2024

Appendix - III (B)

M.Tech.in Marine Biotechnology

Curriculum

To ignite young talented minds having strong foundation in Science to take up major challenges which human race faces and to find practical solutions through marine biotechnological interventions

SPONSOED BY THE DEPARTMENT OF BIOTECHNOLOGY
GOVERNMENT OF INDIA

NATIONAL CENTRE FOR AQUATIC ANIMAL HEALTH
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
LAKESIDE CAMPUS
FINE ARTS AVENUE
COCHIN -682016

M. Tech. Marine Biotechnology

The M.Tech. programme in Marine Biotechnology sponsored by Department of Biotechnology, Government of India is a unique educational programme in its kind in India

Programme Outcome

To ignite young talented minds having strong foundation in Science to take up major challenges which human race faces and to find practical solutions through marine biotechnological interventions to address the following challenges:

1. *Food and nutritional security through enhancement of marine/aquatic food production through intensive aquaculture*
2. *Depleting fuel stock and requirement of next generation fuel (Bio-fuel) for next generation human race*
3. *Climate change and need of its reversal for survival*
4. *Human and animal health related issues and requirement of next generation pharmaceuticals with least or no side effects*

Over above three decades, Government of India has been supporting infrastructure development and research in focused areas of Marine Biotechnology to develop novel processes and products aiming at enhancement of marine biotech industrial processes, biomedical material development, environment management and intensive aquaculture production. In any such movement, appropriate manpower with the right mind set is a vital component, and to satisfy this requirement the M.Tech. programme in Marine Biotechnology has been conceptualized. The curriculum has been built with the global concept of education 'Find Solutions to the Human Problems in Class Rooms'. Through this programme we look forward to generate Academicians, Scientists, Technocrats, Entrepreneurs and Planners to address the above cited issues and to find appropriate solutions. Accordingly, the curriculum has been formulated with a programme specific outcome to generate professionals in 1. Aquatic Animal Health Management, 2. Marine Algal Biotechnology, 3. Marine Pharmacology, 4. Marine Bioprocess Engineering and 5. Genetic Improvement in Aquaculture.

The programme is offered at National Centre for Aquatic Animal Health, Cochin University of Science and Technology under the supervision of an Advisory Board having Vice Chancellor as the patron and a Placement and Biotechnology Entrepreneurship Committee to ensure the placement of students desirous to work in Industries or provide handholding support to students desirous to start their own enterprise/start-ups under different schemes of Central/State Government, both constituted by the University as per the directives of DBT.

Admission to the programme is through qualifying Graduate Aptitude Test in Biotechnology (GAT-B), conducted by National Testing Agency on behalf of the Regional Centre for Biotechnology, Faridabad for the Department of Biotechnology, Government of India. This examination is to rank the eligibility of the candidate among all applicants during the year, and the candidates will be given a GAT-B rank based on which they may apply to M. Tech. programme in Marine Biotechnology.

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Scheme of Examination in M. Tech. in Marine Biotechnology

Duration of the course 4 semesters

Eligibility:

Minimum 60% marks or equivalent CGPA (under grading system) from any recognized university in any one of the following.

Candidates with minimum 60% marks or equivalent CGPA (under grading system) from any recognized university in B.Tech. or BE in Biotechnology/ M.Sc in any branch of Life Sciences including Marine Biology with a qualifying score in Graduate Aptitude Test in Biotechnology (GAT-B) conducted by National Testing Agency on behalf of Department of Biotechnology, Government of India are eligible to apply for admission to the M. Tech. Marine Biotechnology programme.

Accumulated minimum credits required for successful completion of the programme - **80**

Semester 1

Course Code and Title	Instruction		Evaluation		Total
Theory	C/ E	Credits	Continuous assessment	Semester End Examination	
Theory (Core)					
24-431-0101 Biotechnological Interventions in Marine Biodiversity Conservation	C	2	50	50	100
24-431-0102 Marine Genomics and Proteomics	C	3	50	50	100
24-431-0103 Introduction to marine pharmacology	C	3	50	50	100
24-431-0104 Bioprocess Engineering	C	3	50	50	100
Theory (Elective)					
Elective 1	E	2	50	50	100
Elective 2	E	2	50	50	100

Elective 3	E	3	50	50	100
Lab (Skill Development)					
24-431-0105 Skill Development in Recombinant DNA Technology	C	2	50	50	100
24-431-0106 Skill Development in Marine Microbial Diversity Determination	C	2	50	50	100
24-431-0107 Skill Development in Cell culture and hybridoma/Antibody Technology	C	1	50	50	50

Core: 16 Credits; Elective: 7; Credits; Total: 23

Semester 2

Course Code and Title	**Instruction**		**Evaluation**		**Total**
Theory	**C/ E**	**Credits**	**Continuous assessment**	**Semester End Examination**	
Theory (Core)					
24-431-0201 Biotechnological interventions in Aquatic Animal Health	C	3	50	50	100
24-431-0202 Marine Bioprocess Engineering	C	3	50	50	100
24-431-0203 Marine Algal Biotechnology	C	3	50	50	100
24-431-0204 Genetic Improvement for High health brood stock	C	3	50	50	100
Theory (Elective)					
Elective 1	E	2	50	50	100
Elective 2	E	2	50	50	100
Elective 3 MOOC Course	E	2		100	100

Lab (Skill Development)					
24-431-0205 Skill Development in Biotechnological Interventions in Aquatic Animal Health Management	C	2	50	50	100
24-431-0206 Skill Development in Maine Pharmacology	C	1	50	50	100
24-431-0207 Skill Development in Maine Bioprocess Engineering.	C	1	50	50	100
24-431-0208 Skill Development in Model systems, Molecular genetics and Genome engineering	C	1	50	50	100
24-431-0209 Skill development in marine algal biotechnology	C	1	50	50	100
Lab Elective	E	1	50	50	100

Core: 18 Credits; Elective: 7 Credits; Total: 25 credits

Note: As per the University regulations, it is mandatory for the students to undertake one MOOC Course approved by the Departmental Council.

Semester 3

Course Code and Title	**Instruction**		**Evaluation**		**Total**
Theory	**C/ E**	**Credits**	**Continuous assessment**	**Semester End Examination**	
24-431-0301 Bioentrepreneusrhip and industry management	C	2	50	50	100
24-431-0302 Research Methodology and Scientific Communication	C	2	50	50	100

24-431-0303 Intellectual Property Rights, Biosafety and Bioethics	C	2	50	50	100
24-431-0304 Project proposal preparation and submission	C	2	50	50	100
Research Project	**C/E**	**Credits**	**Assessment by the Research Guide**	**Assessment by the Examination Committee**	**Total**
24-431-0305 Research Project Progress Review and Viva Voce Examination in the area of specialization	C	10	50	50	100
Skill Development Programme (continuous evaluation) (Any one of the programmes per student)					
Elective 1	E	5	50	50	100
Elective 2	E	5	50	50	100
Elective 3	E	5	50	50	100
Elective 4	E	5	50	50	100
Elective 5	E	5	50	50	100

Core: 18; Elective:5; Total : 23 credits

Optional

Course	C/ E	Credits	**Continuous assessment**	**Semester End Examination**	
MOOC Course/ Interdisciplinary Elective to be opted from other Departments	E	2	-	100	100

As part of choice based credit system, a student can opt for an interdisciplinary elective course offered by other Departments in the University.

Semester 4

Course Code and Title	**Instruction**		**Evaluation**		
	C / E	**Credits**	**Assessment by the Research Guide***	**Assessment by the Examination Committee**	**Total**

24-431-0401 Research Project - Report Submission and Presentation and Comprehensive Course Viva	C	18	50	50	100

**Based on periodic assessment of the work of the candidate*

Core: 18 credits

List of Elective Courses

24-431-0108 Cell and Hybridoma Technology

24-431-0109 Marine Microbiology

24-431-0110 Bioinformatics, Systems and Computational Biology

24-431-0111 Nano-biotechnology

24-431-0210 Model Systems, Molecular Genetics and Genome Engineering for Stock Improvement

24-431-0211 Marine Pharmacology in Practice

24-431-0212 Enzyme Engineering & Technology

20-431-0213. Skill Development in Marine Animals Handling and Maintenance

Elective: MOOC Course

24-431-0306 Marine Pharma Industry Development

24-431-0307 Genetic Improvement in Aquaculture

24-431-0308 Marine Algal Biotechnology for Industrial Applications

24-431-0309 Aquatic Animal Health Management

20-431-0310 Marine Bioprocess Industry Development

20-431-0311 Products and services of oceans (Inter Departmental Elective Offered for other Departments)

M.Tech. Marine Biotechnology Programme

Total credits: 89 (Core: 70 Elective: 19)

Semester 1: 23; Semester 2: 25; Semester 3: 23; Semester 4: 18.

General regulations to be known by students:

1. A student shall acquire a minimum of 36 credits in the first and second semesters before he/she registers for third semester.
2. The minimum number of credits to be earned by a student for the award of the M.Tech. degree shall be 80 subject to the condition that the candidate successfully completes all the core and elective courses prescribed by the Centre
3. Minimum attendance required: 75%
4. A student shall register and complete at least one online course as one of the Electives.
5. Interdepartmental elective is optional.
6. The pass minimum in a subject is 50 %, with a separate minimum of 45% for end semester examination.

Grading Scale

Range of Marks	Grade	Weightage
Below 50%	F- Failed	0
50-59	D- Satisfactory	6
60-69	C- Good	7
70-79	B - Very Good	8
80-89	A - Excellent	9
90 and above	S - Outstanding	10

Overall performance at the end of the semester will be indicated by Grade Pont Average (GPA) calculated as follows:

$$GPA = \frac{G_1C_1+G_2C_2+G_3C_3+ \ldots\ldots\ldots\ldots G_nC_n}{C_1+C_2+C_3+ \ldots\ldots\ldots\ldots\ldots\ldots C_n}$$

where 'G' refers to the grade weightage and 'C' refers to the credit value of corresponding course undergone by the student.

At the end of the final semester Cumulative Grade Point Average (CGPA) will be calculated based on the above formula.

Classification for the Degree (M.Tech.) will be as follows

Classification	CGPA
First Class with distinction	**8 and above**
First Class	**6.5 and above**
Second Class	**6 and above**

Declaration of Results

The final marks will be reported to the University for tabulation and declaration of results. The University shall issue mark list at the end of each semester.

Syllabi of M.Tech. Marine Biotechnology Programme

Programme Outcome (PO)

To ignite young talented minds having strong foundation in Science to take up major challenges which human race faces and to find practical solutions through marine biotechnological interventions to address the following challenges:

1. Food and nutritional security through enhancement of marine/aquatic food production through intensive aquaculture
2. Depleting fuel stock and requirement of next generation fuel (Bio-fuel) for next generation human race
3. Climate change and need of its reversal for survival
4. Human and animal health related issues and requirement of next generation pharmaceuticals with least or no side effects

Programme Specific Outcome (PSO)

To generate professionals in:

PSO1. Aquatic Animal Health Management,

PSO2. Marine Algal Biotechnology,

PSO3. Marine Pharmacology,

PSO4. Marine Bioprocess Engineering and

PSO5. Genetic Improvement in Aquaculture.

SEMESTER I (TOTAL CREDITS: 23)

Theory (Core)

24-431-0101. BIOTECHNOLOGICAL INTERVENTIONS IN MARINE BIODIVERSITY CONSERVATION - 2 credits

Course Objectives

To give an overview of marine environment and its living and nonliving resources in support of marine biotechnology and marine biodiversity conservation as foundation course

Course Outcomes (CO)

Upon successful completion of this course, students should be able to:

Course Outcome		Cognitive Level
CO 1	Explain the fundamentals of oceanography	Understand
CO 2	Discuss marine biodiversity and marine ecology	Understand
CO 3	Identify marine pollution	Understand
CO 4	Explain the impacts of climate change on marine biodiversity	Understand
CO 5	Describe various measures for biodiversity conservation	Understand
CO 6	Application of the biotechnological measures for protecting the marine biodiversity	Apply

PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	-	-	-	-	-
CO2	2	2	2	2	2
CO3	1	1	1	1	1
CO4	2	2	2	2	2
CO5	3	3	3	3	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit 1: Fundamentals of Oceanography: Physical Oceanography: Seawater and its properties; Air-Sea interaction; Large scale circulation of upper ocean; Tides, Waves, Currents, Ocean circulation and Monsoon; Chemical Oceanography: composition of sea water, elemental and nutrient cycles, salinity & chemical transformations, Gas solubility; inorganic Characteristics of Seawater; Biological Oceanography: Living organisms of ocean: physical parameters & their effects on organisms; characteristics of organisms living in water column; Marine geology, Characterization of Marine Sediments - Constituents, Mass properties, Texture.

Unit II. Marine biodiversity and ecology: Classification of marine environment, Types of aquatic habitats, Diversity and taxonomy of marine organisms, Species abundance, richness and diversity indices, Recruitment, Growth, Mortality, Habitat preferences, Adaptations in marine organisms

and energy transfer, Marine food pyramid, primary production, marine micro and macroalgae – diversity and photosynthetic efficiency; secondary production, productivity distribution in ocean environment, Mechanisms and factors affecting primary production, Tertiary production, Nutrient cycles. Ecology of benthic organisms, Benthic biological processes and benthic biodiversity, Benthic-pelagic coupling. Marine bioresource and blue economy.

Unit III: Marine Pollution and **Climate change impacts on marine biodiversity**: Major marine Pollutants, emerging contaminants, Fate of pollutants in the seas; impact of pollutants on marine life- plankton, nekton, benthos, coral, rooted plants, marine birds and mammals; laws pertaining to protection of marine environment and conservation. Climate change **i**mpacts across different levels of biological organization, Ecosystem level changes due to climate change, Effects on coastal ecosystems, Coastal hypoxia, Coral reef ecosystems, Pelagic and benthic ecosystems, Harmful algal blooms, Spread of pathogens, Climate change on aquaculture, marine bio-invasions. Climate change and loss of marine ecosystem services. Coupled effects of climate change and marine pollution.

Unit IV. Biodiversity and conservation of aquatic species: Marine living resources assessment - Principal methods of utilization of marine living resources, Development of novel methods for optimisation of marine aquaculture; Influencing Factors, Planning and management; IUCN criteria-Red List; Wildlife protection Act; International Treaties & conventions;; Biological Diversity Act and Rules of India; Coastal Zone Management; CRZ, Coastal Aquaculture Act; Fisheries Act; Fisheries Policies and Guidelines; Whaling; fishing ban and its significance, responsible fishing; *in situ* and *ex situ* conservation; Marine Protected Areas; Cryopreservation of Gametes or Gene Banking; Molecular Tools in Conservation of Fisheries Resources: Molecular Markers: development of RAPD, *RFLP*, AFLP, ESTs, SNPs, and micro-satellites.

Unit V: Biotechnological interventions in marine biodiversity conservation: Carbon sequestration and marine biofuel production, Management of microbial nutrient biogeochemical cycling through marine quorum quenching molecules, Aquaculture food production coupled with carbon sequestration and nutrient management, Nutrient management coupled with carbon sequestration n coastal ecosystems, Coral community interactions at molecular level and coral engineering and replantation Biodiversity assessment through molecular methods, Census of marine life, Marine metagenomics and microbial diversity assessment. Functional genomics and new generation tools in biodiversity assessment, Reversal of trophic mismatch through biotechnological interventions. Marine biodiversity and resilience. Identification of genes involved in climate adaptation across marine phyla, Genomics and synthetic biology in marine biodiversity conservation. Conservation genomics.

Recommended text books and references:

1. Carl E. Bond, (1996) Biology of Fishes, 2nd Edition, W.B. Saunders Company, Philadelphia
2. Miller RI, (1994) Mapping the Diversity of Nature, Chapman &HaIl. pp. 218
3. Heywood V.H., (1995) Global Biodiversity Assessment. UNEP, Cambridge University Press PP. 1140
4. Levitus, (2000) Warming the World Ocean, Science
5. Kortzinger, (2004) The Ocean Takes a Breath, Science
6. King, M., (1995). Fisheries Biology: Assessment and Management, Fishing News Books.
7. Agarwal et. al.,(1996). Biodiversity and Environment. APH, pp 351
8. Naskar K. and Mandal R., (1999) Ecology and Biodiversity of Indian Mangroves. Daya. pp 361
9. Jeffrey S. Levinton, CD (2001). Marine Biology: Function, Biodiversity, Ecology (515pp)
10. Artikeya, K., (2005) *Biodiversity: Extinction and Conservation*, (202pp).
11. Jibson R.N. Barnes M. and Atkinson R.J.A. 2002. Oceanography and Marine Biology. Taylor and Francis. 704p.
12. Jhingran, V.G., 1971. Fish and fisheries of India. Hindustan Publishing Corporation of India, Delhi
13. Levinton J.S. 1995. Marine Biology. Function, Biodiversity, Ecology. Oxford University Press Inc., Oxford. 420 p.
14. Meller G. 1996. Introduction to Physical Oceanography. Springer, New York. 284p.
15. Nybakken J.W. 1997. Marine Biology. An Ecological Approach. Addison-Wesley Educational Publishers Inc., California. 481p.
16. Pickard, G.L. and Emery W.J. 1990. Descriptive Physical Oceanography. Elsevier, 336p.
17. Smith, T.B. and Wayne, R.K. 1996 Molecular approaches in conservation, Oxford University Press, US
18. Steven Emerson and John Hedges.2008. Chemical Oceanography and the Marine Carbon Cycle. Cambridge Press. ISBN: 9780521833134
19. http://www.biodiv.org/default.shtml
20. http://www.dnabarcodes.org
21. http://www.coml.org
22. Martin Solan, Rebecca J. Aspden, David M. Paterson. 2012. Marine Biodiversity and Ecosystem Functioning: Frameworks, Methodologies, and Integration. Oxford University Press.
23. K.E. Cooksey. 2012. Molecular Approaches to the Study of the Ocean. Springer Science & Business Media.
24. Alasdair McIntyre. 2011. Life in the World's Oceans: Diversity, Distribution, and Abundance. John Wiley & Sons.

24-431-0102. MARINE GENOMICS AND PROTEOMICS- 3 credits

Course objective:

The objective of this course is to impart a comprehensive knowledge on tools and techniques used in molecular biology and genetic engineering, genomics and proteomics for application in marine genomics and proteomics.

Course Outcomes

On the successful completion of the course, students will be able to

Course Outcomes		Cognitive Level
CO 1	Explain basic techniques and tools used in molecular biology	Understand
CO 2	Classify different types of vectors and cloning techniques used in genetic engineering for application in marine biotechnology for the production of novel proteins.	Apply
CO 3	Apply different tools used in genomics	Apply
CO 4	Analyse genome of marine organisms	Analyze
CO 5	Application of the methods of functional genomics in marine biological systems.	Apply
CO 6	Application of various experimental tools in marine proteomics.	Apply

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	2	2	2
CO2	3	3	3	3	3
CO3	3	3	3	3	3
CO4	3	3	3	3	3
CO5	3	3	3	3	3
CO6	3	3	3	3	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit 1. Tools and techniques in molecular biology: Preparation and analysis of DNA from prokaryotes, eukaryotes and environmental samples; Enzymes for DNA manipulation - Restriction Enzymes, DNA ligase, Klenow enzyme, T4 DNA polymerase, Polynucleotide kinase, Alkaline phosphatase, Principles of PCR, Types of PCR;Cloning of PCR products- T-vectors; Proof reading enzymes; PCR in gene recombination; Deletion; addition; Overlap extension; and SOEing; PCR based mutagenesis; PCR in molecular diagnostics; Mutation detection, Rapid amplification of cDNA ends (RACE).

Unit II: Tools and techniques in genetic engineering: Cloning vectors: Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors; Phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids;

Artificial chromosome vectors (YACs; BACs); Animal Virus derived vectors- SV-40, vaccinia/bacculo and retroviral vectors; Expression vectors; pMal; GST; pET- based vectors; Intein-based vectors; Inclusion bodies; Methodologies to reduce formation of inclusion bodies; Baculovirus and Pichia vectors system; Plant based vectors- Ti and Ri as vectors; Yeast vectors; Shuttle vectors. Microalgal vectors, Techniques in cloning :Restriction and DNA Ligation- Cohesive and blunt end ligation, Linkers, adapters, homopolymer tailing, Transformation in Bacteria, Yeasts and fungi, Plants, Mammalian cells. Expression cloning; Recombinant protein purification- His-tag; GST-tag; MBP-tag; Principles in maximizing gene expression; cDNA and genomic libraries- construction and screening.

Unit III Basics of genomics: Brief overview of prokaryotic and eukaryotic genome organization; Genome mapping methods (genetic and physical); RAPD , RFLP, SNP analyses; Fluorescence *in-situ* Hybridization (FISH) techniques; Advances in gene finding and functional prediction; Chain termination and chemical degradation sequencing methods. Genome-wide association (GWA) analysis; Comparative Genomic Hybridization(CGH); Massively parallel Signature Sequencing (MPSS); Whole genome shot-gun sequencing and its applications; Introduction of Next Generation Sequencing (NGS), Nanopore sequencing. Genome sequencing projects of marine organisms -accessing and retrieving genome project information from the web. Epigenomics

Unit IV Comparative genomics: Identification and classification of organisms using molecular markers- 16S rRNA gene typing/sequencing, SNPs; use of genomes to understand the evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence. Comparative genomics of marine organisms and algae.

Unit V: Functional genomics and proteomics: Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in the genome, gene function- forward and reverse genetics, gene ethics; Marine genomics and metagenomics; protein-protein and protein-DNA interactions; protein chips and functional proteomics; applications of proteomics; introduction to metabolomics, lipidomics, and systems biology. Introduction to metabolic engineering,

Unit VI : Proteomics and methods in proteomics: Over-view of strategies used for the identification and analysis of proteins; Protein extraction from biological samples, (Mammalian Tissues, Yeast, Bacteria, and Plant Tissues); 2-DE of proteins for proteome analysis; Liquid chromatography separations in proteomics (Affinity, Ion Exchange, Reversed-phase, and size exclusion); Enzymatic cleavage of proteins. Analysis of complex protein mixtures using Nano-liquid chromatography (Nano-LC) coupled to Mass-spectrometry analysis. Common ionization methods for peptide/protein analysis; Introduction to Mass spectrometers; MALDI-TOF and LC-MS analyses; Comparative proteomics based on global in-vitro and in-vivo labelling of

proteins/peptides followed by Mass-spectrometry. Analysis of post-translational modification (PTM) of proteins; Characterization of protein interactions using yeast two-hybrid system and Protein microarrays; Proteomics informatics and analysis of protein functions. Marine Proteomics.

Recommended text books and references:

1. Ausbel, F.M., Brent, R., Kingston, RE, Moore, DD, Seidman, JG, Smith, JA, Struhl, K. 2002. Short protocols in molecular biology. Vol 1 and II. John Wiley and Sons Inc.
2. Brown T.A. 2000. Essential Molecular Biology: Vol. 1, A Practical Approach. Oxford University Press, Oxford. 264p.
3. Brown TA, Genomes, 3rd ed. Garland Science 2007
4. Brown, T.A. 2001. Gene Cloning and DNA analysis. An Introduction. Blackwell Science Ltd., UK.
5. Cock, JM, Tessmar-Raibe, K., Boyen,C., Viard F. (Eds). 2010.Introduction to Marine Genomics. Springer.
6. Diana M. (Ed.) 2010.Metagenomics: Theory, Methods and Applications. Caister Academic Press.
7. Green, ED, . Birren, B., Klapholz, S., Meyers RMHieter P. 1997. Genome Analysis. A laboratory Manual. Volumes 1-4. Cold Spring Laboratory Press.
8. Krebs J.E, Goldstein ES, Kilpatrick, ST. 2011. Lewin's Genes X. Jones and Bartlett publishers, LLC.
9. Liebler D.C. 2002. Introduction to Proteomics: Tools for the New Biology. Humana Press Inc., New Jersey. 198p.
10. Primrose, S.B., Twyman. R.M. 2006. Principles of Gene Manipulation and Genomics. 7th Edition, Blackwell Publishing.
11. Sambrook J., Russel, D.W.2001. Molecular Cloning: A Laboratory Manual, Vols 1-3, CSHL, 2001.
12. Simpson, R.J. 2003. Proteins and Proteomics. A Laboratory Manual. Cold Spring Laboratory Press, New York
13. Twyman R.M. 2004. Principles of Proteomics. Garland Science/BIOS Scientific Publishers, New York. 241p
14. Twyman, R.M. 2005. Gene Transfer to animal Cells. Bios Scientific Publishers, Taylor & Francis Group
15. Wink, W. 2006. An Introduction to Molecular Biotechnology. Wiley VCH Verlag GmBH and Co. KGaA, Germany
16. Campbell, A. M., & Heyer, L. J. (2003). *Discovering Genomics, Proteomics, and Bioinformatics.* San Francisco: Benjamin Cummings. OMICS technology-'
17. S.P. Hunt and F. J. Livesey, (2000) Functional Genomics.
18. Voit, E.O., 2000 Computational Analysis of Biochemical Systems: a Practical Guide for Biochemists and Molecular Biologists. Cambridge University Press.

Suggested readings

19. Selected papers from scientific journals.
20. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

24-431-0103. INTRODUCTION TO MARINE PHARMACOLOGY - 3 credits

Course Objectives

Training students in various theoretical and practical aspects of screening, isolation, and characterization of bioactive compounds from marine environment with potential biomedical applications and developing them in to drugs for humans and animals and provides strong foundation to the discipline enabling to get transformed to an entrepreneur.

Course outcome

On the successful completion of the course, students will be able to

Course Outcomes		Cognitive Level
CO 1	Explain the importance of marine environment as source of novel bioactive compounds	Understand
CO 2	Develop suitable methods for isolation and characterization of marine natural products	Create
CO 3	Develop suitable bioassays for screening bioactivities of marine natural products	Apply
CO 4	Describe genomic approach used for discovering novel bioactive compounds	Apply
CO 5	Summarize various marine derived chemical compounds and their bioactivity.	Apply
CO 6	Explain the importance of marine environment as source of novel bioactive compounds	Analyze

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	2	2
CO2	2	2	3	2	2
CO3	3	3	3	3	3
CO4	3	3	3	3	3
CO5	2	2	3	2	2
CO6	3	2	3	3	2

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I. Marine Natural products as Drug Leads: Natural products as Drug lead, Marine Environment as source of natural products, Marine chemical ecology; Bioprospecting deep-sea, polar ocean, twilight zone, symbiotic microorganisms. Tools and techniques for collection of marine organisms and microbes. Leading projects related to Drugs from the Sea.

Unit II: Isolation and Characterization of Marine Natural Products: Isolation and separation of marine natural products (MNP) from marine flora and fauna; Common extraction methods; bioassay guided fractionation; chromatographic methods for separation; TLC, VLC, Flash Chromatography,

HPLC, dereplication strategies, Characterization of isolated compounds, LC-MS, NMR

Unit III: Screening Platforms and Instrumentation: High throughput and high content screening strategies: *In vitro* biochemical and 'cell-based assays; Enzyme linked immunosorbent assay; Radio immunoassay; Scintillation proximity assays; Chromogenic assays; Fluorescence assays; Fluorescence polarization; Microfluidics, Homogenous time resolved fluorescence assays; Fluorescence resonance energy transfer (FRET). BRET, Challenges in natural product research. Dereplication tools in Natural Product research; GNPS and Modern Applications with Molecular Networking, Natural Product Atlas, AntiBase, MarinLit, BioMAP, HPLC programme development for Isolation, HPLC Column selection, Mass Spectrometry and Fragmentation Theory, interpretation of LC-MS and NMR data.

Unit IV: Bioassays for Bioactivity Screening: Anticancer activity screening assays: DNA laddering assay; TUNEL Assay, Comet Assay, SRB Assay, MTT assay; LDH assay; Caspase assay; NCI60 anticancer screening programme; Antibacterial assays; quorum sensing and biofilm inhibition assays, antifungal assays; antiviral assays; Anti-inflammatory assays; Assays for tropical diseases - antimalarial assay, antileishmanial assay; Hypoglycemic/antidiabetic activity assay,HTS based screening for bioactivity-Drug target identification and validation, Assay development for bioactivity screening, Reporter Gene based Assays; Fluorescence resonance energy transfer (FRET) based assay; High throughput screening and High Content Screening platforms; Processes of drug discovery and drug development; In vivo animal model for drug testing: In vivo models for drug testing, model organisms for Cancer, immunological, diabetics, cardiovascular diseases. Use of experimental animal and ethical clearance

Unit V:Source and nature of marine bioactive compounds and biomaterials: Diversity of marine organisms, sources of bioactive compounds, Chemical diversity of marine compounds, Marine Toxins - Paralytic shellfish poisoning (PSP), Neurotoxic shellfish poisoning (NSP), Diarrhetic shellfish poisoning (DSP), Ciguatera poisoning, Amnesic shellfish poisoning (ASP) other miscellaneous toxins; Marine enzymes; pigments; neutracetuicals;, Marine biominerals; Biominerelized structures; Biocomposites; Biopolymers - polysaccharides, chitin, marine collagens;Marine derived drugs- Approved and those in clinical and preclinical stages, their source, mode of action, targeted diseases.

Unit VI: Genomic approach in marine natural products biosynthesis (MNP). Biosynthetic pathways, Polyketide synthase (PKS I& II) non-ribosomal peptide synthetase, hybrid pathways, Mevalonate pathway, Biosynthetic gene cluster (BGC) identification, Cryptic Natural Products- its induction. Metagenome based MNP discovery, synthetic biology approach for MNP synthesis;Bottom-Up approach in natural Products research-Biosynthetic pathways gene, Biosynthetic Gene cluster analysis, Secondary

Metabolite Unique Regions Finder (SMURF), *antiSMASH*, Cryptic Natural Products- HADAC Modifiers.

Recommended text books and references:1.Atta-ur-Rahman, Iqbal Choudhary, M., and Thomsen, W.J. Eds. 2005. Bioassay Techniques for Drug Development (Taylor and Francis).
2.Seethala, R., and Fernandes, P.B. Eds. 2001. Handbook of Drug Screening (Marcel Dekker Inc).
3.Zhang, L., and Demain, A.L. Eds. 2005. Natural Products Drug Discovery and Therapeutic Medicine. Humana Press.
4.Lansing Taylor, D., Harkins, J.R., and Giuliano, K.A. Eds. 2007. Methods in Molecular Biology, Volume 356. Humana Press.
5.Braga, P.C., and Ricci, D. Eds. (2005). Methods in Molecular Biology, Volume 242.
6.Hammes, G.G. ed. 2005. Spectroscopy for the biological sciences. Wiley Interscience.
7.Kastin, A.J. ed. 2006. Handbook of biologically active peptides. Elsevier.
8. D.S. Bhakuni and D.S. Rawat 2005 Bioactive Marine Natural Products (Springer and Anamaya Publishers, New Delhi, India
9**.** Ehrlich**,** Hermann Ed 2010. Biological Materials of Marine Origin. Invertebrates (Springer)
10. http://www.mdpi.com/journal/marinedrugs
11. https://gnps.ucsd.edu/ProteoSAFe/static/gnps-splash.jsp
12. http://pubs.rsc.org/marinlit/
13. https://www.npatlas.org
14.Benjamin Blass . Basic Principles of Drug Discovery and Development ; ISBN: 978-0-12-
411508-8; Academic Press
15. Dean Martin (Ed) Marine Pharmacognosy :Action of Marine Biotoxins at the cellular level
l6. Charles G. Smith, James T. O'Donnell Ed, The Process of New Drug Discovery and Development, Second Edition, CRC Press ISBN 9780849327797
17. John P. Griffin John Posner Geoffrey R. Barker , The Textbook of Pharmaceutical Medicine, 7th Edition , ISBN: 978-0-4

20-431-0104. BIOPROCESS ENGINEERING - 3 credits

Course Objectives

The students are given a comprehensive understanding of fundamentals of bioprocess technology, fermentation kinetics, design of ideal fermenters, and the importance of physical parameters and mechanical aspects for safe and efficient running of fermenters.

Course Outcome

After successful completion of this course, the students will be able to

Course Outcomes		Cognitive Level
CO 1	Identify the importance of different kinetics in fermenter	Understand
CO 2	Practice the process design of Bioreactors (apply)	Create
CO 3	Practice different sterilization methods	Apply
CO 4	Identify the importance of various physical parameters in fermenter	Analyze
CO 5	Choose different structural components in fermenter	Apply
CO6	Apply the principles of bioprocess engineering for marine bioprocessing	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	-	1	-	1	-
CO2	-	2	1	3	1
CO3	-	3	1	2	1
CO4	-	2	1	1	-
CO5	1	3	3	3	1
CO6	3	3	3	3	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Fundamentals of Bioprocess Technology: Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics, Media for industrial fermentations. Batch growth, Effect of substrate concentration. Monod model. Growth kinetics with plasmid instability. Production kinetics in cell culture. Determining cell kinetic parameters from batch data. Kinetics of cell growth.

Unit II: Reactor Engineering: Reactor Engineering in perspective. Sterilization of reactors- batch and continuous. Design equations for ideal reactors: batch fermenter, chemostat, fed-batch fermenter.

Unit III: Design of Bioreactors: Design of chemostat with cell recycle, plug flow reactor for cell culture, Immobilized cell bioreactor, fluidized bed bioreactor, trickle bed reactor.

Unit IV: Physical parameter studies in fermenter: The oxygen requirements of industrial fermentation. Oxygen supply. Determination of KLa values. Factors affecting oxygen transfer rate in fermenters like bubble size, gas hold up, gas velocity, temperature, pressure etc. The relationship between power consumption and operating variables.

Unit V: Mechanical aspects in fermenter: Role of shear in stirred fermenters. Structural components of the fermenter involved in aeration and agitation.

Unit VI: Marine bioprocessing: Media optimization, Bioprocessing of marine natural products- bioactive compounds, marine enzymes, neutraceuticals; bioreactor considerations for production of bioactive compounds, photo-bioreactor, aquaculture bioprocessing of micro-algal biomass, nitrifying bioreactor, novel bioreactor.

Recommended text books and references:

1. Principles of fermentation technology; P. F. Stanbury, A. Whitaker and S.J. Hall, Aditya Books (P) Ltd.
2. Bioprocess Engineering Principles; Pauline M Doran, Academic Press.
3. Biochemical Engineering Fundamentals; James E. Bailey and David F. Ollis, McGraw Hill Book Company.
4. Current Developments in Solid State Fermentation; Ashok Pandey et al. 2008. Springer.
5. Bioreactors: analysis and design: Tapobrata Panda, Mc Graw Hill

Practical (Core)

24-431-0105. LAB 1 - SKILL DEVELOPMENT IN RECOMBINANT DNA TECHNOLOGY - 2 credits

Course Objectives

The objective of this course is to provide students with the practical knowledge and skills in recombinant DNA technology (A viral protein as the target molecule).

Course Outcomes

At the end of this course the students should be able to

Course Outcomes		Cognitive Level
CO 1	Perform isolation and quantification of nucleic acid and proteins	Analyse
CO 2	Practice quantification of gene expression	Apply
CO 3	Produce recombinant proteins	Create
CO 4	Analyse and characterize proteins	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	3	3	3
CO2	3	3	3	3	3
CO3	3	3	3	3	3
CO 4	3	3	3	3	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

LABORATORY EXPERIMENTS

Module 1: Isolation of RNA and gene amplification: Isolation of RNA from white spot virus infected tissues of shrimp *Penaeus monodon*, agarose gel electrophoresis, cDNA synthesis, Primer design and synthesis for VP28 and VP24 genes of white spot virus for gene expression, PCR amplification of VP28 and VP24 genes.

Module 2: Molecular characterization of genes: Cloning of VP28 and Vp24 genes in pGEMT easy vector- Ligation, transformation and screening of transformants by colony PCR, Plasmid extraction, restriction digestion of the plasmid DNA, Gene sequencing and sequence analysis, Molecular identification and phylogenetic analysis.

Module 3: Gene quantification using quantitative PCR: Isolation of RNA from white spot virus infected tissues of shrimp *Penaeus monodon*, agarose gel electrophoresis, cDNA synthesis, Quantification of VP28 and VP24 genes of white spot virus using Real time PCR- preparation of gene standards from plasmids with VP28 and VP24 genes, absolute and relative quantification of genes.

Moduel 4:Recombinant DNA technology: PCR amplification of VP28 and VP24 genes, Preparation of plasmid, pET-32a+ from *E.coli* DH5α and gel analysis, Restriction digestion of vector (gel analysis) and PCR amplified VP28 and VP24 genes, Vector and insert ligation and transformation in *E.coli* DH5α, Plasmid isolation and confirming recombinant by PCR and RE digestion, Transformation of recombinant plasmid in *E.coli* BL21 (DE3) strain (expression host), Induction with IPTG for the expression of genes.

Module 5: Analysis of proteins: Extraction of protein from positive clones, Purification of protein on Ni-NTA column and analysis by SDS-PAGE, staining of protein in gels, Western blotting for confirmation, 2-Dimensional Gel electrophoresis for comparing proteomes of WSSV infected and non-infected *Penaeus mondon*, characterization of proteins using MALDI-TOF mass spectrometry.

24-431-0106. LAB 2 - SKILL DEVELOPMENT IN MARINE MICROBIAL DIVERSITY DETERINATION - 2 credits

Course objective : *To equip the students with methods in microbiology and marine microbial diversity analyses to facilitate them utilize their services in the maintenance of marine environmental health sustainably explore them for various biotechnological applications.*

Course Outcome

At the end of the course students will be able to:

Course Outcomes		Cognitive Level
CO 1	Perform Isolation and characterization of microorganisms from marine environmental samples	Analyse
CO 2	Perform polyphasic taxonomy of the cultivable microorganisms	Apply
CO 3	Study of viable but non culturable microorganisms through metagenomic approach	Create

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	3	3	1
CO2	3	3	3	3	1
CO3	3	3	2	1	1

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

LABORATORY EXPERIMENTS

Module 1: Collection of water, sediment and any marine organism for microbial assays, transportation and preservation without losing viability.

Module 2: Quantitative estimation of microbial biomass in the marine environment - water, sediment and microorganisms.

Module 3. Isolation, purificationand preservation of aerobic, facultative anaerobic and obligate anaerobic heterotrophic bacteria from marine environment.

Module 4. Isolation, purification and preservation of photosynthetic and chemolithotrophic bacteria from marine environment.

Module 5. Polyphasic taxonomy microorganisms - Colony and cell morphology, biochemical characterization, Numerical taxonomy, molecular characterization (16S rRNA, 18S rRNA, ARDRA, DGGE, Phylogenetic tree construction), DNA -_DNA hybridization and cell wall fatty acid profiling.

Module 6. Isolation and characterization of viable but non cultivable microorganisms through metagenomic approach.

24-431-0107: LAB 3 - SKILL DEVELOPMENT IN CELL CULTURE AND HYBRIDOMA/ANTIBODY TECHNOLOGY - 1 credit

Course Objectives

1. To give practical hands-on experience in handling animal cell lines and primary cell cultures developed from various aquatic organisms.
2. To give practical hands-on experience in Hybridoma/Antibody Technology and applications.

Course Outcome

After successful completion of this course, the students will be able to:

Course Outcomes		Cognitive Level
CO 1	Prepare cell culture medium, and maintain cell lines	Apply
CO 2	Develop primary cell cultures from marine organisms	Create
CO 3	Examine viability of cells in culture	Analyse
CO 4	Practice selection and purification of antigens	Apply
CO 5	Practice immunization in animals	Apply
CO 6	Prepare hybrid clones using myeloma cells	Create
CO 7	Undertake clone selection for antibody production	Apply
CO 8	Produce monoclonal/polyclonal antibodies	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO 5
CO1	3	-	2	1	2
CO2	3	-	2	1	1
CO3	3	-	2	2	3
CO4	3	-	1	1	1
CO5	3	-	1	-	-
CO 6	3	-	1	2	1
CO7	3	-	1	-	1
CO8	3	-	1	2	1

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module -1 CELL CULTURE TECHNIQUES (For the maintenance of permanent cell lines and development of novel cell lines for various biotechnological applications):

1. Preparation of media.
2. Developing primary cell culture.
3. Sub culturing and cell line maintenance – anchor dependent and suspension cell cultures.
4. Enumeration of viable cells by dye up take and exclusion.

5. Split ratio and growth cycle.
6. MTT assay.
7. BrdU assay.
8. Cytoskeleton staining.
9. Cryo preservation.

Module -2 HYBRIDOMA/ANTIBODY TECHNOLOGY (For the production of monoclonal antibodies/polyclonal antibodies)

1. Antigen selection and purification
2. Immunization of experimental animals
3. Hybridization with myeloma cells (for monoclonal antibodies)
4. Selection of hybrid clones- HAT system (for monoclonal antibodies)
5. Clonal selection (for monoclonal antibodies)
6. Screening and sub-cloning (for monoclonal antibodies)
7. Production of monoclonal/ polyclonal antibodies
8. Titration of antibodies
9. Checking cross reaction.

SEMESTER II (Total Credits: 24)

Theory (Core)

24-431-0201. BIOTECHNOLOGICAL INTERVENTIONS IN AQUATIC ANIMAL HEALTH MANGEMENT -3 credits

Course Objectives

To provide the students a holistic view on aquatic animal health management and to equip them to practice the same at field level.

Course outcome

On the successful completion of the course, students will be able to :

Course Outcomes		Cognitive Level
CO 1	Explain the significance of health management in aquaculture	Understand
CO 2	Identify diseases and their etiology affecting aquatic animals	Apply
CO 3	Explain the defense mechanism of fish and shellfish	Understand
CO 4	Manage disease outbreaks in aquaculture	Apply
CO 5	Explain the Better Management Practice (BMP) in Aquaculture	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2	2	3

CO2	3	-	1	-	1
CO3	3	1	1	-	3
CO4	3	3	3	3	2
CO5	3	2	3	3	2

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I. Aquaculture production systems: Criteria for selection of organisms for aquaculture; Extensive, semi-intensive and intensive aquaculture practices; Running water aquaculture; Recirculating aquaculture systems; raceways, aquaponics, biofloc technology and integrated multitrophic aquaculture (IMTA), zero water exchange culture system, Cage culture and pen culture;

Unit II. Aquaculture Environment Assessment: Water and sediment sampling and preservation for various analyses; Soil and water chemistry and its relationship with health of the animal and environment; Linking behavioral and clinical signs and water and sediment quality requirements; Assessment of microbial potential for balanced bio-geochemical cycles - carbon, nitrogen, iron, sulphur cycles and determination of bioremediation potential and carrying capacity.

Unit III. Physiology, pathophysiology and immunology of fin and shellfishes: Fish Physiology: Morphology and internal anatomy of finfishes, crustaceans and molluscs; Integument system, Musculoskeletal system, Respiratory system, ventilation and gas exchange, Circulatory system, reticuloendothelial system; Renal and excretory system, Digestive system, Nutrition, metabolism ad growth, Reproductive system, Nervous system, special sense organs, swim bladder, Sound and pressure reception, Endocrine system, Pathophysiology: Case history, Mortality pattern, Clinical signs, Stress and general adaptation syndrome, Systemic pathology, Finfish Immunology: Organs and cells of immune system; Non-specific defense mechanisms,-cytokines, antimicrobial peptides, C-reactive proteins, interferon, Complement system; Specific defense mechanisms- Humoral immunity - B lymphocytes, Structure and function of antibody, classes and diversity of antibody. Cell-mediated immunity, - T lymphocytes, MHC molecules. Shellfish Immunology: Hemocytes, Hemocyte-mediated effector responses-Phagocytosis, Nodulation and encapsulation; ProPhenol Oxidase (proPO) system; Proteinase inhibitor, Agglutinin; Lectin system; Anti-Microbial peptides; Reactive Oxygen Intermediates; Factors affecting immune system – intrinsic and extrinsic; Histology, Histopathology and Immunology techniques.

IV. Diseases in aquaculture: Viral, Bacterial, Fungal, Protozoan and metazoan diseases; Aetiological agents, predisposing factors, clinical signs, Internal and external pathological changes, disease progression, morbidity and mortality pattern; methods of detection, isolation and identification of pathogens and parasites.

V. Aquaculture medicines and aquatic animal health management: Anti microbials, Weedicides, general management chemicals, feed additives, anaesthetics and sedatives, hormones, vaccines, probiotics, prebiotics, bioremediators, Immunostimulants, antagonistic compounds, Phage therapy, Antimicrobial peptides, Quorum quenchers, Diagnostics, Drug delivery systems, Drug residues in aquaculture products, Hazardous analysis and critical control points (HACCP), Guidelines for the regulation of aquaculture drugs, selection and application; holistic approaches in aquatic animal health management.

Recommended textbooks and references:

1. Gal, Y.L., and Ulber, R. eds. 2005. Marine Biotechnology II, Volume 97.Springer-Verlag.
2. Roberts, R.J. (Ed), 2001, Fish Pathology, W.B. Saunders, P. 672
3. Austin B. and Austin, D.A. 1999. Bacterial Fish Pathogens – disease of Farmed and Wild Fish, Springer, Published in Association with Praxis Publishing, P. 457
4. Leung K.Y. 2004. Current Trends in the Study of Bacterial and Viral Fish and Shrimp Diseases. World Scientific Publishing Co. Pte. Ltd., Singapore. 432p.
5. Bright Singh, I.S., Somnath Pai, S., Philip R. & Mohandas, A. (Eds), 2003. Aquaculture Medicine, Centre for Fish Disease Diagnosis and Management, CUSAT, Cochin, P. 336
6. Bardach, J.E. 1997. Sustainable Aquaculture. John Wiley& Sons. 251p.
7. Boyd, C.A. and Tucker C.S. 1998. Pond Aquaculture Water Quality Management. Springer, New York
8. APHA 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition. American Public Health Association, Washington DC
9. Pillai, TVR and Kutty, M.N. 2005. Aquaculture: Principles and Practices. Blackwell Publishing. 624p
10. Parsons T.R. and Strickland J.D.H. 1978. A Practical Handbook of Seawater Analysis. 2nd Edition. Fisheries Research Boards of Canada. 311p.Tucker, J. 1998. Marine Fish Culture. Springer. 760p
11. Dunham R.A. 2004. Aquaculture and Fisheries Biotechnology: Genetic Approaches.CABI Publishing Wallingford, Oxfordshire (UK). 400 p.
12. Raa J., 1996. The use of immunostimulatory substances in fish and shellfish farming. Reviews in Fisheries Science; 4:229–88
13. Treves – Brown, K. M. 2000. Applied Fish Pharmacology, Kluwer Academic Publishers, P. 308
14. Noga, E J. 2000. Fish Diseases – Diagnosis and Treatment, Iowa State University Press/Ames, P. 367

15. Coll, M.J. and Dominiguez-Juncal J. 1995. Applications Of Monoclonal Antibodies In Aquaculture. *Biotech. Adv.* Vol. 13, pp. 45-73.

16. Heppell, J., Davis, H.L. 2000. Application of DNA vaccine technology to aquaculture. Advanced Drug Delivery Reviews 43 (2000) 29–43

17. Luis Balca´zar,J., de Blas,I Ruiz-Zarzuela I., Cunningham, D., Vendrell, D., Luis Mu´zquiz, J. 2006. The role of probiotics in aquaculture. Veterinary Microbiology 114: 173–186

18. Fingerman, M. and Nagabhushanam, R. (eds.). 2000. Recent Advances in Marine Biotechnology, (Series) Immunobiology and Pathology. Science Publishers, USA, 392p.

19. Fingerman, M. and Nagabhushanam, R. (eds.) 2002. Recent Advances in Marine Biotechnology (Series) Seafood Safety and Human Health. Science Publishers, USA. 328p.

20. Roberts, R.J., 2012. Fish pathology. John Wiley & Sons.

20-431-0202. MARINE BIOPROCESS ENGINEERING – 3 credits

Course Objectives

To impart advanced concepts in process plant design, scale up of bioreactors and downstream process and various industrial product separation and purification.

Course Outcome

After successful completion of this course, the students will be able to:

Course Outcomes		Cognitive Level
CO 1	Practice design of a bioprocess plant	Apply
CO 2	Employ scale up of bioreactors	Apply
CO 3	Employ scale up of Downstream process	Apply
CO 4	Practice different product separation and purification methods	Apply
CO 5	Practice the production of probiotics and response surface modifiers	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	1	3	-
CO2	1	2	1	3	-
CO3	1	3	3	3	1
CO4	1	3	3	3	2
CO5	3	1	2	3	1

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: General Bioprocess plant design considerations for marine organisms: Essentials of material and energy balances. Basics of thermodynamics, Process flow sheeting. P&I Diagrams. Pump and compressor selection. Pipe size selection. Materials of construction. Facility design aspects, utility supply aspects, equipment cleaning aspects, CGMP guidelines, validation, safety in bioprocess plant. Process economics-Case studies.

Unit II: Scale up of bioreactors: Effect of scale on oxygenation, mixing, sterilization, pH, temperature, inoculum size , nutrient availability and supply; Stoichiometry, Bioreactor scale up based on constant power consumption per volume, mixing time, impeller tip speed (shear), heat and mass transfer coefficients.

Unit III: Scale up of downstream processes: Adsorption (LVB method), Chromatography (constant resolution), Filtration (constant resistance), and centrifugation (equivalent times), Extractors (geometry based rules).

Unit IV: Isolation and separation techniques: Centrifugation and ultracentrifugation: sedimentation: principles, methods and coefficients, application of sedimentation coefficient, equilibrium time. Reverse osmosis :- Models for reverse osmosis transport; design and operating parameters, solute rejection, permeability coefficient, concentration polarization, design of reverse osmosis module and applications. Dialysis, Electro-dialysis, Membrane reactors. Diafiltration, pervaporation, Biotechnological applications of membrane based separations.

Unit V: Product purification: Liquid - liquid extractions, Precipitation (salt, pH, organic solvent, high molecular weight polymer); Separation of particulate by filtration: dead end filtration, calculation of time required for filtration, and washing, concept of filter medium resistance, Rotary Vacuum Filtration, scale up of filtration systems, design considerations of sterile filters, cross flow filtration: - different modes of operation.

Unit VI: Production of probiotics and response surface modifiers: Definition, Effects, Production method for - Detrodigest, Enterotrophotic, Multipurpose Bio degrader, Garbactum, Aquafeed supplement, PS-1, PS-4, Nitrifying Bacterial consortium, and commercially important immunostimulants.

Recommended text books and references:

1. Roger G. Harrison, Paul Todd, Scott R. Rudge, Demetri P. Petrides, Bioseparations Science and Engineering, Oxford University Press
2. B Sivasankar, Bioseparations - Principles and techniques, Prentice Hall of India, New Delhi
3. E L V Harris and S. Angal, Protein Purification Methods, Ed. IRL Press at Oxford University Press, 1989.
4. P.A. Belter, E.L. Cussler and Wei- Shou Hu, Bioseparations- Downstream Processing for Biotechnology, Wiley- Interscience Publication, 1988.
5. Subramanian Ganapathy, Bioseparation& bioprocessing, (2nd Ed.) Wiley-VCH, 2007
6. J. E. Bailey and D. F. Ollis, Biochemical Engineering Fundamentals, 2nd Edition, Mc-Graw Hill, Inc., 1986.
7. Asenjo J.A. and J.Hong (Eds), Separation Processes in Biotechnology, Taylor and Francis
8. P F Stanbury and A Whitaker, Principles of fermentation technology Pergamon press (1984)
9. M. Moo-Young, Comprehensive Biotechnology" Vol.2 Ed.: (1985)
10. T. Schepler et al, Biotreatment, Downstream Processing and Modelling" (Advances in Biochemical Engineering /Biotechnology, Vol 56) by Springer Verlag.
11. C.A. Costa and J.S. Cabral, Kluwer, Chromatographic and Membrane Processes in Biotechnology" Academic Publisher
12. J.P. Hamel, J.B. Hunter and S.K. Sikdar, Downstream Processing, American Chemical Society
13. M.R. Ladisch, R.C. Wilson, C.C. Painton and S.E. Builder, Protein Purification,
14. Robert K. Scopes, Protein purification: Principle and practice, third edition, Springer, editor: Charles R. Cantor
15. Chemical Engineering Design; R.K. Sinnot, Elsevier
16. Process Engineering and Design; S.B. Thakor& B.I. Bhatt
17. Bioreactors: analysis and design: Tapobrata Panda, Mc Graw Hill

24-431-0203. MARINE ALGAL BIOTECHNOLOGY- 3 credits

Course Objective:

To train the students in the ever growing field of algal biotechnology to undertake innovative ventures for developing marine algal industry for food, fuel, pharmaceuticals, and carbon sequestration for climate change mitigation.

Course Outcomes

At the end of the course the students will be able to:

Course Outcomes		Cognitive Level
CO 1	Describe the fundamentals of algal biology, molecular taxonomy and applications	Understand

CO 2	Apply the methods of biochemical and biological analyses of marine algae	Apply
CO 3	Practice augmented production of microalgae	Apply
CO 4	Practice the methods of cultivation of marine algae	Apply
CO 5	Understand the health management of seaweeds in culture	Understand
CO6	Application of genetic engineering tools in marine algae	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	3	-	-	-
CO2	2	3	1	2	-
CO3	2	3	2	3	-
CO4	2	3	2	1	-
CO5	2	3	1	1	-
CO6	2	3	1	-	2

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Introduction to marine algae: Algal phylogeny and taxonomy- classification of algae, Algal cell- Structure, Cell cycle in algae, Life cycles of marine algae. Conventional and molecular methods of identification, Karyotyping in macroalgae, Algal physiology- Photosynthesis and Light Harvesting, Carbon Acquisition, Hydrogen Production and Nitrogen Fixation in Cyanobacteria, Dark Respiration and Organic Carbon Loss, Nutrients and their Acquisition. Metabolism in marine algae- Primary metabolism; Secondary metabolism, Biosynthesis of secondary metabolites, Terpenes, Polyketides, Amino-acid derived natural products, Shikimates, Miscellaneous classes of algal natural products, Halogenated metabolites in algae. Application of marine algae- in human nutrition- functional foods and antioxidants, live feed in aquaculture, Biofertilizers, Biochemicals, Bioplastics, Cosmetics, nano-biotechnology; Pharmaceuticals from marine algae, antimicrobial compounds; Toxins and other bioactive compounds; Algae in bioremediation; Algae for enhancement of marine productivity, climate stabilization and food security.

Unit II: Chemical and biological analyses of marine algae: Marine microalgae- measurement light requirements of algae, NPK analysis in the culture medium. Algal growth kinetics; Isolation and development of monocultures and axenic cultures; Microscopic analyses of microalgae, Histology of seaweeds, Measurement of algal growth- cell count, dry weight, photosynthetic productivity, fluorescence measurement, Proximate composition of algae- Protein, amino acids, carbohydrates, lipids, fatty acids, minerals, pigment- Carotenoids, Beta-carotene, Chlorophyll, Phycocyanin and phycoerythrin, lutein. Biochemical composition of macroalgae, polysaccharides from seaweeds, biomaterials from algae

Unit III: **Production and biomass processing of marine microalgae for industrial applications:** Factors affecting growth, Culture media Mass culture of microalgae- Statistical optimization of mass production; Open ponds, Photobioreactors, Fermentors, Maintenance of mass cultures; Monitoring of microalgal production systems, Management of contamination, Biomass harvesting and processing techniques; Preservation methods. Product development from marine algae- extraction, purification and analytical methods-pharmaceuticals, antimicrobials, pigments, nutraceuticals, biofuels.

Unit IV: **Cultivation of marine macroalgae**: Scope of seaweed cultivation in India, Basics of seaweed cultivation, site preparation, Preparation of the seaweed planting material- characteristics of healthy plants and seedlings., technique of cutting out healthy seedlings from seaweed plants, Method of cleaning and storing the seedlings; Different methods of plantation of seed stock, such as line method and net method, criteria for selecting a suitable method of plantation of seed stock, balancing and tying seedlings. Cultivation of seaweed: Nutritional requirements of seaweeds, fertilizer application, sampling and monitoring of seaweed cultures- stages of growth of seaweed, indicators of good growth for common types of seaweeds; Measurement of factors such as light intensity, temperature and turbidity responsible for the growth of seaweed: Harvesting of seaweed biomass, handling of the harvested seaweed, procedure of drying, checking moisture content in the harvested seaweed, calculation of yield and quality, Sea weed micropropagation- protocols and practices.

Unit V: Health Management in Macroalgal Culture: Biotic and biotic stress, endophytic and associated microbiome in seaweeds, Fouling in seaweeds, Diseases in major cultures seaweeds- rotten thallus syndrome, ice-ice disease, chytrid blight, red spot disease, white spot disease, diatom felt, cyanobacreria felt, anaaki disease, Green spot disease, white blight disease, blister disease, short hole disease, twisted front disease, hole rotten disease, sport rotting disease, pinhole and brown endophytic disease. Development of diagnostic tools for macroalgal diseases, Health management protocols in seaweed culture.

Unit VI: Algal Genomics, and Genetic and Metabolic Engineering: Marine algal genomics-data access, visualization, and analysis tools for comparative genomics of algae; Algal transcriptomics, Production of transgenic algae- cloning tools and methods; Stain improvement in marine algae, Microalgae as gene expression system- production of antibodies, microalgal vaccines, expression of insecticidal proteins, bioactive chemicals. Genetic engineering of macro-algae, metabolic engineering in algae, Systems and synthetic biology of algae. Metabolome and fluxome of algae, 'Omics' approach for product discovery in marine algae.

Recommended text books and references:

1. Juliet Brodie, Jane Lewis. 2007. Unravelling the algae: the past, present, and future of algal systematics. CRC Press

2. Richmond, A. (ed.) 2004. Handbook of microalgal culture: Biotechnology and applied phycology. Blackwell Science Limited.
3. Andersen, RA. (ed). 2005. Algal culturing techniques. Elsevier Academic Press.
4. Becker, EW1994. Microalgae: Biotechnology and microbiology. Cambridge University Press.
5. Cohen Z. 1999. Chemicals from microalgae. Taylor and Francis Ltd.
6. Chen F and Jian Y. (Eds) 2001. Algae and their biotechnological Potential. Kluwer Academic Publishers.
7. Graham, L.E. and Wilcox, LW. 2000. Algae. Prentice Hall Inc.
8. Faizal Bux, Yusuf Chisti. 2016. Algae Biotechnology: Products and Processes. Springer
9. Navid Reza Moheimani et al., 2015. Biomass and Biofuels from Microalgae: Advances in Engineering and Biology. Springer
10. Se-Kwon Kim (Ed.). 2015. Handbook of Marine Microalgae: Biotechnology Advances, Academic Press.
11. Rosa León, Aurora Galván Cejudo, Emilio Fernández. 2008. Transgenic Microalgae as Green Cell Factories, Springer Science & Business Media,
12. Charles D. Amsler. 2008. Algal Chemical Ecology. Springer.
13. Debabrata Das. 2015. Algal Biorefinery: An Integrated Approach. Springer
14. Michael A. Borowitzka, Navid Reza Moheimani. 2012. Algae for Biofuels and Energy. Springer Science & Business Media.
15. Clemens Posten, Steven Feng Chen, 2015. Microalgae Biotechnology. Springer.
16. Michael A. Borowitzka, John Beardall, John A. Raven. 2016. The Physiology of Microalgae. Springer.
17. Paul M. Dewick. 2011. Medicinal Natural Products: A Biosynthetic Approach. John Wiley & Sons
18. Selected papers from scientific journals.
19. James W. Lee. 2012. Advanced Biofuels and Bioproducts. Springer Science & Business Media.
20. Se-Kwon Kim, Katarzyna Chojnacka. 2015. Marine Algae Extracts: Processes, Products, and Applications, 2 Volume Set. John Wiley & Sons.
21. Catriona L. Hurd, Paul J. Harrison, Kai Bischof, Christopher S. Lobban. 2014.Seaweed Ecology and Physiology. Cambridge University Press.
22. Joël Fleurence, Ira Levine. 2016. Seaweed in Health and Disease Prevention. Academic Press.
23. Christian Wiencke, Kai Bischof. 2012. Seaweed Biology: Novel Insights into Ecophysiology, Ecology and Utilization. Springer Science & Business Media.

20-431-0204: GENETIC IMPROVEMENT FOR HIGH HEALTH BROOD STOCK DEVELOPMENT- 2 credits

Course Objectives

To equip the students with theory and practice of genetic Improvement for high health broodstock development and to facilitate them to practice the same

Course outcome

On the successful completion of the course, students will be able to:

Course Outcomes		Cognitive Level
CO 1	Explain the concepts, principles and significance of fish genetics (Understand)	Understand
CO 2	Undertake experiments on molecular genetics for marker assisted selection of traits for High Health brood stock (Apply)	Apply
CO 3	Undertake hormone manipulation for induced breeding (Apply)	Apply
CO 4	Practice transgenisis in fishes. (Apply)	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	-	-	-	3
CO2	3	-	-	-	3
CO3	2	-	-	-	3
CO4	1	-	-	-	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I:Fish genetics: Modern concept of gene (DNA as genetic material, genetic code, protein synthesis, transfer and regulation of genetic information, transposons and intervening sequences, mini satellites and macro satellites), mutation (natural and induced), Inbreeding, Cross-breeding (selective breeding-qualitative and quantitative traits for selection, methods of selection, designing of breeding programmes), genetic drift. Non-chromosomal inheritance (mitochondrial inheritance) Genetic markers (Biochemical and molecular genetic markers in hybridization and selective breeding), Diallele crossing, chromosome manipulation (Ploidy, sex reversal, multiple alleles, gynogenesis, androgenesis)

Unit II: **Concept of High Health Brood stock:** Concept of high health – Brood stock and brood stock availability, High health in terms of high growth, disease resistance and tolerance to varying environmental conditions; Aquaculture candidate species of finfish and shellfishes and the requirement of high health brood stock; age old method of brood stock availability-draw backs; domestication in aquatic species; Molecular tools

and marker assisted selection (MAS); Molecular Breeding: Genetic selection of high health brood stock; Selective breeding; Breeding programme and segregation of offspring. Quarantine systems in high health brood stock development – Theory and practice, cases studies – Biosecurity protocols and better management practices - National and International; Specific pathogen free and Specific pathogen resistance in high health brood stock development.

Unit III: Molecular genetics for the establishment of High Health Founder Population: Marker assisted selection (MAS): Protein Markers - Allozymes / Isozymes, Sarcoplasmic proteins, Myofibrillar proteins, Eye lens proteins; DNA Markers -Mitochondrial DNA; Nuclear DNA Markers-Random amplified polymorphic DNA(RAPD),Restriction fragment length polymorphism (RFLP),Variable Number of Tandem Repeats (VNTR),Amplified fragment length polymorphism (AFLP),Single Nucleotide Polymorphisms (SNP),Expressed sequence tags (ESTs; Quantitative trait loci (QTLs), coding and non-coding sequences, Repetitive and non-repetitive DNA – Satellite DNA, Mini satellite DNA, Microsatellite DNA, Interspersed DNA – Repetitive DNA, Short interspersed nuclear element (SINE), Long interspersed nuclear element (LINE), Short term repeats (STR), polymorphism and polymorphic DNA.

Unit IV: Reproductive hormones and hormone manipulation in high health brood stock development: Over view of reproductive physiology in finfish and shellfishes, requirement of reproductive hormones in aquaculture and high health brood stock development, Growth hormone (GH)/Somatotropin, Gonadotropin release hormone (GnRH), Human Chorionic Gonadotropin (HCG)/Chorionic Gonadotropin (CG), 17-Methyltestosterone (MT), 17 –Methyl dihydrotestosterone (MDT), 17 – Ethynyltestosterone (ET), 17-Oestradiol (E2), 17-Ethynyloestradiol, Diethylstilbesterol, serotonin – application and evaluation; Reproductive hormones in crustaceans – CHH family hormones in crustaceans – GIH,MIH and CHH, eye stalk ablation and maturation in shrimp, molecular tools in maturing shrimp in lieu of eyestalk ablation.

Unit V: Transgenesis in high health brood stock development: Concept of transgenesis for high health brood stock; Basic methodology; Gene identification; Cloning; Transformation and expression; Transference of genetic trait to F1, F2, F3 generations; Advantages of transgenics in high health brood stock development; Environmental risk associated with transgenic fishes; Ethical issues involved.

Recommended text books and references:

1. Chistiakov, D.A., Hellemans, B., Volckaert, F.A.M. 2006.Microsatellites and their genomic distribution, evolution, function and applications: A review with special reference to fish genetics Aquaculture 255: 1–29
2. Dunham R.A. 2004. Aquaculture and Fisheries Biotechnology: Genetic Approaches.CABI Publishing Wallingford, Oxfordshire (UK). 400 p.

3. Ennion S. and Goldspink G. 1996. Gene Expression and Manipulation in Aquatic Organisms. Cambridge University Press. 228p
4. Hahn K., Brown C.L. and G.D. Pruder. 1994. Standard Agricultural Practices for the Culture of Specific Pathogen Free Organisms and their Application to Aquaculture. Reviews in Fisheries Science. 2(2): 315-330.
5. Hayes, B., He, J., Moen, T., Bennewitz, J. 2006. Use of molecular markers to maximise diversity of founder populations for aquaculture breeding programs. Aquaculture 255:573–578
6. Maclean, N., Penman, D., 1990. The application of gene manipulation to aquaculture. Aquaculture 85, 1–20.
7. Gong Z., Korzh, V., 2004. Fish Development and Genetics. World Scientific Publishing Co. Pte. Ltd. Singapore. 688p.

Suggested Readings

1. McVey, M.P. and McVey, P.J. 1993**.** CRC Handbook of Mariculture: Crustacean aquaculture, 2nd Edition. CRC Press, Boca Raton. 544p.
2. Nash, C.E. and Novotny. 1995. Production of Aquatic Animals: World Animal Science Series. Elsevier Health Sciences. 405p.
3. Gjedrem T. (Ed.). 2005. Selection and Breeding Program in Aquaculture. Springer, New York. 364p.
4. Lim C.R. and Webester, C.D. 2001. Nutrition and Fish Health. Haworth Press, New York. 365p.
5. Pillay T.V.R. and Kutty, M.N. 2005. Aquaculture: Principles and Practices. Blackwell Publishing. 624p.
6. Reinertsen H. and Haaland H. (Eds.). 1995. Sustainable Fish Framing. CRC Pres. 312p.
7. Bright Singh, I.S., Somnath Pai, S., Philip R. & Mohandas, A. (Eds), 2003. Aquaculture Medicine, Centre for Fish Disease Diagnosis and Management, CUSAT, Cochin, P. 336.
8. Bright Singh, I.S. and Y.S. Yadava. 2005. Aquaculture Medicine and Aquatic Animal Health management. Published by Aquaculture Authority, Ministry of Agriculture and national centre for Aquatic Animal Health, Cochin University of Science and Technology, P. 254.

Practical (CORE)

24-431-0205. LAB 1 SKILL DEVELOPMENT IN BIOTECHNOLOGICAL INTERVENTIONS IN AQUATIC ANIMAL HEALTH MANAGEMENT - 2 credits

Course Objectives

To impart hands on training in disease diagnosis and management in aquaculture

Course outcome

On the successful completion of the course, students will be able to

Course Outcome		Cognitive Level
CO 1	Determine and aquaculture environment quality through physic-chemical analysis of	Apply

	water and sediment	
CO 2	Implement the disease diagnostic platform and diagnosis a disease and identify the aetiology	Apply
CO 3	Implement preventive health care and therapeutic measures	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	-	-	-
CO2	3	-	1	-	1
CO3	3	2	3	2	3

3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1. Aquaculture environment quality assessment: Water: Salinity, pH, oxygen, alkalinity, hardness, ammonia, nitrite, nitrate, phosphate, hydrogen sulphide, conductivity; Sediment: pH, Eh, total organic carbon, total organic nitrogen, sediment oxygen demand.

Module 2. Implementation of Disease Diagnostic platform

1. Fish sampling for laboratory observation.
2. Anatomy of fish and shellfish: Dissections to study the internal organs of fishes and shellfishes.
3. Clinical study – skin, internal organs and gill biopsy.
4. Histological methods.
5. Microbiological methods, isolation of aetiological agents - identification, characterization - Immunodiagnostic techniques – agglutination, haemagglutination, precipitation, latex agglutination, immuno fluorescence, immunofluorescence histochemistry, radial immuno diffusion, immuno electrophoresis, counter current electrophoresis and ELISA; DNA based diagnostic techniques; Use of cell lines in disease diagnosis; Electron microscopy in disease diagnosis (Demonstration); Koch's postulate.

Module 3: Application of novel diagnostics - antibody based and DNA based - selection of the pathogen, production of polyclonal/monoclonal antibody, development of ELISA; Development of diagnostic PCR - identification of conserved sequence of the pathogen, designing primers, construction of positive controls and standardization of PCR conditions.

Module 4. Preventive healthcare: Vaccination: Development of vaccines - Inactivation of the pathogen, immunization, determination of antibody titre and challenge to prove effective immunization; Application Immunostimulants -diversity, mode of administration and efficacy; Environmental management: using management chemicals; Application of probiotics and nutritional supplement as preventive healthcare tools; Bioremediation:Detritus degradation, nitrification, and Hydrogen sulphide removal.

Module 5. Fish and Shell fish haematology and immunology - Collection blood/haemolymph**,** Determination of total and differential haemocyte/blood count, Estimation of protein, Prophenol oxidase activity, NBT reduction assay, Alkaline phosphatase and Acid phosphatase, Lysozyme activity, Superoxide dismutase, Catalase, Glutathione peroxidase assay, Haemagglutination, Detection and quantification of antibodies in serum.

24-431-0206. LAB 2- SKILL DEVELOPMENT IN MARINE PHARMACOLOGY - 1 credits

Course Objectives

To provide hands on experience in collection of marine fauna and flora to screen for potential bioactivities and to isolate and characterize the lead compounds with pharmaceutical/biomedical applications.

Course Outcome

After successful completion of the course, the students will be able to:

Course Outcome		Cognitive Level
CO 1	Conduct the collection of marine samples for bioprospecting	Apply
CO 2	Employ different methods for isolation and separation of the bioactive compounds	Apply
CO 3	Implement bioassay guided fractionation of bioactive compounds	Apply
CO4	Purify and characterize the marine natural products	Analyze
CO5	Identify the compounds based on structure and mass	Analyse

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	3	1	1
CO2	1	2	3	2	-
CO3	2	2	3	2	-
CO4	1	2	3	2	-
CO5	1	2	3	2	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1: Collection, transportation and preservation of marine biologicals for drug discovery: Collection of plants and animals, phytoplankton and zooplankton, preservation on site, transportation and storage in the laboratory without the loss of activity.

Module 2: Extraction of bioactive compounds, concentration: Different methods of extraction using different solvents and solvent systems- polar, mid polar and non polar; maceration, percolation, sonication, reflux

extraction, pressurized liquid extraction, Soxhlet extraction, ultrasound assisted extraction, pulsed electric field extraction, enzyme assisted extraction, hydro distillation, steam distillation, molecular distillation, Microwave assisted extraction and Super critical fluid extraction.

Module 3. Bioassay guided fractionation: Chromatographic separation and Bio- assay systems: Anti-viral, antibacterial, antifungal, anti-protozoal, anti-metazoan, anticancer, anti-diabetic, neural protectives, immune stimulation and modulation and other health related issues of humans and animals including fish, downstream processing for a pure compound and confirmation of the activity.

Module 4. Purification, characterization and structural elucidation: Chromatographic purification of the bioactive compounds – Column chromatographic and HPLC based purification, mass spectrometry and NMR based structural elucidation.

Module 5. Identification of the compounds: Based on structure and mass

20-431-0207. SKILL DEVELOPMENT IN MARINE BIOPROCESS ENGINEERING - 1 credit

Course Objectives

To give hands on experience for successful scale-up of production of marine microbial biomass and products using techniques in bioprocess engineering.

Course Outcome

After successful completion of this course, the students will be able to:

Course Outcome		Cognitive Level
CO 1	Practice culture media optimization	Apply
CO 2	Augment the production of microbial biomass using bioprocess principles	Apply
CO 3	Augment the production of biomolecules and metabolites	Apply
CO4	Practice product- separation and purification	Apply
CO5	Design novel method for the large-scale production and purification of metabolites/ biomolecules	Create

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	1	3	-
CO2	2	3	2	3	-
CO3	1	3	2	3	-
CO4	1	3	3	3	-
CO5	2	3	3	3	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

LABORATORY EXPERIMENTS

Module I: Kinetic studies

1. Submerged fermentation and Solid-state fermentation.
2. Batch growth kinetics.
3. Fed-batch growth kinetics.
4. Studying the Enzyme kinetics with and without inhibitor.
5. Immobilized enzyme kinetics.

Module II: Fermentation parameter optimization and Scale up studies

1. Designing and optimization of culture media by Response Surface Methodology (RSM)
2. Measurement of KLa for the fermentation media
3. Studying Mixing time, Residence time distribution of substrates and other physical parameters in a reactor

Module III: Downstream Processing

1. Downstream processing for bioactive compounds and microbial cells
2. Protein precipitation and fractionation.
3. Ion-exchange chromatography and Size exclusion chromatography techniques for downstream processing of microbial products

24-431-0208: LAB 3: MODEL ORGNISMS, MOLECULAR GENETICS AND GENOME ENGINEERING - 1 credit

Course Objectives

1. *To give hands on experience on Zebra fish as the widely used experimental animal model in aquaculture, pharmaceutical and bio-medical industries*
2. *To give hands on experience on Marker assisted selection in molecular breeding to produce high health brood stock*
3. *To give hands on experience in Genome engineering to produce transgenic animal models for aquaculture, pharmaceutical and bio-medical industries*

Course Outcome

After successful completion of this course, the students will be able to:

Course Outcome		Cognitive Level
CO 1	Practice the maintenance of zebra fish in a confined environmental condition and their husbandry	Apply
CO 2	Perform breeding in zebrafish	Apply

CO 3	Identify developmental stages	Analyze
CO 4	Maintain the founder population	Apply
CO 5	Practice designing, amplification and sequencing of molecular markers	Apply
CO 6	Practice **Marker** Assisted Selection of quality traits in experimental animal	Apply
CO 7	Practice selection, amplification and sequencing of gene of interests to produce knock out lines	Apply
CO 8	Develop gene constructs	Create
CO 9	Perform transformation and genetic marker assisted selection of transformed lines	Apply
CO 10	Perform genotyping	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO 5
CO1	3	-	-	-	3
CO2	2	-	-	-	3
CO3	2	-	-	-	3
CO4	2	-	-	-	3
CO5	-	-	-	-	3
CO 6		-	-	-	3
CO7	-	-	-	-	3
CO8	-	-	-	-	3
CO9	3	-	-	-	3
CO 10	1	-	-	-	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module I- Maintenance and breeding of model organisms (ZEBRAFISH)

1. Zebrafish maintenance
2. Breeding
3. Identification of various developmental stages
4. Maintenance of F1 population for experimental purpose

Module II –Marker assisted selection for molecular breeding

Marker Assisted Selection - Molecular markers – RAP, RFLP, AFLP, SNP, Microsatellite DNA, profiling; Determination of QTLs, PIC, SINE, LINE and STR.
Marker assisted selection – Designing a field level experiment in marker assisted selection

Module III. Stock improvement through transgenesis: - Identification of desired genes, amplification cloning, sequencing, transformation of embryos,

generation of F1 population, and confirmation of gene transfer and establishment of founder population (using model fishes)

Module IV. Genome Editing in Cell line and Zebrafish Embryo

1. Maintenance of Cell line and zebrafish eggs for genome editing
2. Gene targeting: Selection of gene for genome editing. Synteny analysis using ENSEMBLE database, Identification of position and exons, selection of gene of interests and Exon position for genome editing, Primer design for gene amplification and genotyping, sequence confirmation
3. Generation of gene construct: Collection of CRISPR vectors and Cas vectors, Bicistronic expression systems, designing of gRNA using Gibson assembly platform, bioinformatics tools for generation of gRNA sequences, prediction tools for off target effects in the genome, generation of CRISPR vector, Concept of Twin guide RNA systems
4. Transformation: microinjection using micromanipulator, lipofection, assessment of transformed cell line and embryo by observing reporter gene. Genotyping and confirmation of the knock out lines.
5. Experimental validation of the genome edited cell line/ embryos.
6. Applications of the developed cell lines/embryos in aquaculture industry/pharmaceutical/ bio-medical industry).

Suggested Readings

Kim H and Kim JS (2014) A guide to genome engineering with programmable nucleases. Nature Reviews Genetics 15:321-334

20-431-0209. SKILL DEVELOPMENT IN MARINE ALGAL BIOTECHNOLOGY -1 credit

Course Objective

To give hands on experience on isolation and purification and analysis of marine algae.

Course Outcome

After successful completion of this course, the students will be able to:

Course Outcome		Cognitive Level
CO 1	Practice the isolation and purification of marine microalgae	Apply
CO 2	Measure the growth of microalgae in culture	Apply
CO 3	Identify marine microalgae and macroalgae	Apply
CO4	Analyze the basic biochemical composition of marine algae	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO 5
CO1	1	3	1	1	-
CO2	1	3	1	1	-
CO3	1	3	1	1	-
CO4	1	3	1	-	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1: Methods in marine microalgal culturing

1. Marine algal sample collection and transportation-microalgae
2. Preparation of growth media
3. Isolation of unialgal cultures
4. Purification of microalgal culture
5. Measurement of light requirements for algal growth

Module 2: Identification of marine microalgae and measurement of growth in microalgal cultures

1. Observation under light microscope
2. Electron microscopic imaging of algal cells
3. Molecular taxonomy of marine microalgae
4. Cell counting of algae using hemocytometer and Sedgewick rafter counter
5. Estimation of dry weight of microalgae
6. Fluorescence measurement for growth analysis in microalgal cultures
7. Measurement of growth rate and generation time in microalgal cultures

Module 3: Basic methods macroalgal culturing

1. Marine algal sample collection and transportation- macroalgae
2. Identification of life cycle stages in seaweeds
3. Molecular taxonomy of macroalgae
4. Preparation of growth media
5. Laboratory maintenance of macroalgae
6. Histology of macroalgae and observation under light microscope
7. Electron microscopic imaging of algal cells
8. Isolation of unialgal cultures

Module 4: Biochemical analysis of marine algae

1. Analyses of biochemical composition of algae- carbohydrates, proteins, lipids, moisture content, ash content and minerals
2. Analysis of pigments from marine macroalgae

References:

1. Andersen, RA. (ed). 2005. Algal culturing techniques. Elsevier Academic Press.
2. Becker, EW1994. Microalgae: Biotechnology and microbiology. Cambridge University Press.
3. Cohen Z. 1999. Chemicals from microalgae. Taylor and Francis Ltd.

SEMESTER III (Total Credits: 23)

Theory (Core)

24-431-0301: BIO-ENTREPRENEURSHIP &INDUSTRY MANAGEMENT - 2 credits

Course Objective:

The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards, and the essential concepts and managerial skills in the development and management of marine biotechnology industries.

Course Outcome

After successful completion of this course, the students will be able to;

Course Outcome		Cognitive Level
CO 1	Explain the fundamentals of marine biotechnology industry management	Understand
CO 2	Develop entrepreneurial skills	Apply
CO 3	Develop skills to manage product development and operations	Apply
CO4	Develop financial management strategies for biotechnology industries	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	2	2	2
CO2	2	2	2	2	2
CO3	2	2	2	2	2
CO4	2	2	2	2	2

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Principles of Industry Management: Management functions - planning, scheduling, organizing, controlling, evaluating; Human resource management - human capital management and organizational behavior,

leadership, motivation, groups and corporate culture; Organizational structure; Welfare activities of an Industry; Disputes; Communication; Management Information Systems; Managerial economics; Legal aspects of management; Managing technology and knowledge; Entrepreneurship; Biotechnology regulatory affairs: Regulatory processes and agencies; Legal Aspects of Biotechnology; Intellectual Property Rights (IPR)- basis of patentability, patent application procedure, compulsory license, infringement of patents; technology transfer; different aspects; valuation of technology, non-exclusive and exclusive types, royalty fixing, global and regional licensing, examples of successful technology, market survey, Product Registration for Regulated and Non-Regulated Markets;

Unit-II: Biotechnology Entrepreneurship and Project Management: Project feasibility study; Preparation of projects reports; Project evaluation techniques; ARR methods; IRR methods; Pay back method; Project monitoring; CPM and PERT. Marketing practices and application; Market forecast; Market research; Marketing plan; Relationship between the marketing and sales functions; Niche market; Market penetration; Market skimming; Marketing a scientific product and a scientific service.

Unit-III: Overview of Biotechnology Industry Management: Product development, assessment of market potential, testing and life cycle analysis; P**roduction management; Maintenance management; Operations management;** Preclinical and c**linical trial design and conduct**; Risk analysis; Quality control and assurance**;** Total quality management; Fundamentals of validation.

Unit-IV: Finance Management for Biotechnology Industry: Vendor analysis; Vendor rating; Inventory management; EO Quantity; Leadtime; BOM; ABC analysis; VED analysis; SCD analysis; Store management; FIFO and LIFO systems. Types of costing and pricing methods; Cost – benefit-analysis; Strategic components; Marketing and sales; Break even analysis; Working capital management; and financial ratios and break-even point financial ratios; Balance sheet; P and l account**.**

Recommended text books and references

1. Adams, D. J., & Sparrow, J. C. (2008). Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences. Bloxham: Scion.
2. Shimasaki, C. D. (2014). Biotechnology Entrepreneurship: Starting, Managing, and Leading Biotech Companies. Amsterdam: Elsevier.
3. Onetti, A., &Zucchella, A. (n.d.). Business Modeling for Life Science and Biotech Companies: Creating Value and Competitive Advantage with the Milestone Bridge. Routledge.
4. Jordan, J. F. (2014). Innovation, Commercialization, and Start-Ups in Life Sciences. London: CRC Press.
5. Desai, V. (2009). The Dynamics of Entrepreneurial Development and Management. New Delhi: Himalaya Pub. House.

6. Acharya, R. 1999. The Emergence and Growth of Biotechnology: Experiences in Industrialized and Developing Countries. Edward Elgar, Cheltenham, England.
7. Afuah A. 2003. Innovation Management, Strategies, Implementation, and Profits. Oxford University Press, Oxford. 400p.
8. Berndt, R. 2000. Innovative Management. Springer, New York. 363p.
9. Burns, L.R. 2005. The Business of Healthcare Innovation. Cambridge University Press Inc., Cambridge. 398p.
10. Carter T. 1997. Contemporary Sales Force Management. Haworth Press Inc. New York, 286p.
11. Certo S.C. 1992. Modern Management: quality, ethics and the global environment. Allyn and Bacon, London, 722p.
12. Collins, S.W. 2004. The Race to Commercialize Biotechnology: Molecules, Markets, and the State in the United States and Japan. Routledge Curzon, New York.
13. Dorf R.C. 1998. The Technology Management Handbook, CRC Press, Boca Raton, 1408p.
14. Easterby-Smith,M. and Lyles, M.A. (Eds) 2003. The Blackwell Handbook of Organizational Learning and Knowledge Management. Blackwell Publishing, Oxford 676p.
15. Friedman, Y. 2004. Building Biotechnology. Starting, Managing, and Understanding Biotechnology Companies. Baker and Taylor, North Carolina, 264 p.
16. Ghose, T.K. and Ghosh P. Biotechnology in India. Springer, New York. 290p.
17. Hitt, M.A., Amit, R., Lucier, C.E. and Robert D. 2002. Strategic Entrepreneurship, Blackwell Publishing Co., Oxford, 368p.
18. Jennewein K. 2005. Intellectual Property Management The Role of Technology-Brands in the Appropriation of Technological Innovation. Springer, New York. 404p.
19. Katzenbach, Jon R; Smith, Douglas K. 2003. Wisdom of Teams: Creating the High- Performance Organization. HarperCollins, New York
20. Kelly L., Dabbah R., Dabbah D. 1998. Total R & D Management: Strategies and Tactics for 21st Century Healthcare Manufacturers. CRC Press, Boca Raton. 672p.
21. Pisano, D.J., Mantus, D. and Pisano P.J. 2003. FDA Regulatory Affairs: A Guide for Prescription Drugs, Medical Devices and Biologics, CRC Press, Boca Raton, 360p.
22. Shanley, R.P. 2003. Financing Technology's Frontier: Decision-Making Models for Investors and Advisors, 2nd Edition 272p., Wiley, New Jersey.
23. Smith, M.C. 1983. Principles of Pharmaceutical Marketing, Third Edition, Haworth Press, USA. 544p.
24. Thamhain, H.J. 1992. Engineering Management: Managing Effectively in Technology-Based Organizations. John Wiley & Sons Inc., New York. 592p.

24-431-0302: RESEARCH METHODOLOGY AND SCIENTIFIC COMMUNICATION SKILLS - 2 credits

Course Objectives

T*he objectives of this course are to give background on history of science, emphasizing methodologies used to do research, use framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics.*

Course Outcome

After successful completion of this course, the students will be able to

Course Outcome		Cognitive Level
CO 1	Explain the history and methodologies of scientific research	Understand
CO 2	Apply statistical tools in data analysis	Apply
CO 3	Practice scientific reading, writing and presentations	Apply
CO4	Practice scientific ethics through case studies	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	3	3	3
CO2	3	3	3	3	3
CO3	3	3	3	3	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Scientific methodologies: Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology. **Preparation for research:** Choosing a mentor, lab and research question; maintaining a lab notebook.

Unit II: **Biostatistics and Data Analysis:Sampling Methods:** Census Vs Sampling methods- Random, stratified, systematic and multistage sampling; Determination of sample size. **Collection and Analysis of Data:** Collection of data; Formation of frequency distribution table; Measures of central tendency and dispersion; Correlation and regression, **Probability and Theoretical Distributions:** Theory of probability; Theoretical distributions- Binomial, Poisson and Normal distributions, **Testing of hypothesis and Design of Experiment:** Testing of hypothesis-Z, T, F and □ 2 tests; Design of experiments and analysis of variance, Use of statistical software in data analysis- statistical software and their application- SPSS, SYSTAT, R, PRIMER

Unit III : Process of communication: Concept of effective communication- setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating;

creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using over- head projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

Unit IV: Scientific communication: Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non- blind review; plagiarism; characteristics of effective technical communication; scientific presentations;

Recommended text books and references

1. Valiela, I. (2001). Doing Science: Design, Analysis, and Communication of Scientific Research. Oxford: Oxford University Press.
2. On Being a Scientist: a Guide to Responsible Conduct in Research. (2009). Washington, D.C.: National Academies Press.
3. Gopen, G. D., & Smith, J. A. The Science of Scientific Writing. American Scientist, 78(Nov-Dec 1990), 550-558.
4. Mohan, K., & Singh, N. P. (2010). Speaking English Effectively. Delhi: Macmillan India.
5. Movie: Naturally Obsessed, The Making of a Scientist.

24-431-0303: INTELLECTUAL PROPERTY RIGHTS, BIOSAFETY AND BIOETHICS -2 Credits

Course Objectives

The objectives of this course are: to provide basic knowledge on intellectual property rights and their implications in biological research and product development; to become familiar with India's IPR Policy; to learn biosafety and risk assessment of products derived from biotechnology and regulation of such products; and to become familiar with ethical issues in biological research.

Course Outcome

After successful completion of this course, the students will be able to:

Course Outcome		Cognitive Level
CO 1	Explain the rationale for and against IPR and especially patents	Understand
CO 2	Identify why India has adopted an IPR Policy and be familiar with broad outline of patent regulations	Understand
CO 3	Recognize different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents	Apply
CO4	Explain the importance of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations	Understand
CO5	Apply ethical aspects related to biological, biomedical, health care and biotechnology research	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	2	2	2
CO2	2	2	2	2	2
CO3	2	2	2	2	2
CO4	3	3	3	3	3
CO5	3	3	3	3	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

UNIT 1: Introduction to IPR: Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of 'prior art': invention in context of "prior art"; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

UNIT II: Patenting: Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application-forms and guidelines including those of National Bio-diversity Authority

(NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting- introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

UNIT III: Biosafety: Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vscisgenic plants or products derived from RNAi, genome editing tools.

UNIT IV: National and international regulations: International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

UNIT V: Bioethics: Introduction, ethical conflicts in biological sciences - interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research – cloning and stem cell research, Human and animal experimentation, animal rights/welfare, Agricultural biotechnology - Genetically engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – bio-piracy.

Recommended text books and references

1. Ganguli, P. (2001). Intellectual Property Rights: Unleashing the Knowledge Economy, New Delhi: Tata McGraw-Hill Pub.
2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI

3. Complete Reference to Intellectual Property Rights Laws. (2007). Snow White Publication Oct.
4. Kuhse, H. (2010). Bioethics: an Anthology. Malden, MA: Blackwell.
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/
6. Karen F. Greif and Jon F. Merz, Current Controversies in the Biological Sciences-Case Studies of Policy Challenges from New Technologies, MIT Press
7. World Trade Organisation. http://www.wto.org
8. World Intellectual Property Organisation. http://www.wipo.int
9. International Union for the Protection of New Varieties of Plants. http://www.upov.int
10. National Portal of India. http://www.archive.india.gov.in
11. National Biodiversity Authority. http://www.nbaindia.org
12. Recombinant DNA Safety Guidelines, 1990 Department of Biotechnology, Ministry of Science and Technology, Govt. of India. Retrieved from http://www.envfor.nic.in/ divisions/csurv/geac/annex-5.pdf
13. Craig, W., Tepfer, M., Degrassi, G., &Ripandelli, D. (2008). An Overview of General Features of Risk Assessments of Genetically Modified Crops. Euphytica, 164(3), 853- 880. doi:10.1007/s10681-007-9643-8
14. Guidelines for Safety Assessment of Foods Derived from Genetically Engineered Plants. 2008.
15. Guidelines and Standard Operating procedures for Confined Field Trials of Regulated Genetically Engineered Plants. 2008. Retrieved from http://www.igmoris.nic.in/ guidelines1.asp
16. Alonso, G. M. (2013). Safety Assessment of Food and Feed Derived from GM Crops: Using Problem Formulation to Ensure "Fit for Purpose" Risk Assessments. Retrieved from http://biosafety.icgeb.org/inhousepublicationscollectionbiosafetyreviews.
17. Wolt, J. D., Keese, P., Raybould, A., Fitzpatrick, J. W., Burachik, M., Gray, A., Wu, F. (2009). Problem Formulation in theEnvironmental Risk Assessment for Genetically Modified Plants. Transgenic Research, 19(3), 425-436. doi:10.1007/s11248-009-9321-9

24-431-0304: PROJECT PROPOSAL PREPARATION & PRESENTATION- 2 Credits

Course Objectives

The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Course Outcome

After successful completion of this course, the students will be able to:

Course Outcome		Cognitive Level
CO 1	Develop a hypothesis	Apply
CO 2	Design experiments to test hypothesis	Apply
CO 3	Analyse the data	Analyze
CO4	Interpret the results	Analyze
CO5	Write scientific proposal	Apply
CO6	Defend research findings to the audience effectively	Understand

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	3	3	3
CO2	3	3	3	3	3
CO3	3	3	3	3	3
CO4	3	3	3	3	3
CO5	3	3	3	3	3
CO6	3	3	3	3	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

UNIT 1: Project Proposal Preparation:

Selection of research lab and research topic: Students shall select a lab wherein they would like to pursue their research. The supervisor or senior researchers shall help the students to read papers in the areas of interest and help them select a topic for the project. The topic of research should be hypothesis driven.

Review of literature: Students shall engage in systematic and critical review of appropriate and relevant literature and appropriately apply qualitative and/or quantitative evaluation processes to generate data keeping in mind ethical standards of conduct in the collection and evaluation of the same.

Writing Research Proposal: With the help of senior researchers, students shall discuss research questions, goals, approaches, methodology, data collection, analysis and interpretation, shall be able to construct logical outline of the project in the scientific format.

UNIT II: Poster Presentation: Students shall present the topic of their project after a few months and explain its novelty and significance.

UNIT III: Oral Presentation: At the end of project, presentation will be made by the students to explain the work done along with summarizing the findings and the outcome.

Recommended text books and references

1. Pam Denicolo, Lucinda Becker (Eds) (2012). Developing Research Proposals. SAGE publications
2. Thomas E. Ogden, Israel A. Goldberg (Eds) 1995. Research Proposals: A Guide to Success , 3rd Edition .Academic Press
3. Crawley Gerard M and Eoin O'Sullivan (Eds). The Grant Writer's Handbook: How to Write a Research Proposal and Succeed (2015). Imperial College Press

24-431-0305. RESEARCH PROJECT UNDER THE AREA OF SPECIALIZATION -Progress Review 1: 10 credits

1. Aquatic Animal Health Management, 2. Marine Algal Biotechnology, 3. Marine Pharmacology, 4. Marine Bioprocess Engineering and 5. Genetic Improvement in Aquaculture.

Toral Credits: 23: Core: 18; Electives: 5

SEMESTER IV: Total Credits: 18

24-431-0401. RESEARCH PROJECT UNDER THE AREA OF SPECIALIZATION -18 credits

Comprising progress review 2, 2. Progress Review 3; 3. Report submission and presentation

Syllabi for Elective Courses

List of Elective Courses

24-431-0101 Cell and Hybridoma Technology

24-431-0102 Marine Microbiology

24-431-0103 Bioinformatics, Systems and Computational Biology

24-431-0104 Nano-biotechnology

24-431-0205 Model Systems, Molecular Genetics and Genome Engineering for Stock Improvement

24-431-0206 Marine Pharmacology in Practice

24-431-0207 Enzyme Engineering & Technology

24-431-0208. Skill Development in Marine Animals Handling and Maintenance.

24-431-0306 Marine Pharma Industry Development

24-431-0307 Genetic Improvement in Aquaculture

24-431-0308 Marine Algal Biotechnology for Industrial plications

24-431-0309 Aquatic Animal Health Management

20-431-0310 Marine Bioprocess Industry Development

20-431-0311 Products and services of oceans (Inter Departmental Elective Offered for other Departments)

24-431-0101: CELL AND HYBRIDOMA TECHNOLOGY -3 CREDITS

Course Objectives

To impart students fundamentals in animal cell technology and technical know-how in developing and maintaining cell cultures and cell lines, and in the development of hybridoma for monoclonal antibody production.

Course outcome

On the successful completion of the course, students will be able to

Course Outcomes		Cognitive Level
CO 1	Explain the significance, types of cell cultures and their maintenance	Understand
CO 2	Explain cells at molecular level	Understand
CO 3	Practice molecular cell biology techniques and genetic engineering	Apply
CO 4	Demonstrate experiments with cell lines	Apply
CO 5	Explain applications of stem cells	Understand
CO6	Perform hybridoma technology	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	-	-	2	3
CO2	1	-	-	-	3
CO3	1	-	-	-	3
CO4	1	-	3	1	3
CO5	1	-	2	1	3
CO6	1	-	-	-	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Introduction to cell culture techniques : History; Definition of primary cell cultures; Diploid cell lines; Established or immortal cell lines; Suspended and anchor dependent cell cultures; Morphological differentiation of cell cultures; Animal Cell Culture Laboratory - lay out, equipments, media, glass and plastic wares; Cell culture techniques – enzymatic disaggregation and explant cell culture techniques, open and closed system, sub-culturing techniques, preservation and revival of cell lines, enumeration of viable cells, cell line characterization.

Unit II: Cell and Cell Cycle: Eukaryotic cell - Cell adhesion, Cell adhesion molecules, Extra cellular matrix, interaction of cells with extracellular matrix, interaction of cells with other cells; cytoskeleton; Eukaryotic cell cycle - major events in cell cycle, cell cycle regulations - regulator genes; Differentiation; Dedifferentiation; Trans-differentiation; Terminal differentiation; Senescence; Apoptosis – genetic pathways for PCD, anti and proapoptotic proteins; signal transduction; Active and passive transport; Carrier proteins - uniporter/ symporter/antiporter; Ion channels - ligand and voltage gated channels; G– proteins; signaling pathways -Ras/MAPK, JAK-STAT.

Unit III: Molecular Cell Biology Techniques and Genetic Engineering:Labeling techniques – radioisotope labeling, digoxigenin labeling, *In situ* hybridization; Cell Hybridization - somatic cell fusion, hybridoma technology; Immortalization techniques - chemically induced immortalization, SV 40 and HPV mediated immortalization; Gene Delivery- transfection, electroporation, nucleofection, lipofection, nanoparticle based techniques, transduction - baculo viral; Reporter gene assays in post transfection/transduction experiments- expression of Green Fluorescent Protein in cell lines; Introduction and expression of various oncogenes and telomerase.

Unit IV: Aquatic Animal Cell Cultures and Biomedical Application: Aquatic animal cell lines ; In vitro testing of new substances/drugs - cytotoxicity assays, lactate dehydrogenase (LDH), Sulforhodamine B (SRB), MTT, Neutral Red uptake, Glucose uptake; Immunofluorescence staining; Assay for apoptosis and senescence; Fish and shell fish cell expression systems - tissue specific promoters, constitutive promoters; Biomedical applications; Cell culture based vaccines.

Unit V: Stem Cells from Aquatic Animals: Stem cells - adult stem cells, embryonic stem cells; Induced pluripotent stem cells (iPS); Stem cells in Marine organisms; Cell-mediated gene transfer strategy using pluripotent embryonic stem (ES) cell cultures.

Unit VI: Hybridoma Technology: Antigen selection and purification, immunization of mice, hybridization, selection of hybrid clones- HAT system and principles of clonal selection, Monoclonal antibodies and polyclonal antibodies, Production of monoclonal antibodies, Hybridomas production, Screening and subcloning of hybridomas, production of monoclonal antibodies, uses of monoclonal antibodies.

Recommended text books and references:

1. Freshney, R.I. 2000. Culture of animal cells- A manual of basic technique 4th Edition. John Wiley & Sons Inc. Publication.
2. Gerald Karp, 2005. Cell and Molecular biology 4th Edition. John Wiley & Sons Inc. Publication.
3. Mitsuhashi., 2011. Invertebrate Tissue Culture Methods. Springer International publication

4. Baruch Rinkevich., Valeria Matranga., 2009. Stem Cells in Marine Organism. Springer International publication
5. Phillip Kaldis, 2006 Cell cycle regulation: Results and problems in cell differentiation, Springer International publication.
6. Macieira-Coelho. A., 2000 Cell Immortalization: Progress in Molecular and Subcellular Biology, Springer International publication, New York.
7. Benjamin Lewin., Lynne Cassimeris., Vishwanath R. Lingappa& George Plopper., 2006 Cells, Jones and Bartlett Publishers, USA
8. David P. Clark., Nanette j. Pazdernik., 2011 Biotechnology: Academic Cell Update, Elsevier Academic Press publication, UK
9. Bright Singh, I.S., Valsamma Joseph, Rosamma Philip & Mohandas, A., 2007 Aquaculture and Marine Biotechnology, NCAAH publication, CUSAT, India.
10. Selected publications

24-431-0102 MARINE MICROBIOLOGY- 2 credits

Course Objectives

To impart a comprehensive understanding on marine microbes and microbial diversity of the oceans and how do marine microorganisms play crucial role in structuring of marine ecosystems and regulation of climate and biogeochemical cycling.

Course outcome

On the successful completion of the course, students will be able to:

Course Outcomes		Cognitive Level
CO 1	Methods used for isolating and culturing of microbes	Understand
CO 2	Classify different types of microbes and their functional characteristics	Understand
CO 3	Analyze the diversity of microbes in ocean	Analyse
CO 4	Employ molecular tools for estimating the diversity of marine microbes	Apply
CO 5	Summarize the role of microbes in marine environment	Understand

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	3	1
CO2	3	3	1	1	1
CO3	3	2	1	1	-
CO4	3	2	2	-	-
CO5	3	2	2	1	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Introduction to Microbiology: History and scope of microbiology; Different kinds of media for isolation and study of microorganisms; sterilization techniques, Microbiological water and sediment samplers; Microscope and microscopy; Concept of pure cultures and methods of obtaining pure cultures; Aerobic, microaerophilic, facultative anaerobic and obligate anaerobic microbes – methods of culture; Isolation methods for viable but non-culturable microorganisms, Control of microorganisms by physical and chemical agents, evaluation of antimicrobial agents' effectiveness.

Unit II: Bacteria, Archaea, Fungi, Protozoans and microalgae: Bacteria: Cell structure: size, shape and arrangements, cell organization – cell membranes, cytoplasmic matrix, nucleoid, cell wall, components external to the cell wall - capsule, slime layers and S - layers, pilli and fimbriae, flagella, motility and chemotaxis. Bacterial endospores; Autotrophic and heterotrophic metabolism, Bacterial nutrition, Bacterial Growth curve, continuous culture of microorganisms.
Archaea: Cell structure: size, shape and arrangements, cell organization,
Fungi: Basic concepts, distribution, importance, structure, nutrition and metabolism, reproduction, characteristics of fungal division and classification.
Protozoans: Basic concepts, distribution, importance, morphology, nutrition, encystment and excystment, locomotory organells, reproduction and classification.
Microalgae: Basic concepts, distribution, structure, algal nutrition, algal reproduction, characteristics, classification.

Unit III: Viruses: General properties of viruses; Cultivation of viruses; Virus preparation; purification and assays; Structure of viruses; Principles of virus taxonomy; Bacteriophages – classification, reproduction of dsDNA, ssDNA, dsRNA and ssRNA phages, Temperate bacteriophages and lysogeny; Viruses of eukaryotes – classification of animal and plant viruses, reproduction, Persistent, latent and slow virus infection.

Unit IV. Introduction to Marine Microbiology: History of Marine Microbiology, Life and work of Claud E. ZoBell; Autochthonous and allochthonous microorganisms, mesophiles, thermophils, psychrophiles and barophiles- diversity and isolation techniques; Diverse habitats of marine microorganisms, larger living organisms as microbial habitats, Physiology of marine microorganisms, Marine microbial adaptations - oligotrophs and copiotrophs, photosynthesis and carbon sequestration.

Unit V: Marine microbial diversity and ecology: Marine microbes; microbial taxonomy and phylogeny; Conventional and molecular methods for assessing microbial diversity, Species evenness and richness, Metagenomic analysis, Operational taxonomic units, Statistical methods in analyzing microbial diversity. Microorganism interactions and microbial ecology of the Oceans; nutrient cycling and microbial involvement, normal microbiota in aquatic animals and animal health, microbiome and health,

pathogenecityofmicroorganisms in the Oceans, Microbial iteractions - Commensalism, Parasitism, Symbiosis; Role of microbes in Oceanprocess- Microbial loop - Role of microbes in marine food web dynamics and biogeochemical processes, Marine viruses and productivity - viral shunt.

Recommended text books and references:

1. Rheinhemer, G. 1980. Aquatic Microbiology, John Wiley & Sons, PP 235
2. Ford, T.E., 1993. Aquatic Microbiology – An Ecological Approach. Blackwell Scientific Publications, London, PP 518.
3. Krichman, D.I., 2000. Microbial Ecology of the Oceans. Wiley – Liss, New York, PP 542
4. Kemp,P.F., Kemp, K.F., Sherr, B.F., Cole, J.J. and Sherr, E.B. 1993. HandbookofMethods in AquaticMicrobialEcology. CRC Press, Boca Raton. 800p.
5. Towner K.J. and Cockayne. 1993. Molecular Methods of MicrobialIdentification and Typing. Chapman and Hall, London. 202p.
6. Munn, C.B. 2004. Marine Microbiology. Ecology and Applications. Garland Science/ BIOS ScientificPublishers, Oxon and New York. 282 p.
7. Cooksey K.E. (Ed.). 1998. Molecular approachestothestudyoftheocean. Chapman and Hall, London. 549p.
8. Michael Pelczar, Jr.(Ed) 2001. Microbiology
9. Joanne Willey (Ed) 2017. Prescott's Microbiology
10. Selected papers from journals.

24-431-0103. BIOINFORMATICS, SYSTEMS AND COMPUTATIONAL BIOLOGY- 2 credits

Course objective

To lay down strong foundation in bioinformatics, Systems and Computational biology through problem-oriented approaches for skill development to facilitate finding answers to questions in marine biotechnology.

Course Outcome

At the end of the course the student will be able to:

Course Outcomes		Cognitive Level
CO 1	Analyse the sequences for phylogeny	Analyze
CO 2	Apply computational tools for analysing genomes, transcriptome and proteome and protein structure prediction and drug discovery from marine systems	Apply
CO 3	Explain the concept of systems biology and synthetic biology	Understand
CO 4	Employ modeling tools for enzyme kinetics	Apply
CO 5	Describe the fundamentals of mathematical modeling	Understand
CO6	Develop metabolic engineering and gene regulatory network models based on mathematical and	Create

	computational modeling tools	

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	-	-	2
CO2	1	1	3	-	3
CO3	1	1	-	1	3
CO4	2	2	1	3	-
CO5	1	2	1	2	-
CO6	1	2	1	1	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Introduction to Bioinformatics: Definition; Brief History; Computational Biology versus Bioinformatics; Scope / Research Areas; Introduction to biological databases, sequence formats, . Data retrieval tools - Entrez, SRS, Pubmed, Medline, OMIM. Marine biodiversity databases- GBIF, CoML, IO-CoML. PCR Primer design, Overview of computer programming for Bioinformatics analysis- Basics of R, Python.

Unit II: Sequence Analysis: Basic concepts of sequence alignment: Match, Mismatch, Gap penalties, Scoring matrix; Classification of sequence alignment; Pairwise Sequence Alignment: Needleman - Wunsch & Smith - Waterman algorithms,– Scoring matrices -BLOSUM, PAM matrices; Multiple Sequence Alignment and Applications: Methods, Interactive alignment, Progressive alignment– ClustalW, T - Coffee; BLAST as a similarity search tool- E-value; Profile Methods - Gribskov profile, PSI-BLAST, Introduction to Phylogenetics; Tree construction; Tree evaluation, Analysis of sequence data from next generation sequencing- Genome, transcriptome and microbiome analysis.

Unit III: Structure Analysis and drug discovery: Genome, transcriptome and proteome analysis, Genome annotation and gene prediction, Protein structure prediction methods; Homology modeling; Threading and *ab-intio* methods; Protein function prediction; Protein structure visualization tools- Swiss PDB Viewer; Target identification and validation; Lead optimization and validation; Structure-based drug design and ligand-based drug design; Modelling of target-small molecule interactions; Fundamentals of molecular docking; Docking tools; ADME-Tox prediction

Unit IV: Introduction to systems and synthetic biology: What is a model - advantages and limitations - system state - variables – parameters – constants - model behavior – classification - steady state, data types and integration - robust and fragile systems - close and open networks, random, directed, branched, unbranched pathways. Fundamentals of synthetic biology.

Modeling biochemical systems: Law of mass action, Reaction Kinetics, Order of reaction, Elasticities, Basic Enzyme kinetics, Enzyme inhibition

and activation, multi-reactant rate laws, cooperativity, allostery, kinetics of gene regulation, basic thermodynamics.

Unit V: Mathematics of modeling and building models: Introduction to graph theory and statistics; Scale free, random, clustering, small world, modularity, complexity; Biological Networks; Network motifs, Sensitivity analysis, parameter estimation and optimization; Discrete v/s continuous modeling, Dynamic mathematical model - state variables and model parameters - steady state behavior, transient behavior - linear and non-linear systems - global and local behavior- deterministic and stochastic models, database and tools for building models. Applications: systems pharmacology, virtual cell, virtual liver, virtual brain.

Unit VI: Modeling systems – from pathways to organism: Modelling formalisms: Boolean, Bayesian, ODE, petri net, stoichiometry; Modeling metabolic pathways and gene regulatory networks, Applications of Bioinformatics, Systems and Computational Biology in Marine Biotechnology and Aquaculture - Biosynthetic gene cluster identification.

Recommended text books and references:

1. David W. Mount Bioinformatics – Sequence and Genome analysis**,** Cold Spring Harbor Laboratory Press, New York, 2001
2. Stephen A. Krawetz & David D. Womble Introduction to Bioinformatics A Theoretical and Practical Approach. Humana Press, Totowa, NJ,2003
3. Arthur M. Lesk**,** Introduction to Bioinformatics, Oxford University Press, New Delhi, 2003.
4. D.Higgins and W.Taylor (Eds), Bioinformatics-Sequence, Structure and databanks**,** Oxford University Press, New Delhi, 2000.
5. Berbert M. Sauro, Enzyme kinetics for Systems Biology. 2011
6. Hans Bisswanger, Enzyme kinetics: principles and methods. 2008
7. Kohl M, Standards, databases, and modeling tools in systems biology. Methods in Molecular Biology. 2011; 696:413-27.
8. Coskun S.A., A.E. Cicek, N Lai, R.K. Dash, Z M Ozsoyoglu and G Ozsoyoglu. An online model composition tool for system biology models. BMC Systems Biology 2013: 7, 88
9. Gomez-Cabrero D., I Abugessaisa, D Maier, et al. Data integration in the era of omics: current and future challenges. BMC Systems Biology 2014, 8(Suppl 2):I1.
10. Dhar PK, A. Giuliani. Laws in Biology: why so few? Sys. Synth. Biol 2010: 4, 7-13

24-431-0104: NANO BIOTECHNOLOGY - 2 credits

Course Objective:
This course aims at providing general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with combination of top-down approach of microelectronics and micro- mechanics with bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve everyday life.

Course outcome:
After successful completion of this course, the students will be able to:

Course Outcomes		Cognitive Level
CO 1	Describe basic science behind the properties of materials at the nanometer scale	Understand
CO 2	Explain principles behind advanced experimental and computational techniques for studying nanomaterial	Understand
CO 3	Analyze the use of nanoparticles in biomedical application	Analyze
CO 4	Explain applications of nanobiocatalysis	Understand
CO 5	Understand about different nanomaterials	Understand
CO6	Understand and assess the toxicity of nanomaterials.	Analyse

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	-	-	-	1	-
CO2	-			1	-
CO3	-	-	-	-	-
CO4	1	1	3	3	2
CO5	1	1	2	1	1
CO6	2	2	2	1	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Introduction to Nano biotechnology: Introduction to Nano-biotechnology; Concepts, historical perspective; Different types of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Biosynthesis, and characterization of different nanomaterials.

Unit II: Nano-films: Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.

Unit III: Nano – particles: Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

Unit IV: Applications of Nano-particles: Nanoparticles for diagnostics and imaging (theragnostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.

Unit V: Nano – materials: Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates

Unit VI: Nano-toxicity: Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life cycle assessment, containment.

Recommended text books and references

1. GeroDecher, Joseph B. Schlenoff, (2003); Multilayer Thin Films: Sequential Assembly of Nanocomposite Materials, Wiley-VCH Verlag GmbH & Co. KGaA
2. David S. Goodsell, (2004); Bionanotechnology: Lessons from Nature, Wiley-Liss
3. Neelina H. Malsch, Biomedical Nanotechnology, CRC Press
4. Greg T. Hermanson, (2013); Bioconjugate Techniques, (3rd Edition); Elsevier
5. Recent review papers in the area of Nanomedicine.

20-431-0205: MODEL ORGANISMS, MOLECULAR GENETICS AND GENOME ENGINEERING FOR STOCK IMPROVEMENT- 2 credits

Course Objective: To impart fundamentals in Model systems, Molecular Genetics**,** and the technical knowhow in genome editing using CRISPR/Cas genome editing platform.

Course outcome

On the successful completion of the course, students will be able to:

Course Outcomes		Cognitive Level
CO 1	Explain the importance of Aquatic Animal Model systems, and their maintenance	Understand
CO 2	Describe molecular genetics	Understand
CO 3	Explain various molecular mechanisms of DNA	Apply

	damage and repair	
CO 4	Explain various molecular mechanism in genetic recombinations	Understand
CO 5	Undertake gene targeting	Apply
CO 6	Undertake different methods of genome engineering	Apply
CO 7	Employ genome editing tools and genetic circuits	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	-	-	-	3
CO2	1	1	1	-	3
CO3	1	1	-	-	3
CO4	1	1	-	-	3
CO5	2	2	-	-	3
CO6	2	2	-	-	3
CO7	2	2	-	-	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I Aquatic Animal Model systems in genetic improvement of brood stock: In vitro and in vivo model systems, Fresh water and Marine Animal Model systems; Maintenance and breeding of marine model organisms, criteria for selecting model animals, using aquatic model systems. Zebra fish and marine medaka as a model animals; Importance of Zebra fish, and Medaka, Basic requirements for maintain Zebra fish, and Medaka.

Unit II Forward genetics in genetic improvement of brood stock: Evolution of concept of gene: Allele, multiple alleles, one gene one enzyme, one gene one polypeptide hypothesis, structural and functional allelism, pseudoallele, complementation tests. microRNAs, change in chromosome number and structure, genomic instability, DNA repair genes, DNA methylation. Mutation: Categories &Types, phenotypic effects of mutations – lethal, conditional, biochemical, loss of function, gain of function, germinal verses somatic mutants, molecular basis of mutation, insertional mutagenesis, suppressor mutations, causes of mutations, mutator genes, reversion of mutation, detection, adaptive response by *Ada* gene.

Unit III Recombination: Homologous recombination, non-homologous end joining (NHEJ) and microhomology-mediated end joining (MMEJ) at the molecular level, Holliday junctions and homologous recombination. (Holliday & DSB repair model); site-specific recombination and transposition of DNA. Double-strand break repair (DSBR) pathway, synthesis-dependent strand annealing (SDSA).

Unit IV Reverse Genetics in stock improvement: Gene targeting, gene trapping, replacement strategy based on homologous recombination,

Knock-out, Knock-in strategies, knock-out lines for forward genetics, site-specific recombinase technology; Cre-Lox recombination, Cre-Lox system, FLP-FRT recombination system, Transposable element excision; Berkeley Drosophila Genome Project (BDGP). Post-transcriptional gene silencing (PTGS). Methods of dsRNA delivery for PTGS; Micro injection, feeding/soaking, transgenic methods.

Unit V Genome editing in genetic improvement of stocks: Site-directed mutagenesis and transgenics; zinc-finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs), and clustered regularly interspaced short palindromic repeat (CRISPR) and CRISPR associated (Cas) nucleases. Heterologous reporter genes., CRISPR/CaS mediated genome editing: History of CRISPR/CaS, Genome-Editing Technologies: Concept, Pros, and Cons of Various Genome-Editing Techniques and Bioethical Concerns for Clinical Application, gRNA, crRNA, PAM sequence, spacer and –protospacer, CRISPR vectors, U6 snRNA promoters, Cas9 expression vectors, bicistronic expression vectors, application of dCas9, CRISPR–dCas toolbox for genetic engineering and synthetic biology, CRISPR interference, CRISPR activation. Genotyping

Recommended text books and references

1. Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin. K.C., Molecular Cell Biology 8th Edition Published by W.H freeman and Company, New York
2. Naruse, Kiyoshi, Tanaka, Minoru, Takeda, Hiroyuki. Medaka: A Model for Organogenesis, Human Disease, and Evolution, 2011. Springer Japan
3. William H. Detrich, III. The Zebrafish: Disease Models and Chemical Screens Academic Press, 2011
4. Steve F. Perry, Marc Ekker, Anthony P. Farrell, Colin J. Brauner. Fish Physiology: Zebrafish. Academic Press, 2010
5. Vijai Singh, Pawan Kumar Dhar. Genome Engineering Via CRISPR-Cas9 System. Elsevier Science & Technology, 2020
6. Nicholas Foulkes. Genetics, Genomics and Fish Phenomics. Academic Press, 2016
7. Takashi Yamamoto. Targeted Genome Editing Using Site-Specific Nucleases: ZFNs, TALENs, and the CRISPR/Cas9 System.Springer, 2015.
8. Gurbachan S. Miglani. Essentials of Molecular Genetics. Alpha Science International Limited, 2015
9. Chapman and Hall, 1990. Terence A. Brown. Genetics: a molecular approach
10. Gurbachan S. Miglani. Genome Editing: A Comprehensive Treatise. Alpha Science International, Limited, 2019
11. Jayesh P, Aswathy C, Mnomi S, Joseph V, Singh ISB (2024). Genetic improvement in edible fish: status, constraints, and prospects on CRISPR-based genome engineering. 3 Biotech 14, 44 https://doi.org/10.1007/s13205-023-03891-7 (IF – 2.9).

24-431-0206. MARINE PHARMACOLOGY IN PRACTICE - 2 credits
Course Objectives

Advanced training in drug discovery from marine biological systems, and developing them to administration module.

Course outcome

On the successful completion of the course, students will be able to

Course Outcome		Cognitive Level
CO 1	Execute discovery of drugs from marine biologicals.	Apply
CO 2	Extraction, concentration, and purification,	Apply
CO 3	Developing them to drugs of choice	Apply
CO 4	Developing delivery systems	Apply
CO 5	Production of bioactive compounds	Create
CO 6	Develop drug delivery systems	Create

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	3	2	-
CO2	2	3	3	2	-
CO3	1	2	3	2	-
CO4	2	2	3	2	-
CO5	3	2	3	2	2
CO 6	3	2	3	2	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1: Collection, storage and transportation and preservation of marine biologicals for bioprospecting – Collection of plants and animals, phytoplankton and zooplankton, temporary preservation on site, transportation, and storage in the laboratory without the loss of activity.

Module 2: Extraction of the bioactive: Different methods of extraction using different solvents and solvent systems- polar, mid polar and non polar; maceration, percolation, sonication, reflux extraction, pressurized liquid extraction, Soxhlet extraction, ultrasound assisted extraction, pulsed electric field extraction, enzyme assisted extraction, hydro distillation and steam distillation, molecular distillation, Microwave assisted extraction and Super critical fluid extraction.

Module 3: Bioassay guided fractionation of bioactive compounds and purification: Chromatographic separation and Bio- assay systems: Anti-viral, antibacterial, antifungal, anti-protozoal, ant metazoan, anticancer, anti-diabetic, neural protectives, immune stimulation and modulation and other health related issues of humans and animals including fish – Invitro and in vivo systems, methodologies and infrastructure required,

downstream processing for a pure compound and confirmation of the activity.

Module 4: Characterization and Structural elucidation: FTIR, NMR(1D and 2D) and HiRes Mass analysis, LC- MS, Efficient Dereplication strategies using Global Natural product Social molecular networking (GNPS)/natural product atlas/Antibase; clinical trials – first, second and third.,

Module 5: Production: Production of the bioactive compound through extraction from the natural renewable bioresource, chemical synthesis of analogues and synthetic biology production.

Module 6: Drug Delivery system: Route of delivery, delivery vehicles, targeted drug delivery, controlled release formulations, Modulated drug release and zero-order drug release, Delivery of biologic drugs, Nanoparticle drug delivery, Acoustic targeted drug delivery, Asymmetric membrane capsule, Bioavailability, Bovine submaxillary mucin coatings, Chemotactic drug-targeting, Drug delivery to the brain, Drug carrier, Gated drug delivery systems, Magnetic drug delivery, Neural drug delivery systems, Retrometabolic drug design, Self-emulsifying drug delivery systems- self emulsifying formulations, self-micro emulsifying formulations, self-nano emulsifying formulations, Stretch-triggered drug delivery, Tecrea, Thin film drug delivery, pH dependent delivery, enzyme dependent delivery, pulsatile time -depended delivery, pressure depended delivery, brain targeted drug delivery systems, controlled drug delivery using microfluidic devices, rate programmed drug delivery systems, activation modulated drug delivery systems.

Recommended text books and references

1. Atta-ur-Rahman, Iqbal Choudhary, M., and Thomsen, W.J. Eds. 2005. Bioassay Techniques for Drug Development (Taylor and Francis).
2. Seethala, R., and Fernandes, P.B. Eds. 2001. Handbook of Drug Screening (Marcel Dekker Inc).
3. Zhang, L., and Demain, A.L. Eds. 2005. Natural Products Drug Discovery and Therapeutic Medicine. Humana Press.
4. Lansing Taylor, D., Harkins, J.R., and Giuliano, K.A. Eds. 2007. Methods in Molecular Biology, Volume 356. Humana Press.
5. Braga, P.C., and Ricci, D. Eds. (2005). Methods in Molecular Biology, Volume 242.
6. Hammes, G.G. ed. 2005. Spectroscopy for the biological sciences. Wiley Interscience.
7. Kastin, A.J. ed. 2006. Handbook of biologically active peptides. Elsevier.
8. Ehrlich**,** Hermann Ed 2010. Biological Materials of Marine Origin. Invertebrates (Springer)
10. http://www.mdpi.com/journal/marinedrugs
11. https://gnps.ucsd.edu/ProteoSAFe/static/gnps-splash.jsp
12. http://pubs.rsc.org/marinlit/
13. *Dean Martin*(Ed) Marine Pharmacognosy :Action of Marine Biotoxins at the cellular leve

l4. Charles G. Smith, James T. O'Donnell Ed, The Process of New Drug Discovery and Development, Second Edition, CRC Press ISBN 9780849327797
15. John P. Griffin John Posner Geoffrey R. Barker , The Textbook of Pharmaceutical Medicine, 7th Edition , ISBN: 978-0-470-65987-8, BMJ Books

20-431-0206. Skill Development in Marine Animals Handling and Maintenance. Credit 1

Course Objective: To provide skill and understanding on the collection of marine animals and the maintenance of the animals under laboratory conditions.

Course Outcome
After successful completion of the course, the students will be able to

Course Outcome		Cognitive Level
CO 1	Develop comprehensive understanding on food and feeding habits and habitats of the marine animals	Understand
CO 2	Carry out marine sampling and transport live animals to the laboratory	Apply
CO 3	Develop an understanding on the design and development of refugium for the maintenance of marine animals	Understand
CO 4	Practice the handling of marine animals maintained in the laboratory	Apply
CO 5	Implement the breeding programmes of marine animals in a refugium	Create

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	1	3
CO2	3	1	2	1	3
CO3	3	1	2	-	3
CO4	3	2	3	-	3
CO5	3	1	2	-	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1. Marine animal phyla: Porifera, Cnidaria, Platyhelminthes, Nematoda, Annelids, Arthropoda, Mollusks, Echinodermata, Chordata – Description and habitat specialties, food and feeding.

Module 2. Collection and transportation: Methods of collection – different collection devices, live maintenance, and transportation – Materials required and methodologies.

Module 3: Marine refugium for the maintenance of marine animals: Concept of refugium, design refugium for different groups of animals, feeding, upkeep, food and feeding, water quality and health management of the animals.

Module 4. Handling: Safe - handling the animals for experimentation, handling methods, tools available and animal husbandry.

Module 5. Breeding: Breeding the animals in refugium, breeding requirements and maintenance of young ones, their food and feeding.

24-431-0207. ENZYME ENGINEERING & TECHNOLOGY - 2 credits

Course Objective:

The objectives of this course are to teach principles of enzyme engineering and enzyme technology.

Course outcome:

After successful completion of this course, the students will be able to

Course Outcome		Cognitive Level
CO 1	Explain essential principles of enzyme engineering and technology	Understand
CO 2	Practice applications in biotechnology processes	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	3	-
CO2	1	2	1	3	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit 1 Enzymes, coenzymes and cofactors: Enzymes: Classification, mode of action, activation, specificity, Source of enzymes; production, isolation and purification of enzymes; Characterization in terms of pH, temperature, ionic strength, substrate and product tolerance, effects of metal ions; Coenzymes and cofactors: Coenzymes, classification of vitamins, role and mechanism of action of some important coenzyme (NAD+/NADP+, FAD, lipoic acid, tetrahydrofolate, B12-coenzyme), role of cofactors with specific examples.

Unit II Enzyme kinetics: Enzyme as biological catalysts; Enzyme action, active site, functional group, enzyme substrate complex, cofactors, Michaelis-Menten equation, Km and Vmax, enzyme inhibition; order of reaction, methods of plotting enzyme kinetics data; Enzyme turnover number. competitive, non-competitive, uncompetitive, irreversible; order of reaction, methods of plotting enzyme kinetics data; determination of Kcat, Km, Vmax, Ki, Half-life, activation and deactivation energy etc, Cross-linked enzyme aggregates, Cross linked enzymes, enzyme crystals, their use and preparation; Solution of numerical problems; Energy yielding and energy-requiring reactions; Calculation of equilibrium constants; Activation energy etc.; Multisubstrate enzymes and kinetics mechanisms; Enzyme induction, repression, covalent modification, Isoenzymes, allosteric effects.

Unit III: Enzyme engineering: Introduction, Random and rational approach of protein engineering; Directed evolution and its application in Biocatalysis; various approaches of creating variant enzyme molecules; Future of Biocatalysis; Ideal biocatalyst.

Unit IV: Applications of enzyme technology: Immobilized enzyme technology: Different techniques of immobilization of enzymes and whole cells; Advantages and disadvantages of immobilization; Kinetics of immobilized enzymes, design and operation of immobilized enzymes reactors; Type of reactors, classification, retention of enzymes in a reactor, kinetics of enzyme reactors; Reactor performance with inhibition, operation of enzyme reactors; case studies; starch conversion; APA production, biotransformations using soluble as well as immobilized enzymes; Calculation of diffusional resistances and Thiele's modulus, multi-step immobilized enzyme systems; Solution of numerical problems; Application and future of immobilized enzyme technology; Enzyme in organic solvents and ionic liquids: Various organic solvents and ionic liquids used in biocatalysis; Potential in organic solvents and ionic liquids; Applications of enzymes in analysis

Recommended text books and references

1. Stryer, L. (2002). Biochemistry. Freeman. New York.
2. Lehninger, A. L. (2004). Principles of Biochemistry (4th ed.). Worth. New York, NY
3. Voet, D., & Voet, J. G. (2004). Biochemistry (4th ed.). Wiley & Sons. Hoboken, NJ: J
4. Rehm, H. & J. Reed, G., (1986). Enzyme Technology. Volume 7a. John Wiley & Sons.
5. Irwin H. Segel, (1976). Biochemical Calculations: How to Solve Mathematical Problems in General Biochemistry, 2nd revised Ed. John Wiley & Sons.
6. Biotol, (1992). Bioreactor Design & Product Yield. Butterworth-Heinemann
7. Wang, D. I. C. (1979). Fermentation and Enzyme Technology. Wiley. New York.

SKILL DEVELOPMENT PROGRAMME (5 credits for each course, Student need to take any one depending on his/her area of research interest). (CONTINUOUS EVALUATION)

FOR GENERATING PROFESSIONALS IN THE AREA

24-431-0306. MARINE PHARMA INDUSTRY DEVELOPMENT
(Industry sectors to be mapped: Pharmaceutical/ bio-medical industry)

Course Objective:
The primary objective of the course is:
High level technical expertise in developing marine pharmacology industry and to become a certified Pharmaceutical Industry Professional

Course Outcome:
By undertaking this skill development programme, the student will be able to

Course Outcome		Cognitive Level
CO 1	Give leadership in developing marine pharmacology industry de novo or run the facility already existing.	Apply
CO 2	Give leadership to drug discovery and develop to an industrial process	Create
CO 3	To be certified pharmaceutical industry professional	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	3	3	-
CO2	2	2	3	3	-
CO3	2	2	3	3	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1: Production of drugs identified from sea: Extraction from the biomass, purification, and concentration; Chemical Synthesis of analogues and evaluation, Different synthetic strategies; Synthetic Biology production and biomanufacturing; drug manufacturing systems – infrastructure required, operations, up and downstream -

Module 2. Various certification and licensing processes: Drug licensing in India- Licensing for manufacturing, loan drug license, import drug license. Multidrug license, sale drug license, restricted license for general stores, essential requirements for obtaining drug license- documentation and validity of procedures.

Module 3. Practicing drug delivery : Route of delivery, delivery vehicles, targeted drug delivery, controlled release formulations, Modulated drug release and zero-order drug release, Delivery of biologic drugs, Nanoparticle drug delivery, Acoustic targeted drug delivery, Asymmetric membrane capsule, Bioavailability, Bovine submaxillary mucin coatings, Chemotactic drug-targeting, Drug delivery to the brain, Drug carrier, Gated drug delivery systems, Magnetic drug delivery, Neural drug delivery systems, Retrometabolic drug design, Self-emulsifying drug delivery systems- self emulsifying formulations, self-micro emulsifying formulations, self-nano emulsifying formulations, Stretch-triggered drug delivery, , Thin film drug

delivery, pH dependent delivery, enzyme dependent delivery, pulsatile time - depended delivery, pressure depended delivery, brain targeted drug delivery systems, controlled drug delivery using microfluidic devices, rate programmed drug delivery systems, activation modulated drug delivery systems.

Module 4. Patent protection and its impact on the pharmaceutical business: Pharmaceutical Innovation and Generic Competition in the Pharmaceutical Industry, Patenting Practices by Pharmaceutical Companies, Defining Strategic Patenting, Patent protection through an extended approach, Trademarks in the pharmaceutical industries.

Module 5. Technology transfer- IPR, access and Benefit Sharing: National Biodiversity Act, National Biodiversity Strategy, resource utilization, Intellectual Property Right (IPR), access and Benefit sharing, Convention on Biological Diversity (*CBD*), Kyoto Protocol.

Recommended text books and references

1. Atta-ur-Rahman, Iqbal Choudhary, M., and Thomsen, W.J. Eds. 2005. Bioassay Techniques for Drug Development (Taylor and Francis)
2. Raymond Cooper, George Nicola (2014) Natural Products Chemistry: Sources, Separations and Structures, CRC press
3. Roger G. Linington, Philip G. Williams, John B. MacMillan (2015). Problems in Organic Structure Determination: A Practical Approach to NMR Spectroscopy, CRC press
4. Steven M. Colegate, Russell J. Molyneux (2007). Bioactive Natural Products: Detection, Isolation, and Structural Determination, Second Edition,CRC press
5. Zhang, L., and Demain, A.L. Eds. 2005. Natural Products Drug Discovery and Therapeutic Medicine. Humana Press.

20-431-0307 GENETIC IMPROVEMENT IN AQUACULTURE

(Industry sectors to be mapped: Aquaculture industry

Course Objective

The objective of the course is to train the students to develop skills in genetic improvement in aquaculture based on chromosome manipulations, Marker assisted selection, transgenesis, and targeted alterations.

Course Outcome:

By undertaking this skill development programme, the student will be able to:

Course Outcome		Cognitive Level
CO 1	Perform population genetic evaluation to	Apply

	facilitate brood stocks. (Apply)	
CO 2	Undertake Marker assisted selection for selective breeding (Apply)	Apply
CO 3	Undertake transgenesis (Apply)	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	-	-	-	3
CO2	3	-	-	-	3
CO3	3	-	-	-	3
CO4	3	-	-	-	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1. Population genetics for brood stock development: Importance of population genetics in establishing founder populations, Genetic variability determination of a founder population using Microsatellite markers, SNP, AFLP and RAPD – determination of Polymorphic Information Content (PIC), Resolving Power (RP), Effective Multiplex Ratio (EMR), Marker Index (MI), Unweighted Pair Group Method Analysis (UPGMA), Principal Component Analysis (PI), Average Genetic Similarity Matrix using Jaccard's Coefficient (AGSM), Dice formula, Genetic similarity index 2nab/na+nb, Heterozygosity and allelic frequency, Wright fisher model, Multivariate analysis – nonlinear – Support vector Machine based on the molecular markers; identification of a wild population with heterogeneity and development of protocols and for developing a founder population for molecular breeding to increase disease resistance, deposition of omega-3 polyunsaturated fatty acids and environmental friendship.

Module 2. Application of polyploid techniques for aquaculture:Ploidy in fishes: Induction techniques and performances of triploid fish, Potential of allotriploid fish, Tetraploid for mass production of triploid and other ploidies, Mosaicisms occurred in polyploids, Production of higher polyploidies, Polyploidization using unreduced eggs;**Application of gynogenetic and androgenetic techniques to aquaculture**: Production of cloned line by gynogenesis, Isogenic line established by repeating meiotic gynogenesis, Cloning by gynogenesis of spontaneous unreduced eggs, Androgenesis as a method to produce individuals from spermatozoa; **The use of chromosome manipulations to investigate sex-determining systems; Regulation of the use of chromosomally manipulated fish worldwide.**

Module 3. Marker assisted selection and molecular breeding: Identification of selectable markers and application for selection of fish population for growth, disease resistance, nutritional enrichment, resilience to environmental changes; Development of selective breeding programme and establishment of F1, F2 and F3 populations and confirmation of the stability and persistence of the trait and establishment Genetically Improved strains.

Module 4. Development of transgenic fish for growth, diseases resistance, nutritional enrichment, and environmental resilience: Identification of gene of interest, cloning, transformation of eggs/embryos; determination of gene transfer, confirmation of expression, Transference of genetic trait to F1, F2, F3 generations and establishment of stable line of transgenic fish as the founder population, addressing legal and environmental issues.

Module 5. Genetic improvement through targeted alterations of fish genomes: Site-specific nucleases (SSN)mega nucleases, Zinc-finger nucleases (ZFN), Transcription activator-like effector nucleases (TALEN) and Clustered regularly interspaced palindromic repeats/Cas9 – Principles and practices based on model systems.

Recommended text books and references

1. Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin. K.C., Molecular Cell Biology 8th Edition Published by W.H freeman and Company, New York
2. Naruse, Kiyoshi, Tanaka, Minoru, Takeda, Hiroyuki. Medaka: A Model for Organogenesis, Human Disease, and Evolution, 2011. Springer Japa
3. William H. Detrich, III. The Zebrafish: Disease Models and Chemical Screens Academic Press, 2011
4. Steve F. Perry, Marc Ekker, Anthony P. Farrell, Colin J. Brauner. Fish Physiology: Zebrafish. Academic Press, 2010
5. Vijai Singh, Pawan Kumar Dhar. Genome Engineering Via CRISPR-Cas9 System. Elsevier Science & Technology, 2020
6. Nicholas Foulkes. Genetics, Genomics and Fish Phenomics. Academic Press, 2016
7. Takashi Yamamoto. Targeted Genome Editing Using Site-Specific Nucleases: ZFNs, TALENs, and the CRISPR/Cas9 System.Springer, 2015.
8. Gurbachan S. Miglani. Essentials of Molecular Genetics. Alpha Science International Limited, 2015
9. Chapman and Hall, 1990. Terence A. Brown. Genetics: a molecular approach
10. Gurbachan S. Miglani. Genome Editing: A Comprehensive Treatise. Alpha Science International, Limited, 2019
11. Kim H and Kim JS (2014) A guide to genome engineering with programmable nucleases. Nature Reviews Genetics 15:321-334.

24-431-0308. MARINE ALGAL BIOTECHNOLOGY FOR NDUSTRIAL APPLICATIONS

(Industry sectors to be mapped: Aquaculture industry/energy/ nutraceutical)

Course objective

The objective of the course is to train the students to develop skills in the production and utilization of marine algae for industrial applications to take up independent assignments as well entrepreneurship.

Course Outcome:

By undertaking this skill development programme, the student will be able to:

Course outcome		Cognitive Level
CO 1	Carry out strain improvement in marine algae for various industrial applications	Create
CO 2	Develop cultures of marine macroalgae	Create
CO 3	Develop bioprocess technology for large scale marine algal production and downstream processing	Apply
CO 4	Develop products and processes from marine algae for industrial applications (Create)	Create

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	3	1	2	-
CO2	2	3	2	2	-
CO3	2	3	2	2	-
CO4	2	3	2	2	-
CO5	2	3	2	2	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1: Strain improvement in marine algae

1. Strain improvement of marine microalgae for various application
2. Karyotyping of seaweeds
3. Analysis of plasmids in algae
4. Methods for strain improvement in marine macroalgae

Module 2: Macroalgal culture development

1. Preparation of growth media for seaweed micropropagation

2. Sterilization of explant
3. Micropropagation and observation
4. Seaweed microbiome analyses
5. Basic protocols for seaweed mariculture

Module 3: Bioprocess Technology for mass production of marine microalgae

1. Bioprocess technology for mass production of marine microalgae- statistical optimization of growth media and conditions
2. Design criteria for potobioreactor
3. Scaling up of microalgal culture for large scale culture- photobioreactor, raceway ponds
4. Kinetics of microalgal growth in large scale production systems
5. Management of contamination in microalgal mass production systems
6. Estimation of productivity in large scale culture systems
7. Harvesting of microalgal biomass
8. Preservation and storage of microalgal biomass for various applications

Module 4: Product and process development from marine algae

1. **Marine algae for biofuel:** Biodiesel production through transesterification, Extraction and characterization of hydrocarbons from algae, Bioethanol production from marine algae, Estimation of algal biofuel properties

2. **Marine algae for biomaterial:** Extraction of carrageenan, agarose, fucoidan, ulvan and alginate from marine algae, Biocompatibility, biodegradability, and potent bioactive characteristics marine algal polysaccharides, Development of marine algae-based biomaterials for drug delivery, tissue engineering, wound healing, and nanotechnology-based applications.

3. **Marine algae for nutrition:** Production of nutraceuticals from marine algae for human and animal nutrition- fatty acids, carotenoids, amino acids
4. Macroalgal biomass for bioplastics, gelling/viscosity in food applications, textiles
5. Biofertilizer development from marine algae
6. Extraction and characterization of different bioactive compounds from marine algae- terpens, phlorotannins, polyamines, polyketides, oxilipins, betains
7. Development algae based feed ingredients for aquaculture application

Recommended text books and references

1. Richmond, A. (ed.) 2004. Handbook of microalgal culture: Biotechnology and applied phycology. Blackwell Science Limited.

2. Andersen, RA. (ed). 2005. Algal culturing techniques. Elsevier Academic Press.
3. Faizal Bux, Yusuf Chisti. 2016. Algae Biotechnology: Products and Processes. Springer
4. Navid Reza Moheimani et al., 2015. Biomass and Biofuels from Microalgae: Advances in Engineering and Biology. Springer
5. Debabrata Das. 2015. Algal Biorefinery: An Integrated Approach. Springer
6. Michael A. Borowitzka, Navid Reza Moheimani. 2012. Algae for Biofuels and Energy. Springer Science & Business Media.
7. Kelly and Dworjanyn. 2008. The potential of marine biomass for anaerobic biogas production. The Crown Estate.
8. Se-Kwon Kim, Choul-Gyun Lee. 2015. Marine Bioenergy: Trends and Developments. CRC Press.
9. Carrie A Eckert, Cong T Trinh. 2016. Biotechnology for Biofuel Production and Optimization. Elsevier.
10. Lisbeth Olsson. 2007. Biofuels. Springer Berlin Heidelberg.
11. Shang-Tian Yang, Hesham El-Ensashy, NutthaThongchul. 2013.Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals, and Polymers. John Wiley & Sons.
12. Vijai Kumar Gupta, Maria G. Tuohy. 2013. Biofuel Technologies: Recent Developments. Springer Science & Business Media.
13. Lavens, P., P. Sorgeloos, 1999. Manual on the production and use of live food for aquaculture. FAO Fisheries Technical Paper No. 361. FAO, Rome, Italy. 305 pp.
14. Stottrup, J.G., L. A. McEvoy, 2003. Live Feeds in Marine Aquaculture. Blackwell Scientific Publications Ltd, Oxford, United Kingdom. 318 pp.
15. Stephen H Schwartz. 2008. Aquaculture Research Trends. Nova Publishers Inc., New York.
16. D. Merrifield and E. Ringø (Eds). 2014. Aquaculture Nutrition: Gut Health, Probiotics and Prebiotics (eds), John Wiley & Sons, Ltd, Chichester, UK

24-431-0309. AQUATIC ANIMAL HEALTH MANAGEMENT

(Industry sectors to be mapped: aquaculture industry)

Objective of the course:

The objective of the course is to train the students to develop, manage and sustain aquaculture production system and serve as a consultant/entrepreneur and take up major ventures on the field

Course Outcome:

By undertaking the skill development programme, the student will be able to:

Course Outcome		Cognitive Level
CO 1	Undertake aquatic animal health management at field level	Apply

CO 2	Perform molecular diagnosis (Apply)	Apply
CO 3	Develop therapeutics against bacterial and viral pathogens	Create
CO 4	Analyze Health management strategies	Analyze

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1	1	2
CO2	3	1	1	1	1
CO3	3	3	3	3	1
CO4	3	3	3	3	3

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1 Aquaculture Engineering -Designing different kinds of culture systems: Extensive, semi-intensive, and intensive systems; RAS, Biofloc technology, Aquaponics, Raceways, IMTS based on the biological requirements of the cultured species, selection tools and devices required and implementation**.**

Module 2 Practical approaches to aquaculture environment management- Cases studies: Documentation of the aquaculture environment characteristics, identification of the deviations, decision making, selection and identification of the required tools and devices and implementation of corrective measures, assessment of progress and rectification of the problems.

Module 3 Aquaculture medicines application – case studies: Identification and documentation of health problems at field level, selection of the dianostics tools and application, disease diagnosis, arrival at the appropriate therapeutic and long-term prophylactic methods, implementation and assessment of progress and rectification of the problems.

Module 4 Selection and application of Diagnostics: Concept of disease diagnosis: first level, Second level, Sampling, Preservation of samples, Examination, Molecular diagnostic techniques: Nucleic acid probes, dot blot hybridization, *in situ* hybridization, Fluorescence in situ hybridization (FISH), PCR based diagnostics,: Primer design for target DNA, Modified PCR methods: Nested PCR, Reverse transcriptase- polymerase chain reaction (RT-PCR), Touch-down PCR, Multiplex PCR; Optimization, contamination risk, Development of molecular diagnostic tools for the identification of viruses and bacteria. Training will be performed with the available positive control/organisms at this pathogen Repository of the Centre: Viral, Bacterial, Fungal pathogens, Protozoan and metazoan parasites.

Immuno diagnostic techniques: Agglutination tests, precipitation tests: radial immunodiffusion, immune electrophoresis, counter current electrophoresis, ELISA- Antibody-based diagnostics against pathogenic

bacteria common in aquaculture: developmental strategies of polyclonal and monoclonal antibodies against bacterial and viral pathogens. Development of antibody based diagnostic kits

Module 5 Selection and application of response surface modifiers – Pro and pre-biotics, immunostimulants, Vaccines and antimicrobial and antiprotozoal and ant metazoan agents: Case study: Need based selection and application of Pro and pre-biotics, immunostimulants, Vaccines and antimicrobial and antiprotozoal and ant metazoan agents; development of novel aquaculture medicines against new and emerging pathogens and parasites.

Module 6. Preventive health care in aquaculture: Case study: Development and implementation of robust aquaculture systems integrating aquaculture medicines, tools, and devices.

References:

1. Dunham R.A. 2004. Aquaculture and Fisheries Biotechnology: Genetic Approaches.CABI Publishing Wallingford, Oxfordshire (UK). 400 p.
2. Raa J., 1996The use of immunostimulatory substances in fish and shellfish farming. Reviews in Fisheries Science; 4:229–88
3. Treves – Brown, K. M. 2000. Applied Fish Pharmacology, Kluwer Academic Publishers, P. 308
4. Noga, E J. 2000. Fish Diseases – Diagnosis and Treatment, Iowa State University Press/Ames, P. 367
5. Coll, M.J. and Dominiguez-Juncal J. 1995. Applications Of Monoclonal Antibodies In Aquaculture. *Biotech. Adv.* Vol. 13, pp. 45-73.
6. Heppell, J., Davis, H.L. 2000. Application of DNA vaccine technology to aquaculture. Advanced
7. Bright Singh, I.S., Somnath Pai, S., Philip R. & Mohandas, A. (Eds), 2003. Aquaculture Medicine, Centre for Fish Disease Diagnosis and Management, CUSAT, Cochin, P. 336
8. Bright Singh, I.S and Yadava YS Aquaculture Medicine and Aquatic Animal Health Management. Published by Aquaculture Authority, Ministry of Agriculture.
9. Roberts, R.J., 2012. Fish pathology. John Wiley & Sons.
10. Kibenge, F.S.B., Godoy, M.G. (2016). Aquaculture Virology. Academic Press
11. Woo, P. T., (Eds.) (2006). Fish diseases and disorders: Protozoan and Metazoan Infections (Vol. 1). CABI.
12. Leatherland, J. F. & Woo, P. T., (Eds.). (2006). Fish diseases and disorders: Non-infectious Disorders, (Vol. 2). CABI.
13. Woo, P. T. & Bruno, D. W. (Eds.). (2006). Fish diseases and disorders: Viral, Bacterial and Fungal Infections, (Vol. 3). CABI.
14. Ringo, E., Merrifield, D. (2014). Aquaculture Nutrition: Gut Health, Probiotics and Prebiotics. Wiley.
15. Austin, B. and Austin, D.A., 1993. Bacterial fish pathogens (No. Ed. 2). Ellis Horwood Ltd..

20-431-0310. MARINE BIOPROCESS INDUSTRY DEVELOPMENT

(Industry sectors to be mapped: food industry/bio-pharmaceutical/ Bio-medical industry)

Course objective:

There exists a big gap between discovery of a compound/biomaterial of human/animal/environment importance and their sustainable commercial production and market availability. This situation has arisen due to the lack of a precise bioprocess technology for biomanufacturing. This curriculum is built to bridge this gap by integrating biology, chemistry, and engineering on a single platform.

Course Outcome:

By undertaking this skill development programme the student will be able to:

Course Outcome		Cognitive Level
CO 1	Impart understanding of the marine natural products and biomaterials which can be brought under manufacturing and commercialization	Understand
CO 2	Design and develop upstream and downstream processes of specific natural products	Design
CO 3	Establish a company/start -up for the commercial production	Apply

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	3	3	-
CO2	2	2	3	3	-
CO3	2	3	3	3	-

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Module 1. Marine natural biomaterials brought under marine bioprocess industry: Antagonistic compounds, Anticancer/antidiabetic/anti-inflammatory Compounds, Neural protectives/immunomodulators, industrially important compound: Pigments, enzymes, preservatives, biopolymers, and any others.

Module 2. Market demand and socio-economic implications: Area or point of application, quantitative requirements, prospects, threats, resource availability, cost of raw material, legal issues, environmental implications, competitors, over all socio-economic implications of the product.

Module 3. Synthetic biology production and biomanufacturing: Identify the key molecule(s) and associated biosynthetic pathways, collect bio-parts and appropriate chassis, Modelling for pathway reconstruction in to the

chassis, Development of cell factory to produce the compound of interest, Development of appropriate downstream process

Module 4. Upstream process design: Quantification of the marine natural product in focus, seed culture development, selection of the production process – submerged and the solid-state fermentation, growth associated/non growth associated/mixed growth associated production, process design and the production: searching the parameter/conditions for the optimum production, selection and design of culture medium, optimization of culture conditions for product production, kinetic studies in lab and fermenter level, batch/fed batch/continuous culturing, agitation and aeration studies.

Module 5. Downstream process design: Biomass separation, bioproduct separation, purification, packing, storage, transportation, waste management and cost benefit analysis, Branding, Trade mark, IPR generation.

Module 6. Scale up (Up and down stream processes) and Company formation: Confirmation of the market demand at both National and International level, legal, ethical, socio -economic implications; Scaling up based on constant P/V, Constant Reynolds number, Constant mixing time, Constant Impeller tip speed and any other at the fermenter level from lab to pilot to industrial scale; Procedures for the formation of a Company/Start - ups.

References:

1. Principles of fermentation technology; P. F. Stanbury, A. Whitaker and S.J. Hall, Aditya Books (P) Ltd.
2. Bioprocess Engineering Principles; Pauline M Doran, Academic Press.
3. Biochemical Engineering Fundamentals; James E. Bailey and David F. Ollis, McGraw Hill Book Company.
4. Current Developments in Solid State Fermentation; Ashok Pandey et al. 2008. Springer.
5. Bioreactors: analylsis and design: Tapobrata Panda, Mc Graw Hill
6. Roger G. Harrison, Paul Todd, Scott R. Rudge, Demetri P. Petrides, Bioseparations Science and Engineering, Oxford University Press
7. B Sivasankar, Bioseparations - Principles and techniques, Prentice Hall of India, New Delhi
8. E L V Harris and S. Angal, Protein Purification Methods, Ed. IRL Press at Oxford University Press, 1989.
9. P.A. Belter, E.L. Cussler and Wei- Shou Hu, Bioseparations- Downstream Processing for Biotechnology, Wiley- Interscience Publication, 1988.Subramanian Ganapathy, Bioseparation& bioprocessing, (2nd Ed.) Wiley-
10. Marine bioprocess engineering by R OSINGA, J TRAMPER, J G BURGEES, & R H WIJFFELS

M.Tech. Marine Biotechnology Programme

Total credits: 88 (Core: 69 Elective: 19)

Semester 1: 23; Semester 2: 24; Semester 3: 23; Semester 4: 18.

INTERDISCIPLINARY ELECTIVE *(To be offered to students of other Departments)*

20-431-0311. PRODUCTS AND SERVICES OF OCEANS- 2 CREDITS

Course Objectives

Through this course students will come to know how and why Oceans are important and are to be protected.

Course outcome

On the successful completion of the course, students will be able to +

Course Outcome		Cognitive Level
CO 1	Describe about products from ocean	Understand
CO 2	Explain Biomimetics and its application	Understand
CO 3	Explain different types of marine biomaterials	Understand
CO 4	Explain the role of ocean in food industry	Understand

CO – PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	3	2	2
CO2	1	2	3	2	1
CO3	1	2	3	2	1
CO4	2	2	3	2	1

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High, "-" = No correlation.

Unit I: Earth as ocean planet

Evolution of oceans and life on earth, Ocean as a habitat, Biological divisions of the sea- estuaries and backwaters, lagoons, mangroves, coastal waters, inshore, offshore, deep sea/oceanic; Biodiversity of the oceans; marine flora and fauna; Plankton, Nekton, Marine reptiles, birds and mammals; Benthos, Marine boring and fouling organisms, Marine microorganisms, Microbiome, Adaptations for living in marine environment, Marine ecosystems structuring life on earth

Unit II: Ocean as a source of food

Marine food chain and food web, Microbial loop and viral shunt,Ocean as a source of food**,** Fisheries of Indian seas; marine fish production in India; recent developments in survey of marine fishery resources; concept of sustainable fisheries, fisheries of the important species/groups– demersal, pelagic and deep sea; Decline in fisheries and the need for diversification of

mariculture and aquaculture, potential fisheries zones, remote sensing applications.

Unit III Marine Biomaterials

Marine biominerals; Biominerelized structures and Biocomposites-skeletal formations, macro- and microscleres, spicules, spines, bristles, cell walls, cyst walls, loricae; Non-mineralized Structures-bioelastomers like abductin, resilin, gorgonin, spongin; antipathin, bioadhesives like byssus and related DOPA-based polymers; biocements and glue, Macromolecular Biopolymers - polysaccharides, chitin, marine collagens. Self-made Biological Materials-tubular structures of marine invertebrates like some protists, foraminifera or worms, made due to co-agglutination of external mineral debris, sand grains or other particles, Marine biomaterials in gene delivery, Application of marine biomaterials

Unit IV Marine biomimetics

Marine biomimetics and marine technology, Marine environment as source of inspiration for innovation and design, Bioinspired propulsion mechanisms based on Manta ray locomotion, Marine applications of the biomimetic humpback whale flipper, Marine inspired underwater robotics, Marine inspired biomaterial for tissue regeneration, design-based tissue engineering inspired by jellyfish, Advances in marine biomimetics, Applications of biomimetics

Unit V Marine natural products

Ocean as a source of natural products**,** Diversity of marine derived compounds - Alkaloid, Terpenoids and steroides, nucleoside, amino acids, peptides, depsipeptide, polyketide, Macrolide; Marine Toxins, Marine Enzymes- protease, lipase, chitinase, glucanase Methods and advances in marine natural product discovery. Combining metabolic profiling and genomics in marine natural product discovery. Applications of marine natural products

Unit VI: Ecosystem services of oceans

Marine Goods and Services, Ocean as habitats, Oceans in nutrient cycling and primary production, Ocean in regulating global climate, Coastal wetland protection; source of genetic resources, detoxification and sediment trapping. Cultural services- recreational; educational; aesthetic; and spiritual, Oceans in navigation, jobs, fisheries, food, marine transportation, trade, fuel, and energy, Impacts of global climate change and pollution on ecosystem services of oceans, Economic value and payment for ecosystem services, Maintenance of ecosystem goods and services by conservation.

Recommended text books and references

1. Hermann Ehrlich. 2015. Biological Materials of Marine Origin: Vertebrates, Springer.
2. Hermann Ehrlich. 2010. Biological Materials of Marine Origin: Invertebrates, Springer.

3. Joao F. Mano, 2013. Biomimetic Approaches for Biomaterials Development, John Wiley & Sons
4. Iain A. Anderson, Julian Vincent, John Montgomery, 2016. Ocean Innovation: Biomimetics Beneath the Waves, CRC Press.
5. Pinet P.R. 2000. Invitation to Oceanography. 2nd Edition. Jones and Bartlett Publishers, Sudbury. 555p.
6. Se-Kwon Kim (Ed.), 2013. Marine Biomaterials: Characterization, Isolation and Applications, CRC Press.
7. Se-Kwon Kim (Ed.), 2015. Functional Marine Biomaterials: Properties and Applications, CRC Press.
8. UNEP-WCMC, 2011. Marine and coastal ecosystem services: Valuation methods and their application. UNEP-WCMC Biodiversity Series No. 33. 46 pp.

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