KERALA UNIVERSITY OF FISHERIES AND OCEAN STUDIES

Panangad, Kochi- 682506, Kerala

M. Sc. Microbiology

Syllabus

2024

Regulations, Eligibility, Scheme and Syllabus For
M. Sc. Microbiology
(Effective from 2024 Admission onwards)

All the general rules and regulations laid down by the Kerala University of Fisheries and Ocean Studies PGCurriculum shall be applicable.

I. SCOPE OF THE PROGRAMME

School of Ocean Science and Technology, KUFOS offers M.Sc. Microbiology program for highlyqualified and motivated students. Microbiology teaches students to take an interdisciplinary approach to the understanding of prokaryotic and eukaryotic microbiology. It also offers training in physiology, ecology, evolution, microbial diseases, molecular biology, recombinant DNA technology, bioinformatics, bioactive substances and other related subjects. Marine microbes are essential to the successful maintenance of our biosphere, but we have only very limited understandingof the diversity and function of the microbial life in our marine ecosystems. The study of marine microbiology involves research of fundamental issues such as the phylogenetic relationships, the functioning of marine food webs, biogeochemical cycles, climate change, the fate of pollutants and bioremediation, the biodiversity of the ocean, microbial diseases and drugs from the sea.

We are trying to educate a new generation of marine microbial scientists, and providing them with the tools to better understanding of microbial life and the matter in which it affects our biosphere. The breadth of theoretical and practical experiences at KUFOS enables students to address questions ranging from biogeochemistry to genomic analysis, from single-cell interactions to behavior in mixed communities.

II. ELIGIBILITY CRITERIA

Those students who possess B.Sc./B.Tech.Degree in Microbiology/ Biotechnology/ Life Sciences/ Zoology/ Botany/ Food Science/ Biochemistry/ Chemistry/ Aquaculture/ Fisheries Scienceare eligible for admission to this Programme.

III. PROGRAMME AND SCHEME OF EXAMINATIONS

1. M.Sc. Microbiology programme shall have 5 core courses, 3 core practical courses and 1 elective each in 1stsemester, 2nd and 3rd semester. Apart from these courses, an open elective courses offered by the School has to be taken in 2nd and 3rdsemester. In the 4th semester project work/ dissertation will have to be carried out by the candidate in the department or any other recognized institute or laboratory under the guidance of a faculty/external guide. Evaluation of project work/ dissertation, and viva-voce will be conducted at the end of 4th semester. Students are expected to takeup 1 Massive Open Online Courses (MOOCs-offered by platforms like Swayam, NPTEL) per year (1stand 3rd Semester).
2. There shall be external university examination of 3 hour duration for each theory courses at the end of each semester, to be conducted after the completion of specified working days.
3. Each theory shall have 3 credits and practical course has either 1 or 2 credits.
4. Each practical examination is of 3 hour duration and shall carry one or two credits each.
5. Project / dissertation evaluation and viva-voce shall be conducted at the end of the programme only.
6. Project / dissertation, and viva voce shall carry 18 credits. An on the job training (atleast 15days duration)/field studies have to be carried out at during the second semester.
7. Each theory question paper may contain 10 short answer types of weightage 1, 4 short essays out of

6 questions of weightage 5. Two long essays out of 4 questions of weightage 10.

IV. EVALUATION AND GRADING

The evaluation scheme for each course shall contain two parts (a) Internal evaluation and (b) external evaluation. 50%marks shall be given to internal evaluation and the remaining 50% to external evaluation.

Internal evaluation: The internal evaluation shall be based on predetermined transparent system involving periodic written tests, assignments, seminars and attendance in respect of theory courses and based on written tests, laboratory skill/records/viva and attendance in respect of practical courses. The weightage assigned to various components for internal evaluation is as follows:

Components of Internal Evaluation

	Component	Weightage
A	Assignment	10
B	Seminar	5
C	Attendance	5
D	Class room participation	5
D	Test	25

To ensure transparency of the evaluation process, the internal assessment grade awarded to the students in each course in a semester shall be published on the notice board at least one week before the commencement of external examination. There shall not be any chance for improvement for internal grade.

The course teacher shall maintain the academic record of each student registered for the course, which shall be forwarded to the University through the Director of the School.

External evaluation: The external examination in theory courses is to be conducted by the University with question papers set by external experts. The evaluation of the answer scripts shall be done by both internal and external examiners based on a well-defined scheme of valuation. The external valuation shall be done immediately after the examination preferably in a Centralized Valuation Camp.

Photocopies of the answer scripts of the external examination shall be made available to the students for scrutiny on request.

1V. Grievance Redress Mechanism for internal evaluation

Students' grievances pertaining to the award of internal marks shall be brought to the notice of the teacher concerned. In the case of failure to settle the grievances, the matter shall be placed in a three member departmental committee consisting of School Director, HOD and the concerned teacher. School Director/HOD will be the Chairman of the committee and the decision of the committee shall be final.

V. Evaluation of Project Report/ Dissertation

Dissertation will be valued by two examiners who conduct the viva voce/practical examination (external) at the end of the 4th semester. Distribution of 20 weightage allotted for dissertation will be as follows

	Weightage
Methodology	4
Content	4
Presentation	4
Answering question	4
Originality or overall outlook	4
Total	**20**

OUTCOMES-BASED CURRICULUM

A high priority task in the context of future education development agenda in India is fostering quality higher education enabling effective participation of young people in knowledge production and participationin the knowledge economy, improving national competitiveness in a globalized world and for equipping young people with skills relevant for global and national standards and enhancing the opportunities or social mobility. Sustained initiatives are required for institutionalizing an outcome-oriented higher education system and enhancing employability through learning outcomes-based curriculum framework, improving/upgrading academic resources and learning environment, raising the quality of teaching and research across all higher education institutions; technology use and integration to improve teaching- learning processes and reach a larger body of students through alternative learning modes such as open and distance learning modes and use of MOOCs.

Other priority areas of action of fostering quality education include translation of academic research into innovations for practical use in society and economy, promoting efficient and transparent governance and management of higher education system, enhancing the capacity of the higher education system to govern itself through coordinated regulatory reform and increasing both public and private sector investment in higher education, with special emphasis on targeted and effective equity-related initiatives.

The overall **OBJECTIVES OF THE LEARNING OUTCOMES-BASED CURRICULUM FRAMEWORK** are to:

- help formulate graduate attributes, qualification descriptors, programme learning outcomes andcourse learning outcomes that are expected to be demonstrated by the holder of a qualification;
- enable prospective students, parents, employers and others to understand the nature and level of learning outcomes (knowledge, skills, attitudes and values) or attributes a graduate of a programme should be capable of demonstrating on successful completion of the programme of study;
- maintain national standards and international comparability of learning outcomes and academic standards to ensure global competitiveness, and to facilitate student/graduate mobility; and
- provide higher education institutions an important point of reference for designing teaching-learning strategies, assessing student learning levels, and periodic review of programmes and academic standards

Programme Specific Outcomes (PSOs):

At the end of the two year programme the student will be able to

- **PSO 1** Explain the basic concepts of Microbiology, Biochemistry, Immunology, Biostatistics, Bioinformatics, Cell and Molecular Biology

- **PSO 2** Isolate, identify, classify and differentiate the different groups of microbes in the fields of Marine Microbiology, Environmental Microbiology, Industrial Microbiology, Food Microbiology and Fishery Microbiology

- **PSO 3** Describe the applications and roles of Microbes in fields such as Environmental Microbiology, Industrial Microbiology, Food Microbiology, Marine Virology, Fishery Microbiology, Immunology and Biotechnology

- **PSO 4** Design and execute experiments related to Basic Microbiology, Basic Biochemistry, Marine Microbiology, Fishery Microbiology, Environmental Microbiology, Industrial Microbiology, Immunology, Molecular Biology, Recombinant DNA Technology, Biostatistics, Bioinformatics and Microbial Genetics.

- **PSO 5** Execute a short research project incorporating techniques of Basic/ Advanced Microbiology and allied fields under supervision and communicate their scientific findings effectively.

ABBREVIATIONS

R- remember, U-Understand, Ap-Apply, An –Analyze, E- Evaluate, C-Create

Kerala University of Fisheries and Ocean Studies

M. Sc. Microbiology - Course Structure, Scheme & Syllabus

(Credit Semester System – 2024Admission onwards)

I Semester

Course	Course Code	Course Title	Credits	Instructional Hrs/week				Marks	
				L	T	P	Total	Internal (%)	External (%)
Core	MMB 2101 T	General Microbiology	**3**	3			**3**	**50**	**50**
Core	MMB 2102 P	Laboratory Course I Basic Techniques in Microbiology	**2**			4	**4**	**100**	
Core	MMB 2103 T	Microbial Biochemistry	**3**	3			**3**	**50**	**50**
Core	MMB 2104 T	Analytical Techniques	**3**	3			**3**	**50**	**50**
Core	MMB 2105 P	Laboratory Course II Biochemistry & Analytical Techniques	**1**			3	**3**	**100**	
Core	MMB 2106 T	Microbial Ecology	**3**	3			**3**	**50**	**50**
Core	MMB 2107 T	Microbial Taxonomy and Systematics	**3**	3	1		**4**	**50**	**50**
Core	MMB 2108 P	Laboratory Course III Basic Techniques in Microbial Ecology & Taxonomy	**2**			4	**4**	**100**	
MOOC		MOOC of 4 weeks duration (compulsory without credit)							
Elective	MMBE 2109 MMBE 2110 MMBE 2111	1. Marine extremophiles 2. Diagnostic Techniques in Microbiology 3 . Cell Biology	**2**	3			**3** **Choose any 1**	**50**	**50**
		Total	**22**				**30**		

II **Semester**

Course	Course Code	Course Title	Credits	Instructional Hrs/week				Internal (%)	External (%)
				L	T	P	Total		
Core	MMB 2201 T	Microbial Genetics and Genetic Engineering	**3**	3			**3**	50	50
Core	MMB 2202 P	Laboratory Course IV Microbial Genetics and Genetic Engineering	**1**			3	**3**	100	
Core	MMB 2203 T	Immunology	**3**	3			**3**	50	50
Core	MMB 2204 T	Bacteriology	**3**	3			**3**	50	50
Core	MMB 2205 P	Laboratory Course V Immunology Bacteriology	**2**			4	**4**	100	
Core	MMB 2206 T	Environmental Microbiology	**2**	3			**3**	50	50
Core	MMB 2207 T	Marine Microbiology	**3**	3			**3**	50	50
Core	MMB 2208 P	Laboratory Course VI Marine , Environmental Microbiology	**2**			4	**4**	100	
Elective	MMBE 2209 MMBE 2210	1. Marine Pollution and Bioremediation 2. Marine Virology	**2**	2			**2** **Choose any one**	50	50
OEC			**3**	3			**3**	50	50
On the Job Training	OJT	Internship of min 15 days (compulsory without credit)/ field visit						100	
		Total	**24**	**31**					

III **Semester**

Course	Course Code	Course Title	Credits	Instructional Hrs/week				Internal (%)	External (%)
				L	T	P	Total		
Core	MMB 2301T	Industrial Microbiology	**3**	3			**3**	**50**	**50**
Core	MMB 2302 T	Food Microbiology	**3**	3			**3**	**50**	**50**
Core	MMB 2303 T	Fishery Microbiology	**3**	3			**3**	**50**	**50**
Core	MMB 2304 P	Laboratory Course VII Food, Industrial & Fishery Microbiology	**2**			6	**6**	**100**	
Core	MMB 2305 T	Biostatistics & Bio Informatics	**3**	3			**3**	**50**	**50**
Core	MMB 2306P	Laboratory Course VIII Biostatistics & Bio Informatics	**1**			3	**3**	**100**	
Core	MMB 2307 T	Molecular biology & r DNA technology	**3**	3			**3**	**50**	**50**
Core	MMB 2308 P	Laboratory Course IX Molecular biology & r DNA technology	**1**			3	**3**	**50**	**50**
Elective	MMB E 2309 MMB E 2310 MMB E 2311	1.Marine Microbes and Diseases 2.Bioethics, Biosafety Microbial Quality Assurance, and Intellectual Property Rights 3Marine Microbial Prospecting and Technology	**2**	2			**2**	**50 Choose Any 1**	**50**
OEC		OEC	**3**	3			**3**	**50**	**50**
MOOC		like Research Methodology/ Academic & Research paper writing							
		Total	**24**				**32**		

IV **Semester**

Course	Course Code	Course Title	Credits	Hrs/ week	Internal (%)	External (%)
Core	MMB 2401	Dissertation	**20**	Full time		100
Total credits			**20**			
Total credits for the programme			**90**			

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Syllabus of the Degree Programme

M.Sc. Microbiology

INTRODUCTION

Marine Microbiology is an exciting area of study and is still unfolding. It has emerged as one of the most important areas of modern science. New discoveries are continuously taking place in this fascinating and fast moving discipline. Marine microbes astonish us not only by their astronomical numbers but also by their metabolic capabilities, incredible diversity and intense activity.

A two years' M.Sc. degree program is formulated for developing competent Marine Microbiologists for whom significant job opportunities exist in this country. M.Sc. Microbiology programme is interdisciplinaryin nature comprising of biochemistry, microbiology and biotechnology.

The main thrust of this post graduate programme would be hands on laboratory experience in different areas of this subject. The students admitted in the programme shall be required to take up dissertation work on any emerging areas of Microbiology. In addition, they are required to undergo on the job training, field visits, industrial visits, etc. which would immensely help them to understand and analyze in depth the problemsand challenges existing in this field.

Semester I

MMB 2101 T - GENERAL MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	List out and describe the contributions of key scientists in Microbiology	**R**	1
CO2	Describe the ultrastructure and morphology of bacteria and viruses, including their specific components and arrangements	**U**	1
CO 3	Explain various cultivation techniques for bacteria, fungi, and viruses, including aerobic and anaerobic culture methods, and identify factors influencing microbial growth	**U**	4
CO 4	Classify the different physical and chemical agents used in the control of Microbes based on their mode of action and apply these agent according to the requirement	**Ap**	2,3
CO5	Summarize the principle, parts, working and applications of various microscopic techniques and explain specimen preparation and staining for light and electron microscopy	**U**	1,4

MMD 2101	General Microbiology	3

Module 1

History of Microbiology**:** The historical foundations and development of microbiology-Spontaneous generation Conflict - Contributions of Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Edward Jenner, Winogradsky, Paul Ehrlich, Lederberg & Zinder, Lwoff, Arber & Smith, Temin & Baltimore, Montaigner and Galo. An overview of microbial world.

Module II

Structure of Microbes: Ultrastructure of bacteria-Morphology and structure of bacteria-size shape, structure and arrangement, cell wall structure, cell inclusions, cell wall less forms, plama membrane, capsule/ slime, flagella structure, pili, fimbriae,endospore.

Structure of Virus- Morphology and structure of viruses, Bacteriophages, viroids, prions ,life cycle

Module III

Cultivation of Microbes :Bacteria- Bacterial growth curve, batch culture, continuous culture, fed batch, factors influencing growth, Culture techniques- aerobic and anaerobic culture techniques, culture media- Simple media, Differential media, Special media, enriched media, enrichment media and methods-aerobic and anaerobic media.

Viable but non-culturable (VBNC) organisms

Fungal media- cultivation of fungi

Cultivation of Virus- cell culture-(primary, contiuos culture), animal inoculation, egg inoculation, detection of virus in culture, plaque assay

Preservation of microbes

Module IV

Control of Microbes- Physical and chemical: Sterilization - Principles and methods, physical and chemical methods. Disinfectants - modes of action. Testing ofdisinfectants. dilution test, phenol- coefficient test. Antibiotics -Antibacterial, antifungal, antiviral, mechanism of action. Classification of antibiotics based on mechanism of action. Drugresistance in bacteria. Antibioticsensitivity tests. disc method, well method and MIC.

Module V

Microscopy and specimen preparation:Microscopy- basic principles and applications –Light – Compound – Phase contrast – Dark Field -Fluorescence Microscopy Scanning Electron Microscopy (SEM)-Transmission Electron Microscopy(TEM) - - Confocal Microscopy (CSLM), Scanning Probe Microscopy-Scanning Tunnelling Microscopy- (STM) and Atomic Force Microscopy, Specimen preparation and staining for light microscope- wet mount, hanging drop technique, Stainiing, simple staining, differential staining-Grams

staining, endospore staining, negative staining. acid fast staining. Specimen preparation for electron microscope.

Suggested Reading:

1. Pommerville, J.C., 2017. Fundamentals of microbiology. Jones & Bartlett Publishers. 11t^{h} edtn
2. Adam P. F., Jean-Yves Maillard, Syed Sattar, 2013. Russell, Hugo and Ayliffe's Principles and Practice of Disinfection, Preservation and Sterilization, 5th edtn
3. Hogg, S., 2013. Essential microbiology. John Wiley & Sons. 2nd edtn
4. David Cooke, 2018. Microbiology: Concepts and Applications, Callisto Reference
5. Joanne M. Willey, Linda Sherwood, Christopher J. Woolverton 2017. Prescott's Microbiology. McGraw-Hill Education
6. Pelzar 1993. Microbiology. Tata McGraw-Hill Education
7. PelczarTR M J Chan ECS and Kreig N R (2006). Microbiology.Fifth edition, Tata McGraw-Hill INC. New York.
8. Hans G. Schlegel. (1993) General microbiology. 7th edition. Cambridge university press.
9. Dubey RC and Maheswari DK (2012). A text of Microbiology (Revised edition). S.Chand and Company Ltd., New Delhi.
10. Geeta Sumbali and Mehrotra RS (2009). Principles of Microbiology.First edition, Tata McGraw Hill P. Ltd., New Delhi
11. Michael T. Madigan, John M. Martinko, Kelly S. Bender, Daniel H. Buckley,David A. Stahl January 12, (2014)Brock Biology of Microorganisms (14thEdition) ISBN-10:0321897390; ISBN-13:978-0321897398.(Indian Edition (2017) ISBN-978-93-3258686-4)

MMB 2102 P - BASIC TECHNIQUES IN MICROBIOLOGY PRACTICAL 2

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Prepare media and perform various microbial culture techniques	**AP**	**1,4**
CO2	Perform various staining techniques, motility test and identify the organism	**AP**	**1,4**
CO3	Perform antibiotic susceptibility testing and interpret the results	**E**	**1,4**

MMB 2102 P	**Basic Techniques in Microbiology**	**Practical**	**2**

Laboratory Course I

1. Media preparation – Liquid and Solid media, Agar deep, slant and plate.
2. Pure culture techniques – Streak plate, pour plate, spread plate, serial dilution.
3. Motility determination- soft agar inoculation, hanging drop
4. Staining: Smear fixation, Simple, Gram, Spore, Capsule and Negative
5. Growth curve -Spectroscopic method
6. Anaerobic culture techniques; Mc Intosh Fildes anaerobic jar, Wright‟s tube method, RCM
7. Antibiotic sensitivity testing.

MMB 2103 T -MICROBIAL BIOCHEMISTRY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Explain the fundamental properties of water, acids and bases, buffers, and explain the structure and classification of carbohydrates, lipids, amino acids, and proteins	**U**	**1**
CO2	Describe the structure and function of nucleic acids, the organization of DNA, RNA structures, and various protein interactions	**U**	**1**
CO 3	Explain enzyme kinetics, regulation, and applications in various industries**.**	**Ap**	1,4
CO 4	Illustrate the pathways of energy production in bacteria, including aerobic and anaerobic respiration, glycolysis, TCA cycle, and other metabolic pathways.	**U**	**1**
CO5	Summarize the mechanisms of photosynthesis in photosynthetic bacteria and cyanobacteria	**U**	**1**

MMB 2103 T	**Microbial Biochemistry**	**3**

Module 1

An overview of elements, chemical reactions and biomolecules in living organisms. Avagadro's number, mole, mole fraction, Molarity, Equivalent weight, Normality, Molality, percentage solution preparation. Molecular structure of water, physical properties of water, Its effect on Biomolecules. Acids and Bases, Dissociation of weak acids and bases Determination of pH using indicators and pH meter and derivation of mathematical expression of pH. Meaning of ka and pKa values. Buffers-buffer action, buffers in biological systems, Henderson-Hasselbalch equation with derivation. Macromolecules, Carbohydrates: Classification, function and properties. Lipids: Classification and properties of saturated and unsaturated fatty acids, complex lipids and sterols in microbial system. Amino acids and proteins: Classification of amino acids, Peptide bonds, classification and functions of proteins, glycoproteins (O-linked and N-linked);. Protein sequencing.

Module II

Nucleic acid:Structure and function, Purines, Pyramidines, Nucleosides and Nucleotides. Types of DNA-A, B and Z. Super coiling of the DNA molecule; topoisomers and superhelices; Higher orders of DNA Structure: Chromatin Structure: Histones and Nucleosomes;Conformation of Chromatin fibers; Organizationof the DNA Sequence: Genes, pseudo genes, extragenic regions (beta globin gene and gene family) duplicated genes; Reassociation kinetics, Repetitive DNA sequences. RNA Structure: Types of RNA; structure of mRNA, tRNA, rRNA,with emphasis on importance of structure to its function. Protein - DNA interaction-helix turn helix, helix loop helix, zinc fingers, homeo box. Other DNA binding proteins. Protein RNA interaction- RNA recognition motif. Protein-protein interaction, leucine zippers, bHLH, bZip motifs, **PTB, SH2 and SH3 domains.Protein lipid interaction – PH domain.**

Module III

Enzyme-Classification and nomenclature, Active site, apoenzyme, holoenzyme, prosthetic group, co enzymes and its functions. Mechanism of enzyme action, activation energy. Factors affecting the velocity of enzyme action, Michaelis Menton kinetics- derivation of MM equation, Km value determination and its significance, Vmax and its significance, LB plot and its application, turn over number. Expression of enzyme activity, enzyme specificity. Enzyme inhibition, enzyme regulation, allosteric regulation.Isoenzymes. Isolation and purification of enzymes, Applications of enzymes in chemical and food industry, enzyme immobilization, biosensors and clinical applications of enzymes.

Module IV

Energy production in bacteria – energy and ATP, aerobic and anaerobic respiration, glycolysis, tricarboxylic acid cycle, electron transport and oxidative phosphorylation, phosphoketolase pathway, pentose phosphate pathway, gluconeogenesis and glyoxylate cycle.

Module V

Photosynthetic bacteria and cyanobacteria- pigments of photosynthetic apparatus, mechanism of photosynthesis in bacteria.

Suggested Reading

1. Biochemistry (2008) by Rastogi, Publisher: Mcgraw Hill ISBN: 0070527954 ISBN-13:9780070527959, 978-0070527959
2. Biochemistry(2004) by Donald Voet, Judith G Voet Publisher: JohnWiley&SonsInc,
3. Berg,J.M., Stryer,L(2002) Biochemistry W.H Freeman&Company
4. Nelson,D.L.,Cox,M(2008) Lehninger's Principles of Biochemistry Mac Millan
5. Genes IX by Benjamin Lewin(2008)Publisher: J&b
6. Jain,J.L(2005)Fundamentals of Biochemistry 6 th edition S.Chand&Co
7. Deb,A.C(2001) Fundamentals of Biochemistry New Central Book Agency(P) Ltd
8. Principles of Biochemistry,4/e(2006)by Robert Horton H,Laurence A Moran, GrayScrimgeour K Publisher Pearson
9. Biochemistry – The clinical reactions of living cells -David E Metzler; Academic press, New York

10. Pelczar,M.J., Chan,E.C.S and Kraig(1977) Microbiology Mc Graw-Hill
11. Talaro, K.P. ,and Talaro A(2004) Foundations of Microbiology 5 th edition Mc Graw-Hill
12. Molecular Biology of the Gene 5/e(s)by James D Watson, Tania A Baker, Stephen P Bell (2008) Publisher: Dorling Kindersley (India) Pvt Ltd ISBN: 8177581813 ISBN-13: 9788177581812, 978-8177581812
13. Aneja, K.R., Jain ,P. and Aneja, R(2008)Text book of Basic and Applied Microbiology New Age International

MMB 2104T - ANALYTICAL TECHNIQUES

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	To recall the principles of hydrodynamics for the separation of biomolecules and to differentiate between various methods of centrifugation.	U	**1**
CO2	Explain the fundamental principles of chromatographic separation and explain the working principles and applications of various chromatographic techniques.	U	1,4
CO3	Describe the principle and instrumentation of various electrophoretic techniques and explain the application of various blotting techniques for the identification and analysis of biomolecules.	U	1,4
CO4	Summarise the principles, instrumentation, and applications of various spectroscopic techniques and apply the concepts of advanced spectrometry techniques for structural elucidation.	Ap	1,4
CO5	Describe the concept of radioactivity and its use in tracer techniques for biological research and in studying metabolic processes in biology.	U	1

MMB 2104	**Analytical Techniques**	**3**

Module I

Hydrodyanmic methods of separation of biomolecules such as viscosity and sedimentation- their principles, variants and applications. Ultra-centrifugation;differential and density gradient centrifugation.

Module II

Chromatographic separation- Principles and applications of Paper, Thin layer & HPTLC, Gas, Gas-liquid, Liquid chromatography, HPLC and FPLC

Module III

Electrophoretic methods of separation; Principles, instrumentation and applications, Types, Paper and gel electrophoresis, Different variants of polyacrylamide gel electrophoresis (PAGE) like native and SDS- PAGE, 2D-PAGE, capillary electrophoresis. Principle, instrumentation, methods and applications of

Western,Southern& Northern Blotting techniques.

Module IV

Principle, instrumentation, and applications of UV-Visible, Infra-red and Fluorescence, spectroscopy. and FTIR. Matrix assisted LASER desorption/ionization- time of flight-mass spectroscopy, (MALDI-TOF MS).Flow cytometry and applications. Methods for studying the structure of macromolecules- X Ray crystallography, Nuclear magnetic resonance spectroscopy(NMR), FTNMR,Electron Spin Resonance (ESR).

Module V

Tracer techniques in biology: Concept of radioactivity, radioactivity counting methods with principles of different types of counters, concept of α, β and γ emitters, scintillation counters, γ-ray spectrometers, autoradiography, applications of radioactive tracers in biology, principles and applications of phosphor imager.

Suggested Reading:

1. West & Todd. Biochemistry. 4th ed. Oxford and IBH. 2. Horst Friebolin. Basic One and Two-dimensional spectroscopy. VCH Publ, 1991
2. Modern Experimental Biochemistry. Rodney F Boyer. Benjamin/Cummings publishing company Inc. Redwoodcity, California.
3. Practical Biochemistry-Principles and techniques. Keith Wilson and John walker(Eds),University press, CambridgeUK.
4. Chromatographic methods. A Braithwate and FJ Smith.Chapman and hall, NewYork.
5. Gel Electrophoresis of Nucleic acids-A Practical approach. Rickwood D and BD Hames. IRL Press, NewYork
6. Spectrophotometry and Spectrofluorimetry:A Practical Approach. Harris DAand CL Bashford(Ed.)IRL Press, Oxford.
7. Introduction to Spectroscopy. DonaldL.Pavia Gary M.Lipman, George S Kriz. Harcourt brace College Publishers, Orlands, Florida
8. Freifelder D. M. Physical Biochemistry- Application to Biochemistry and Molecular Biology, 2nd ed., W.H. Freeman, 1982.
9. Principles and Techniques of Biochemistry and Molecular Biology, ed, Keith Wilson & John Walker, March 2010, Cambridge Univ Press.
10. Murphy D. B. Fundamental of Light Microscopy & Electron Imaging. 1st ed. Wiley-Liss, 2001.

MMB 2105 P - BIOCHEMISTRY & ANALYTICAL TECHNIQUES

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Prepare buffer solutions and determine its pH	**Ap**	1,4
CO2	Estimate the absorption maxima of given sample spectroscopically	**Ap**	1,4
CO3	Quantify the protein, glucose, glycogen, DNA & RNA content of given microbial samples	**E**	1,4
CO4	Perform paper and TLC for the identification of unknown amino acids	**E**	1,4
CO 5	Determine the molecular weight of the given protein sample using SDS PAGE	**Ap**	1,4

MMB 2105 P	Biochemistry & Analytical Techniques	1

1. Preparation of buffer (Tris, phosphate, acetate buffer)
2. Determination of (H+)ion concentration
3. Verification of Beer-Lambert's law using colored solution
4. Determination of absorption maxima of given sample using spectrophotometer.
5. Estimating the concentration in a microbial sample
   i) Glucose by Anthrone method
   ii) Protein by Lowry's method
   iii) Nucleic acid by DNA (diphenylamine method)
   iv) RNA by Orcinol method
6. Separation and identification of amino acids by paper chromatography and Thin Layer Chromatography.
7. Separations of bacterial protein isolation and separation by SDS - PAGE.
8. Measurement of cellulase by reducing sugar assay test.
9. Estimation of glycogen in a bacterial cell.
10. Estimation of glucose in a bacterial cell.
11. Estimation of protein in a bacterial cell by Lowry' method.
12. Estimation of amino acid content in a bacterial cell using colorimetric method.

MMB 2106- MICROBIAL ECOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Recall the physical, chemical and biological characteristics of freshwater and marine ecosystem.	**U**	**1,3**
CO2	Explain the role of microbes in biogeochemical processes and climate change in marine system.	**U**	**1,3**
CO3	Summarize the interactions between microbes and eukaryotes in marine environment.	**U**	**1,3**
CO4	Elaborate and identify the most suitable method for determining the marine microbial diversity.	**Ap**	**1,3**
CO5	Explain marine pollution and bioremediation.	**U**	**1,3**

MMB 2106 T	Microbial Ecology	3

Module I

Introduction Freshwater and seawater – Oceanography - World Oceans, Seas and Rivers and Associated Coastal Ecosystems – Mangroves, Estuaries, Coral Reef etc.– Importance of Oceans, Ecological Divisions of the Sea.

Physical and chemical properties of seawater – abiotic and biotic factors of the oceans.physical characteristics – waves, currents and water circulation, light, temperature; chemical characteristics – salinity,pH, nutrients, dissolved gases, eutrophic and oligotrophic environments, algal blooms-red tide and blue tide.

Module II

The role of microbes in the ocean processes- changing paradigm, Carbon cycling, Photosynthesis and primary productivity, Productivity and nutrients- Nutrient limitation, Microbial aspects of nitrogen cycling, The importance of iron, The microbial loop in ocean food webs- classic and modern food web, marine snow,the formation and fate of DOM and POM, the Role of microorganisms in other biogeochemical cycles: phosphorous, sulphur, iron, manganese.

Protistan grazing, viral lysis, Microbial processes in eutrophication of coastal waters,

Microbial processes and climate- role of marine microbial communities in modulating climate change - production and consumption of greenhouse gases, the impact of climate variations on microbial process`ses in the sea

Module III

Marine microbial interactions- Symbiosis – Symbiosis of microalgae with animals (types of association, dinoflagellate endosymbiots-Coral and microbial associates, Tridacnid clams), Symbiosis of chemoautotrophic prokaryotes with animals- chemoautotrophic endosymbionts in hydrothermal vent animals, Episymbiotic bacteria in vent animals, chemoautotrophic in hydrothermal non-vent animals, phylogeny and acquisition symbiotic bacteria, Light organ symbiosis in fish and invertebrates- Flashlight fishes and anglerfishes, Sepiolids, microbially mediated bioluminescence and toxin secretions, Microbial symbionts of sponges, symbiosis and mixotrophy in protists, metabolic consortia and mutualism between prokaryotes, Microscale Microbial Interactions

Module –IV

Marine microbial community structure and diversity

Methods in microbial oceanography – Sampling methods -Sampling equipment: water samplers such as Niskin sampler, Hydro-Bios sampler, Rosette samplers; sediment sampler such as van Veen grabs and corers,measures of productivity-Analysis of primary productivity: the radiocarbon method, Analysis of bacterial productivity: the thymidine uptake method, Measurement of respiration rates: light-dark bottle method,

Biodiversity Research in the Marine Environment, components of diversity: richness and evenness, Tools to study marine microbial diversity: Microscopic methods, flow cytometry (bacteria, picoplankton, picoeukaryotes, viruses), Antibody labelling techniques, Laboratory culture, VBNC Advanced techniques for isolating microorganism (Ichip for High-Throughput In Situ Cultivation & other techniques), Culture-independent methods/ molecular methods , Metagenomics for study marine microbial diversity (ocean surveyS), detecting microbial activates in the marine environment-

Module -V

Marine Pollution: Sources of pollution, The effect of man-made and natural disturbances - climate change, oil spill accidents, Ocean acidification and microbes, microbial responds to pollution- coral bleeching, Biofilms- Molecular and microscopic measures of biofilm populations – microfouling – ship hulls, harbour, culture regions, sediment – water interface, gut microflora, Complex microbial communities, problems and prevention of microfouling, Microbial indicators of marine pollution and control –Biosensors, bioremediation in marine environment.

Suggested reading

1. Colin MUNN Marine microbiology Ecology and Application
2. Microbial Ecology of the Oceans (ed. Kirchman, D. L.) 85–120 (Wiley-Liss Inc., 2000)
3. David M. Karl Microbial oceanography: paradigms, processes and promise by, Nature Reviews Microbiology 5, 759-769
4. Atlas RM Microbial ecology: fundamentals and applications,– 1998
5. David M. Karl Microbial oceanography: paradigms, processes and promise by, Nature Reviews Microbiology

MMB 2107 – MICROBIAL TAXONOMY AND SYSTEMATICS

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Outline the concept of taxonomy, systematics and classification.	**R**	**1,2**
CO2	Explain the characteristics of bacteria, archaebacteria and actinobacteria	**U**	**1,2**
CO3	Classify and identify bacteria on the basis of morphological, biochemical, serological and molecular characteristics	**Ap**	**1,2**
CO4	Explain the general characteristics and classification of Algae, Protozoa, Fungi and Virus	**U**	**1,2**
CO5	Summarize the molecular techniques such as Metagenomics and NGS used in studying microbial diversity	**U**	**1,2,3**

MMB 2107 T Microbial Taxonomy and Systematics 3

Module I

Microbial taxonomy and systematics Concepts of taxonomy (characterization, classification and nomenclature) and systematics;

classification of microorganisms- Haeckel three Kingdom classification, Whittaker five Kingdom classification, and Woese three domain classification,

Module II

Bacteria and Archae-Taxonomy

Principles of bacterial taxonomy- Phenetic , Numerical taxonomy, Polyphasic taxonomy, Phylogenetic Phenotypic characters - Morphology, Biochemical tests (e.g. API, BIOLOG, VITEK), Bacteriophage typing, SerotypingChemotaxonomic markers - Cell wall components, lipid composition cellular fatty acid (FAME analysis), isoprenoid quinones, protein profiles (e.g. MALDI-TOF), cytochrome composition.Bergey's Manual of systematic Bacteriology- with General characteristics of each division

General characteristics of Archae and classification(Phyla Euryarchaeota, Nanoarchaeota, Koracheota, Crenarchaeota, Thaumarchaeota)

General characteristics Actinomycetes

Module III

General characteristics and classification of algae (Fritsch). Structure and reproduction of Chlamydomonous sp.

General characteristics and classification of fungi. Structure and reproduction of *Aspergillus niger* and *Saccharomycetes*

Module IV

General characteristics and classification of Protozoa

General characteristics and classification of Viruses

Module V

Molecular techniques - molecular tools in microbial diversity Nucleic acid based techniques -Molecular tools/culture independent methods to study marine microbial diversity, DNA-DNA hybridization, G+C content, 16S rRNA sequencing, PCR based fingerprinting - RAPD, ribotyping, DNA sequencing, Fluorescence in situ hybridization (FISH), Phylogenetic analysis. MALDI-TOF

Metagenomics; Community fingerprinting, limitations of analysis of nucleic acids directly from marine environment, Genomic fingerprinting and molecular markers

DNA sequencing-Next Generation Sequencing

Suggested reading

1. Vos, P., Garrity, G., Jones, D., Krieg, N.R., Ludwig, W., Rainey, F.A., Schleifer, K.H. and Whitman, W.B. eds., 2011. Bergey's manual of systematic bacteriology: Volume 3: The Firmicutes (Vol. 3). Springer Science & Business MediaDon J. Brenner, Noel R. Krieg, James T. Staley (eds). 2005. Bergey's Manual of Systematic Bacteriology Second Edition. Springer
2. Michael T. Madigan, John M. Martinko, Kelly S. Bender, Daniel H. Buckley,David A. Stahl January 12, (2014)Brock Biology of Microorganisms (14thEdition) ISBN-10:0321897390; ISBN-13:978-0321897398.(Indian Edition (2017) ISBN-978-93-3258686-4)
3. Romalde, J.L., Balboa, S. and Ventosa, A., 2019. Microbial Taxonomy, Phylogeny and Biodiversity. Frontiers in microbiology, 10, p.1324.
4. Bertrand, J.C. ed., 2015. Environmental microbiology: fundamentals and applications. Dordrecht: Springer.
5. Rekadwad, B., 2020. Microbial Systematics: Taxonomy, Microbial Ecology, Diversity.
6. Priest, F.G. and Goodfellow, M. eds., 2012. Applied microbial systematics. Springer Science & Business Media
7. Priest, F.G., Ramos-Cormenzana, A. and Tindall, B.J. eds., 2012. Bacterial diversity and systematics (Vol. 75). Springer Science & Business Media.
8. Prescott L M, J P Harley and D A Klein (2005). Microbiology.Sixth edition, International edition, McGraw Hill.
9. PelczarTR M J Chan ECS and Kreig N R (2006). Microbiology.Fifth edition, Tata McGraw-Hill INC. New York
10. Mark Osborn and Cindy Smith (eds). 2005. Molecular microbial ecology. Published: Taylor & Francis, New York, NY. ISBN: 1859962831

MMB 2108 P -BASIC TECHNIQUES IN MICROBIAL ECOLOGY & TAXONOMY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Perform biochemical test and analyze results of the give cultures	**AN**	**1,2,4**
CO2	Examine the hydrolytic profile of the given organism	**AN**	**1,2,4**
CO3	Assess optimal pH, temperature and salt requirement of marine bacteria isolates from different ecosystem	**E**	**1,2,4**
CO4	Perform the isolation and describe the morphological and cultural characteristics of actinobacteria	**AP**	**1,2,4**
CO5	Perform the isolation and describe the morphological and cultural characteristics of yeast and fungus	**AP**	**1,2,4**

MMB 2108 P	**Basic Techniques in Microbial Ecology & Taxonomy**	**Practical**	**2**

Laboratory Course III

1. Morphological, physiological and biochemical characterization of bacteria
    a. IMViC test
    b. Hydrogen sulphide test
    c. Oxidase test
    d. Catalase test
    e. Urease test
    f. Nitrate reduction test
    g. Screening for hydrolytic enzymes– Starch, Gelatin, Casein, Lipase
    h. Carbohydrate fermentation.
2. Assessment of salt requirement of marine isolates from different ecosystem
3. Analysis of physico-chemical parameters
4. Morphology and cultural characteristics of actinomycetes (*Streptomyces* sp)
5. Morphology and cultural characteristics of yeast(*Saccharomyces cerevisiae*,)/fungi)

Semester II
MMB 2201 T - MICROBIAL GENETICS AND GENETIC ENGINEERING

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Summarize the DNA chemistry, structure, physical properties and significance of supercoiling and DNA- protein interactions.	**U**	**1**
CO2	Describe the key elements in genetic engineering including enzymes, vectors and host systems	**U**	1,4
CO3	Explain different gene transfer techniques, selection and screening techniques of recombinants	**Ap**	1,4
CO4	Outline the application of PCR , Sequencing, Mutagenesis , Microarray and DNA markers in rDNA technology	**U**	1,4
CO5	Illustrate the applications of rDNA technology and the relevance of Bioethics in Biotechnology	**Ap**	**1**

MMB 2201 T	**Microbial Genetics and Genetic Engineering**	**3**

Module I

DNA structure: Chemistry of DNA, Forces stabilizing DNA structure, Helix parameters, Forms of DNA (A, B, C, D, T, and Z), Watson –Crick and Hoogsteen base pairing, Physical properties of ds DNA (UV-Absorption spectra, Denaturation and Renaturation, Cot curves, DNA hybridization), Chemicals that react with DNA. DNA topology: DNA supercoiling, Supercoiled forms of DNA, Superhelical density, energetics of supercoiled DNA, Biology of supercoiled DNA (Topological domains of DNA, DNA topoisomerases, Mechanisms of supercoiling in cells, Mechanism of action of Topoisomerase I and II, effect of supercoiling on structure of DNA and role of supercoiling in gene expression and DNA replication) DNA-protein Interactions: General features, Interaction of Helix-turn Helix motif, B-sheet, ZnDNA binding domains with DNA.

Module II

History of genetic engineering. Enzymes used in genetic engineering: Restriction endonucleases, DNA polymerase, Reverse transcriptase, Polynucleotide kinase, DNA ligase, DNAse, RNAse, Terminal deoxynucleotidyl transferase, Alkaline phosphatase. Characteristics of E. coli as host for cloning, Basic design of a cloning vector, Vectors for cloning: Plasmids, Bacteriophage λ, Filamentous phage vectors, cosmids, BAC, YAC and HAC vectors, Shuttle vectors, Expression vectors, Gene expression based on bacteriophage T7 RNA polymerase. Specialist-purpose vectors. Cloning vectors used with Bacillus subtilis, Properties of yeast as host for cloning, Types of vectors designed for cloning in yeast, Vectors for cloning in animal cells– SV 40, Adenovirus, Baculovirus, Retrovirus vectors. Types of vectors used in higher plants – Caulimoviruses vectors, Geminiviruses vectors, Agrobacterium tumefaciens based Ti plasmid vectors. Ligation of DNA

fragments– using DNA ligases, homopolymer tailing, linkers and adaptors.

Module III

Gene transfer techniques: Introducing genes into prokaryotes - Natural gene transfer methods, Calcium chloride mediated transformation, Transfection with phage vectors. Methods of introduction of foreign DNA in animal system- DNA/calcium phosphate coprecipitate method, Phospholipids as gene-delivery vehicles, Electroporation, Microinjection, Microprojectile, ultra sonication, liposome fusion and microlaser. Gene cloning strategies: Construction of genomic and cDNA libraries. Shot gun cloning. Selection and screening of recombinant clones- Methods based on nucleic acid hybridization- Colony hybridization, Plaque lift hybridization, Finding specific clones by functional complementation, Reporter genes. Studying of gene function through protein interactions-Two hybrid screening, Phage display libraries.

Module IV

Techniques: DNA sequencing methods -Sanger sequencing method, Next generation sequencing methods– Pyrosequencing, Polony sequencing. Polymerase chain reaction and its applications, Different types of PCR (Hot start PCR, Multiplex PCR, Nested PCR, Real-time PCR, In Situ PCR, Inverse PCR, Reverse Transcriptase PCR, Methylation-specific PCR). Altering genes- Site-directed mutagenesis- Primer extension method for site directed mutation, PCR based site directed mutagenesis, Transposon mutagenesis, Random mutagenesis. DNA microarrays. Fluorescence in-situ hybridization. Analysis of DNA protein interactions- Electrophoretic mobility shift assay, Filter-binding assay, Chromatin Immunoprecipitation (ChIP) assay, DNase I Footprinting, Methylation Interference assay. DNA markers for genome analysis (RFLP, RAPD, AFLP, SNPs). Tools for analyzing gene expression reporter genes, Analysis of gene regulation Purification and detection tags.

Module V

Applications of recombinant DNA technology: Engineering microbes for the production of therapeutic proteins -insulin and growth hormones. Concept of gene knock out technique. Methods developed for the production of transgenic mice and applications of transgenic mice, Applications of recombinant DNA technology in forensic science. Gene Therapy- Gene silencing by RNA interference technology. Biotechnology: Ethical issues and necessity of bioethics. Basic concepts of IPR.

Suggested reading

1. Joseph Sambrook, David William Russell. 2001. Molecular cloning: a laboratory manual, Volume 3, 3rd edition, By CSHL Press, New York.
2. Sandy Primrose. 2006. Principles of Gene Manipulation and Genomics. 7th Edition, By Black Well Publishers.
3. Bernard R. Glick, Jack J. Pasternak, Cheryl L. Patten. 2010. Molecular biotechnology: Principles and applications of recombinant DNA, 4th edition, By ASM press.
4. Brown T.A. 2004. Gene Cloning and DNA analysis. 2nd edition. By ASM press.

MMB 2202 P- MICROBIAL GENETICS AND GENETIC ENGINEERING

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Perform the isolation, size determination, and purity check of microbial DNA	**E**	1,4
CO 2	Carry out PCR, RAPD and RFLP	**Ap**	1,4
CO 3	Perform the isolation of plasmid DNA and RNA from bacteria	**Ap**	1,4
CO4	Identify the steps in transduction and conjugation	**U**	1,4

MMB 2202 P	**Microbial Genetics and Genetic Engineering**	**1**

Laboratory Course IV

1) Isolation of microbial genomic DNA
2) Size determination by DNA by agarose gel electrophoresis
3) To check purity and quantity of DNA by Spectrophometeric method
4) Polymerase Chain Reaction
5) RFLP
6) RAPD
7) Generalized transduction in *E. coli*.
8) Demonstration of genetic recombination in bacteria by conjugation.
9) To perform Ames test for detecting carcinogen or mutagen.
10) Isolation of plasmids from Microbes

To isolate total RNA and mRNA from bacteria

MMB 2203- IMMUNOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	List out the historical background of immunology and explain immunity-its type and mechanism.	**U**	**1**
CO2	Explain the role of cells and organs in immune system	**U**	**1,3**
CO3	Describe antigen, antibody structure and their interactions and application of Monoclonal antibodies.	**U**	**1,3**
CO4	Compare the receptors on T and B cells for antigen recognition and describe B cell and T cell differentiation	**An**	**1,3**
CO5	Identify the role of immune reactions in transplantation, hypersensitivity, immunodeficiency disease, autoimmunity and vaccine administration	**Ap**	**1,3,4**

MMB 2203 T	Immunology	3

Module I

Historical background and scope of immunology,

Immunity, Types of immunity- innate, acquired, passive and active ,Primary, Secondary and tertiary. Mechanisms of innate immunity- barriers, inflammation, phagocytosis- mechanisms, Pattern recognition receptors- Soluble (Antimicrobial peptides, CRP, MBL) and Membrane associated (TLR, Scavenger, NOD).

Complement system, , Biological effects of complements

Module II

Cells of the immune system.Organs-Primary and secondary lymphoid organs

Antigens – types, properties, Epitopes, haptens, adjuvant, cross reactivity. Immunoglobulin - structure, classes and functions Fc receptors. Monoclonal antibodies- production and application,

Module III

Serology - antigens and antibody reactions - Agglutination and precipitation reaction. Strength of antigen and antibody bindings - affinity & avidity.

Monoclonal antibodies and their applications.. Immunofluorscence RIA, RAST, ELISA and Flowcytometry.

Module IV

MHC antigens - types and functions. Antigen processing and presentation

Humoral Immune response- Primary and secondary immune response

Receptors on T and B cells for antigen recognition, Response of B Cell to antigens-B cell- generation, activation, differentiation (Antibody formation, Clonal selection theory).

Cell mediated Immune response, T-Cell subsets, T-cell maturation, activation and differentiation. cytokines

Module V

Transplantation immunology - Tissue transplantation and grafting . Mechanism of graft acceptance and rejection. HLA typing immunosuppressive therapy,

Immunohaematology -ABO and Rh factor.

Hypersensitivity reactions

Tumor immunology. Tumor antigens, Immune response in malignancy,

Immunodeficiency diseases: Primary immunodeficiency disorders: severe combined immunodeficiency (SCID disorders) and Secondary immunodeficiency disorders: AIDS, ,

- auto immunity: mechanism, types: Rheumatoid arthritis, Systemic lupus erythematosus, Multiple sclerosis and myasthenia gravis. Vaccines - Types and vaccination methods

Suggested Reading

1. Kuby Immunology 7th Edition 2013
2. William E. Paul , 2008. Fundamental Immunology. Lippincott Williams and Wilkins, 6th edtn
3. Actor, J.K., 2019. Introductory Immunology, 2nd: Basic Concepts for Interdisciplinary Applications. Academic Press.
4. Todd, I., Spickett, G. and Fairclough, L., 2015. Lecture notes: immunology. John Wiley & Sons. 7th edtn
5. Parija, S.C., 2014. Textbook of Microbiology & Immunology-E-book. Elsevier Health Sciences.
6. Kumar, A., 2013. Textbook of Immunology. The Energy and Resources Institute (TERI).
7. Gabriel Virella, 2019. Medical Immunology, CRC Press. 5th edtn

MMB2204 - BACTERIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Explain the morphological and cultural characteristics of the major bacterial pathogens	**U**	**1,2**
CO 2	Identify biochemical characteristics, and other features of the major bacterial pathogens	**Ap**	**1,2,3,4**
CO3	Describe the pathogenesis, virulence factors and epidemiology of major bacterial pathogens	**U**	**1,2,3**
CO3	Illustrate the laboratory diagnostic techniques used for identification major bacterial pathogens and identify the causative organism based on these tests	**Ap**	**1,2,3,4**
CO4	Describe the treatment and prophylactic measures to be adopted for various pathogens	**U**	**1,2,3**

MMB 2204 T	**Bacteriology**	**3**

Module I

Gram Positive & Negative cocci

Identifying characters- morphological and cultural; pathogenicity, epidemiology and laboratory identification, prophylaxis, treatment of - cocci such as *Staphylococci, Streptococci*, and *Neisseria*

Module II

Gram Positive Rods

Identifying characters- morphological and cultural; pathogenicity, epidemiology and laboratory identification, prophylaxis, treatment of *Bacillus anthracis, Corynebacterium diphtheriae, Clostridium botulinum*

Module III Gram Negative Rods

Escherichia coli, Klebsiella pneumoniae, Salmonella typhi, Shigella, Bordetella pertussis, Pseudomonas aeruginosa, Vibrio cholera

Module IV

Branching bacteria

Mycobacterium tuberculosis,. Actinomycetes- Nocardia, Actinomyces,

Module V

Spiral & cell wall less bacteria

Spirochaetes-*Treponema pallidum*,, *Mycoplasma pneumoniae.*

Miscellaneous Bacteria- Listeria, Campylobacter, Helicobacter

Suggested Reading

1. Vos, P., Garrity, G., Jones, D., Krieg, N.R., Ludwig, W., Rainey, F.A., Schleifer, K.H. and Whitman, W.B. eds., 2011. Bergey's manual of systematic bacteriology: Volume 3: The Firmicutes (Vol. 3). Springer Science & Business MediaDon J. Brenner, Noel R. Krieg, James T. Staley (eds). 2005. Bergey's Manual of Systematic Bacteriology Second Edition. Springer
2. Topley, W.W.C., Wilson, G.S., Parker, T., and Collier, L.H. (1990). Topley and Wilson's Principles of Bacteriology, Virology and Immunology (Edward Arnold)
3. Zinsser, H., and Joklik, W.K. (1992). Zinsser microbiology (Lange) 20th ed.
4. Ananthanarayan, R., and Paniker, C.K.J. (2006). Textbook of microbiology (Orient Blackswan) 7thed

MMB 2205 P - BACTERIOLOGY AND IMMUNOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Demonstrate the agglutination and precipitation reactions and interpret the results	**Ap**	**1,3,4**
CO2	Identify the given pathogen based on morphology, cultural characteristics and biochemical tests	**AN**	**1,2,3,4**
CO3	Isolate and identify bacterial pathogen from mixed culture	**AN**	**1,2,3,4**

MMB 2205 P	Immunology and Bacteriology	Practical	2

Laboratory Course V

Immunology

1 Agglutination and precipitation reactions

- WIDAL
  VDRL
- Blood grouping
- Characterization of Antigens-Ouchterlony's Immunodiffusion
- Immunoelectrophoresis
- ELISA

Bacteriology

2 Study of the morphology, staining characters, cultural characters and identification of Some important bacteria

- *Staphylococci*
- *E.coli*
- *Klebsiella*
- *Salmonella*
- *Bacillus*

3Isolation and identification of bacteria from mixed culture

4 Rapid methods for Detection-API, Chrom Agar

MMB 2206 - ENVIRONMENTAL MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Summarize the role of microbes present in air and space as well as describe effects of air pollution	**U**	**1,3**
CO2	Examine the significance and enumeration of microbes present in water and describe methods employed in water purification and waste water treatment	**Ap**	**1,3**
CO3	Explain the role of microbes in soil and biogeochemical cycles	**U**	**1,3**
CO4	Describe plant-microbe interactions and identify the role of microbes in agriculture	**Ap**	**1,3**
CO5	Examine the application of microbes in waste treatment and environmental management/ bioremediation	**Ap**	**1,3,4**

MMB 2206 T	Environmental Microbiology	3

Module -I

Aerobiology- Microbial contamination of air - Sources of contamination- Microbial indicators of air pollution. Enumeration of bacteria in air, Air sampling devices. Air sanitation, Significance of air Microflora, Outline of Airborne diseases (Bacterial - Whooping cough, Diphtheria, Pneumonia; Fungal - Aspergillosis, Cryptococcosis; Viral – Chickenpox, Influenza, Measle), Effect of Air pollution on plants andHumans.

Space Microbiology [Astro /Exomicrobiology]: Introduction and current research in this area

Module -II

Aquatic microbiology: Microbiology of water - Water pollution and water borne pathogens - Bacteriological examination of water - Indicator organisms.MPN, Purification and disinfection of water Microbiology of sewage - Waste water treatment - BOD, COD, Purification of drinking water

Module -III

Soil Microbiology-Structure, Types, Physical and Chemical properties-Soil microbes (Types and Enumeration)-Weathering and Humus formation, Soil pollution-Sources Bio geochemical cycling - Nitrogen, Carbon, Phosphorus, Sulphur cycles and its importance

Module -IV

Microbial interaction - Plant-microbe, microbe-microbe interactions. Mycorhizzae, Biological Nitrogenfixers-Symbiotic and free living nitrogen fixers- physiology and genetics of nitrogen fixers, Phosphate solubilizers, Phytopathogens - Bacterial, fungal, Viral diseases. (Wilt, Blight, Canker, Mosaic) - Control measures. Biofertilizers, Microbial control of pests and diseases. Integrated pest management. GM crops and its importance.

Module V

Recycling of Solid wastes-Composting-Biogas, Biodegradation of Complex Polymers (Cellulose, Hemicellulose, Lignin, Chitin and Pectin), Bioremediation (In-situ, Ex-situ, Intrinsic, Engineered, Solid phase, Slurry phase, Mobilization and Immobilization systems) Bioaugmentation and Biostimulation, Biosurfactant, Bioleaching (Copper and Uranium) – Microbial corrosion, Hydrocarbon degration, Degradation of recalcitrant polymers and xenobiotics eg., cellulose, lignin and lignocellulose. GMOS and Environment. Applications of GIS and RS techniques in Environmental monitoring Microbial enhanced oil recovery

Suggested Reading

1. Pepper, I.L., Gerba, C.P., Gentry, T.J. and Maier, R.M. eds., 2011. Environmental microbiology. Academic press. 2nd edtn
2. Barton, L.L. and McLean, R.J., 2019. Environmental Microbiology and Microbial Ecology. John Wiley & Sons.
3. Subba, R., 2017. Soil microbiology. Oxford and IBH Publishing. 4th edtn
4. Deep Dey 2019 Space Microbiology: Modern Research and Advantages for Human Colonization on Mars International Journal for Research in Applied Sciences and Biotechnology

5. Gerda Horneck, David M. Klaus, and Rocco L. Mancinelli. 2010 Space Microbiology Microbiology and Molecular Reviews p. 121–156
6. Okafor, N., 2011. Environmental microbiology of aquatic and waste systems. Springer Science & Business Media.
7. Mohee, R. and Mudhoo, A., 2012. Bioremediation and sustainability: research and applications. John Wiley & Sons.
8. Atlas RM Microbial ecology: fundamentals and applications,– 1998
9. Mohapatra P K.2008 Environmental Microbiology IK International Pubishing House Pvt Ltd.

MMB 2207 -MARINE MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	List out different environments and niches supporting microbial communities in marine system**.**	**R**	**1,2**
CO2	Summarize the characteristics of bacteria and archaea present in the marine ecosystem.	**U**	**1,2,3**
CO3	Explain the features of marine eukaryotic microbes	**U**	**1,2**
CO4	Describe the nature of viruses and bacteriophages in marine system.	**U**	**1,2**

MMB 2207 T	Marine Microbiology	3

Module I Microbes and Marine Environment

Introduction marine microbiology, The world's oceans and seas , Chemical and physical factors in the marine environment- Properties of seawater, Solar radiation and temperature . Marine microbial habitats - The water column and marine snow 10, Sediments, at surfaces—biofilms and microbial mats ,Sea ice ,Hydrothermal vents and cold seeps, Living organisms as microbial habitats
Overview of Marine microbial community in marine environment: phytoplankton and cyanobacteria, photoheterotrophic bacteria, heterotrophic bacteria, marine archaea, heterotrophic protists, marine fungi, marine viruses

Module II
Marine bacteria and Archae
Prokaryote diversity in marine ecosystems
Brief study on nature/characteristics of following groups
Anoxygenic phototrophic bacteria; Oxygenic phototrophs—the Cyanobacteria;
The nitrifying bacteria; Sulfur-and iron-oxidizing chemolithotrophs; Hydrogen-oxidizing bacteria ; Aerobic methanotrophs and methylotrophs; Pseudomonas, Alteromonas and Shewanella ;Free-living aerobic nitrogen-fixing bacteria ;The Enterobacteriaceae; Vibrio and related genera;Rickettsias ;Spirilla Buddingand stalked Proteobacteria; Planctomycetes—stalked bacteria ; Sulfur-and sulfate-reducing Proteobacteria; Gram-positive

Bacteria The Cytophaga-Flavobacterium-Bacteroides (CFB) group;Verrucomicrobia;Spirochaetes ; 'Deeply branching' hyperthermophiles ;Aquifex ;Thermotoga

Phylogenetic groups in the domain Archaea ;The Euryarchaeota The Crenarchaeota

Module III

Marine eukaryotic microbes
Introduction to the protists and fungi
Overview of eukaryotic cell structure and function
Nanoplanktonic flagellates ,Dinoflagellates ,Bioluminescence and biological clocks
Ciliates, Diatoms ,Coccolithophorids Radiolarians and foraminifera
Marine Fungi and Yeasts

Module IV

Marine virus
The nature of marine viruses: Viruses infecting prokaryotes Enumerating viruses and virus-like particles Morphology of marine viruses Estimates of virus abundance
Observing phage-infected cells Virus inactivation, Lysogeny Effect of viruses on plankton mortality Viruses of eukaryotic plankton

Suggested Reading

1. Munn, C.B., 2019. Marine microbiology: ecology & applications. CRC Press. 3rd edtn
2. Gasol, J.M. and Kirchman, D.L. eds., 2018. Microbial ecology of the oceans. John Wiley & Sons. 3rd edtn
3. Stal, L.J. and Cretoiu, M.S., 2016. The marine microbiome. Springer International: Switzerland.
4. Kim, S.K. ed., 2015. Springer handbook of marine biotechnology. Springer.
5. Middelboe, M. and Brussaard, C.P. eds., 2018. Marine Viruses 2016. MDPI

MMB 2208 P LABORATORY COURSE VI MARINE AND ENVIRONMENTAL MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Isolate and characterize microbes from mangroves, coastal waters and marine sediments	**Ap**	**1,2,4**
CO2	Perform water quality analysis and interpret its results	**E**	**1,2,3,4**
CO3	Demonstrate the isolation of microbes from rhizospheric soil , symbiotic and free living nitrogen fixers and enumerate	**Ap**	**1,2,3,4**
CO 4	Perform the isolation of microbes from air by the open plate method and enumerate	**Ap**	**1,2,4**

MMB 2208 P Laboratory Course VI Marine and Environmental Microbiology 2

Sample collection methodology

1. Isolation and characterization of microbes from mangroves
2. Isolation and characterization of microbes from coastal waters
3. Isolation and characterization of microbes from sediments
4. Hydrolytic enzyme profiling of the marine isolates.

Environmental Microbiology

8 Microbial Water quality analysis-MPN

9Estimation DO

10Estimation BOD

11Estimation COD

12 isolation of Microbes from Rhizospere soil

12 Isolation of Nitrogen fixers from soil

Free living Nitrogen fixers

Symbiotic nitrogen fixers

Isolation of Microbes from air-Open plate

On the Job Training

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Apply essential microbiological laboratory techniques, including microbial culturing, staining, and identification, in real-world settings with proficiency	**Ap**	**1, 2,3**
CO2	Collect, Analyze and Interpret Microbiological Data	**E**	**4,5**
CO3	Adhere to Laboratory Safety and Quality Control Measures	**Ap**	**4,5**
CO4	Prepare accurate and clear reports or presentations, showcasing professionalism and scientific literacy.	**Ap**	**5**

Semester III
MMB 2301- INDUSTRIAL MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Describe the concept of fermentation, screening, preservation and strain improvement methods	**U**	**1,3**
CO2	Explain fermentation techniques, media, inoculum preparation and use of antifoam agents and growth kinetics	**U**	**1,3**
CO3	Outline the various parts, design, working and control of fermenters	**U**	**1,3**
CO4	Describe the steps in scale up and down streaming processing in terms of fermentation economics and its area of application	**An**	**1,3**
CO5	Explain the steps involved in the production of industrially important products like antibiotics, recombinant products, vitamins, enzymes and acids.	**Ap**	**1,3,4**

MMB 2301T	**Industrial Microbiology**	**3**

Module I

Introduction to fermentation process and microbes in industrial processes. Range of fermentation processes. History -development of fermentation industry, component parts of fermentation process.

Sources and characters of industrially potent microbes. Isolation, purification and preservation of industrially useful microbes, Screening methods and methods for strain improvement.

Module II

Industrial fermentations. Types of fermentations. Components of fermentation process,

Media for industrial fermentation, sterilization, inoculum preparation, raw materials used in

industrial fermentation media, antifoam agents, Solid substrate fermentation (SSF) -

Principles and application, Submerged Fermentation. Aerobic and anaerobic fermentation,

Problems in fermentation process and handling.

Module III

Fermentor – parts, design, construction and types, , CSTR, Airlift, Packed Bed, Fluidized Bed, Bubble column, Monitoring and control of fermentors, Control of physical and chemical conditions, online and off line instrumentation, pH, temperature, DO probes.

Module IV

Fermentation media formulation and modification. Kinetics of growth in batch, continuous, fed-batch fermentation, Fermentation process: Inoculum preparation, Scaling up of fermentation, Assay of fermentation products (physical, chemical and biological assay)

Methods usedfor down-stream processing and product recovery- filtration, centrifugation, celldisruption, extraction, dialysis, chromatography, membrane processes, drying , crystallization. Purification, Drying.

Fermentation economics.

ModuleV

Microbiology and production of ethanol and alcoholic beverages, Beer manufacturing and production of distilled beverages. Microbial polyesters, biosurfactants, and recombinant products. Microbial process for the production of antibiotics (penicillin and streptomycin), vitamins (Vit. C, Vit. B12), organic acids (citric acid, lactic acid) amino acids, alkaloids,nucleotides and microbial transformation of steroids, Baker's yeast production,

. Production of microbial enzymes - amylases and proteases and their applications. Immobilization of microbial cells and enzymes – methods and applications.

Suggested Reading

1. Michael J. Waites, Neil L. Morgan, John S. Rockey, Gary Higton, 2013. Industrial Microbiology: An Introduction, John Wiley & Sons
2. Stanbury, P.F., Whitaker, A. and Hall, S.J., 2017. Principles of fermentation technology. Elsevier. 3nd edtn
3. L. E. J. R. Casida, 2015. Industrial Microbiology. New Age International Pvt
4. P T Kalaichelvan, I Arul Pandi, 2019. Bioprocess Technology. MJP Publisher
5. Wilson, D.B., Sahm, H., Stahmann, K.P. and Koffas, M. eds., 2019. Industrial Microbiology. John Wiley & Sons
6. Aneja K.R., Jain, P and Aneja. (2008) A text Book of Basic and Applied Microbiology

New Age International

7. Reed, G (2004).Prescott& Dunn's Industrial Microbiology CBS Publishers

8. Patel,A.H(2000) Industrial Microbiology MacMillan

9. Bhosh,T.K., Fiechter,A and Blakebrough,N. Advances in Biochemical Engineering

Springer

MMB 2302 - FOOD MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	List out the principles and factors influencing microbial spoilage of food and Summarize microbial contamination and spoilage of different kinds of food	**U**	**1,3,4**

CO2	Describe different food preservation techniques and their areas of application	**Ap**	**1,3**
CO3	Summarize the role of microbes in production of fermented foods and their benefits	**U**	**1,3**
CO4	Describe the symptoms and causative agents of food borne infections and intoxications	**Ap**	**1,3,4**
CO5	Elaborate on Food quality management systems its implementation and benefits	**E**	**1,3**

MMB 2302 T	**Food Microbiology**	**3**

Module I

Food as a substrate – Incidence and types of microorganisms in food –, Factors affecting the microbial growth in food –intrinsic, extrinsic, implicit and processing factors. Hurdle effect, Sources of microbial contamination of food- General principles underlying spoilage of food- causes of spoilage, classification of foods based on case of spoilage

Module II

Food contamination and spoilage. Microbial spoilage of cereals, poultry, Sea foods, meat, egg, milk and milk products stored grains fruits and Vegetables Spoilage of canned foods.

Microbiological examination of food. Indicator organisms – Direct examination – culture techniques – enumeration methods – plate – Viable & Total Count; Alternative methods – Dye reduction tests , electrical methods , ATP determination: Rapid methods, immunological methods – DNA / RNA methodology – Laboratory accreditation.

Module III

Principles of food preservations:, physical and chemical methods. Natural food preservatives Asepsis, Preservation by use of High temperature Determination of thermal process,12 D concept, Low temperature, Canning, Drying, Radiation and Food additives.

Developments in the history of fermented foods, Nutritional value of fermented foods. Lactic

acid bacteria, Genera of lactic acid bacteria and their properties, Homofermentative and

Heterofermentative LAB, Heterolactic end products from pyruvate metabolism.

Fermented foods - Meat and fishery products – Country cured hams, Dry sausages, traditional fermented foods-idli batter, fermented vegetables,sauerkraut. Fermented milk products – Butter, Butter milk, Sour cream, Youghurt, kefir and Cheese. making of pickles,

Nisin and its applications,SCP, Probiotics- health benefit and mechanism of action, prebiotics, and synbiotics

Module IV

Food borne infections and intoxications. Bacterial food poisoning- infection types, Vibrios, Salmonella, enteropathogenicE. coli, Clostridium perfringens, Campillobacter, Shigella. Intoxication type- Clostridium botulinum, Staphylococcus aureus, Bacillus cerius.Mycotoxins- aflatoxin, ochratoxin.Food-borne viral infections- Enteroviruses, Hepatitis virus, Polio virus.Algal toxins- paralytic shellfish toxin, ciguatera toxin.Pathogenic parasites.

Module V

In house Committee for quality assurance, Persons involved, Internal Microbial Quality control Policy, Quality Check at every step from collection of raw materials till it reaches the customer , Implementation of ISO standards, definitions, principles and use of HACCP in Food Industry . Good Manufacturing Practise

Suggested Reading

1. Doyle, M.P., Diez-Gonzalez, F. and Hill, C. eds., 2020. Food microbiology: fundamentals and frontiers. John Wiley & Sons.
2. Frazier, W. C. 2004. Food Microbiology. Tata McGraw Hills Publishing Company Limited
3. Erkmen, O. and Bozoglu, T.F., 2016. Food Microbiology, 2 Volume Set: Principles into Practice. John Wiley & Sons.
4. 4. M. R. Adams, M. O. Moss , 2008, Food Microbiology. 3rd edtn, Royal Society of Chemistry.
5. Carl A. Batt, 2014. Encyclopedia of Food Microbiology. Academic Press, 2nd edtn
6. James. M. Jay, 2012. Modern food microbiology. Springer Netherlands, Technology & Engineering -. 4th edtn
7. . Dubey. R.C. and Maheswari. D.K. A Textbook of Microbiology, 1999. 1ed .
8. M.R.Adams & M.O.Moss 2009 Food Microbiology.3rd Edition — Panima Publishers.

MMB 2303T -FISHERY MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Recall the microbiology of freshwater and marine fish, raw and processed finfish and shell fish.	**R**	**1,3**
CO2	Describe the epidemiology, pathogenesis and control of fish pathogens	**U**	**1,3**
CO3	Summarize the physical, chemical and biological methods used for fish preservation.	**U**	**1,3**
CO4	Illustrate the physical, chemical and biological methods for the detection of fish pathogens and apply it to determine the seafood quality and safety	**Ap**	**1,2,3,4**

CO5	Explain the human bacterial pathogens and toxins associated with fish and fishery products	**E**	**1,3**

MMB 2303 T	**Fishery Microbiology**	**3**

Module 1

Microorganisms associated with fish and Shellfish

Commensals and pathogens: of fresh water and marine fish and shell fish, harvested fish and shell fish

Microbiology of Raw fish and processed fish,-cured, smoked and dried fish

Microbes involved in spoilage of molluscans and crustaceans, Growth and survival of pathogens in fish and shellfish,

Module II

Classification of diseases; Methods of disease prevention;

Detailed study of bacteria pathogenic to finfish and shellfish with emphasis on morphology, epidemiology, pathogenesis, treatment and control:

*Flavobacterium, Flexibacter, Edwardsiella, Pseudomonas, Vibrio, Aeromonas, Renibacterium, Streptococcus, Yersinia, Mycobacteri*a and *Nocardia.*

Module III

Various methods for processing of fishes;

Methods for the preservation of fish and shellfish- Biopreservation, food preservation with chemicals and by biocontrol, food preservation by modified atmosphere, radiation preservation of seafood and nature of microbial radiation resistance, preservation of foods with low temperature, food preservation with high temperatures, preservation of seafood by drying

Effect of heat, chilling, freezing and chemical preservatives on bacteria, yeasts and fungi associated with fishes

Module IV

Seafood quality and safety

Indicators of seafood microbial quality and safety- some indicators of product quality, indicators of food safety, Coliforms, Enterococci, Bifidobacteria, Coliphages or enteroviruses

Quality control and regulations for microbial quality of fishes, shellfish and Marine living resources used for food and drugs

Chemical, biological and physical methods for the detection of microorganisms and their products in fish and shellfish, Chemical methods- Thermostable nuclease assay, litmus lysate assay for endotoxins, Adenosine triphosphate measurement, radiometry, fluorogenic and chromogenic substrates. Immunological methods- Serotyping, fluorescent antibody assay, radioimmunoassay, ELISA, gel diffusion assay. Physical methods- Biosensors, Impedance, Micro-calorimetry, Flowcytometry.

Module V

Human bacterial Pathogens associated with fishes and their products - *Aeromona*s spp., *Clostridiu*m *botulinum, Clostridium perfringens, Listeria spp., Plesiomonas, Salmonella spp., Staphylococcus aureus, Vibrio cholera, Vibrio parahaemolyticus, Vibrio vulnificus* and common *Enterobactereacea*

Marine toxins – Paralytic Shellfish Poisoning (PSP) Toxins, Amnesic Shellfish Poisoning (ASP) Toxins, Diarrhetic Poisoning Toxins, Lipophilic Shellfish Toxins (LST), Neurotoxin Shellfish Poisoning (NSP) Toxins, Venerupin shellfish poisoning, Ciguatera toxins, tetradotoxins, Azaspiracids, Cyclic Imines and their origin.

Suggested Reading

1. F. Parthiban, Sugan Felix 2018, Microbiology of Fish and Fishery Products, Daya Publishing House, 2018

2. Ward, D.R. and Hackney, C.A., 2012. Microbiology of marine food products. Springer Science & Business Media.

3. Montet, D. and Ray, R.C. eds., 2011. Aquaculture Microbiology and Biotechnology, Volume Two. CRC Pres

4 Rhea Fernandes Microbiology Handbook: fish and seafood, Edited by

5 Woo and Bruno Fish diseases and disorders: Vol 3 : viral, bacterial and fungal infections by

6 R.J. Roberts Fish Pathology 4th Edn Wiley Blackwell

7

MMB 2304P – LAB VII FOOD & FISHERY MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Isolate and enumerate organisms from food sample	**Ap**	**1,2,4**
CO2	Perform Milk quality test and interpret the results	**E**	**1,2,4**
CO3	Determine Thermal Death Point , Thermal Death Time	**E**	**1,2,4**
CO4	Carry out the production of extracellular enzyme (by SmF (amylase) and downstream processing	**AP**	**1,2,4**
CO5	Isolate and identify pathogens from seafood and its environment	**AP**	**1,2,3,4**

MMB 2304	Food , Industrial & Fishery Microbiology	Practical	2

Laboratory Course VI

Food microbiology

1. Isolation of Microorganisms from spoiled foods

- Milk
- Bread
- Cereal
- Meat

2. Milk quality testing-Methylene blue dye reduction test (MBRT)

3.Determination Thermal Death Point , Thermal Death Time

4.Industrial Microbiology

5. Wine Production

6. Organic acid production-Citric acid

7.Amino acid production-Glutamic acid

8.Production of extracellular enzymes (by SmF (like protease/ amylase)/ SSF(cellulase)

9.Purification of an enzyme

Fishery

1. Isolation and identification of pathogens from seafood and its environment

- *Salmonella* spp.
- *Vibrio cholerae*
- *Vibrio parahemolyticus*
- *Listeria monocytogenes (Demo)*
- *Bacillus cereus*
- *EnteropathogenicE.coli*
- *Clostridium perfringens(Demo)*
- *Clostridium botulinum(Demo)*
- *Staphylococcus aureus*
- *Shigella* spp.

MMB 2305T - BIOSTATISTICS AND BIOINFORMATICS

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	List out the scope of biostatistics, and explain probability analysis and data collection of variables	**U**	**1**
CO2	Explain the measures of tendency, dispersion, correlation and regression and apply formulas in calculating measures of tendency, dispersion, correlation and regression	**Ap**	**1,4**

CO3	Analyze the given data, test the hypothesis or level of significance and interpret the results and make use of statistical software tools/packages Excel, SPSS, Anova. Prism, graph pad software.	**E**	**1,4**
CO4	Explain the scope and history of bioinformatics along with databases	**U**	**1**
CO5	Apply in bioinformatics in comparison of sequences using Sequence analysis software, construct phylogenetic and illustrate the use of bioinformatics tools in Pharmaceutical industry, Drug designing, Immunology, Agriculture and Forestry.	**Ap**	**1,2,4**

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MMB	**2305 T**	**Biostatistics & Bio Informatics**	**3**

Module I

Definition- Scope of Biostatistics, Probability analysis, Variables in Biology- Collection, Classification and Tabulation of data. Frequency distribution. Diagrammatical and graphical representations- Bar diagram, Histogram, Pie diagram

Module -II

Measures of Central tendency- Arithmetic Mean, Median, Mode. Calculation of Mean, Median, Mode in series of discrete and continuous observations. Open end classification. Measures of dispersion- standard deviation, standard error etc. ANOVA- one way and two way classification.

Correlation and regression- Karl Pearson's coefficient of correlation, Positive and Negative Correlation. Regression- linear and non-linear, regression coefficient

Module -III

Basic ideas of significant tests- Testing of hypothesis, Level of significance, tests based on - z-test, Student's t-test, Chi square test. Testing of goodness of fit. comparison of means of two samples, three or more samples, statistical packages, use of statistical softwares, Excel, SPSS, Anova. Prism, graph pad software.

Module –IV

Scope of bioinformatics, History and development, major biological data bases and its classification - sequence databases, structural data bases, derived and specialized data bases genomic databases, sequence andstructure file formats, creating databases, Data organisation, Searching data bases.

Module –V

Basic idea of sequence comparison- Pair wise and multiple sequence alignment, Applications of multiple sequence alignment. Sequence analysis softwares- BLAST, FASTA, CLUSTAL.

16 S rDNA sequencing and phylogenetic tree construction.

Applications of bioinformatics- Pharmaceutical industry, Drug designing, Immunology, Agriculture and Forestry.

Suggested Reading

1. 1. Williams, B., 2017. Biostatistics: concepts and applications for biologists. CRC Press.
2. Forthofer, R.N. and Lee, E.S., 2014. Introduction to biostatistics: a guide to design, analysis,and discovery. Elsevier.
3. Gupta SP, 2011. Statistical Methods. Sultan Chand & Sons. 28thed.
4. Xiong, J., 2006. Essential bioinformatics. Cambridge University Press.
5. Choudhuri, S., 2014. Bioinformatics for beginners: genes, genomes, molecular evolution, databases and analytical tools. Elsevier.
6. Gupta SP (2010) Statistical Methods. Sultan Chand & Sons. 28thed.
7. Palanisamy. S and Manoharan M.(1994). Statistical methods for Biologists. Palaniparamount
8. Khan I.A, Khanum.A,(2008) Fundamentals of Biostatistics. Ukaas Publications, Hyderabad. 3rded.
9. . George W. Snedecor, William G.(1989) Cochran Statistical Methods. Iowa State University Press. 8thed.

MMB 2306 P - Biostatistics & Bio Informatics (Laboratory Course VIII)

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Outline the use of computers, MS Office in data analysis	**U**	**1**
CO2	Compute the measures of central tendency, dispersion, correlation coefficient and Analyze the given Data using SPSS and MS-Excel and present the data graphically.	**AN**	**1,4**
CO3	Make use of bioinformatics tools BLAST, MEGA for comparison of sequences and phylogenetic tree construction	**AP**	**1,2,4**

MMB 2306 P Biostatistics & Bio Informatics	**Practical**	**1**

Laboratory Course VIII

- Introduction to computers, types of computers, operating systems (Windows).
- Computer networks, types of networks.
- MS- Office
- Data analysis using SPSS and MS-Excel in the following topics: Graphical representation of data, computation of various measures of central tendency and dispersion. Computation of correlation coefficient, fitting of simple linear regression.
- Construction of confidence intervals concerning mean.
- Parametric tests of hypothesis concerning mean. -Chi-square tests for goodness of fit and independence
- Bioinformatics Tools
- BLAST
- CLUSTAL/MUSCLE-alignment, phylogenetic tree construction (Neighbour Joining Method)
- MEGA

MMB 2307 T - MOLECULAR BIOLOGY & RECOMBINANT DNA TECHNOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Recall the process of replication and the role of inhibitors in replication	**R**	**1**
CO2	Explain the process and stages of transcription and the relevance of post transcriptional modification. Analyze the molecular mechanism of RNA based technology.	**U**	1
CO3	Summarize the translational machinery and the significance of Post translational modification and protein targeting.	**U**	1
CO4	Illustrate the tools and techniques used in Genetic engineering and identify its areas of application	**Ap**	1,4
CO5	Identify the areas of application genetic engineering like transgenic technology, animal cloning, medical science, archeology and forensic science.	**Ap**	1,4

MMB 2307	**T**	**Molecular biology & r DNA technology**	**3**

Module I

DNA Replication- Chromosomes, Process of DNA replication, Semiconservative, discontinuous uni and bidirectional, Okazaki fragments, DNA polymerases in eukaryotes and prokaryotes, Klenow fragment, modes of replication, theta, rolling circle, D-loop replication, Primosome, SSB, Helicase, Ligase, methylation and control, repetitive DNA sequences, minisatellite, microsatellite, DNA protein interaction, DNA Linking number and topoisomerase, Inhibition of replication.

Module II

Transcription-Process of transcription, stages in transcription, RNA polymerases in prokaryotes and eukaryotes, sigma factor in prokaryotes, Rho dependent and Rho independent termination. Enhancers, Transcription factors in Eukaryotes, Differences in transcription between prokaryotes and Eukaryotes, post transcriptional modifications, Polyadenylation, capping, r-RNA processing, Splicing- Splicesome, lariat structure, Group I,II and III Introns, Ribozyme, Importance of ribozyme, properties, application, RNaseP, RNAse III, RNAseII, monocistronic and polycistronic m-RNA, Joint transcript of r-RNA and tRNA in prokaryotes and their processing. Transplicing, alternate splicing, inhibitors of Transcription.

Molecular mechanism of gene regulation in prokaryotes-Transcriptional regulation in prokaryotes; Inducible & repressible system, +ve, &-ve regulation; Operon concept, structure of operon, Lac, Trp, AraC operon, Catabolic repression, attenuation. Role of Hormones in gene regulation. RNA World, RNA based technology -Molecular mechanism of Ribozyme, Antisense RNA, SiRNA, MicroRNA, Ribozwitches and their applications; Telomerase structure and function. Nucleic acid as therapeutic agent.

Module III

Translation - Process of translation. Stages in translation, genetic code, properties, wobble hypothesis, eukaryotes and prokaryotes ribosomes, mRNAs, tRNAs, aminoacyl t-RNA synthetases, protein factors initiation complex, peptidyltransferases, releasing factors, differences between prokaryotic and eukaryotic systems, inhibition of translation. Post translation modification by cleavage, self-assembly, assisted self-assembly chaperones, acylation, phosphorylation, acetylation and glycosylation. Histone acetylation and deacetylases, chromosome remodelling complex. Intein splicing. Protein targeting, cotranslational import, post translational import, SRP-structure and function, Blobel's concept, Lysosome targeting, M6P address Glycosylation, core glycosylation terminal glycosylation, Dolichol phosphate. Targeting to nucleus, peroxisomes, chloroplast and mitochondria.

Module IV

Tools and techniques for genetic Engineering - History of rDNA Technology, Cohen and Boyer Patents, Isolation of DNA and RNA from different sources, enzymes used in genetic engineering with special reference to restriction enzymes, ligases, and other DNA modifying enzymes. Modification of restriction fragments, vaccinia topoisomerases, TA cloning, and homopolymer tailing.

Vectors for E. coli with special reference to plasmid vectors pBR322, pUC, their development, features and selection procedures, direct selection plasmid vectors, low and high copy number plasmid vectors, Bacteriophages (λ and M13) with special reference to λEMBL, λZAP- their development, features, selection procedures, in vitro packaging mechanisms, cosmids, features, advantages and cosmid cloning schemes, phagemids with special reference to pBluescript, Construction of genomic libraries and cDNA libraries, procedures for recombinant selection and library screening, PCR enzymes, primer design, real time PCR, RT PCR, Nested PCR, Inverse PCR, Assymmetric PCR, applications of PCR Cloning, Chemical synthesisof DNA, DNA sequencing-plus and minus sequencing, Sangers dideoxy sequencing Maxam and Gilert method, advanced sequencing procedures – pyrosequencing, Illumina, ABI / SOLID and their applications.

Module V

Applications of Genetic Engineering - Applications of transgenic Technology Improving quality and storage life of fruits and vegetables. Plants with novel features, Pharming. Animal cloning, Ethics of cloning. Applications of Molecular Biology in forensic sciences, medical science, archeology and paleontology.

Suggested Reading

1. REA's Problem Solvers in Genetics, Research Education Association, 61, Ethel Roadwest, New Jersey
2. Modern Genetic Analysis, Griffiths, Lewontin, Gilbertand Miller Freeman's and Co, New York
3. Principles of gene manipulation-Old, Twyman and Primrose
4. Gene cloning and DNA analysis-T.A Brown
5. Cell Biology, Smith and Wood
6. Cell and Molecular Biology by Gerald Karp, Academic Press
7. Cell and Molecular Biology by Cooper
8. Cell Biology by DeRobertis
9. Molecular Biotechnology-Glick and Pasternae
10. Genes-Benjamin Lewin

MMB 2308 P - MOLECULAR BIOLOGY & R DNA TECHNOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Perform bacterial DNA isolation and analyze the quality and quantity of DNA using spectroscopy and gel electrophoresis	**E**	**1,4**
CO2	Illustrate Restriction digestion and interpret the digestion patterns of different restriction enzymes	**Ap**	**1,4**
CO3	Perform competent cell preparation for bacterial transformation and evaluate the bacterial transformation efficiency by Blue-white screening.	**An**	**1,4**
CO4	Demonstrate SDS-PAGE for the separation of proteins based on molecular weight and interpret the results	**E**	**1,4**

MMB 2308 T	**Molecular biology & r DNA technology**	**Practical**	**1**

Laboratory Course IX

1) DNA isolation from bacteria
2) Restriction digestion
3) Competent cell preparation
4) Bacterial transformation , blue white screening
5) Expression and purification of recombinant proteins(Demo)
6) PAGE
7) Blotting techniques (Western and Dot blottings)

SEMESTER IV

MMB 2401	**DISSERTATION**	**20**

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	**Plan and execute research project incorporating basic and advanced techniques in microbiology and allied fields under supervision**	**Ap**	1, 2, 3,4, 5
CO 2	**Collect, analyze, interpret and evaluate the data effectively**	**E**	2,4,5
CO 3	**Present the findings of their study effectively for the dissertation evaluation**	**C**	5

1.

Electives

Semester I
MMBE 2109 - MARINE EXTREMOPHILES

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Recall the physiological features, adaptation strategies, growth kinetics, and habitats extremophiles	**R**	**1,3**
CO2	Explain the characteristics, adaptations and significance of selected anaerobes and barophiles	**U**	**1,2,3**
CO3	Explain the characteristics and adaptations and significance of selected Cryophiles, *Psychrophiles, Psychrotrophs and Thermophiles*	**U**	**1,2,3**
CO4	Describe the characteristics and adaptations and significance of selected Oligotrophs, Osmophiles, Halophiles and Xerophiles	**U**	**1,2,3**
CO5	Explain the characteristics and uniqueness of alkalophiles., acidophile and neutrophils	U	**1,2,3**

MMB E 2209	**Marine extremophiles**	**2**

Module I

Concept of extremophiles versus conventional microbial forms and archaea.. Extreme Marine Econiches: Marine trenches and ridges, Submarine vents, Deep sea basins and Antarctic sea ice and lakes.

Key Molecular components, Unique Physiological features, Adaptation strategies, growth kinetics, significance in biogeochemical cycles of the following:

Importance of extreme environments (hydrothermal vents, cold seeps, hot springs, polar regions, hypersaline, alkaline and acidic environments) – environmental parameters - adaptation and survival of temperature-substrate, nutrition, tube worm and bacteria, ecology and diversity of extremophiles: microorganisms - psychrophilic, halophilic, thermophilic, acidophilic microorganisms, tube worms, and chemosynthetic bacteria, microbes and ultra-low frozen invertebrates from deep-sea hydrothermal vents and cold-water sulphide/methane seeps

Module II

Anaerobes: *Anaerobranca horikoshi, Methanobacterium thermoautotrophicus* Barophiles/ Peizophiles: Actinobacteria

Module III

Cryophiles, *Psychrophiles, Psychrotrophs and Thermophiles: Polaromonas, Shewanella, Flavobacterium, Desulphovibrio, Bacillus infernus, Aqifex, Rhodothermus*

Module IV

Oligotrophs, Osmophiles, Halophiles and Xerophiles: *Plagibacter; Rhodotorula; Halomonas, Marinococcus,*

Walmia

Radiophiles, Metallophiles& Xenobiotic utilizers: *Deinococcus, Hymenobacter*, *Feroplasma*, *Pseudomonas*, *Caulobacter*

Module V

Alkaliphiles, Acidophiles & Neutrophiles: Aeromonas, Rhodotorula, Caulobacter, Geobacillus

Suggested Reading

1. Durvasula, R.V. and Rao, D.S. eds., 2018. Extremophiles: From Biology to Biotechnology. CRC Press.
2. Se-Kwon Kim, 2020. Encyclopedia of Marine Biotechnology. John Wiley & Sons.
3. Horikoshi, K. and Tsujii, K. eds., 1999. Extremophiles in deep-sea environments. Springer Science & Business Media.
4. Horikoshi, K., Antranikian, G., Bull, A.T., Robb, F.T. and Stetter, K.O. eds., 2010. Extremophiles handbook. Springer Science & Business Media.
5. Horikoshi, K., 2016. Extremophiles: where it all began. Springer.
6. Brock, T. D.: Thermophilic Microorganisms and Life at High Temperatures, Springer, New York, 1978, 465 pages
7. Extreme microorganisms and the methods to handle them by Fred A Rainey and Aharon Oren
8. Horikoshi, K. and W. D. Grant: Extremophiles-Microbial Life in Extreme Environments, Wiley, New York, 1998, 322 pages.
9. Ventosa, A., J. J. Nieto, and Oren A.: "Biology of moderately halophilic aerobic bacteria," Microbiology and Molecular Biology Reviews, 1998, vol. 62, pages 504-544.
10 Extremophiles by Johri B.N. 2000. Springer V erlag. , New York.
11 Microbial Diversity by Colwd , D. 1999, Academic Press.
12 Microbial Life in Extreme Environments. Edited by D. J. Kushner. Academic Press.
13. Microbiology of Extreme Environments. Edited by Clive Edward. Open University Press. Milton Keynes.
14 Microbiology of Extreme Environments and its potential for Biotechnology. Edited by M.S.

MMBE 2110 T -DIAGNOSTIC TECHNIQUES IN MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Recall various safe practices in microbiology laboratory	**R**	**1,3**
CO2	Explain the morphological, cultural and biochemical characteristics utilized for microbial identification.	**U**	**1,2,3**
CO3	Explain the principle, procedure and application of serological methods employed for microbial identification	**Ap**	**1,2,3**
CO4	Summarize the principle and working of automated methods used in Microbiology	**U**	**1,2,3**
CO5	Explain the molecular methods employed for the detection of microorganisms	Ap	**1,2,3**

MMB E 2210	Diagnostic Techniques in Microbiology	2

Module I

Laboratory safety-Good lab hygiene,. Microbiological hazards-Biological Safety cabinet: Class I, II & III, Biosafety levels, Universal precautions, Decontamination, Hazardous waste-Infectious waste, Sharp waste and waste disposal.

Module II

Microbiological methods- Morphology, Cultural characteristics, Biochemical characteristic-Indole, Methyl red, Voges Prauskauer, Citrate, Sugar fermentation , TSI, Oxidase, Catalase, Coagulase, DNAase, Urease, Gelatinase, Cellulase. H2S production. Bacitracin, Optochin sensitivity, Antibiotic susceptibility assay- Kirby –Bauer method of Disk Diffusion, Tube dilution technique

Module III

Immunological/ Serological diagnosis- Definition of antigen, antibody, Ag-Ab reaction-precipitation and agglutination. Immunological detection methods- Immunodiffusion- Ouchterlony technique, Immunoelectrophoresis- Couter Immuno Electrophoresis (CIA), RadioImmuno Assay, ELISA, WIDAL, VDRL, ASO Coombs Test, Haemmagglutination inhibition, Quellung reaction, Mantoux test,

Module IV

Automated Methods for Diagnostic microbiology: Principles employed by common automated systems for detection and identification of viable pathogens - Turbidity as an indicator of growth, Colorimetric and pattern recognition methods for microbial identification – Vitek bacterial identification system, Flurophore- labelled/ oxidation-reduction substrate metabolism as indicator of growth & substrate utilization-Biolog identification, API 20 E strips, measurement of CO2 as product of metabolic activity- BACTEC system, analysis of Fatty acid profile – using GLC-MIDI Sherloch Microbial Identification Systems,

Module V

Molecular techniques: DNA probes, Blotting techniques-Western blotting, PCR, Emergingtechniques in microbiology laboratory- MALDI-TOF Mass Spectrometry –description of this technique in brief.

Suggested Reading

1. Shanson D.C., Speller D.C. E. Microbiology in clinical practice,III edition, Butterworth & Heinemann Publication
2. Kenneth D M Clatchey Clinical Laboratory Medicine 2nd Edition

3. Carry-Ann D Burnham . Automation and Emerging Technology in Clinical Microbiology Paul G. Engelkirk, Janet L. Duben-Engelkirk Diagnosis of infectious diseases: Essentials of diagnostics
4. Yi-Wei Tang, Charles W. Stratton, 2018. Advanced Techniques in Diagnostic Microbiology: Volume 1: Techniques, Springer , 3rd edtn
5. Sails, A. and Tang, Y.W., 2015. Current and Emerging Technologies for the Diagnosis of Microbial Infections. Academic Press.
6. Cook, N., D'Agostino, M. and Thompson, K.C. eds., 2015. Molecular Microbial Diagnostic Methods: Pathways to Implementation for the Food and Water Industries. Academic Press.
7. Charles S. Pavia, 2020. Methods in Microbiology, Elsevier.
8. Delost, M.D., 2014. Introduction to diagnostic microbiology for the laboratory sciences. Jones & Bartlett Publisher

MMB E 2211 - CELL BIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Illustrate the cell structure and membrane biology of plant, animal and microbial cells.	U	**1**
CO2	Describe in detail the structure of plasma membrane and various membrane transport mechanisms.	U	1
CO3	Explain various stages of cell cycle, inhibitors, various mechanisms of cell cycle regulation.	U	1
CO4	Summarize cell death mechanisms and their pathways	U	1
CO5	Outline the etiology of cancer biology	**U**	1

MMB E 2211	**Cell Biology**	**2**

Module II

Cell structure:Plant, animal and microbial cells. Nucleus, Cytoskeleton and cell organelles- Golgi Apparatus, ER, Lysosomes, Peroxisomes,Vacuoles,Glyoxysomes, Mitochondria and Chloroplast. Structure and functions. Specilized forms of membranes: brush border, flagella, pili, fimbriae, red cell membranes and microsomal membrane. Physical and biochemical methods to study the structure and function of membrane.

Module II

Plasma membrane

Structure and functions of Plasma membrane. Membrane Transport: Endocytosis and exocytosis;Transport across membranes; porins facilitated diffusion, Porter molecules: facilitated transport - symport, antiport, uniport. Anion porter, glucose porter; Active transport: proton pumps; Na+ K+ pumps, Ca+ pumps; Ion channels: Types and characteristics of ion channels. Gap and tight junctions, Quorum sensing

Module III

Cell cycle- different stages, check points, MPF, cyclins and cyclin dependant protein kinases, regulation of cell cycle, Role of Rb & p53, Cell cycle inhibitors,

Module IV

Cell death : Apoptosis and necrosis, apoptotic pathways, theories on apoptosis,

Module V

Cancer: etiology of cancer,mutagens, oncogenic viruses, types of tumor, induction of cancer, properties of cancer cells,oncogenes, oncogene and signal transduction, tumor suppressors.

Suggested Reading

1. Karp G, Iwasa J, Marshall W. 2019 . Karp's Cell and Molecular Biology 9th Edition. Wiley
2. Geoffrey M. Cooper 2018 The Cell: A Molecular Approach 8th Edition Oxford University Press
3. Smith C A and Wood E J. 1996 Cell biology. Second edition:. Chapman and Hall, London.
4. Weinberg and Weinberg. 2014 The Biology of Cancer .Second edition. WW Norton & Co
5. Bruce Alberts, Karen Hopkin, Alexander D. Johnson, David Morgan, Martin Raff, KeithRoberts, Peter Walter · 2018 Essential Cell Biology Norton

Semester II

MMBE-2209- MARINE POLLUTION AND BIOREMEDIATION

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Describe marine/coastal pollutants, their sources and effects on marine fauna, flora, and microorganisms and pollution monitoring .	**U**	**1,3**
CO2	Explain the role of microbes in climate change, processes involved in coastal pollution, and their application as indicator organisms and biosensors in pollution monitoring.	**Ap**	**1,3,4**
CO3	Illustrate steps in biodegradation and biotransformation of different hydrocarbon compounds.	**U**	**1,3**
CO4	Describe various bioremediation and phytoremediation techniques and compare their advantages, and limitations.	**An**	**1,3**
CO5	Examine the microbiological quality of water in aquaculture with special emphasis on fish pathogens and explore the application of molecular biology and genetic engineering in bio-monitoring and bioremediation.	**Ap**	**1,3**

MMB E 2209	**Marine Pollution and Bioremediation**	**2**

Module I

Sources marine pollution, kinds of pollution and pollutants, enteric viral pollution, effects of marine pollution on marine fauna and flora, effects of marine pollution on microorganisms, eutrophication of estuarine and coastal ecosystems, monitoring of marine pollution, environment protection regulations, impact assessment and standards, marine microbes and climate change.

Module II

Microbial processes in coastal pollution, microbial pollutants, interactions-stimulation, inhibition, microbial transformations, pollutants effects on microbial populations, effect on water column bacteria, and sediment bacteria, mitigation of pollutants by bacteria – inorganic and organic pollutants, emergent environmental pollution problems. Indicator organisms,biosensors for pollution monitoring.

Module III

Biodegradation and biotransformation of aromatic, aliphatic hydrocarbons both aerobic and anaerobic metabolic pathways, enzymes and reactions, xenobiotics and recalcitrant compounds, microbial detoxification of toxic and recalcitrant organics and heavy metals.

Module IV

Bioremediation,concepts of bioremediation technologies,type of bioremediation, advantages and limitation of different types of bioremediation, microbiological bioremediation,combined biological treatment processes, phytoremediation

Module V

Microbiological quality of water in aquaculture: monitoring for physico-chemical parameters and potential pathogens of fish and shellfish, Water-borne pathogens in coastal and marine environments, Application of molecular biology and genetic engineering in bio-monitoring and bioremediation of environmental pollutants, Biosensors for pollution monitoring

Suggested Reading

1. Naik, M.M. and Dubey, S.K., 2017. Marine Pollution and Microbial Remediation. Springer.
2. De-Sheng Pei , Muhammad Junaid. 2019. Marine Pollution: Current Status, Impacts and Remedies. Bentham Science Publishers.
3. Beiras, R., 2018. Marine pollution: sources, fate and effects of pollutants in coastal ecosystems. Elsevier.
4. Hester, R.E., 2011. Marine pollution and human health (Vol. 33). Royal Society of Chemistry.
5. Fingerman, M. ed., 2016. Bioremediation of aquatic and terrestrial ecosystems. CRC Press.
6. Prince, R. and Atlas, R.M., 2005. Bioremediation of marine oil spills. Bioremediation: Applied microbial solutions for real-world environmental cleanup, pp.269-292.

MMBE 2210 - MARINE VIROLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Recall the features of marine viruses, its classification, diversity and significance	**U**	**1,2,3**
CO2	Describe the host range of marine viruses (Bacteria, Cyanobacteria and phytoplanktons) and their interactions	**U**	**1**
CO3	Explain virus multiplication and quantification assay techniques	**Ap**	**1,3**
CO4	Summarize viral pathogens of fish / shell fish and their pathogenesis	**U**	**1**
CO5	Outline the viral pathogens of marine mammals	**U**	**1**

MMB E 2210	**Marine Virology**	**2**

Module I

Introduction

Introduction: The discovery of viruses, virus and biodiversity, virus in sea;
Nature, structure and classification, Taxonomic Diversity among Marine Viruses: Metagenomic approaches to study the diversity of marine viruses
Host range : Marine phages and their host: Archaea, bacteria and cyanobacteria, phytoplanktons, algae, Marine viruses and their hosts: fish and shrimp; Giant marine virus
Multiplication and Assay of Phages and Viruses

Module II

Bacteriophage life cycles - lysogenic (latent) and lytic (virulent);Viral multiplication One step growth profile.;Assay: plaque assay (PA); most-probable number (MPN); transmission electron microscopy (TEM); epifluorescence microscopy (EfM); flow cytometry (FC); virus cultivation

Module III

Significance of viruses in marine ecosystem Movement of viruses between biomes; Marine viruses as major players in the global ecosystem and global climate change, Effect of viruses on ecology of the marine ecosystem, Marine virus interactions with prokaryotes, planktons, non-host Organisms,

Module IV

Viral pathogens of fish: Lymphocystis virus, Infectious pancreatic necrosis virus (IPNV), Nervous necrosis virus (NNV), Infectious salmon anaemia virus (ISAV), Salmon Alphavirus (SAV), Infectious haematopoietic necrosis virus (IHNV), Viral hemorrhagic septicemia virus (VHSV),
Viruses in shell-fish and health hazards: Norwalk virus and Hepatitis virus A

Module V

Viral pathogens of Marine mammals (in brief) Adenovirus: Caliciviruses (San Miguel Sea Lion Virus): Herpesvirus: Influenza Virus: Morbillivirus:

Suggested Reading

1. Kydyrmanov, K. O. Karamendin 2019 Viruses of Marine Mammals and Metagenomic Monitoring of Infectious Diseases Bulletin of National Academy of scences of Republic of Kazakhstan
2. G.D. Bossart and P.J. Duignan (2018) Emerging viruses in marine mammals CAB Reviews 2018 13,
3. Mathias Middelboe and Corina P.D. Brussaard (2017) Marine Viruses 2016. First Edition 2017 ISBN 978-3-03842-621-9 (PDF)
4. Mathias Middelboe and Corina P.D. Brussaard (2017) Marine Viruses: Key Players in Marine Ecosystems Viruses , 9, 302
5. Grieg F Steward, Alexander I Culley, and Elisha M Wood-Charlson 2013 Marine Viruses Encyclopedia of Biodiversity, Volume 5
6. E. Sano, S. Carlson, L.Wegley and F. Rohwer. Movement of Viruses between Biomes (2004) Appl Environ Microbiol 70: 5842–5846.
7. M. Breitbart, L. R . Thompson, C.A. Suttle and M.B. Sullivan Exploring the Vast Diversity of Marine Viruses (2007).. Oceanography 20:135-139.
8. F. Rohwer and R.V. Thurber (2009) Viruses manipulate the marine environment. Nature 459, 207-212.
9. R. Danovaro, C. Corinaldesi, A. Dell'Anno, J.A. Fuhrman, J.J. Middelburg, R.T. Noble and C.A. Suttle Marine viruses and global climate change (2011).. FEMS Microbiol Rev 35: 993–1034
10. M. Crane and A. Hyatt Viruses of Fish: (2011) An Overview of Significant Pathogens Viruses3: 2025–2046.
11. P.T.K. Woo Fish Diseases and Disorders. Vol 3: Viral, Bacterial and Fungal Infections.
12. A. Bosch and S.F. Le Guyader Viruses in Shellfish (2010) Food Environmental Virology 2: 115-116
13. Jed A. Fuhrman (1999) Marine viruses and their biogeochemical and ecological effects Nature Vol 399

MMBE 2309 – MARINE MICROBES AND DISEASES

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Describe the mechanisms of pathogenicity of selected marine bacteria and discuss health risks associated with sewage pollution in marine environments.	**U**	**1,3**
CO2	Describe the various types of shellfish poisoning caused by toxic dinoflagellates and diatoms, including PSP, NSP, DSP, ASP, and CFP, and their respective toxins.	**U**	**1,3**
CO3	Discuss the impact of microalgal toxins, viruses, bacteria, fungi, and environmental pollution on the health of marine mammals.	**Ap**	**1,3**
CO4	Explain the major bacterial and viral diseases affecting bivalve mollusks, crustaceans, and corals in aquaculture and choose appropriate control measures.	**Ap**	**1,3**

Semester III			
MMB E	**2309**	**Marine Microbes and Diseases**	**2**

Module I

Human disease—bacteria and viruses

Mechanisms of pathogenicity, Indigenous marine bacteria *Vibrio cholera, Vibrio vulnificus Vibrio parahaemolyticus* ,*Clostridium botulinum*, Scombroid fish poisoning Pufferfish (Fugu) poisoning
Health hazards from sewage pollution at sea Sewage as a source of bacterial and viral infections Monitoring for potential pathogens—the indicator concept Coliforms and *Escherichia coli*, Fecal streptococci (entero cocci) Quality standards for recreational marine waters Shellfish hygiene Alternative indicators Direct testing for pathogens Heavy metal mobilization

Module II

Toxic dinoflagellates and diatoms ‘

Red tides’ and ‘harmful algal blooms’ Shellfish poisoning Reason for toxin production by dinoflagellates and diatoms,Paralytic shellfish poisoning (PSP) Neurotoxic shellfish poisoning (NSP) Diarrhetic shellfish poisoning (DSP) and azaspiracid poisoning Amnesic shellfish poisoning (ASP) Ciguatera fish poisoning (CFP) Pfiesteria piscicida ,Monitoring and control of HABs

Module III

Diseases of marine mammals

Difficulties of studying these diseases, Effects of microalgal toxins, Virus infections Morbilliviruses, Other viruses Bacterial and fungal infections, Effects of environmental pollution on infectious diseases ,Zoonoses

Module IV

Diseases of invertebrates

Introduction

Bacterial and viral diseases of bivalve molluscs Bacterial and viral diseases of crustaceans

Diseases in aquaculture Viruses Rickettsias and mycoplasmas, *Aerococcus viridans* var. *homari Vibrio* spp.

Control of disease in crustaceans Diseases of corals

Suggested Reading

1. Colin Munn Marine microbiology Ecology and Application.
2. Middelboe, M. and Brussaard, C.P. eds., 2018. Marine Viruses 2016. MDPI
3. Middelboe1, M and C P. D. Brussaard.2017 Marine Viruses: Key Players in Marine Ecosystems Viruses.; 9(10): 302.
4. Egan and Gardiner. 2016 Microbial Dysbiosis: Rethinking Disease in Marine Ecosystems Frontiers in Microbiology Volume 7 . Article 991
5. M. Crane and A. Hyatt Viruses of Fish 2011: An Overview of Significant Pathogens (Viruses3: 2025–2046.
6. P. K. Bienfang et al.,2011 Prominent Human Health Impacts from Several Marine Microbes: History, Ecology, and Public Health Implications (A Review Article). International Journal ofMicrobiology
7. P.T.K. Woo .Fish Diseases and Disorders. Vol 3: Viral, Bacterial and Fungal Infections.
8. Bosch and S.F. Le Guyader (2010) Viruses in Shellfish . Food Environm Virol 2: 115-116.
9. Sindermann C J. 1990 Principle diseases of marine fish and shellfish Second Edition. Academic Press
10. Edward C. Noga Fish disease diagnosis
11. Leatherland J. F. and Wook PKT Fish diseases and disorders

MMB E 2310 - BIOETHICS, BIOSAFETY MICROBIAL QUALITY ASSURANCE, AND INTELLECTUAL PROPERTY RIGHTS

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Recall the basic issues of Bioethics, Biosafety, Food safety and IPR	**R**	**1**
CO2	Explain the foundations of bioethics and develop ethical perceptions on bioethical issues like cloning and gene therapy.	**Ap**	**1**
CO3	Recognize safety concerns and ethical issues in the area of Genetically Modified Organisms and the use of animals in research	**Ap**	**1,3**
CO4	Summarize Food safety- issues and factors affecting shelf life of food products , Food laws and regulations	**U**	**1,3**
CO5	Explain different types of Intellectual Property Rights patents, copy right, trademarks, designs, information Technology and illustrate the process of patent filling.	**U**	**1**

MMB E 2310 Bioethics, Biosafety Microbial Quality Assurance, and Intellectual Property Rights 2

Module –I

Introduction to ethics and bioethics, Principles of Bioethics, Bioethic committees, Biotechnology and ethics Biotechnology in agriculture and environment: GM crops and GMO‟s - benefits and risks – ethical aspects of genetic testing – ethical aspects relating to use of genetic information and bio-warfare.

Ethical implications of cloning -Reproductive cloning , therapeutic cloning ; Ethical, legal and socio-economic aspects of gene therapy, germ line, somatic, embryonic and adult stem cell research. Biotechnology and biopiracy – ELSI of human genome ethical issues related to creations of Dolly and on reproductive cloning- Human Fertilization and Embryology Act & Cloning Prohibition Bill 1997

Module -II

Biosafety and Genetically Modified Organisms – Introduction to biosafety. Biosafety issues in biotechnology – risk assessment and risk management – safety protocols: risk groups – biosafety levels – biosafety guidelines and regulations (National and International) – operation of biosafety guidelines and regulations –types of biosafety containment Ethics in use of animals for scientific research; Ethical clearance norms for conducting studies on human subjects; Definition of GMOs & LMOs; Advanced Information Agreement (AIA) procedure - procedures for GMOs intended for direct use, risk assessment, handling, transport, packaging and identification of GMOs. National Environment Policy.

Module -III

Food safety and Quality assurance - Food safety- issues and factors affecting. Shelf life of Food Products- factors affecting shelf life and methods to check the shelf life. Food laws and regulations- National food legislation/ authorities and their role, product certifications (ISI mark of BIS), international organization and agreements-food and agricultural organization (FAO), world health organization (WHO), codex alimentarius, codex India, world international organization for standardization (ISO) Food safety and qualitymanagement systems: general principle of food safety, risk management, hazard analysis critical control point system (HACCP), Food Packaging: Need, material used and labelling.

Module –IV

Introduction to intellectual property and intellectual property rights Types, patents, copy rights, trade marks, design rights, geographical indications – importance of IPR – patentable and non patentables – patenting life – legal protection of biotechnological inventions – world intellectual property rights organization (WIPO) . Need for protection of Intellectual Property Types of IP: International Treaties and Conventions on IPRs, TRIPS Agreement, PCT Agreement, Patent Act of India

Module -V

Procedure for filing a PCT application, forms of patents and patentability, The patentability of microorganisms, process and product patenting, Indian and international agencies involved in IPR & patenting, Patent databases, Patent infringement. Traditional knowledge and Patent law for protection; Geographical Indicators.

Suggested Readings

1. Jose Cibelli, Robert Lanza , Keith H.S. Campbell, , Michael D. West, 2013 Principles of cloning, 2nd E6dition,
2. , Mike W.; Schinzinge 2005Ethics in Engineering 4th Edition by Martinr, Tata McGraw Hill
3. Science,
4. Richard Sherlock, John D. , 2002, Morrey,Ethical Issues in BiotechnologyRowman
5. & Littlefield.
6. Frederic H. Erbisch, Karim M. Maredia (2004). Intellectual Property Rights in Agricultural Biotechnology, CABI Publisher.
7. Mittal D.P. (1999). Indian Patents Law. Taxmann Allied Services (p) Ltd.
8. Christian Lenk, Nils Hoppe, Roberto Andorno (2007). Ethics and Law of Intellectual Property: Current Problems in Politics, Science and Technology, Ashgate Publisher (p) Ltd.
9. Felix Thiele, Richard E. Ashcroft (2005). Bioethics in a Small World. Springer.
10. John Bryant (2002) Bioethics for Scientists. John Wiley and Sons Publisher
11. .World Health Organization, Geneva (2004) Laboratory Biosafety Manual, 3rd Edition (Revised)
12. Diane O. Fleming. (2006); Biological safety: Principles and Practices, 4th edition. ASM Press
13. Beier, F.K., Crespi, R.S. and Straus, T. (1985) Biotechnology and Patent Protection-An International Review. Oxford and IBH Publishing Co. New Delhi
14. Sasson A. (1988) Biotechnologies and Development, UNESCO Publications
15. Singh K (1993) Intellectual Property rights on Biotechnology- A status report. BCIL, New Delhi

16. Regulatory Framework for GMOs in India (2006) Ministry of Environment and Forest, Government of India, New Delhi

17. Cartagena Protocol on Biosafety (2006) Ministry of Environment and Forest, Government of India, New Delhi

18. Birch, G. and Campbell-Platt, G. (Eds.). (1993) Food Safety - the Challenge Ahead. Intercept Ltd., Andover, England

19. Finley, J., Robinson, S. and Armstrong, D. (Eds.). 1992. Food Safety Assessment. Vol. 484 of ACS symposium series. American Chemical Society, Washington D.C

20. Jones, J. (1992). Food Safety. 2nd ed. Eagen Press, St. Paul Minnesota

21. Sohrab.(2001) A Practical Guide For Implementation Of Integrated ISO 9001 HACCP System For Food Processing Industries. Allied Publishers.

MMBE 2311 T - MARINE MICROBIAL PROSPECTING AND TECHNOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Explain the concept of marine microbial bioprospecting and also describe sampling and strategies involved in the search of novel target molecules that include enzymes, therapeutics, antimicrobials, biotransformations and biofuels.	**U**	**1,3**
CO2	Describe the biological and toxicological aspects of marine natural product and its clinical evaluation	**U**	**1,3**
CO3	Summarize *In vitro* biochemical and cell based assays and conventional and High throughput screening strategies in Marine bioprospecting	**U**	**1,2**
CO4	Describe function based screens (proteomics and metabolomics), Sequence based screens (genomics), substrate induced gene expression screens (SIGEX) catabolic gene expression screens and its application in Marine bioprospecting	**Ap**	**1,3**

CO5	Analyze case studies on Marine Products from Archaea, cyanobacteria the Proteobacteria;	**An**	**1**

MMB 2311	**Marine Microbial Prospecting and Technology**	**2**

Module 1

Bioprospecting: Concept of exploiting marine microbial resource and their cellular components from marine environment and marine invertebrates. Sampling and search strategies for novel targets under: microbial cultures, enzymes, therapeutics, antimicrobials, biotransformations and biofuels.

Module II

Biological and toxicological aspects of marine natural product drug discovery, Clinical evaluation of MNPs in drug discovery.

Module III

In vitro biochemical and cell based assays. Conventional and High throughput screening strategy: Conventional: Plating, Enrichment, Extinction culturing; Microscopic techniques, Micro manipulations (FISH), Optical tweezers, Micro autoradiography.

Module IV

Function based screens (proteomics and metabolomics), Sequence based screens (genomics), substrate induced gene expression screens (SIGEX) catabolic gene expression screens. Metagenomics, Microarrays, Combinatory chemistry, combinatory biosynthesis and biochemistry assays. Data bases, Natural product libraries

Module V

Case studies on Marine Products and process and commercial development using Microbes: Archaea, cyanobacteria and Proteobacteria; microbial products.

Suggested Reading

2. Daan J. A. Crommelin, Robert D. Sindelar and Bernd Meibohm(2007) Pharmaceutical Biotechnology: Fundamentals and Applications, informa healthcare.
3. Gary Walsh, (2007), Pharmaceutical Biotechnology – Concepts and Applications (EBook), John Wiley & Sons Ltd.
4. Hillisch A and Hilgenfeld R (2009) Modern Methods of drug discovery.Springer International Edition.
5. Jogdand S. N., (2006) Biopharmaceuticals, Himalaya Publishing House, Mumbai.
6. Kadam S S, Mahadik K R and Bothara K G (2009).Principles of medicinal Chemistry.Vol II NiraliPrakashan Pune.
7. Sambamurthi, K.(2006) Pharmaceutical Biotechnology, New Age International.
8. Scheuer, P.J. Marine Natural Products, Volume 1&2 (1978) Volume (1980, 81), Academic Press

Wolff ME.Burger's Medicinal Chemistry and Drug Discovery, Principle and Practice. John Wileyand Sons, New York

OEC to be offered by the Department		
OST	**Diagnostic Microbiology**	**3**

OST 2204 -DIAGNOSTIC MICROBIOLOGY

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Recall various safe practices in microbiology laboratory	**R**	**1,3**
CO2	Explain the morphological, cultural and biochemical characteristics utilized for microbial identification.	**U**	**1,2,3**
CO3	Explain the principle, procedure of serological methods employed for microbial identification	**U**	**1,2,3**
CO4	Summarize the principle and working of automated methods used in Microbiology	**U**	**1,2,3**
CO5	Describe the molecular methods employed for the detection of microorganisms	U	**1,2,3**

Module I

Laboratory safety-Good lab hygiene,. Microbiological hazards-Biological Safety cabinet: Class I, II & III, Biosafety levels, Universal precautions, Decontamination, Hazardous waste-Infectious waste, Sharp waste and waste disposal.

Module II

Microbiological methods- Morphology, Cultural characteristics, Biochemical characteristic-Indole, Methyl red, Voges Prauskauer, Citrate, Sugar fermentation , Oxidase, Catalase, Antibiotic susceptibility assay- Kirby –Bauer method of Disk Diffusion, Tube dilution technique

Module III

Immunological/ Serological diagnosis- Definition of antigen, antibody, Ag-Ab reaction-precipitation and agglutination. Immunological detection methods- Immunodiffusion- Ouchterlony technique, Immunoelectrophoresis- Couter Immuno Electrophoresis (CIA), RadioImmuno Assay, ELISA, WIDAL, VDRL, ASO Mantoux test,

Module IV

Automated Methods for Diagnostic microbiology:, Colorimetric and pattern recognition methods for microbial identification – Vitek bacterial identification system, Flurophore- labelled/ oxidation-reduction substrate metabolism as indicator of growth & substrate utilization-Biolog identification, API 20 E strips, measurement of CO_2 as product of metabolic activity- BACTEC system,

Module V

Molecular techniques: DNA probes, Blotting techniques-Western blotting, PCR, Emergingtechniques in microbiology laboratory- MALDI-TOF Mass Spectrometry –description of this technique in brief.

Suggested Reading

1. Shanson D.C., Speller D.C. E. Microbiology in clinical practice,III edition, Butterworth & Heinemann Publication

2. Kenneth D M Clatchey Clinical Laboratory Medicine 2nd Edition
3. Carry-Ann D Burnham . Automation and Emerging Technology in Clinical Microbiology Paul G. Engelkirk, Janet L. Duben-Engelkirk Diagnosis of infectious diseases: Essentials of diagnostics

OST 2304 MARINE MICROBES AND DISEASES

CO	EXPECTED COURSE OUTCOME	LEARNING DOMAINS	PSO
CO1	Describe the mechanisms of pathogenicity of selected marine bacteria and discuss health risks associated with sewage pollution in marine environments.	**U**	**1,3**
CO2	Describe the various types of shellfish poisoning caused by toxic dinoflagellates and diatoms, including PSP, NSP, DSP, ASP, and CFP, and their respective toxins.	**U**	**1,3**
CO3	Summarize the impact of microalgal toxins, viruses, bacteria, fungi, and environmental pollution on the health of marine mammals.	**U**	**1,3**
CO4	Explain the major bacterial and viral diseases affecting bivalve mollusks, crustaceans, and corals in aquaculture	**U**	**1,3**

OST	**Marine Microbes and Diseases**	**3**

Module I

Human disease—bacteria and viruses

Mechanisms of pathogenicity, Indigenous marine bacteria *Vibrio cholera, Vibrio vulnificus Vibrio parahaemolyticus ,Clostridium botulinum*, Scombroid fish poisoning Pufferfish (Fugu) poisoning

Health hazards from sewage pollution at sea Sewage as a source of bacterial and viral infections Monitoring for potential pathogens—the indicator concept Coliforms and Escherichia coli, Fecal streptococci (entero cocci) Quality standards for recreational marine waters Shellfish hygiene Alternative indicators Direct testing for pathogens Heavy metal mobilization

Module II

Toxic dinoflagellates and diatoms ‘

Red tides’ and ‘harmful algal blooms’ Shellfish poisoning Reason for toxin production by dinoflagellates and diatoms,Paralytic shellfish poisoning (PSP) Neurotoxic shellfish poisoning (NSP) Diarrhetic shellfish poisoning (DSP) and azaspiracid poisoning Amnesic shellfish poisoning (ASP) Ciguatera fish poisoning (CFP) Pfiesteria piscicida ,Monitoring and control of HABs

Module III

Diseases of marine mammals

Difficulties of studying these diseases, Effects of microalgal toxins, Virus infections Morbilliviruses, Other viruses Bacterial and fungal infections, Effects of environmental pollution on infectiousdiseases ,Zoonoses

Module IV

Diseases of invertebrates Introduction Bacterial and viral diseases of bivalve molluscs Bacterial and viral diseases of crustaceans

Diseases in aquaculture Viruses Rickettsias and mycoplasmas, *Aerococcus viridans var. homari* Vibrio spp. Control of disease in crustaceans Diseases of corals

Suggested Reading

1. Colin Munn Marine microbiology Ecology and Application.

2. Middelboe, M. and Brussaard, C.P. eds., 2018. Marine Viruses 2016. MDPI

3. Middelboe1, M and C P. D. Brussaard.2017 Marine Viruses: Key Players in Marine Ecosystems Viruses.; 9(10): 302.

4. Egan and Gardiner. 2016 Microbial Dysbiosis: Rethinking Disease in Marine Ecosystems Frontiers in Microbiology Volume 7 . Article 991

5. M. Crane and A. Hyatt Viruses of Fish 2011: An Overview of Significant Pathogens (Viruses3: 2025–2046.

6. P. K. Bienfang et al.,2011 Prominent Human Health Impacts from Several Marine Microbes: History, Ecology, and Public Health Implications (A Review Article). International Journal of Microbiology

7. P.T.K. Woo .Fish Diseases and Disorders. Vol 3: Viral, Bacterial and Fungal Infections.

8. Bosch and S.F. Le Guyader (2010) Viruses in Shellfish . Food Environm Virol 2: 115-116.

9. Principle diseases of marine fish and shellfish by Carl J. Sindermann.

10. Fish disease diagnosis and by Edward C. Noga

11. Fish diseases and disorders by J. F. Leatherland and PKT Wook