (2007). *Evolution of primary producers in the sea.* (First Edition), Amsterdam: Elsevier Academic Press. 2. Kumar, S. V., Misquitta, R. W., Reddy, V. S., Rao, B. J., & Rajam, M. V. (2004). Genetic transformation of the green alga *Chlamydomonas reinhardtii* by *Agrobacterium tumefaciens. Plant Science,* 166(3), 731–738. doi:10.1016/j.plantsci.2003.11.012 3. Lewin, R.A. (1962). *Physiology and biochemistry of algae.* (First Edition), Academic Press.	

	4. Margalef, R. (1978). Life-forms of phytoplankton as survival alternatives in an unstable environment. *Oceanologica Acta,* 1(4), 439–509. 5. Parsons, T. R., Takahashi, M., & Hargrave, B. (1977). *Biological oceanography processes.* (Second Edition), Oxford: Pergamon Press. 6. Phillips, J. D. H. (1980). *Quantitative aquatic biological indicators.* (Second Edition), Applied Science Publishers. 7. Raymont, J. E. G. (1983). *Plankton and productivity in the oceans.* Vol. 1 and 2. (Second Edition). Toronto: Pergamon Press.	
Learning Outcome:	The students will learn about the diversity and genomics of phytoplankton, their role in ecosystem functioning and commercial product synthesis; and the role of phytoplankton in regulating climate change.	

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Course Code: MMPE-502
Title of the Course: Phytoplankton Ecology Practical
Number of Credits: 01

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

Course Code: MMTE-503
Title of the Course: Marine Microbial Prospecting and Technology
Number of Credits: 03

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Part I Courses.

Objective:	The course explores marine microbes as a potential source for isolation of novel compounds and the regulatory frameworks for their usage.	
Content:	**Module I** Bioprospecting: Concept of exploiting marine microbial resources. Microbes: free-living and associated with marine invertebrates, macroalgae, phytoplankton. Diversity of bio-active metabolites. Collection, sampling and analytical techniques for natural product isolation. Sampling and search strategies for novel targets under: enzymes, therapeutics, antimicrobials and biofuels. Legal framework for collection and conservation of marine niches and microbes. Convention on Biological Diversity, Rio (1992/1994). Bioethics and Biosafety. Quarantine regulations. Biopiracy. Cartegena & Montreal Protocols. FAO International Treaty (2001-2004), Bonn Declaration on Access and Benefit-Sharing. **Module II** Conventional and high throughput screening strategy. Conventional: Plating, enrichment, extinction culturing, micro manipulations, optical tweezers, microautoradiography. Novel: Proteomics and metabolomics, genomics; Substrate-Induced Gene Expression Screens (SIGEX), catabolic gene expression screens, metagenomics, microarrays, combinatory chemistry, combinatory biosynthesis and biochemistry assays. Databases, natural product libraries. **Module III** Deposition of microbes and biomolecules. Culture collection/ repository, deposition of sequences of nucleic acids, proteins and structures of biomolecules. Geo-indicators. Commercial development of marine natural products like chitosan, algal products, SCPs, β-carotene and vitamins. Case studies on marine products and process development using microbes: archaea, cyanobacteria and proteobacteria.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/tutorials/assignments/self-study/case-studies.	
References/ Readings:	1. Borkar, S. (2015). *Bioprospects of coastal Eubacteria.* Springer Publishers. 2. Bull, A. T. (2003). *Microbial diversity and bioprospecting.* ASM Press. 3. Goldman, E., & Green, L. H. (2019). *Practical handbook of microbiology.* (Fourth Edition), CRC Press. 4. Kennish, M. J. (2019). *Practical handbook of estuarine and marine pollution.* CRC Press. 5. Kennish, M. J. (2022). *Practical Handbook of Marine Science.* (Fourth Edition), CRC Press. 6. Reddy, S. M., Charya, M. A. S., & Girisham, S. (2012). *Microbial diversity: Exploration and bioprospecting.* Scientific Publishers.	

	7. Thomas, T. R., Kavlekar, D. P., & Lokabharathi, P. A. (2010). Marine drugs from sponge-microbe association: a review. *Marine Drugs,* 8, 1417-1468.	
Learning Outcomes:	1. The analytical methods for natural product isolation and their applications. 2. Knowledge on the regulatory frameworks for their usage.	

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Course Code: MMPE-504
Title of the Course: Marine Microbial Prospecting and Technology Practical
Number of Credits: 01

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

Course Code: MMTE-505
Title of the Course: Microbial Growth and Enzyme Kinetics
Number of Credits: 03

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Part I Courses.
Objective:	Development of concepts in microbial enzymology and the microbial processes used in industries to produce microbial products.

Content:	**Module I** Microbial growth kinetics. Batch kinetics: Monod's model (single substrate), deviations from Monod's model, dual substrates, multiple substrates, substrate inhibition, product synthesis (primary and secondary metabolite), toxic inhibition, death constant. Fed-batch kinetics: fixed volume, variable volume and cyclic fed-batch, applications and examples. Continuous cultivation system: relationship between specific growth rate (μ) and dilution rate, comparison between various cultivation systems. **Module II** Enzyme kinetics: Michaelis - Menten Equation, Line-Weaver Burk plot for one substrate reactions, significance of V_{max} and K_m. Enzyme turnover: K_s and K_d, its measurement and significance, mechanism of enzyme degradation and reversible and irreversible inhibition: competitive, uncompetitive and non-competitive. **Module III** Enzyme catalysis mechanisms, identification of functional groups, factors affecting catalytic efficiency, proximity and orientation effects. Enzyme regulation: control of activity, availability of substrate and inhibitor or enhancer molecules, change in the covalent structure of enzyme. Regulatory enzymes: Allosteric (aspartate transcarbamylase) and covalently modulated enzymes (glycogen phosphorylase, glutamine synthetase); Mechanism of action and their significance in metabolism. Zymogens and isozymes. Multienzyme systems: disassociated system (catabolic enzymes), multienzyme complex (pyruvate dehydrogenase); membrane-bound system (electron carrying enzymes).	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments/ self-study.	
References/ Readings:	1. Stanbury, P. F., Whitaker, A., & Hall, S. J. (2005). *Principles of fermentation technology*. (Third Edition), Butterworth-Heinemann Publishers. 2. Flickinger, M. C., & Drew S. W. (2002). The *encyclopedia of bioprocess technology: Fermentation, biocatalysis and bioseparation*, Vols. 1 - 5, New Jersey: John Wiley Publishers. 3. Atkinson, B., & Mavituna, F. (1992). *Biochemical engineering and biotechnology handbook*. (Second Edition), Stockton Press. 4. Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2008). *Principles of biochemistry*. (Fifth Edition), New York: Worth Publishers. 5. Dixon, M., & Webb, E. C. (2014). *Enzymes*. (Second Edition) Elsevier. 6. Price N. C., & Stevens, L. (2009). *Fundamentals of enzymology*. (Third Edition), Oxford University Press.	
Learning Outcome:	1. An understanding of microbial growth and enzyme kinetics on different substrates, and their industrial applications.	

Course Code: MMPE-506
Title of the Course: Microbial Growth and Enzyme Kinetics Practical
Number of Credits: 01

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

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Course Code: MMTE-507
Title of the Course: Genetic Engineering
Number of credits: 03

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Part I Courses.	
Objective:	This course aims to introduce the tools and techniques in molecular cloning, DNA editing and protein expression in wide variety of hosts and their applications in genetic engineering.	
Content:	**Module I** Introduction to genetic engineering.	15 hrs.

	Tools and techniques involved in genetic manipulation – I: restriction endonucleases, exonucleases, DNA ligases, terminal DNA transferase, DNA polymerases, reverse transcriptase, T4 polynucleotide kinases, alkaline phosphatase, S-1 nuclease, mung bean nuclease, RNases. Gene cloning systems/Hosts: Gene cloning in *E. coli* and other organisms such as *Bacillus subtilis*, *Saccharomyces cerevisiae*. Retroviruses and retroposons. **Module II** Tools and techniques involved in genetic manipulation – II: Expression vectors – Prokaryotic (pET, pGEX-2T). Characteristics of expression vectors – strong bacterial and viral promoters (lac, trp, tac, SV 40, T7, T3) for induction of gene expression. Cloning vectors – plasmid (pUC19, pBR 322), λ phage-based vectors (M-13, 2µ plasmid), cosmid vectors, phasmid vectors, shuttle vectors, high capacity cloning vectors (BAC and YACs), Ti plasmid. Construction of cDNA, cloning, its expression and techniques – transformation, electroporation, transfection, gene gun. Other recombinant DNA techniques – use of radioactive and non- radioactive nucleotides for DNA probe preparation and detection of hybrids, restriction mapping, RFLP, PCR, RT-PCR, Real time PCR. Microarray. DNA sequencing methods. Chromosome walking. CRISPR-Cas. **Module III** Application of genetic engineering in diagnostics, agriculture, medicine, pharmaceuticals, industries and allied areas. Genetically modified foods/crops, recombinant drugs, vaccines, interferons and hormones. Recombinant proteins and drugs, enzymes, biomolecules and fermentation products, bioremediation and biomonitoring (biosensors) of toxic environmental pollutants. Ethics in genetic engineering.	15 hrs. 15 hrs.
Pedagogy:	Lectures/tutorials/assignments/self-study.	
References/ Readings:	1. Old, R. W., & Primrose, S. B. (1980). *Principles of gene manipulation: An introduction to genetic engineering.* University of California Press. 2. Glick, B. R., Pasternak, J. J., & Patten, C. L. (1994). *Molecular biotechnology: Principles and applications of recombinant DNA*. ASM Press. 3. Brown, T. A. (2010). *Gene cloning & DNA analysis*. Wiley-Blackwell. 4. Glover, D. M. (1984*). Gene cloning: The mechanics of DNA manipulation.* Springer-Science+Business Media. 5. Green, M. R., & Sambrook, J. (2001). *Molecular cloning: A laboratory manual*. New York: Cold Spring Harbor Laboratory. 6. Davis, L. G., Dibner, M. D., & Battey, J. F. (1986). *Basic methods in molecular biology*. Elsevier.	
Learning Outcome:	Understanding of tools and techniques involved in gene cloning and expression.	

Course Code: MMPE-508
Title of the Course: Genetic Engineering Practical
Number of Credits: 01

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

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Course Code: MMTE-509
Title of the Course: Archaea
Number of Credits: 03

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course develops concept of three domains of life, ecology, physiology, diversity, cell structure, metabolism, energetics and genetics of archaea.	
Content:	**Module I** Carl Woese's three domain classification of life, classification of archaea. Cellular organization of archaea. Ecology, physiology and diversity of Archaea. Nutrition, growth and growth kinetics and physiological versatility. Stress response of methanogenic, halophilic, thermophilic, thermoacidophilic, barophilic, alkaliphilic and psychrophilic archaea. Methanotrophs, methylotrophs. Global econiches: deep sea, hydrothermal vents, Dead Sea, solar salterns, geothermal vents, solfataras, Antarctica, soda lake. Study of archaeal diversity. Unculturable archaeal studies by metagenomics. Archaeal culture retrieval methods. Novel samplers. Preservation and maintenance of archaeal cultures. Significance of Archaea: biogeochemical cycling, biotechnology. **Module II** Metabolism and energetics of Archaea: modified anabolic pathways of carbohydrates and lipids, methanogenesis and acetoclastic reactions. Modified central metabolic pathways – EMP, ED, incomplete TCA, reverse Kreb cycle, carbon dioxide reduction pathways – reductive acetyl-CoA pathway, 3-hydroxypropionate pathway.	15 hrs. 15 hrs. 15 hrs.

	Chemolithoautotrophy. Bioenergetics – ATP synthesis (i) respiration-driven; (ii) light-driven, involving bacteriorhodopsin; and (iii) chloride-driven, involving halorhodopsin. **Module III** Genome of Archaea: size of genome, G + C content, associated proteins, archaeal histones and nucleosomes, introns in archaea. Archaeal RNA polymerases, reverse DNA gyrase. Plasmids, transposons -IS elements. Modifications in tRNA and rRNA structure. Novel 7S rRNA. DNA replication, transcription and translation in archaea. Gene organization in Archaea: (i) *his* operon; (ii) *bob* operon; and (iii) *mcr* operon.	
Pedagogy:	Lectures/tutorials/assignments/self-study.	
References/ Readings:	1. Woese, C. R., & Fox, G. E. (1977). Phylogenetic structure of the prokaryotic domain: the primary kingdoms. *Proceedings of the National Academy of Sciences USA*. 74, 5088–5090. 2. Cavicchioli, R. (2007). *Archaea: Molecular and cellular biology*. ASM Press. 3. Garrett, R. A., & Hans-Peter, K. (2007). *Archaea: Evolution, physiology and molecular biology.* John Wiley and Sons. 4. Munn, C. (2004). *Marine microbiology: Ecology and applications*. Garland Science, Taylor and Francis Group. 5. Boone, D. R., & Castenholz, R. W. (1984). *Bergey's manual of systematic bacteriology. Vol. I, The Archaea and the deeply branching and phototrophic bacteria*. Springer. 6. Corcelli, A., & Lobasso, S. (2006). Characterization of Lipids of Halophilic Archaea. *Methods in Microbiology*. 35, 585-613. 7. Rothe, O., & Thomm, M. (2000). A simplified method for the cultivation of extreme anaerobic archaea based on the use of sodium sulfite as reducing agent. *Extremophiles*. 4, 247-252.	
Learning Outcome:	Understanding the third domain of life – Archaea, its ecology, physiology, biochemistry, genetics and applications.	

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Course Code: MMPE-510
Title of the Course: Archaea Practical
Number of Credits: 01

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course focuses on sampling, isolation and identification techniques of archaea from different econiches and the study of archaeal pigments.	
Content:	**Module I** 1. Isolation and culturing of archaea (6 hrs, Ref. 1). 2. Identification of archaeal isolates (6 hrs, Ref. 2). 3. Biochemical tests for archaea (6 hrs, Ref. 2). 4. Extraction of archaeal pigment and characterization using UV-Vis spectroscopy (6 hrs, Ref. 2).	30 hrs.

	5. Screening for archaeal enzymes (6 hrs, Ref. 3).	
Pedagogy:	Experiments in the laboratory.	
References/ Readings:	1. Rothe, O., & Thomm, M. (2000). A simplified method for the cultivation of extreme anaerobic archaea based on the use of sodium sulfite as reducing agent. *Extremophiles*. 4, 247-252. 2. Boone, D. R., & Castenholz, R. W. (1984). *Bergey's manual of systematic bacteriology. Vol. I, The Archaea and the deeply branching and phototrophic bacteria*. Springer. 3. Kumar, S., Karan, R., Kapoor, S., et al. (2012). Screening and isolation of halophilic bacteria producing industrially important enzymes. *Brazilian Journal of Microbiology*. 43(4),1595-603. doi: 10.1590/S1517-838220120004000044.	
Learning Outcomes:	1. Sampling of archaea from different econiches. 2. The isolation, culturing and identification of archaea. 3. Bioprospecting of bioactive molecules from archaea.	

Course Code: MMTE-511
Title of the Course: Ecology and Applications of Marine Fungi
Number of Credits: 03

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course deals with detailed classification and identification of fungi, fungal ecology in marine and extreme habitats, fungal genetics and applications of fungal enzymes and various primary and secondary metabolites.	
Content:	**Module I** Fungal diversity and distribution: Phylogeny and detailed classification of fungi. Econiches of marine fungi – polyhaline coastal environments (salt marshes, mangroves, estuaries, oceans); hypersaline environment (solar salterns, Salt Lake, Dead Sea); deep sea (hydrothermal vents). Extremophilic fungi – halophiles, xerophiles, oligotrophs, barophiles, psychrophiles, thermophiles. Techniques to study marine and extremophilic fungi **–** sample collection and isolation procedures, identification – morphotyping, secondary metabolites, molecular finger printing, FAME, karyotyping, gene sequencing. **Module II** Physiology and genetics: Growth cycle and development. Fungal hormones (attractants), morphogenesis and differentiation. Secondary metabolites – pigments, mycotoxins. Fungal genetics **– c**ross over and tetrad analysis, gene conversion, mating type switching. Deuteromycotina – parasexuality, cytoplasmic inheritance. Fungal associations – symbionts, saprophytes and parasites on higher forms of marine life. **Module III**	15 hrs. 15 hrs.

	Threats and applications: Mycoses – diseases of fish, bivalves and corals. Bioprospecting and bioremediation – industrially important enzymes, secondary metabolites, nutraceuticals, antimicrobials, antitumour agents, pigments. Biodegradation and bioremediation.	15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments/ self-study.	
References/ Readings:	1. Alexopoulus, C. J., Mims, C. W., & Blackwell, M. (2017). *Introductory mycology*. (Fourth Edition), New Delhi: John Wiley & Sons. 2. Mehrotra, R. S., & Aneja K. R., (1990). *An Introduction to Mycology*. New Delhi: Wiley Eastern Limited. 3. Deacon, J. W. (1984). *Introduction to modern mycology*. Oxford Blackwell Scientific Publications. 4. Moore, D. (2011). *21st Century guidebook to fungi*. New York: Cambridge University Press. 5. Moore, D., & Frazer, L. A. N. (2002). *Essential fungal genetics*. New York: Springer Publishers. 6. Onions, A. H. S., Allsop, D., & Eggins H. O. W., (1981). *Smith's introduction to industrial mycology*. London: Edward Arnold Publishers. 7. Domsch, K. H., Gams, W., & Anderson, T-H., (2007). *Compendium of soil fungi*. (Second Edition), Eching, IHW-Verlag. 8. Borse, B. D., Bhat, J. D., Borse, K. N., Tuwar, N. S., & Pawar, N. S. (2012). *Marine fungi of India (Monograph)*, Panaji: Broadway Publishing House. 9. Raghukumar, C. (2012). *Biology of marine fungi*. Springer Publishers, Berlin Heidelberg. 10. Raghukumar, S. (2017). *Fungi in coastal and oceanic marine ecosystems*. Switzerland : Springer Publishers. doi: 10.1007/978-3-319-54304-8. 11. Borkovich, K. A., & Ebbole, D. J., (2010). *Cellular and molecular biology of filamentous fungi*. Washington DC: ASM Press.	
Learning Outcome:	The students will be able to apply the knowledge in fungal taxonomy, bioremediation and bioprospecting of secondary metabolites and industrially important fungal enzymes.	

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Course Code: MMPE-512
Title of the Course: Ecology and Applications of Marine Fungi Practical
Number of Credits: 01

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	The course deals with sampling techniques for marine samples, and isolation and identification of marine fungi.	
Content:	**Module I** 1. Study of fungal cultures: colony and morphological characteristics (6 hrs, Ref. 1-3).	30 hrs.

	2. Isolation and identification of fungi from marine ecosystem (16 hrs, Ref. 1-3). 3. Biosorption experiment using marine fungal isolates (8 hrs, Ref. 4-5).	
Pedagogy:	Laboratory experiments/ tutorials.	
References/ Readings:	1. Alexopoulus, C. J., Mims, C. W., & Blackwell, M. (2017). *Introductory mycology*. (Fourth Edition), New Delhi: John Wiley & Sons. 2. Mehrotra, R. S., & Aneja K. R., (1990). *An Introduction to Mycology*. New Delhi: Wiley Eastern Limited. 3. Borse, B. D., Bhat, J. D., Borse, K. N., Tuwar, N. S., & Pawar, N. S. (2012). *Marine fungi of India (Monograph)*, Panaji: Broadway Publishing House. 4. Dusengemungu, L., Kasali, G., Gwanama, C., & Ouma, K. O. (2020). Recent advances in biosorption of copper and cobalt by filamentous fungi, *Frontiers in Microbiology*, 11, 582016. 5. Lotlikar, N. P., Damare, S. R., Meena, R. M., Linsy, P., & Mascarenhas, B. (2018). Potential of marine-derived fungi to remove hexavalent chromium pollutant from culture broth. *Indian Journal of Microbiology*, 58(2), 182-192.	
Learning Outcome:	Apply the knowledge in fungal taxonomy, bioremediation and bioprospecting.	

Course Code: MMTE-513
Title of the Course: Marine Pollution and Monitoring
Number of Credits: 03

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	Introduce the students to various marine pollutants, their impact on marine ecosystems and humans.	
Content:	**Module I** Marine environment, pollutants, toxicity, point and non-point sources of pollution. Oil spills, tarballs, polyaromatic hydrocarbons, domestic sewage, agricultural waste, industrial discharge, thermal power plant discharge, pesticides, persistent organic pollutants, pharmaceuticals, personal care products, antibiotics, metals, metalloids, organo metals, radioactive waste. Deep-sea mining, marine debris – sources, constituents, derelict fishing gear, plastics/ microplastics, garbage patches in the oceans. **Module II** Eutrophication, biofouling and bioinvasion, biocorrosion. Bioaccumulation and biomagnification. Impact of pollutants on estuarine, mangroves, coastal and open ocean, coral reefs, phytoplankton, zooplankton, fish, shellfish. Effect of marine pollutants on productivity and humans: harmful algal blooms, Minamata and itai itai diseases.	15 hrs. 15 hrs.

	Module III Ocean health index, biomonitoring and bioremediation, genomics in marine monitoring, biosensors, biotracers. Remote sensing in pollution monitoring, marine pollution monitoring programs, marine environmental impact assessment.	15 hrs.
Pedagogy:	Lectures/tutorials/assignments/case studies.	
References/ Readings:	1. Satyanarayana, T., Johri, B., & Anil, T. (2012). *Microorganisms in environmental management.* Germany: Springer Dordrecht. 2. Judith, S.W. (2015). *Marine pollution: What everyone needs to know.* USA: Oxford University Press. 3. King, R. B., Sheldon, J. K., & Long, G. M. (2019). *Practical environmental bioremediation: The field guide.* Florida: CRC Press. 4. Kennish, M. J. (1997). *Practical handbook of estuarine and marine pollution.* CRC Press, Boca Raton. 5. Naik, M., & Dubey, S. K. (2017). *Marine pollution and microbial remediation.* India: Springer Publications. 6. Prince, R. C., & Atlas, R. M. (2016). Bioremediation of Marine Oil Spills. In: Steffan, R. (Eds.). *Consequences of microbial interactions with hydrocarbons, oils and lipids: biodegradation and bioremediation. Handbook of hydrocarbon and lipid microbiology,* Springer, Cham.	
Learning Outcomes:	1. Provides knowledge on how marine pollutants can affect marine organisms and humans. 2. Understanding of how marine pollution can be monitored using different tools and techniques.	

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Course Code: MMPE-514
Title of the Course: Marine Pollution and Monitoring Practical
Number of Credits: 01

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	Estimate the impact of pollutants from the marine microbes' environment	
Content:	**Module I** 1. Impact of lead/arsenic on marine microbes (6 hrs, Ref. 1). 2. Impact of naphthalene/anthracene on marine microbes (6 hrs, Ref. 1). 3. Determination of biochemical oxygen demand (6 hrs, Ref. 2). 4. Determination of chemical oxygen demand (6 hrs, Ref. 3). 5. Size classification of marine debris/plastic (6 hrs, Ref. 4).	30 hrs.
Pedogogy:	Laboratory experiments/ Field trips.	

References/ Readings:	1. Cappuccino, J. G., & Sherman, N. (1998). *Microbiology: A laboratory manual.* California: Benjamin/Cummings Science Publishing. 2. Martin, D. F. (1972*). Marine chemistry (01).* London: Academic Press. 3. Rice, E. W., & Bridgewater, L. (2012). *Standard methods for the examination of water and wastewater analysis* (Second Edition), Washington DC: American Public Health Association. 4. Kroon, F. J., Motti, C. E., Jensen, L. H., & Berry, K. L. (2018). Classification of marine microdebris: A review and case study on fish from the Great Barrier Reef, Australia. *Science Reports,* 8(1), 1-15.	
Learning Outcome:	Hands-on training to understand the impact of pollutants on marine microorganisms.	

Course Code: MMTE-515
Title of the Course: Marine Environment and Public Health
Number of Credits: 03

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

	Module III Bioinvasion, transport of pathogens through ballast water – impact, monitoring, rules and regulations. Quarantine, certification and import risk analysis. Application of health management protocols and biosecurity principles in aquaculture. Long-term strategies in health management. Advances in disease control and management. Principles of SPF/SPR. Biosecurity in aquaculture.	15 hrs.
Pedagogy:	Lectures/tutorials/assignments/self-study/case studies.	
References/ Readings:	1. Hester, R. E., & Harrison, R. M. (2011). *Marine pollution and human health, Vol. 33, Issues in environmental science and technology.* Royal Society of Chemistry. 2. Belkin, S., & Colwell, R. R. (2005). *Oceans and health: Pathogens in marine environment.* Springer Publishers. 3. Noga, E. J. (2010). Fish disease: Diagnosis and treatment. (Second Edition). Wiley-Blackwell Publishers. 4. Rheinheimer, G. (1985). *Aquatic microbiology.* (Third Edition). John Wiley Publishers. 5. Clark, R. B., Frid, C., & Attrill, M. (2001). *Marine pollution.* Oxford University Press. 6. Wedemeyer, G. A., Meyer, F. P., & Smith, L. (1976). *Environmental stress and fish diseases.* New Jersey: TFH Publications. 7. Buller, N. B., & Plumb, J. A. (2004). *Bacteria from fish and other aquatic animals: A practical identification manual.* CABI Publishing.	
Learning Outcomes:	1. Understanding the impact of marine pollutants and climate change on marine biota and humans. 2. Application of long-term strategies in public health management and understanding the advances in disease control in the marine environment.	

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Course Code: MMPE-516
Title of the Course: Marine Environment and Public Health Practical
Number of Credits: 01

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course focuses on protocols/ strategies for characterization of pathogenic organisms from the marine environment and for determining the efficacy of sanitizers used in aquaculture.	
Content:	**Module I** 1. Detection of different indicator and pathogenic organisms from marine environments such as *S. aureus, E. coli, V. cholerae, Salmonella, Shigella* by conventional and rapid methods (12 hrs, Ref. 1-3). 2. Characterization of pathogenic isolates - determination of salinity tolerance and antibiotic resistance profiles (10 hrs, Ref. 4-6).	30 hrs.

	3. Testing the efficacy of aquaculture sanitizer (phenol) (08 hrs, Ref. 7).	
Pedagogy:	Experiments in the laboratory.	
References/ Readings:	1. Griffin, D. W., Lipp, E. K., McLaughlin, M. R., & Rose, J. B. (2001). Marine recreation and public health microbiology: Quest for the ideal indicator: This article addresses the historic, recent, and future directions in microbiological water quality indicator research. *BioScience,* 51(10), 817-825. 2. *Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: World Health Organization.* (2022). Licence: CC BY-NC-SA 3.0 IGO. 3. Liu, C., Shi, C., Li, M., Wang, M., Ma, C., & Wang, Z. (2019). Rapid and simple detection of viable foodborne pathogen *Staphylococcus aureus. Frontiers in Chemistry,* 7, 124.	
	4. Ventosa, A., Nieto, J. J., & Oren, A. (1998). Biology of moderately halophilic aerobic bacteria. *Microbiology and Molecular Biology Reviews,* 62(2), 504-544. 5. Balouiri, M., Sadiki, M., & Ibnsouda, S. K. (2016). Methods for in vitro evaluating antimicrobial activity: A review. *Journal of Pharmaceutical Analysis,* 6(2), 71-79. 6. Schmidt, T. M. (2019). Encyclopedia of microbiology. (Fourth Edition), Academic Press. 7. Rideal, S., & Ainslie Walker, J. T. (1903). Standardisation of disinfectants. *Journal of the Sanitary Institute,* 24(3), 424-441.	
Learning Outcomes:	1. Students will learn to quantify and characterize bacterial pathogens and compare against relevant standard guidelines. 2. They will be familiarized with effective strategies for monitoring aquaculture systems.	

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Course Code: MMTE-517
Title of the Course: Polar Microbiology
Number of Credits: 03

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course highlights the unique characteristics of polar environments (the Arctic, Antarctic and the Southern Ocean), with emphasis on their microbial ecology, diversity, community interactions, and response to climate change.	
Content:	**Module I** Polar environments (Arctic, Antarctica, Southern Ocean), polar econiches (atmosphere, dry valleys, ornithogenic soils, permafrost, cryoconites, sea ice, glaciers, lakes). Microbial ecology. Strategies to isolate and characterize polar microorganisms. Biotechnological importance of polar microorganisms: psychroenzymes, anti-freeze proteins, novel antibiotics and other bioactive compounds.	15 hrs.

	Module II Microbial diversity and factors influencing microorganisms in polar environments: archaea – *Thaumarchaeota;* bacteria – *Glaciecola psychrophila, Pseudoalteromonas haloplanktis, Marinomonas primoryensis*; cyanobacteria – *Oscillatoria*; fungi and yeast – *Glaciozyma psychrophila*, and diatoms – *Fragilariopsis cylindrus*; cellular, structural and physiological characteristics, community interactions and food webs, biogeochemical cycling. Viruses in polar ecosystems. **Module III** The polar environment as a vulnerable ecosystem. Impact of anthropogenic pollutants and climate change on microbial communities. Effects of greenhouse gases, ozone depletion, global warming and ocean acidification on polar ecosystems. Melting of glaciers, intrusion of Atlantic waters into the Arctic region. The introduction, transport and fate of pollutants in polar environments: oil spills, microplastics, heavy metals, Persistent Organic Pollutants (POPs) xenobiotic compounds, acid rain, radioactive isotopes. Effects of iron fertilization on productivity and carbon export in the High-Nutrient-Low-Chlorophyll (HNLC) regions of the Southern Ocean and its impact on the Antarctic region.	15 hrs. 15 hrs.
Pedagogy:	Lectures/tutorials/assignments/self-study/case studies.	
References/ Readings:	1. Bathmann, U. (2005). Ecological and biogeochemical response of Antarctic ecosystems to iron fertilization and implications on global carbon cycle. *Ocean and Polar Research,* 27(2), 231-235. 2. Bej, A. K., Aislabie, J., & Atlas, R. M. (2009). *Polar Microbiology: The ecology, biodiversity and bioremediation potential of microorganisms in extremely cold environments.* CRC Press. 3. D'Amico, S., Collins, T., Marx, J. C., Feller, G., & Gerday, C. (2006). Psychrophilic microorganisms: challenges for life. *EMBO Reports,* 7(4), 385-389. 4. Duarte, C. M. (2008). *Impacts of global warming on polar ecosystem.* Fundacion BBVA. 5. Margesin, R., & Miteva, V. (2011). Diversity and ecology of psychrophilic microorganisms. *Research in Microbiology,* 162, 346-361. 6. Miller, R. V., & Whyte, L. G. (2014). *Polar Microbiology: Life in a deep freeze.* Washington DC: ASM Press. 7. Smetacek, V., & Nicol, S. (2005). Polar ocean ecosystems in a changing world. *Nature Insight Reviews,* 437, 362-368.	
Learning Outcomes:	1. The uniqueness of the polar environment. 2. To understand the sensitivity of polar environments to climate change and pollutants.	

Course Code: MMTE-518
Title of the Course: Deep Sea Microbiology
Number of Credits: 03

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course focuses on concepts in microbiology and ecology of the various habitats in deep marine environment.	
Content:	**Module I** The deep-sea environment. Basic and in-depth conceptualization of deep marine subsurface. Types of deep-sea habitats and resident microbiota, dark ocean biosphere/aphotic pelagic ocean habitats, trenches, ridges, habitats beneath the ocean water column, such as marine sediments, oceanic crust, abyssopelagic/abyssal, hadal plains, deep permafrost sediments. Antarctic Ocean and Southern Ocean deep environments. Marine deposits (sapropels, nodules). **Module II** Sampling equipment: deep sea sampling equipment, submersibles, remotely operated underwater vehicles. Techniques for collecting water and sediment samples, corers: gravity, piston and multiple corers (MUC), giant box corer (GBC); drilling techniques, MEBO sea floor drill rig. Culturing of deep sea microbes (piezophilic/ barophilic microorganisms). Introduction to anaerobic and pressure culture chambers/systems, techniques for isolation and culturing of deep sea microorganisms under *in situ* and simulated deep sea conditions. **Module III** Hydrothermal vents, metals at hydrothermal vents, food webs, chemosynthesis, microbial communities. Diversity of higher organisms including the tube worm *Riftia pachyptila,* sponges, corals. Cold seeps. Nutrient cycling.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/tutorials/assignments.	
References/ Readings:	1. Munn, C. (2011). *Marine microbiology: Ecology and applications*. (Second Edition), New York: Garland Science, Taylor and Francis Group. 2. Jorgensen, B. B., & Boetius, A. (2007). Feast and famine: microbial life in the deep sea bed. *Nature Reviews Microbiology*. 5, 770-781. 3. Nakagawa, S., & Takai, K., (2008). Deep-sea vent chemoautotrophs: diversity, biochemistry and ecological significance. *FEMS Microbial Ecology*. 68, 1-84. 4. Karl, D. M. (1995). *The microbiology of deep-sea hydrothermal vents.* New York: CRC Press.	

	5. Sharma, R. (2017). *Deep-sea mining resource potential, technical and environmental considerations*. Switzerland: Springer International Publishing. 6. Kallmeyer, J., & Wagner, D. (2012). *Microbial life of the deep biosphere*. De Gruyter. eISBN: 9783110300130. 7. Orcutt, B. N., Sylvan, J. B., Knab, N. J., Edwards, K. J. (2011). Microbial ecology of the dark ocean above, at, and below the seafloor. *Microbiology and Molecular Biology Reviews*, 75, 361-422. 8. Seibold, E., & Berger, W. (2017). *The sea floor : An introduction to marine geology*. (Fourth Edition), Switzerland: Springer International Publishing.	
Learning Outcome:	The students will be able to understand the deep sea environments, sampling techniques and their microbial life.	

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Course Code: MMTE-519
Title of the Course: Marine Microbial Toxins
Number of Credits: 01

Prerequisites:	Students should have undergone Part I Courses in their respective post-graduate disciplines.	
Objective:	This course helps students to understand the production, fate and commercial aspects of marine microbial biotoxins.	
Content:	**Module I** Marine microbial toxins: cholera toxin, botulinum toxin, saxitoxins, okadaic acid, dinophysistoxins, pectenotoxins, yessotoxin, brevetoxin, karlotoxins, ciguatoxins, domoic acid, azaspiracids, spirolides; structural diversity, biosynthetic pathways, biological functions, mechanisms of action, ecological role, biomagnification and biotransformation across trophic levels. Factors affecting toxin production. Syndromes caused by microbial toxins. Analytical methods for the detection of microbial toxins: bioassays, Liquid Chromatography – Mass Spectrometry, High Performance Liquid Chromatography (HPLC). Toxins in pharmacology.	15 hrs.
Pedagogy:	Lectures/tutorials/assignments/self-study/case-studies.	
References/ Readings:	1. Waters, A. L., Hill, R. T., Place, A. R., & Hamann, M. T. (2010). The expanding role of marine microbes in pharmaceutical development. *Current Opinion in Biotechnology,* 21(6), 780-786. 2. Santi Delia, A., Caruso, G., Melcarne, L., Caruso, G., Parisi, S., & Laganà, P. (2015). Biological toxins from marine and freshwater microalgae. In: *Microbial toxins and related contamination in the food industry*. Springer, Cham. 3. Lelong, A., Hegaret, H., Soudant, P., & Bates, S. S. (2012). *Pseudo-nitzschia* (Bacillariophyceae) species, domoic acid and amnesic	

	shellfish poisoning: revisiting previous paradigms. *Phycologia,* 51(2), 168-216. 4. McCallum, M. E., & Balskus, E. P. (2019). Enzymes that detoxify marine toxins. *Nature,* 570, 315-316. 5. Stonik, V. A., & Stonik, I. V. (2016). Toxins produced by marine microorganisms: A short review. In: Gopalakrishnakone, P. et al. (Eds.). *Marine and Freshwater Toxins, Toxinology.* DOI 10.1007/978-94-007-6419-4_2.	
Learning Outcome:	The students will get an insight into the mechanisms, fate, analytical methods and commercial aspects associated with marine microbial toxins.	

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Course Code: MMPE-520
Title of the Course: Scientific Writing Skills Practical
Number of Credits: 01

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

Course Code: MMTE-521
Title of the Course: Ocean Observations and Techniques
Number of Credits: 03

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Semester III Courses.	
Objective:	Introduce the students to analytical techniques and instrumentations used for oceanographic and remote sensing studies.	
Content:	**Module 1** Indian oceanographic research vessels and their facilities. Platform and Instruments: gliders, Argo, floats, acoustic doppler current profiler, current meters, radar, seawater samplers, Conductivity-Temperature-Depth (CTD), XBT plankton net, grab and corer, echosounder, SONAR, underwater robots and vehicles. **Module II** Confocal laser scanning microscopy for study of biofilms. Changes in redox potentials. Carbon measurement methods: CHNS elemental analyzer, total inorganic carbon by a coulometer, dissolved organic carbon using high-temperature combustion method, sediment traps (moored arrays/drifting traps). ^{234}Thorium as a tracer for POC export estimates, respiration measurements of plankton, fluorometric assessment of enzymatic activity using 4-Methylumbelliferyl (MUF) substrate. Genomic and metagenomics approaches. **Module III** Marine bio-optics, electromagnetic radiation, Photosynthetically Active Radiation (PAR), optical properties of seawater, ocean color, Chromophoric Dissolved Organic Matter (CDOM), polar-orbiting and geosynchronous satellites, satellites and sensors. Applications of remote sensing and societal benefits: primary productivity, sea surface temperature, salinity, wind speed and direction, ocean currents, ocean-atmosphere heat exchange, bloom dynamics, assessment of carbon reservoirs and fluxes, potential fishing zones. Pelagic and migratory fish. Species conservation.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/tutorials/assignments/self-study/case-studies.	
References/ Readings:	1. Andreas, S., & Brassington, G. B. (2011). *Operational oceanography in the 21st century.* Germany: Springer. 2. Jeffrey, S. W., & Vesk, M. (1997). Introduction to marine phytoplankton and their pigment signatures. In: *Phytoplankton pigments in oceanography.* Paris: UNESCO Publishing. 3. Martin, S. (2004). *An introduction to ocean remote sensing.* UK: Cambridge University Press. 4. Venkatesan, R., Tandon, A., D'Asaro, E.A., & Atmanand, M. A. (2018). *Observing the oceans in real time.* USA: Springer. 5. Munn, C. (2011). *Marine microbiology: Ecology & applications.* New York: Taylor Francis Group.	
Learning Outcome:	Understanding the ocean processes using different instruments and techniques.	

Course Code: MMPE-522
Title of the Course: Ocean Observations and Techniques Practical
Number of Credits: 01

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

Course Code: MMTE-523
Title of the Course: Microbial Remediation in Marine Ecosystems
Number of Credits: 02

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Semester III Courses.	
Objective:	This course focuses on the use of using marine microorganisms as a tool for remediation of diverse pollutants.	
Content:	**Module I** Concept of bioremediation, various strategies (bio-augmentation, bio-stimulation, co-metabolism, use of microbial consortia and genetically-modified microorganisms). Bioremediation of metals mediated by marine microbes: heavy metal resistant bacteria/fungi/archaea. Metal resistance mechanisms (efflux mechanism, intracellular bioaccumulation, extracellular sequestration and surface biosorption, bioprecipitation, biotransformation and redox reaction, volatilization).	15 hrs.

	Bioremediation of hydrocarbons in marine environments: oil spills/ tar ball management. Biodegradation – reactions, enzymes and pathways. Biosurfactants. **Module II** Biodegradation of Complex Polysaccharides (CPs) by marine microorganisms: algal waste, CP-degrading enzymes – agarase, alginate lyase, carragenase, cellulase, and their role in degradation. Biodegradation of seafood waste by microorganisms: seafood waste, calcium carbonate-solubilizing bacteria, phosphate-solubilizing bacteria; the role of chitinase and protease enzymes, use of microbial consortia, application of seafood waste for ethanol production. Bioremediation of xenobiotics and pollutants in hypersaline environments using Sulfate-Reducing Bacteria (SRB) and archaea: pollutants in hypersaline environments – metals, xenobiotics, remediation strategies involving SRB, application in remediation of industrial effluents.	15 hrs.
Pedagogy:	Lectures/tutorials/assignments.	
References/ Readings:	1. Satyanarayana, T., Johri, B., & Anil, T. (2012). *Microorganisms in environmental management.* Springer Publishers. 2. Prince, R. C., & Atlas, R. M. (2017). Bioremediation of marine oil spills. In: *Handbook of hydrocarbon and lipid microbiology.* Springer Publishers. 3. Judith, S.W. (2015). *Marine pollution: What everyone needs to know.* Oxford University Press. 4. Munn, C. B. (2020). *Marine microbiology: Ecology and applications.* (Third Edition), New York: Garland Science, Taylor and Francis Group. 5. King, R. B., Sheldon, J. K., & Long, G. M. (1997). *Practical environmental bioremediation: the field guide,* Lewis Publishers. 6. Kennish, M. J. (1996). *Practical handbook of estuarine and marine pollution.* CRC Press, Francis and Taylor. 7. Naik, M., & Dubey, S. K. (2017). *Marine pollution and microbial remediation.* Springer Publications. 8. Meena, S. N., & Naik, M. M. (2019). *Advances in biological sciences research.* Elsevier Publications.	
Learning Outcome:	Application of marine microorganisms towards pollution abatement.	

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Course Code: MMPE-524
Title of the Course: Microbial Remediation in Marine Ecosystems Practical

Number of Credits: 01

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

Course Code: MMTE-525
Title of the Course: Bioinformatics in Marine Microbiology
Number of Credits: 02

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Semester III Courses.	
Objective:	To understand the basics of bioinformatics and learn to analyse phylogeny and metagenomics data for diversity studies.	
Content:	**Module I** Introduction to microbiome research. Data mining – DNA sequence assembly and annotation of genes. Types of User Interface (CUI, GUI). Biological Databases and search tools. Sequence alignment: Pairwise, Multiple. Similarity and homology of sequences. Orthologs, paralogs, analogs. Sequence alignment tools. Similarity and distance, similarity scores, weight matrices, Heuristic method, Hidden Markov Models. Gene annotation, phylogenetics: gene phylogeny versus species phylogeny. Sequence-based classification and identification, Operational Taxonomic Units, rooted and unrooted trees. Approaches	15 hrs.

	in phylogenetic analysis – phenetic, cladistic, evolutionary systematic approach. Methods in tree construction – distance-based methods (UPGMA, NJ, ME), character-based methods (MP, ML). **Module II** Metagenomics: 16S rRNA amplicon sequencing for metagenomics or targeted metagenomics pipelines to analyse the raw data generated from next generation platforms. Quality check and filtering of sequences, pairing of reads, grouping of reads into OTUs or/and Amplicon Sequence Variants (ASVs). Databases for taxonomic identification. Alignment of OTUs, α-(within group) and β-diversity (between groups) comparison. Full Shotgun DNA metagenomics – de-multiplexing of raw reads, quality check, conversion to FASTQ format files, QIIME/QIIME2, clustering into OTUs, assigning taxonomy to the clusters, Prokka, metAMOS. Introduction to predictive functional analyses and tools for visualization.	15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments/ interactive learning.	
References/ Readings:	1. Lesk, A. M. (2005). *Introduction to bioinformatics.* Oxford University Press. 2. Jean-Michel, C. (2005). *Bioinformatics: a beginner's guide*. India: Wiley Dreamtech. 3. Shanmughavel, P. (2005). *Principles of bioinformatics*. Jaipur: Pointer Publishers. 4. Jeremy, J. R., (2004). *Bioinformatics: an introduction*. India: Springer Publishers. 5. Rastogi, C. (2004). *Bioinformatics: concepts, skills & applications.* New Delhi: CBS Publishers. 6. Mount, D. (2000). *Bioinformatics: sequence and genome analysis*. New York: Cold Spring Harbor Laboratory Press. 7. Baxevanis, A. (2001). *Bioinformatics: a practical guide to the analysis of genes and proteins*. New York: John Wiley & Sons. 8. Srinivas, V.R. (2005). *Bioinformatics: a modern approach*. New Delhi: Prentice Hall of India. 9. Ignacimuthu, S. (2008). *Basic bioinformatics.* New Delhi: Narosa Publishing House. 10. Khan, I.A. (2005). *Elementary bioinformatics*. Hyderabad: Pharma Book Syndicate.	
Learning Outcomes:	1. Students will be able to use bioinformatics tools in research. 2. Apply the knowledge for phylogenetic and metagenomics work in studying microbial diversity.	

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Course Code: MMPE-526
Title of the Course: Bioinformatics in Marine Microbiology Practical
Number of Credits: 01

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Semester III Courses.	
Objective:	To understand database search, sequence-based identification and phylogenetic tree construction for evolutionary studies.	
Content:	**Module I** 1. NCBI search tool, nBLAST (2 hrs, Ref. 1-6). 2. Downloading type sequences, creating FASTA files for alignment, sequence alignment (2 hrs, Ref. 1-6). 3. Construction of phylogenetic trees (4 hrs, Ref. 1-6). 4. Introduction to Galaxy workflow (10 hrs, Ref. 7-10). 5. QIIME2 workflow (12 hrs, Ref. 7-10).	30 hrs.
Pedagogy:	Experiments/ videos/ tutorials in the laboratory.	
References/ Readings:	1. Lesk, A. M. (2005). *Introduction to bioinformatics.* Oxford University Press. 2. Jean-Michel, C. (2005). *Bioinformatics: a beginner's guide*. India: Wiley Dreamtech. 3. Jeremy, J. R., (2004). *Bioinformatics: an introduction*. India: Springer Publishers. 4. Mount, D. (2000). *Bioinformatics: sequence and genome analysis*. New York: Cold Spring Harbor Laboratory Press. 5. Baxevanis, A. (2001). *Bioinformatics: a practical guide to the analysis of genes and proteins*. New York: John Wiley & Sons. 6. Ignacimuthu, S. (2008). *Basic bioinformatics.* New Delhi: Narosa Publishing House. 7. Greenwald, W. W., Klitgord, N., Seguritan, V., Yooseph, S., Venter, J. C., Gamer, C., Nelson, K.E., & Li, W. (2017). Utilization of defined microbial communities enables effective evaluation of meta-genomic assemblies. *BMC Genomics*, 18, 296. 8. Sczyrba, A. *et al.* (2017). Critical assessment of metagenome interpretation – a benchmark of computational metagenomics software. *Nature Methods,* 14(11), 1063-1073. 9. Vollmers, J., Wiegand, S., & Kaaster, A-K. (2017). Comparing and evaluating metagenome assembly tools from a microbiologist's perspective – not only size matters! *PloS One*, 12 (1), e0169662. 10. Hiltemann, S. D., Boers, S. A., van der Spek, P. J., Jansen, R., Hays, J. P., & Stubbs, A. P. (2019). Galaxy mothur toolset (GmT): a user-friendly application for 16S rRNA gene sequencing analysis using mothur. *GigaScience*, 8, 1-5.	
Learning Outcome:	Students will be able to gain working knowledge of computational tools and methods for phylogenetic and metagenomics work in studying microbial diversity.	

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Course Code: MMTE-527

Title of the Course: Nanotechnology
Number of Credits: 02

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

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Course Code: MMPE-528
Title of the Course: Nanotechnology Practical
Number of Credits: 01

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Semester III Courses.

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

Course Code: MMTE-529
Title of the Course: Blue Economy
Number of Credits: 01

Prerequisites:	Students should have undergone M.Sc. Marine Microbiology Semester III Courses.	
Objective:	To create awareness of global and national stand on blue economy, its economic and ecological significance.	
Content:	**Module I** Introduction to blue economy: Rio +20 summit, definition, importance and implications. Framework for sustainable development. International legal framework for fisheries. Small Islands Development States (SIDS). Climate change impact. Indian Ocean Rim Association (IORA) Blue carbon hub (mangroves, tidal marshes, sea grasses). Blue economy: issues and opportunities. Indian's blue economy policy	15 hrs.

	framework. National Fisheries Development Board (NFDB) schemes and blue revolution. Potential of blue economy in Indian Ocean: fish production, deep sea minerals and trade benefits.	
Pedagogy:	Lectures/ tutorials/ assignments/ self-study.	
References/ Readings:	1. Morgan, P. J., Huang, M. C., Voyer, M., Benzaken, D., & Watanabe, A. (2022). *Blue economy and blue finance toward sustainable development and ocean governance.* ISBN 978-4-89974-252-4. https://doi.org/10.56506/HDLZ1912. 2. Blue economy policy - https://incois.gov.in/documents/Blue_Economy_policy.pdf 3. Diez, S. M., Patil, P. G., Morton, J., Rodriguez, D. J., Vanzella, A., Robin, D., Maes, T., & Corbin, C. (2019). *Marine pollution in the Caribbean: Not a minute to waste.* Washington DC: World Bank Group. 4. http://documents.worldbank.org/curated/en/482391554225185720/pdf/Marine-Pollution-in-the-Caribbean-Not-a-Minute-to-Waste.pdf 5. NFDB Schemes & blue revolution – Inland fisheries schemes. National Fisheries Development Board. http://nfdb.gov.in.	
Learning Outcome:	Students will gain knowledge and understanding of blue economy and its significance.	

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Course Code: MMTE-530
Title of the Course: Probiotics and Prebiotics in Aquaculture
Number of Credits: 01

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

Learning Outcome:	Students will be acquainted with the different probiotics and their importance in aquaculture.	

Course Code: MMTE-531
Title of the Course: Marine Drug Development and Metabolism
Number of Credits: 01

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

	8. Differding, E. (2017). The drug discovery and development industry in India – two decades of proprietary small-molecule R&D. *ChemMedChem Reviews*. 12, 786-818. *doi:10.1002/cmdc.201700043.*	
Learning Outcome:	Understanding of drug discovery, development and metabolism.	

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Annexure II

Course Code: MMRM-XXX
Title of the Course: Research Methodology – Marine Microbiology (Ph.D.)
Number of Credits: 04

Prerequisites:	Provisional Ph.D. registration in Marine Microbiology.	
Objective:	To provide knowledge on basic and advanced methods to conduct research in the area of marine microbiology.	
Content:	**Module I** Selection of research topic. Literature survey. Research methods in marine microbiology. Procedures and protocols followed in collection of water, sediment and other types of samples for analysis. Pre-treatment and preservation methods. On-board/on-site measurement of parameters.	15 hrs.
	Module II Experimentation in the laboratory. Experimental design. Pilot studies. Good Microbiological Practices (GMP). Techniques for isolation and culturing of microorganisms. Knowledge of instruments used in marine microbiology. Errors in analytical measurements, accuracy, precision and validation of analytical data. Calibration of instruments. Reference standard materials. Documentation and record keeping.	15 hrs.
	Module III Statistical tools and softwares used in data processing. Presentation and manuscript writing skills. Different types of manuscripts: short communication, research articles, review articles. Citation of references. Reference managers like ENDNOTE and MENDELEY. Standard reference citation styles. Plagiarism check softwares.	15 hrs.
	Module IV Safety practices in the laboratory. Biosafety levels and practices. Handling of hazardous chemicals and gases. Disposal of chemical and biological waste. Fire safety protocols and first aid measures.	15 hrs.

Pedagogy:	Lectures/tutorials/assignments/self-study/case-studies.	
References/ Readings:	1. Grinnel, F. (1992). *The scientific attitude.* New York: The Guilford Press. 2. Marsh, B. (2003). *The Chicago guide to communicating science.* Chicago: University of Chicago Press. 3. Grasshoff. K., Ehrhardt, M., & Kremling, K. (Eds.). (1983). *Methods of seawater analysis.* (Second Edition), Verlag Chemie. 4. Sokal, R. R., & Rohlf, F. J. (1981). *Biometry.* San Francisco: Freeman & Company. 5. Morrison, D. F. (1990). *Multivariate statistical methods.* Singapore: McGraw-Hill Education.	
Learning Outcome:	The students will be able to employ various methods and techniques to independently address research problems in the area of marine microbiology.	

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