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

Syllabus of M.Sc. (Marine Microbiology) Programme

Approved by the Board of Studies in Microbiology on 23rd April 2012.

The department of Microbiology offers a two-year full time M.Sc. Marine Microbiology programme w.e.f. June 2012. This is an Innovative programme of teaching and research in interdisciplinary and emerging areas sponsored by UGC.

A brief description of the course:

- **Purpose**: The course is designed to develop human resource in the field of Marine Microbiology at the level where the candidates will be equipped to take up research programmes and jobs in the related Industries sector, Institutions and Academics. The main objective of this Programme is to train manpower in the field of Marine Microbiology.
- **Prerequisites**: B. Sc (Microbiology)
- **Credits:** The Programme consists of Courses with a total of 80 credits – Theory: 60 credits, Practicals: 20 credits
- **Number of Semesters, Course distribution**: The Programme comprises 4 Semesters; each Semester has Courses equivalent of 20 credits
- **Dissertation**: Compulsory, with 12 credits, in Semester III & IV, to impart training in research
- **Field work/Case studies/Cruise/Field trip/Report writing/Training in other University/Institute**: to impart specialized practical training in specific areas of Marine Microbiology.

M. Sc Marine Microbiology: Course structure
In the following tables L refers to Lectures, T to Tutorials and P to Practicals. Description of course appears on the page numbers listed in the tables.

Compulsory Courses

Course Number and Name	L-P (hours/week)	Credits	Page number
1st semester			
MMC 101-Microbial Biochemistry	3-3	4	3
MMC 102-Microbial Genetics	3-3	4	5
MMC 103-Microbial Taxonomy and Systematics	3-3	4	7
MMC 104-Techniques and Instrumentation in Microbiology	3-3	4	8
MMC 105-Biostatistics	3-3	4	10
2nd semester			
MMC 201-Industrial Microbiology	3-3	4	12
MMC 202-Archaea - Ecology, Physiology, biochemistry and Genetics	3-3	4	14
MMC 203 -Molecular Biology	3-3	4	16
MMC 204-Marine Microbiology I	3-3	4	18
MMC 205-Genetic Engineering	3-3	4	20

Optional Courses

Course Number and Name	L-P (hours/week)	Credits	Page number
3rd semester			
MMO 301-Marine Pollution & Microbial Remediation	3-3	4	22
MMO 302-Marine Microbial Prospecting and Technology	3-3	4	24
MMO 303 -Marine Microbial Genomics	3-3	4	25
MMO 304-Marine Environment & Health management	3-3	4	27
MMO 305-Marine Extremophilic Microorganisms	3-3	4	29
MMO 306-Marine Virology	3-0	3	30
MMO 307 Techniques in Microbial Oceanography	3-3	4	31
4th semester			
MMO 401- Microbial Ecology of the Deep Marine Environment	4-0	4	33
MMO 402-Fishery Microbiology	3-3	4	34
MMO 403-Polar Microbiology	3-3	3	36
MMO 404-Remote Sensing & GIS	3-3	4	
MMO 405-Bioinformatics	3-3	4	
MMO 406-Marine Mycology	3-3	4	37
MMO 407-Cruise	0-6	2	
MMO 408-Summer training/Field trip/Study tour	0-6	2	39
MMD Dissertation	0-18	12	

MMC 101 – Microbial Biochemistry
Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1 Proteins and Enzymology (15)

1.1 Proteins: structure, principles of separation and purification, molecular weight determination; sequencing and synthesis

1.2 Enzymes: Activity, Inhibition, Mechanism of action; Regulatory – Allosteric and Covalently Modulated Enzymes and their significance in metabolism.

1.3 Amino acid biosynthethic pathways and their regulation

2 Carbohydrates and Lipids (15)

2.1a Carbohydrate Metabolism

Carbohydrates: Central pathways of metabolism – regulatory mechanisms, bioenergetics and significance - EMP and alternate pathways: Entner-Doudoroff, HMP and oxidative pentose phosphate; TCA cycle (glucose aerobic and anaerobic, malate metabolism), Glyoxylate cycle

Utilization of sugars such as lactose, galactose, maltose and of polysaccharides such as starch, glycogen, cellulose, pectin

2.1b Carbohydrate Metabolism

Gluconeogenesis from TCA intermediates / amino acids / acetyl-CoA; biosynthesis of polysaccharides and interconversion of sugars

2.2 Lipid Metabolism

Lipids: fatty acids - structure, properties; classification of lipids, structure, properties, lipid composition of microorganisms

Catabolism: Bioenergetics of β-oxidation of fatty acids, long chain fatty acids

Anabolism: (a) Biosynthesis of fatty acids: saturated, unsaturated

(b) Biosynthesis of triglycerides, phospholipids, sterols

3 Other Metabolic Pathways and Bioenergetics of Metabolism (15)

3.1 Nucleotide biosynthesis

Biosynthesis and its regulation of purine and pyrimidine nucleotides, deoxyribo nucleotides

Biosynthesis of nucleotide coenzymes

3.2 Bioenergetics and ATP generation

Exergonic and endergonic reactions;

Redox enzymes, aerobic electron transport and oxidative phosphorylation;

Intermediary metabolism - flexibility economy.

3.3 Photosynthetic Metabolism

Organisms and photosynthetic pigments, fundamental processes in photosynthesis

Photosynthetic electron transcript and photophosphorylation

3.4 Chemolithotrophy

Organisms, substrates, bioenergetics of metabolism

3.5 Antimicrobials

Bacteriocins and antibiotics - mode of action and resistance

Practicals **(45)**

1 Study of standard protein sample
1.1 Precipitation of protein from solution by salting out; dialysis
1.2 Gel filtration / molecular exclusion chromatography
1.3 Specific activity, fold purification, percentage yield of enzyme
2 Extraction of microbial whole cell protein
2.1 Growth and harvesting of the culture
2.2 Cell lysis: homogenisation/ sonication
2.3 Protein estimation of lysate - quantification per unit biomass
3 Protein Profile / Molecular weight determination by SDS-PAGE

Reference Books

1 Lehninger Principles of Biochemistry edited by Albert Lehninger , Michael Cox , David L. Nelson. W. H. Freeman & Company
2 Microbial Physiology edited by Albert G. Moat and John W. Foster.
3 Companion to Microbiology edited by Bull, Alan T. and Meadow, Pauline.
4 An introduction to practical biochemistry edited by David T. Plummers.
5 Biochemical Methods edited by S. Sadasivam, A. Manickam. New Age International (P) Limited (Publ).
6 Laboratory Manual in Biochemistry edited by J. Jayaraman. John Wiley & Sons Australia, Limited (Publ).

MMC 102 – Microbial Genetics
Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1

1.1 Classical Mendelian Genetics and Deviation from Mendelian Principles, Genomes in Mitochondria and Plastids, mitochondria and chloroplast have diverse genomes, Mitochondrial genes have been inherited by Non-Mendelian mechanism, why mitochondria and plastids (chloroplast) have their own genetic system? **(03)**

1.2 Special types of chromosomes - Polytene and Lampbrush chromosomes and their genetic significance **(07)**
Structural chromosomal Aberrations and their significance: Deletion, Duplication, Inversion, Translocation
Bacterial genomes – organization, replication, segregation and regulation
Structure of Prokaryotic and Eukaryotic Genes (interrupted Genes), Prokaryotic genes are colinear with their proteins, Prokaryotic & Eukaryotic genome Size, Gene numbers, types and families of genes, pseudogenes and their significance.

1.3 Viral Genetics : Genomic organization and Replication of viruses- T4, Lambda , M13, SV40, Hepatitis B, Poliomyeletis, HIV, H-1 N-1 (Swine Flu). **(05)**
Lambda Phage and its strategies-Lytic and Lysogenic cycles.
Retroviruses and Retroposons-introduction and genetic significance.

2

2.1 Genomic (DNA) Rearrangements: Mechanism of General and Programmed DNA rearrangements, Role of transposons in DNA rearrangements. **(05)**
Transposons: IS elements – Composite transposons (Tn 3, Tn 5, Tn 7, Tn 10), Copia and P type, Mechanism of transposition, transposons as research tools.

2.2 Mutagenesis, mutation and mutants: spontaneous and induced mutations, different types of mutants, molecular basis of mutagenesis, site specific and random mutagenesis. Tn mutagenesis; transition & transversion, tautomeric shift **(10)**
Point mutations and consequences: silent mutation, missense mutation, nonsense mutation, Read through mutation
Mutagenic chemicals and radiations and their mechanism of action: EMS, MMS, acridines, Acriflavins, NTG, Hydroxylamine; mutagenic radiations-UV and gamma rays
Importance of mutations

3 **(15)**

3.1 Fungal Genetics: Yeast (*Saccharomyces cerevisiae*, *S. pombe*)
Neurospora genomes as model genetic systems;
Chromosome replication, yeast artificial chromosomes, Crosses, tetrad analysis, genetic compatibility and non-compatibility genes, heterokaryosis, Parasexuality, Parthenogenesis, Gene conversion, mutagenesis (Petite mutants of yeast);

3.2 Bacterial plasmids: Types of plasmids, F plasmids and their use in genetic analysis, colicin and col plasmids, R plasmids and plasmids with genes encoding metal resistance and degradation of organic recalcitrants (PAH, PCB's, etc)., Replication mechanism of plasmids, regulation of copy number and compatibility; Bacterial plasmids as research tools.

Practicals **(45)**

1 Isolation of plasmid DNA from recombinant E.coli cells by Boil Prep method (Holmes and Quigley,1989).
2 Isolation of Genomic DNA of Bacterial cells using Rapid genomic DNA extraction method.
3 Isolation of plasmid DNA from bacterial cells by Alkaline Lysis method (Birnboim and Doly,1979).
4 Agarose gel electrophoresis, visualization and documentation of plasmid DNA using Gel Doc system.
5 Agarose gel electrophoresis of genomic DNA, visualization of genomic DNA and recording of gel using Gel doc system.
6 Spectrophotometric quantitation and purity of genomic DNA of bacterial cells.
7 Recovery of genomic DNA embedded in agarose gels (Freeze Squeeze, column)
8 UV mutagenesis and screening of pigment deficient mutants of *Serratia* sp.
9 Determination of UV survival of *Serratia* sp.

Reference Books

1 Microbial Genetics by David Freifelder (2009)
2 Microbial Genetics by Maloy et al. 2009
3 Modern Microbial Genetics by Streips and Yasbin (2009)
4 Molecular Genetics of Bacteria by J. W. Dale , John Wiley publishers, (2009)
5 Genetics by M.W. Strickberger (2009)
6 Principles of Genetics by Gardner, Simmons and Snustad (2009)
7 Bacterial Plasmids by Hardy

MMC 103 – Microbial Taxonomy and Systematics
Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1

1.1 **Microbial taxonomy and systematics** **(03)**
Concepts of taxonomy (characterization, classification and nomenclature) and systematics; classification of microorganisms, three domain and six-kingdom systems

1.2 **Phenotypic characters** - Morphology, Biochemical tests (e.g. API, BIOLOG), Bacteriophage typing, Serotyping **(04)**

1.3 **Chemotaxonomic markers** - Cell wall components, lipid composition cellular fatty acid (FAME analysis), isoprenoid quinones, protein profiles (e.g. MALDI-TOF), cytochrome composition **(08)**

1.4 **Nucleic acid based techniques** – G+C content (T_m and HPLC); 16S rRNA gene sequencing; phylogenetic analysis; DNA-DNA hybridization **(09)**

1.5 Concepts of species, numerical taxonomy and polyphasic taxonomy **(06)**

2 Salient features of phylum, class and orders with representative examples of the following – Archaea, Eubacteria (bacteria, cyanobacteria, actinomycetes), Mycota, Protista (algae, protozoan, diatoms); and viruses **(15)**

Practicals **(45)**

1 Morphological, physiological and biochemical characterization of bacteria
2 Chemotaxonomic analysis - cell wall, cell lipid, quinones, cytochromes
3 Characterization of actinomycetes (*Streptomyces* sp.)
4 Characterization of yeast (*Saccharomyces cerevisiae*, *Schizosaccharomyces pombe*)
5 Identification of cyanobacteria

Reference Books

1 Goodfellow, M. and Minnikin, D.E. (eds.), Chemical methods in bacterial systematics, The Society for Applied Bacteriology. Technical Series No. 20, Academic Press.
2 Sneath, A. H. P., Mair, S. N. and Sharpe, E. M. (eds.), Bergey's manual of systematic bacteriology Vol. 2. Williams & Wilkins Bacteriology Symposium, Series No 2, Academic Press, London/New York.
3 Goodfellow, M., Mordarski, M. and Williams, S. T. (eds.), The biology of the actinomycetes.
4 Barlow, A. (ed.), The prokaryotes: a handbook on the biology of bacteria: ecophysiology, isolation, identification, applications, Volume 1 Springer-Verlag.
5 Kurtzman, C. P., Fell, J. W. and Boekhout, T. (eds.), The yeasts - a taxonomic study.
6 Norris, J. R. and Ribbons, D.W. (eds.), (1971) Methods in microbiology, Vol. 18 & 19.
7 Reddy, C.A. (ed.), Methods for general and molecular microbiology
8 Priest, F. G. and Austin, B. Modern bacterial taxonomy, Chapman and Hall.

MMC 104 – Techniques and Instrumentation in Microbiology
Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1

1.1 **Chromatographic techniques:** GC, HPLC, detectors, column/s matrix- Ion-exchange, affinity and molecular exclusion. (using examples for separation of microbial lipids, pigments, nucleic acids and proteins/enzymes) **(05)**

1.2 **Centrifugation:** Principles, methodology, application; Density gradient centrifugation; Ultracentrifugation (Separation of ribosomal subunits of bacteria) **(03)**

1.3 **Spectrophotometry:** Atomic Absorption Spectrophotometry (AAS), UV-Visible, fluorimetry, Fourier transformation infra-red spectroscopy (FTIR), MALDI-TOF, IR, NMR, MS **(07)**

2

2.1 **Microscopy:** Epifluorescence filter technique (DEFT), SEM, TEM, Confocal and AFM **(05)**

2.2 **Radio-isotope and tracer techniques:** Isotope and types of isotopes, Radio-activity counters, Autoradiography, Radiorespirometry **(05)**

2.3 **Cell and tissue culture techniques:** Primary and secondary/established cell lines, Monolayer and suspension cultures, Fluorescence activated cell sorting (FACS), Biohazards and Biosafety cabinet **(05)**

3

3.1 **Electrophoretic technique:** PAGE, IEF, Agarose gel electrophoresis, PFGE, DGGE, TGGE, Capillary electrophoresis, Single stranded conformation polymorphism (SSCP), Electroporator, Micro-array technique **(06)**

3.2 **Isolation of cell organelles:** Different methods of cell lysis/ breakage and isolation and purification of various cell organelles - Cell surface structures, cell envelopes, plasma membranes, peptidoglycan, Outer membrane, ribosomes, protoplasts, vesicles, spheroplast, DNA, RNA **(06)**

3.3 **Others:** X-ray diffraction, Oxygen analyser, Biosensors **(03)**

Practicals **(45)**

1 Isolation and cultivation of microbial cells
2 Preparation of bacterial cell protoplast
3 Preparation of bacterial cell envelopes
4 Cell disruption by sonicator and efficacy of sonication
5 Microscopy – compound, phase contrast – of bacterial cells
6 Counting of bacterial cells using epifluorescence microscopy
7 Density gradient separation of mixed bacterial cells/ bacterial cell envelope
8 Quantification of cell metabolite (fluorescent compounds) by spectrofluorimeter
9 Extraction of microbial pigments and profiling using UV-Vis spectrophotometer
10 Polyacrylamide gel electrophoresis (PAGE), Zymogram
11 Separation of pigments by column chromatography and HPLC
12 Demonstration: SEM, GC, NMR, IR, MS

Reference Books

1 Norris, J. R. and Ribbons, D.W., Methods in Microbiology, Volume 5, Part B, Pages iii-vii, 1-695.

2 Colowick, S. P. and Kaplan, N. O., Methods in Enzymology, Vol. VI, Academic Press, N.Y.

3 Parakhia, M.V., Tomar, R. S., Patel, S. and Golakiya, B.A., Molecular Biology and Biotechnology : Microbial Methods, New India, Pitampura.

4 Sambrook, J., Fritsch E. F. and Maniatis, T., Molecular Cloning A laboratory manual, Cold Spring Harbor Laboratory Press, USA.

5 Wilson, K. and Walker, J., Principles and Techniques of Biochemistry and Molecular biology, Cambridge University Press, N.Y., USA.

MMC 105 – Biostatistics

Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1

1.1a **Characteristics of biological data:** Variables and constants, discrete and continuous variables, relationship and prediction, variable in biology (measurement, ranked, attributes), derived variables (ratio, index, rates), types of measurements of biological data (interval scale, ratio scale, ordinal scale, nominal scale, discrete and continuous data); **(03)**

1.1b **Elementary theory of errors:** exact and approximate numbers, source and classification of errors, decimal notation and rounding off numbers, absolute and relative errors, valid significant digits, relationship between number of valid digit and error, the error of sum, difference, product, quotient, power and root, rules of calculating digits **(03)**

1.2 **Data handling:** Population and samples, random samples, parameter and statistics, accuracy and precision, accuracy in observations Tabulation and frequency distribution, relative frequency distribution, cumulative frequency distribution **(05)**

Graphical representation: types of graphs, preparation and their applications

1.3 **Introduction to Bioinformatics** **(04)**

Concepts and applications

2

2.1 Measures of central tendency: characteristics of ideal measure, **(05)**

Arithmetic mean – simple, weighted, combined, and corrected mean, limitations of arithmetic mean; Median – calculation for raw data, for grouped data, for continuous series, limitations of median; Mode – computation of mode for individual series, by grouping method, in a continuous frequency distribution, limitations of modes; Relationship between mean, median and mode; mid-range, geometric mean, harmonic mean, partition value, quartiles, deciles, percentiles

2.2 Measure of dispersion: variability, Range, mean deviation, coefficient of mean deviation, , standard deviation (individual observations, grouped data, continuous series), variance, coefficient of variance, limitation **(05)**

Skewness – definition, positive, negative, purpose, measure, relative measure, Karl pearson's Coefficient, Bowley's Coefficient, Kelly's Measure, Moments

2.3 Correlation analysis – Correlation, covariance, correlation coefficient for ungrouped data, Spearson's Rank Correlation coefficient, scatter and dot diagram (graphical method) **(05)**

Regression analysis - Linear and exponential function - DNSA conversion by reducing sugar, survival/growth of bacteria, regression coefficients, properties, standard error of estimates, prediction, regression analysis for linear equation

3

3.1 Probability: Probability, Combinatorial Techniques, Elementary Genetics, Conditional Probability, Bayes' Rule, Statistical Independence, Binomial, Poisson, Normal Distributions **(05)**

3.2 Hypothesis Testing – parameter and statistics, sampling theory, sampling and non-sampling error, estimation theory, confidence limits testing of hypothesis, test of significance; Students' T-test, t- distribution, computation, paired t-test **(05)**

3.3 Chi-square test, F-test and ANOVA **(05)**

Practicals **(45)**

1 Excel spreadsheet and data analysis
2 Linear equation analysis (regression analysis)
3 Exponential equation analysis (Survival curve)
4 Chi square test
5 Normal distribution
6 Hypothesis testing

Reference Books

1 Quantitative techniques by Kothari, Vikas Publishing House
2 Biostatistics by Arora and Malhan, Himalaya Publishing House
3 Computational mathematics by Danilina et al., Mir Publishers
4 Biostatistics by Surya, Himalaya Publishing House

MMC 201 – Industrial Microbiology
Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1

1.1 History of Industrial Microbiology, fermentation processes, descriptive layout and components of fermentation process for extracellular and intracellular microbial products **(05)**

1.2 Microbial growth kinetics: **(05)**
Batch kinetics – Monod's model (single substrate), deviations from Monod's model, dual substrates – sequential utilization, multiple substrates – simultaneous utilization, substrate inhibition, product synthesis (primary and secondary metabolite), toxic inhibition, death constant

1.3 Microbial growth kinetics: **(07)**
Fed-batch kinetics – fixed volume, variable volume and cyclic fed-batch, applications and examples of fed-batch systems,
Continuous cultivation system – relationship between specific growth rate (μ) and dilution rate, multistage systems, feedback systems (internal and external feedback), applications and examples of continuous cultivation system; comparison between various cultivation systems

2

2.1 Optimization and modeling of fermentation process – single variable design, multivariate screening designs, critical factor analysis, optimization designs for two or more factor, singlet method; Metabolic and flux control analysis **(05)**

2.2 Bioreactor design and operation: classification of reactors; Ideal mixed v/s plug flow reactor; designing parameters for reactors (stirred tank reactor, airlift reactor, plug flow reactor), rheology of fermentation broth **(05)**

2.3 Bioreactor design and operation: gas-liquid mass transfer, heat transfer, analysis of dimension less parameters and their application (aeration number, power number and Reynold's number; Scale-up of bioprocesses: parameters used in scale-up and problems associated with scale-up **(05)**

3

3.1 Solid substrate fermentation (SSF): Principles and application; Surface fermentation Comparison between SSF, Surface fermentation and SmF. Problems in fermentation process and handling (foam, contamination, strain degeneration, etc), Immobilized enzymes and cell systems **(05)**

3.2 Fermentation monitor and control: Common measurement and control systems (speed, temperature, gas, pH, Dissolved oxygen, foam, redox, air flow, weight, pressure, biomass), On-line and off-line analysis, Digital controllers, control algorithm, flow charting, incubation control, advanced fermentation control and computer-based automation of process. **(05)**

3.3 Industrial scale Down-stream processing and product recovery: principle and general description of instrumentation, Recovery of particulates (cells and solid particles), recovery of intracellular products, primary isolation (extraction, sorption), precipitation, industrial processes for chromatography and fixed bed adsorption, membrane separations; Type Processes - Antibiotic (Penicillin including semi-synthetic) **(05)**

Practicals **(45)**

1 Fermentation kinetics – growth of *E.coli*/*S.cerevisiae* and determination of μ_{max}, Ks, Yx/s, m
2 Rheology of substrate solutions, culture broth and harvested cell suspension
3 Designing of fermentor – stirred tank reactor
4 Aeration efficiency using dissolved oxygen analysis
5 Immobilization using alginate
6 Baker's yeast – ISI quality assurance

Reference Books

1 Manual of Industrial Microbiology and Biotechnology, Demain et al., Wiley
2 Fermentation and Biochemical Engineering Handbook - Principles, Process Design, and Equipment, Vogel and Tadaro, William Andrew Publishing
3 Biochemical Engineering and Biotechnology Handbook, Atkinson, Grove's Dictionaries
4 Encyclopedia of Bioprocess Technology, Fermentation, Biocatalysis and Bioseparation, Volumes 1 - 5, Flickinger and Drew, Wiley
5 Principles of Fermentation Technology, Stanbury et al., Butterworth-Heinemann

MMC 202 – Archaea- Ecology, Physiology, Biochemistry and Genetics
Course credit: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1

1.1 Emergence of Archaeobacteria and the domain Archaea: Three major lineages of life – Archaea, Eubacteria, Eukarya Similarities and dissimilarities - Archaea, eubacteria and eukaryotes Uniqueness of archaebacteria v/s other Extremophilic microorganisms **(01)**

1.2 Significance of Archaea: **(02)**
Biotechnology, Biogeochemical cycling, Evolutionary developments

1.3 Ecology, physiology and diversity of Archaea **(03)**
Global econiches; Culture – Retrieval- methods, novel samplers, Non-culture-methods. Preservation
Nutrition, Growth and growth kinetics and physiological versatility, Stress Response, Methanogens (*Methanobacterium thermoautotrophicum*); Halophiles (*Halobacterim halobium*); Thermophiles (*Thermoplasma*) and Thermoacidophiles (*Sulfolobus*).

1.4 Cell structure and architecture of Archaea: **(09)**
Cellular organization - cell morphotypes, cell envelopes, Purple membrane, cell organelles - ribosomes, appendages; molecular organization
Novel bio-molecules: GDEMs and macrocyclic lipid, enzymes, Co- enzymes Methanopterin, formaldehyde activation factor, Component B, Coenzyme M, F420, F430, corrinoids. DNA Binding and Repair proteins

2 Metabolism and energetics of Archaea **(15)**

2.1 Modified anabolic pathways. (carbohydrates, lipids), Methanogenesis and acetoclastic reactions

2.2 Modified Central metabolic pathways including C1, C3 compounds.
Incomplete TCA; Carbon dioxide reduction pathways

2.3 Bioenergetics: (i) respiration driven (ii) light driven (iii) chloride driven (iv) cation driven ATP synthesis. Anaerobiosis.

2.4 Bacterioruberin pathway

2.5 Lipid synthesis

3 Genome of Archaea **(15)**

3.1 Size of genome, G + C content, associated proteins

3.2 FI-DNA, FII-DNA,Plasmids, IS elements, AT-rich-islands.
Modifications in tRNA and rRNA structure. Novel 7S rRNA. Signature sequences. DNA Replication, Recombination and DNA Repair in archaea

3.3 Gene organization in Archaea: (i) fdh operon (ii) his operon (iii) bob operon (iv) mcr operon.

3.4 Archaeal virus like particles and phages.

Practicals **(45)**

1 Isolation and Culturing of Archaea
2 Identification of isolate:
a Analysis of morphological features by SEM.
b Cellular lipids - Extraction and chromatographic resolution of lipids
3 Bioprospecting for hydrolytic enzymes / for Archaeocin

Reference Books

1 The Bacteria: A Treatise on Structure and Function. Archaebacteria, vol. 8, pp. 525–544, Woese C. R. and Wolfe R. S. (eds), Academic Press.

2 Archaea: New Models for Prokaryotic Biology edited by Paul Blum, Beadle Caister (Academic Press).

3 Archaea: Evolution, Physiology, and Molecular Biology edited by Garrett and Klenk (Amazon.com)

4 Archaea: Molecular and Cellular Biology, model archaea, archaeal genomes, other haloarchaea, archaeal flagella (Amazon.com)

MMC 203 – Molecular Biology

Course credit: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1

1.1 Nucleic Acids- structure of DNA and RNA, Bondings and different types of DNA (B-DNA & Z-DNA); DNA packaging in bacteria, viruses and eukaryotes, Hybrid genome of Eucaryotes: Regulatory sequences, yeast as a minimal model eukaryote, Arabidopsis as a model of higher eukaryote; Diversity of genomes and the tree of life. **(10)**

1.2 DNA, chromosomes and Genomes: structure and function of DNA, chromosomal DNA and its packaging in the chromatin fibre, chromatin structure, structural features (Telomere, Centromere and Repetitive sequences) of chromosomes and their functions. **(05)**

Packaging of Viral genomes; bacterial genome - nucleoid, Evolution of Genomes; Gene duplication and mutations.

2 **(15)**

2.1 DNA Damage and repair, recombination

DNA damage elements/factors, Types of DNA damage (spontaneous and induced DNA damage), mechanisms/pathways to remove damaged DNA: Excision repair, mismatch repair, recombination repair in *E.coli*, SOS Repair, role of Rec A in DNA damage repair, Photoreactivation repair in *E.coli* involving photolyase.

2.2 Mechanisms of Genetic Recombination: General and site specific recombination, Heteroduplex DNA formation (Homologous recombination), Synaptonemal Complex, Bacterial Rec BCD system and its stimulation of chi sequences; role of Rec A protein, homologous recombination, Holliday junctions.

3 **(15)**

3.1 How cells read the Genome: From DNA to Proteins -

(a) From DNA to RNA

(b) From RNA to Protein

(c) The RNA world and origin of life

3.2 Gene structure & Control of Gene expression in Prokaryotes and eukaryotes:

An overview of Gene control, DNA binding motifs in Gene regulatory proteins, Genetic switches and their role in control of gene expressions; molecular Genetic mechanisms that create specialized cell types,

Post-transcriptional controls-transcription attenuation, Riboswitches, Alternate splicing, RNA editing, RNA Interference,

Translation of mRNA in Prokaryotes and Eukaryotes and role of Regulatory Switches, leader sequences and protein localization.

Practicals **(45)**

1 Demonstration of working principle of Gel Documentation system.

2 Demonstration of working principle of Thermal Cycler.

3 PCR amplification of a specific gene (target DNA sequence) from genomic DNA. Agarose Gel analysis of PCR product to check it's size and purity.

4 Curing of plasmid DNA by acridine orange/SDS and determination of plasmid loss by loss of resistance to antibiotic and agarose gel electrophoresis.

5 Fluctuation test

6 NTG – Mutagenesis and Screening of NTG – induced heavy metal resistant mutants

Reference Books

1 Molecular Biology of Cell by Alberts *et al*. 2009
2 Molecular cell Biology by Darnell , Lodish and Baltimore
3 Molecular Biology of Gene by Watson *et al.* 2009
4 Essentials of Molecular Biology by David Freifelder, 2009
5 Genes IX/X by Benjamin Lewin 2009/2010
6 Principles of Genetics by Gardner, Simmons and Snustad-2009
7 Principles of genetics by Tamarin- 2009
8 Basic Methods in Molecular Biology by Davis *et al*. 2007(Elsevier)
9 Advanced Molecular Biology by R. M. Twyman , 2008

MMC 204 – Marine Microbiology I
Course credit: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1 **(15)**

1.1 Introduction to oceanography: the world's oceans and seas, properties of seawater, physico-chemical factors in the marine environment such as temperature, density, nutrients, salinity, dissolved gases, waves, tides, oceanic currents, Ekman transport and upwelling; oceanic phenomena such as Coriolis effect, eddies, gyres, El Nino Southern Ocean (ENSO), El Nino, La Nina.

1.2 Marine microbial habitats: estuaries, mangroves, salt marshes, beach and coastal ecosystems, reef and coral reefs, water column, sediments.

2 **Marine microbes: their growth, physiology and contribution to ocean processes** **(15)**

2.1 Modes of microbial growth: viable but non-culturable (VBNC) microorganisms, biofilms, microbial mats, epibiosis

2.2 Physiology of marine microbes: metabolic diversity and energy-yielding processes: microbial loop; marine snow; phototrophy and primary productivity, fermentation, aerobic respiration, anaerobic respiration (denitrification, sulphate reduction, methanogenesis); nitrification, annamox, sulphur oxidation, methanotrophy; carbon dioxide fixation in autotrophs; the role of microorganisms in biogeochemical cyling: carbon, nitrogen, phosphorous, sulphur, iron, manganese.

3 **Methods in marine microbiology** **(15)**

3.1 Sampling equipment: water samplers such as Niskin sampler, Hydro-Bios sampler, Rosette samplers; sediment samplers such as van Veen grabs and corers

3.2 Analysis of primary productivity: the radiocarbon method

3.3 Analysis of bacterial productivity: the thymidine uptake method

3.4 Measurement of respiration rates: light-dark bottle method

3.5 Tools to study marine microbial diversity: flow cytometry (bacteria, picoplankton, picoeukaryotes, viruses); molecular approaches such as metagenomics, community fingerprinting and Fluorescence in situ hybridization (FISH).

Practicals **(45)**

1 Isolation and identification of microbes from mangroves, coastal waters and sediments with special emphasis on sample collection methodology, collection trips in boats/ trawlers

2 Assessment of salt requirement of marine isolates from different ecosystem

3 Analysis of physico-chemical parameters

4 Study of biofilm microorganisms

5 Hydrolytic enzyme profiling of the marine bacterial isolates

6 Nitrification and denitrification by the marine bacterial isolates

Reference Books

1 Hunter-Cevera, J., Karl, D. and Buckley, M., Marine Microbial Diversity: the key to Earth's habitability, American Academy of Microbiology.

2 Mitchell, R. and Kirchman, D. L. Microbial Ecology of the Oceans, Wiley-Blackwell Publishers.

3 Belkin, S. and Colwell, R. R., Ocean & health: Pathogens in the Marine Environment, Springer.

4 Meller, C. B. and Wheeler, P. A., Biological Oceanography, Wiley-Blackwell Publishers

5 Munn, C. Marine Microbiology: ecology and applications, Garland Science, Taylor and Francis group, N.Y.

6 Oliver, J. D. (1982) Taxonomic scheme for the identification of marine bacteria by Deep Sea Research Part A. Oceanographic Research Papers, 29 (6): 795 -798.

MMC 205 – Genetic Engineering
Course Credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1 **(15)**

1.1 **Introduction to genetic engineering (Recombinant DNA technology)**
Enzymes used in Recombinant DNA technology: restriction endonucleases, exonucleases, DNA ligases (T_4 & *E.coli* ligases), Terminal DNA transferase, DNA Polymerases (Taq, Amplitaq, vent,Exo-vent, Pfu, T4 etc), Reverse transcriptase, T_4 polynucleotide kinases, Alkaline-phosphatase, S-1 Nuclease, Mung bean nuclease, RNases.

1.2 Gene cloning systems/Hosts: Gene cloning in E.coli and other organisms such as *Bacillus subtilis*, *Saccharomyces cerevisiae* (yeast) and other microbial eukaryotes

1.3 Cloning vectors: plasmid(pUC19, pBR 322 and their derivatives), λ phage, cosmid, Phasmid (Lambda Zap); shuttle /transfer vectors,

1.4 Sequencing Vectors: pUC 19 and M-13 Phage vector,

1.5 High capacity Cloning vectors: BAC and YACs.

1.6 Expression vectors: Prokaryotic (pET, pGEX-2T and others) and their characteristics; regulatable strong bacterial and viral promoters (*lac,trp,tac, Lambda PL ,SV40, T7* etc) for induction of gene expression.

1.7 Preparation of rDNA molecule and its transfer to appropriate host (bacteria/yeast/plant cell/animal cell) using a suitable technique: transformation, electroporation , transfection, gene gun, Particle bombardment etc.

2 **(10)**

2.1 Gene Cloning strategies: Cohesive end cloning & Blunt end cloning, Shot gun cloning and directed cloning; Genomic DNA cloning and cDNA cloning, screening of Gene libraries for recombinant clones.

2.2 Other Recombinant DNA techniques: Use of radioactive and non - radioactive nucleotides for DNA probe preparation and detection of hybrids, Gel retardation assay, Restriction mapping, RFLP, PCR, RT-PCR, Real time PCR and its applications, DNA micro arrays and their use in Genomics; DNA sequencing using Sanger's Dideoxy chain termination method and automated sequencer; chromosome walking, Hybrid release and hybrid arrest translation to screen the clones, site directed mutagenesis.

3 **(10)**

3.1 **Application of Genetic Engineering in Biology, forensics and medicine**

3.1a Screening of Genetic diseases using DNA probes (DNA diagnostics); Production of recombinant proteins and drugs(insulin, tissue plasminogen activator, erythropoietin, human growth hormones, Antibodies (including Bispecific antibodies for cancer treatment), vaccines, interferons, DNA vaccines: merits and demerits; Edible vaccines- merits and demerits; DNA typing and finger printing

3.1b Manipulation of gene expression in Prokaryotes; Strategies to isolate functional promoters, gene expression from strong and regulatable promoters, Developing fusion proteins and separation of cloned protein by protease induced cleavage, Genetic manipulation to increase recombinant protein stability and secretion using signal sequences.

3.2 Application of Genetic Engineering in Agriculture

3.2a Development of transgenic crops resistant to insect pests, bacterial, fungal and viral pathogens.

3.2b Strategies to develop transgenic crops and horticulture plants using various tools of recombinant DNA technology: Development of Bt Brinjal, Golden Rice and flavre savre tomato.

3.2c Importance of *Agrobacterium tumefaciens* in genetic manipulation of plants (Role of Ti plasmids), Role of *Bacillus thuringiensis* (*Bt* genes) to develop insect pest resistant crops.

4. **(10)**

4.1 Application of Genetic Engineering in Industry

Genetic manipulation of microbes to over produce industrially valuable enzymes, recombinant pharmaceuticals, nutraceuticals and other biomolecules , production of fermentation products using recombinant organisms, SCP production.

4.2 Application of Genetic engineering in Biomonitoring and Bioremediation of environmental pollutants

Microbial degradation of xenobiotics such as PAH by recombinant microbes, bioremediation of toxic heavy metals, biohydrometallurgy using recombinant microbes for recovery of precious metals. Genetic manipulation of microbes to develop biosensors for monitoring toxic organic and inorganic pollutants.

(45)

Practical

1 Restriction mapping of bacterial plasmid
2 Transformation of bacteria with plasmid
3 Cloning of DNA fragment in pUC 19.
4 Demonstration of insertional inactivation marker

Reference Books

1 Principles of Gene manipulation – R.W. Old and S.B. primrose
2 Molecular Biotechnology: Principles and Applications of recombinant DNA- B.R. Glick and J. J. Pasternak
3 Genetic Engineering –Williamson
4 Gene Cloning - Glover
5 Molecular Cloning: A Laboratory Manual - Sambrook *et al*. 1989
6 Basic Methods in Molecular Biology- L. G. Davis, M. D. Dibner and J.F. Battey
7 Methods for General and Molecular Bacteriology - Gerhardt, Murray, Wood and Krieg
8 Methods in Microbiology - Vol. 21 (Plasmid Technology) - Edited by J. Grinsted and P. M. Bennett
9 Genetic Engineering – Kreutzer and Massey

MM 301 - Marine Pollution and Microbial Remediation
Course credit: 4 - Three credits theory and one credit practical

Theory **(Contact Hours)**

1 Coastal, estuarine and marine hazards (15)

1.1 Marine pollutants and their sources:
Oil spills (Exxon valdez, Alaska), tar balls, heavy metals (Hg, Cd, Pb, Fe), metalloids (arsenic, selenium, tellurium), organo metal (Tributyl tin), radioactive waste, deep sea mining, ballast water, domestic sewage, industrial wastes, hotels along coastal belt, medical waste, inorganic nutrients (Fe, nitrate, phosphate) runoff from agricultural land (fertilizers) into marine environments, nanoparticles from electronics industry, ammonium nitrate from mining industry.

1.2 Persistent organic pollutants (POPs) in marine/coastal waters:
Polyaromatic hydrocarbons (PAHs), pesticides, other recalcitrants and xenobiotics

1.3 Coastal Environment related legislation in India:
National parks/marine parks, sanctuaries, reserve forests, wildlife habitats, mangroves, corals/coral reefs.

2 Impacts of marine pollution on marine ecosystems and community structure (15)

2.1 Eutrophication, anaerobiosis, biomagnification, biofouling, bioadhesion, biocorrosion.

2.2 Effect of marine pollutants on productivity and sustainability of marine econiche:

2.2a Effect of marine pollution (toxicity) on phytoplankton (primary producers), zooplankton, fishes, coral reefs, barnacles, crabs, mussels, humans.

2.2b Minamata, itai itai diseases, neurological disorders, reproductive disorder, carcinogenesis and teratogenic effects.

2.2c Environmental impact assessment (EIA).

2.2d Application of marine microorganisms towards pollution abatement and sustainable development.

3 Biomonitoring and bioremediation of marine pollutants (15)

3.1 Biomonitoring :
Bioindicators (bioindicator bacteria), biotracers and biosensors

3.2 Bioremediation

3.2a Bioremediation of metals mediated by marine bacteria:
Heavy metal resistant marine bacteria from coastal waters, marine sediments, hydrothermal vent and marine microbes associated with bivalves and sponges. Biochemical and molecular mechanisms of lead, cadmium & mercury resistance in marine bacteria/fungi and phytoplankton which can be harnessed for bioremediation technologies e.g. Efflux mechanism, intracellular bioaccumulation, extracellular sequestration and surface biosorption, Bioprecipitation, biotransformation and redox reaction, volatilization.

3.2b Biodegradation:
Bioremediation of hydrocarbons in marine environments, oil spill/tar ball management. Biodegradation – reactions, enzymes and pathways. Biosurfactants (bioemulsifier), cometabolism, bioaugmentation, biostimulation.

3.2c Waste water treatment plants:
Primary, secondary and tertiary treatment of waste water from industries and hotels before discharging into marine waters.

3.2d Microbial consortia:
Applications of microbial consortia in bioremediation of heavy metals and crude oil from polluted marine sites. Concept of use of genetically engineered marine microorganisms for bioremediation of metals and aromatic hydrocarbons, following safety regulations.

Practicals **(45)**

1 Use of hydrocarbon degrading marine bacteria to test degradation of sodium benzoate/benzene and organometals (Tributyl tin).
2 Enrichment and isolation of crude oil degrading marine bacteria.
3 Isolation of biosurfactant producing microorganisms.
4 Isolation of cadmium/lead/selenite/tellurite resistant estuarine bacteria/fungi and their application in bioremediation.

Reference Books

1 Cavera, J.H., Karl, D. and Buckley, M. Marine microbial diversity: Key to earth's habitability, ASM.
2 Mitchell, R. and Kirchman, D.L. Microbial ecology of the oceans, Wiley.
3 Belkin, S and Cowell, R.R. Ocean & health: Pathogens of the marine environment, Springer.
4 Meller, C. and Wheeler, P.A. Biological oceanography, Wiley.
5 Satyanarayana, T., Johri, B. and Anil, T. Microorganisms in environmental management, Springer.
6 Naik, M.M. and Dubey, S.K. (2013) Lead resistant bacteria: Lead resistance mechanisms, their applications in lead bioremediation and biomonitoring. Ecotoxicology & Environmental safety. 98: 1-7.
7 Prince, R. C. Bioremediation of marine oil spills. In: Handbook of hydrocarbon and lipid microbiology, Springer.
8 Judith, S.W. Marine pollution: What everyone needs to know. Oxford University Press
9 Munn, C. Marine Microbiology: ecology and applications, Garland Science, Taylor and Francis group, N.Y.

MMO 302 – Marine Microbial Prospecting and Technology
Course credit: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1 **Bioprospecting: C**oncept of exploiting marine microbial resource and their cellular components from marine environment and marine invertebrates **(02)**

2 **Sampling and search strategies for novel targets under:** microbial cultures, enzymes, therapeutics, antimicrobials, biotransformations and biofuels. **(05)**

3 **Legal framework for collection and Conservation of Marine niches and microbes.** Convention on Biological Diversity, Rio (1992/1994). Biosafety Protocol, Quarantine regulations, Biopiracy, Cartegena& Montreal, FAO International Treaty (2001-2004), Bonn Declaration on Access and Benefit-sharing (ABS). **(08)**

4

4a **Conventional and High throughput screening strategy:**

i. Conventional: Plating, Enrichment, Extinction culturing; Microscopic techniques, Micro manipulations (FISH), Optical tweezers, Micro autoradiography. **(05)**

ii. Novel: Function based screens(proteomics and metaboliomics), 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 **(07)**

4b **Deposition of microbes and biomolecules:** **(03)**
Culture collection/ Repository, deposition of sequences of nucleic acids, proteins and structures of microbial molecules and products

5 **Case studies on Marine Products and process development using Microbes:** Archaea, cyanobacteria and Proteobacteria; microbial products (MEOR) **(15)**

Practicals **(45)**

1 Isolation and Screening for marine microbes from sediments, marine organisms (bionts) for: pigments, enzymes, antibiotics, therapeutic and industrially molecules. Microbial transformation.

Reference Books

1 Microbial Diversity and Bioprospecting Alan Bull Amazon Publisher
2 Microbial Diversity Exploration & Bioprospecting by R. Reddy, S. Charya, S. Girisham.
3 Relevant research papers and review articles on the subject

MMO 303 – Marine Microbial Genomics

Course credit: 4 – Three credits theory and one credit practical

	Theory	**(Contact Hours)**
1	**Significance of Marine Microbial Genomics**	**(04)**
2	**Marine microbial genomics & Microbial diversity:**	**(07)**
a	Nucleic acid based methods to study marine microbial diversity	
b	Sequencing of ribosomal RNA genes	
c	PCR, DGGE,TGGE and TRFLP analysis	
d	Genomic fingerprinting to analyze culturable microbes	
e	G:C ratio and DNA- DNA Hybridization	
f	DNA Sequencing: Whole genome Sequencing, Pyrosequencing	
3	**Microbial genomics of selected microorganisms (bacteria, cyanobacteria, archaea and viruses):**	**(07)**
a	Organization of Prokaryotic microbial genomes : sizes and ORF contents	
b	Prokaryotic genomes: Bioinformatic analyses and Gene distributions	
c	Organization of Eukaryotic microbial genomes	
4	**Other genomes and evolution of genomes:**	**(05)**
a	Genomes of Organelles	
b	Evolution and gene families	
c	Genomic mining	
5	**Molecular analysis (Culture independent) of Microbial communities:**	**(08)**
a	Viability and Quantification using staining techniques	
b	Genetic stains	
c	Linking specific genes to specific organisms using PCR	
d	Environmental genomics (Metagenomics)	
6	**Microbial gene transfer and ecological perspective**	**(02)**
7	**Tools to study Microbial Genomics:**	**(08)**
a	Genomic cloning techniques: Vectors for genomic cloning and sequencing Sequencing the genome: Conventional and High throughput sequencing Annotating the genome	
b	Gene function and regulation studies: Proteomics, Microarrays and Transcriptomics	
8	**Genomics of specific marine bacteria:**	**(04)**
a	Quorum sensing in luminescent bacteria	
b	Hydrocarbon degradation by marine bacteria	
c	Adaptation to extremes of temperature and pressure	

Practicals **(45)**

1 Extraction of environmental DNA from marine/coastal sediments and electrophoresis
2 Screening of marine bacteria for presence of plasmid
3 Extraction of genomic DNA from marine bacterial strains and electrophoresis.
4 Spectrophotometric determination of concentration of DNA from environmental samples.
5 Determination of purity of environmental DNA samples.
6 PCR amplification of 16S rDNA using environmental (metagenomic) DNA samples as template DNA and electrophoresis.
7 Demonstration of Metagenomic library construction and Screening of Metagenomic clones.

Reference Books

1 Molecular Marine Microbiology - Douglas H. Bartlett, 2000.
2 Marine microbiology- Ecology and Applications - Colin Munn, 2011
3 Brock's Biology of Microorganisms – Michael T. Madigan and John M. Martink, 2006.
4 Genomes 3 - T. A. Brown. 2007, Garland Science publishing
5 Principles of Gene Manipulation and Genomics - S. B. Primrose and R. M. Twyman, Blackwell publishing, 2007.
6 Molecular Biology: Genes to Proteins - Burton E. Tropp., 2012.
7 Molecular Biology of the Cell - Alberts *et al*., 2008.

MMO 304 – Marine Environment and Public Health Management
Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1

1.1 Environmental variables related to marine, coastal and aquatic ecosystems; Water quality and sediment characteristics; Climate change and impact on human health – migration of Vibrio, flooding of coastline; El Nino Southern Oscillations; disaster management (outline); Understanding marine ecosystem and human health with DPSIR model **(05)**

1.2 Marine and coastal pollution - effects on living organisms. Water pollution - microbial changes induced by inorganic and organic pollutants, industrial effluents and domestic sewage. **(05)**
Impact of bioaccumulation and biomagnifications of mercury, cadmium, lead, etc. in fishes, role of microbes. Microbial pollution in industries-corrosion of iron, acid-mine drainage, cooling systems and others. and its impact on marine ecosystems.

1.3 Impact of pollutants on environment and living resources; Challenges for monitoring and control of pollution and overfishing; Standards for various types of water; **(05)**

2

2.1 Biological indicators and indices of water quality; Microbial indicator systems – Fecal Indicator Bacteria (FIB), uses and limitation of FIB, development of ideal indictor system (Clostridium, Cryptosporidium, adenoviruses, Bacteroides, Coliphages) – status, uses and limitation Sanitation in aquaculture systems. **(05)**

2.2 Human pathogens - autochthonous and allochthonous pathogens, pathogen distribution; bacterial pathogens and diseases transmitted through marine and coastal water, faecal contamination, Vibrio, Wound sepsis, entro-viruses. Disease monitoring and surveillance. **(05)**

2.3 Biological pollution – Algal blooms and environmental microflora, their effect on fish production, biological and chemical control of algal bloom, Microbial toxins, Nitrogen balance in aquatic ecosystem.

3

3.1 Bioinvasion, Ballast water - impact, monitoring, rules and regulation, quarantine, certification and import risk analysis **(04)**

3.2 Commonly used drugs/chemicals in aquaculture, drug delivery; Vaccines and vaccination, probiotics and bioremedial measures **(06)**

3.3 Application of health management protocols and biosecurity principles in aquaculture; Long term strategy in health management; Advances in disease control and management; Principles of SPF/SPR. Biosecurity in aquaculture **(05)**

Practicals **(45)**

1 Estimation of major pollutants using spectrophotometry.
2 Hematological, histopathological and biochemical analysis of fish exposed to specific pollutants.
3 Testing the efficacy of aquaculture sanitizers
4 Microbial pollution of water, detection and characterization of different indicator and pathogenic organisms such as *S. aureus*, *E. coli*, *V. cholerae*, *Salmonella*, *Shigella*, by conventional and rapid methods, antibiotic resistant microbes in the marine environment.

Reference Books

1 Hester and Harrison. 2011. Marine Environment and Human Health (http://pubs.rsc.org/en/content/ebook/978-1-84973-240-6)
2 Belkin, S. and Colwell RR. 2005. Oceans and Health: Pathogens in Marine environment. Springer
3 Stoskopf M K. 1993. Fish medicine. W B Saunders company Philadelphia. 882 p.
4 Noga E J. 1996. Fish disease. Diagnosis and treatment. Mosby-Year book Inc., St. Louis, Missouri. 367 p.
5 John Plumb 1999. Health Maintenance and Principal Microbial Diseases of Cultured Fishes. Second Edition. Blackwell Publishing 344p.
6 Soil Microbiology by Subbarao.
7 Aquatic Microbiology by Rheinheimer
8 Marine Pollution by Clark
9 Environment stress and fish diseases by Gary A. Wedemeyer, Fred P. Meyer and Lynnwood Smith
10 Health maintenance and principal microbial diseases of cultured fishes by John a. Plumb
11 Bacteria from Fish and Other Aquatic Animals: A Practical Identification Manual (Cabi Publishing) by Nicky B. Buller and John A. Plumb

MMO 305 – Marine Extremophilic Microorganisms
Course credits: 4 – Three credits theory and one credit practical

Theory		**(Contact Hours)**
1	Concept of extremophiles versus conventional microbial forms and archaea.	**(01)**
2	Extreme Marine Econiches: Marine trenches and ridges, Submarine vents, Deep sea basins and Antarctic sea ice and lakes.	**(02)**
3	Key Molecular components, Unique Physiological features, Adaptation strategies, growth kinetics, significance in biogeochemical cycles of the following:	
3.1	Anaerobes**:** *Anaerobranca horikoshi*, *Methanobacterium thermoautotrophicu*s Barophiles/ Peizophiles**:** Actinobacteria	**(10)**
3.2	Cryophiles, Psychrophiles, Psychrotrophs and Thermophiles**:** *Polaromonas*, *Shewanella*, *Flavobacterium*, *Desulphovibrio*, *Bacillus infernus*, *Aqifex*, *Rhodothermus*	**(10)**
3.3	Oligotrophs, Osmophiles, Halophiles and Xerophiles: *Plagibacter; Rhodotorula*; *Halomonas*, *Marinococcus, Walmia*	**(07)**
3.4	Radiophiles, Metallophiles& Xenobiotic utilizers: *Deinococcus, Hymenobacter, Feroplasma, Pseudomonas, Caulobacter*	**(10)**
3.5	Alkaliphiles, Acidophiles & Neutrophiles: *Aeromonas, Rhodotorula, Caulobacter, Geobacillus*	

Practicals		**(45)**
1	Culturing of Anaerobes, Oligotrophs	
i	Tolerance levels of: Thermophiles, Metallophiles and xenobiotics	
ii	UV resistance	
iii	Detection of osmolytes in halophiles.	

Reference Books

1 Brock, T. D.: *Thermophilic Microorganisms and Life at High Temperatures*, Springer, New York, 1978, 465 pages

2 Extreme microorganisms and the methods to handle them by Fred A Rainey and Aharon Oren

3 Horikoshi, K. and W. D. Grant: *Extremophiles-Microbial Life in Extreme Environments*, Wiley, New York, 1998, 322 pages.

4 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.

MMO 306 – Marine Virology
Course credits: 3 – Three credits theory

Theory **(Contact Hours)**

1 Virus Structure, Diversity and Assay (15)

1.1 Viruses - Introduction, nature, structure and classification

1.2 Marine phages and their host: Archaea, bacteria and cyanobacteria, phytoplanktons, algae

1.3 Marine viruses and their hosts: fish and shrimp; Giant marine virus

1.4 Metagenomic approaches to study the diversity of marine viruses

2 Multiplication and Assay of Phages and Viruses (15)

2.1 Bacteriophage life cycles - lysogenic (latent) and lytic (virulent)

2.2 Viral multiplication

2.3 One step growth profile.

2.4 Assay: plaque assay (PA); most-probable number (MPN); transmission electron microscopy (TEM); epifluorescence microscopy (EfM); flow cytometry (FC)

3 Significance of viruses in marine ecosystem (15)

3.1 Movement of viruses between biomes

3.2 Effect of viruses on ecology of the marine ecosystem

3.3 Marine viruses and global climate change

3.4 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),

3.5 Viruses in shell-fish and health hazards: Norwalk virus and Hepatitis virus A

Reference Books

1 Movement of Viruses between Biomes (2004**).** E. Sano, S. Carlson, L.Wegley and F. Rohwer. Appl Environ Microbiol 70: 5842–5846.

2 Exploring the Vast Diversity of Marine Viruses (2007). M. Breitbart, L. R . Thompson, C.A. Suttle and M.B. Sullivan. Oceanography 20:135-139.

3 Viruses manipulate the marine environment (2009) F. Rohwer and R.V. Thurber. Nature 459, 207-212.

4 Marine viruses and global climate change (2011). R. Danovaro, C. Corinaldesi, A. Dell'Anno, J.A. Fuhrman, J.J. Middelburg, R.T. Noble and C.A. Suttle. FEMS Microbiol Rev 35: 993–1034

5 Viruses of Fish: An Overview of Significant Pathogens (2011) M. Crane and A. HyattViruses3: 2025–2046.

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

7 Viruses in Shellfish (2010) A. Bosch and S.F. Le GuyaderFood EnvironmVirol 2: 115-116.

MMO 307 - Techniques in Microbial Oceanography
Course credits: 4 - Three credits theory and one credit practical

Theory **(Contact Hours)**

1 Spatial estimates and ocean-biogeochemistry based on Remote sensing measurements of **(15)**

Chl a, C-DOM, Total; suspended matter, detection of phytoplankton bloom forming groups from scattering and reflectance, primary and new-productivity, photosynthetically available radiation (PAR), Sea-surface temperature, salinity, aerosol optical thickness and types, UV-index of radiations, Cloud-cover, wind-speed and direction, Ocean-currents, ocean-atmosphere heat-exchange, ice-cover, ozone layer etc.

2

2.1 Water-column profiling: Conductivity-Temperature-Depth (CTD), Sea-bird CTD rosette, Depth – Pressure transducer, Temperature – Thermistor, turbidity, pH, salinity – Conductivity sensor, oxygen and nutrient. **(03)**

Water-current / circulation: Acoustic doppler current profiler (ADCP).

Determination of Euphotic Zone: Secchi-disk, PAR (Photosynthetically available radiation) sensor.

Bioptical measurements: Radiometry, Aerosol optical thickness, Fast repetition rate fluorimetry (FRRF), Flourescence induction and relaxation (FIRe) technique, Absorption and fluorescence of dissolved organic matter (C-DOM) using spectrophotometry, Flow-field-flow fractionation, particulate absorption (filter-pad technique).

2.2 Sampling strategies and gears: **(02)**

Sampling strategies incorporating time, space and replicates.

Water sampling: at discrete depths**,** Niskin sampler mounted on CTD rosette; plankton samples from tows**,** hand-held plankton net, Bongo-paired zooplankton net, Multiple plankton net.

Sediment sampling: Grab samplers (van-veen), Box-corers, Epibenthic sled, Gravity corer, Hydraulically damped gravity corer.

2.3 Physico-chemical parameters: pH**,** dissolved oxygen**,** polarographic sensor, Winkler's titration**,** dissolved inorganic nutrients (Nitrate, Nitrite, phosphate, silicate, Ammonia)**,** continuous flow analysis using SKALAR auatoanalyzer, spectrophotometry**,** elemental composition**,** CHNS analyzer**,** Total Inorganic Carbon**,** Coulometry**,** dissolved organic carbon**,** high temperature combustion method using DOC analyzer**,** particulate organic carbon/ nitrogen**,** high combustion elemental analyzer**,** Chlorophyll *a*, fluorometry, spectrophotometry; phytoplankton pigments**,** HPLC**,** primary production**,** tracer technique - ^{14}C, ^{13}C**,** new-production**,** tracer technique - ^{15}N**,** carbon cxport**,** sediment traps (Moored arrays/drifting traps), ^{234}Thorium based POC export estimates. **(10)**

3

3.1 **Enumeration of microbes:** Traditional plating and counting of CFU's, MPN based enumeration and isolation of targeted physiological/metabolic groups, dilution-to-extinction based high throughput methods for retrieval of oligotrophs, counts of fluorescent stained cells using epifluorescent microscopy, total counts by flow-cytometry**,** phytoplankton analysis using FlowCAM. **(05)**

3.2 **Metabolism and Diversity:** Bacterial community production using Tritiated Thymidine (rates of DNA synthesis), Tritiated leucine (rates of protein synthesis); Respiration measurements of plankton size fractions, and Respiratory quotient to estimate carbon-flux; labeled substrate uptake and growth kinetics of microbial consortia/isolates to study flux of C, N, P.; physiological profiling (CLPP) using BIOLOG plates; Fluorometric assessment of enzymic activity using 4-Methylumbelliferyl (MUF) substrate analogues; scanning confocal-laser microscopy for study of bio-films, changes in redox-potentials in fluorescent stained micro-zones; denaturation gradient gel electrophoresis (DGGE) of MPN/environmental sample enrichments; Metabolites analysis (using Nuclear magnetic resonance (NMR) spectroscopy and mass spectrometry (MS), Matrix-assisted laser desorption ionization time of flight (MALDI-TOF); Secondary ion mass spectrometry (SIMS), Fourier transform ion cyclotron resonance MS, Orbitrap MS, etc). **(10)**

Practicals **(45)**

1 Enumeration of microbes by direct counts: epifluorescent microscopy.
2 Retrieval of microbes associated with marine blooms/sponges.
3 Preparation of buffers, sample, stains, markers, gel for DGGE.
4 Study of microbial community associated with marine blooms by DGGE and analysis.
5 Study of other marine microorganisms, i.e. diatoms, microzooplankton
6 Measurements of CDOM using fluorometer.

Reference Books

1 Grasshoff, K., Ehrhardt, M., Kremling, K., Methods of seawater analysis. Verlag Chem., Weinheim.
2 Jeffrey, S.W and Vesk, M., Introduction to marine phytoplankton and their pigment signatures. In: Phytoplankton Pigments in Oceanography. UNESCO publishing, Paris.
3 Parsons, T.R., Maita, Y and Lalli, C.M., Manual of chemical and biological methods for seawater analysis. Pergamon press.
4 Strickland, J.D.H. and Parsons, T.R., A Manual of seawater analysis. Queen's printer and controller of stationery, Ottawa.

MMO 401- Microbial Ecology of the Deep Marine Environment
Course credits: 4 – Four credits theory

Theory **(Contact Hours)**

1 The deep sea environment **(15)**

Basic and in-depth conceptualization of deep marine subsurface; dark ocean biosphere/aphotic pelagic ocean habitats beneath the ocean water column, such as marine sediments, oceanic crust, abyssopelagic/abyssal, hadal plains and hydrothermal vents; microbial communities, interdependence and interaction with the environment.

Types of deep sea habitats and resident microbiota: marine trenches, ridges, endoliths, submarine vents, deep sea basins, submarine canyons, icy niches, deep permafrost sediments, Antarctic Ocean and Southern Ocean deep environments; piezophilic/ barophilic microorganisms in the deep sea.

2 **(15)**

2.1 Sampling equipment

Deep sea sampling equipment: submersibles (DSV Alvin, DSV Shinkai 6500; remotely operated underwater vehicle Ventana; Deep sea challenger DCV 1)

Techniques for collecting water and sediment samples, corers: gravity, piston and Kasten corers, multiple corer (MUC), giant box corer (GBC); drilling techniques, MEBO sea floor drill rig.

2.2 Culturing of deep sea microbes

Anaerobic and pressure culture chambers/systems; techniques for isolation and culturing deep sea microorganisms under simulated deep sea conditions.

3 Hydrothermal vents **(15)**

Global hydrothermal vents, black, white and clear smokers, gradients of temperature, nutrients, gases, metals at hydrothermal vents, food webs, chemosynthesis, microbial communities – archaea, bacteria; and fungi; diversity of higher organisms including the tube worm *Riftia pachyptil*, sponges, corals.

4 **(15)**

4.1 Marine deposits

Sapropel, carbonates, phosphorite, ancient halite, metallic nodules, marine basalts.

4.2 Biogeochemical cycling, enzymes and energetic

nutrient cycling, Fe and S-related ecoenergetics; oxidation of complex organic matter to carbon dioxide via Fe (III) oxide reduction or fermentation; *Nitrosopumilus maritimus*; piezo-enzymes; and implications in evolution and biotechnology.

Reference Books

1 Munn, C. Marine Microbiology: ecology and applications, Garland Science, Taylor and Francis group, N.Y.

2 Jorgensen B. B. and Boetius A. (2007) Feast and Famine: microbial life in the deep sea bed. Nature Reviews Microbiology 5: 770-781.

3 Nakagawa S and Takai K (2008) Deep-sea vent chemoautotrophs: diversity, biochemistry and ecological significance. FEMS Microbial Ecology 68: 1-84.

MMO 402 - Fishery Microbiology
Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

1. **(15)**

1.1 Type of fishes, shellfishes and other coastal aquatic and marine living resources present in Indian Ocean, Arabian Sea and Bay of Bengal, concept of aquaculture and marine culture of fishes.

1.2 Microbiology of Raw fish and processed fish, Various methods for processing of fishes; Biopreservation, food processing, fermentation and aquaculture; effect of heat, chilling, freezing and chemical preservatives on bacteria, yeasts and fungi associated with fishes.

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

2 Bacteria associated with fish and Shellfish **(15)**

2.1 Commensals and pathogens; Classification of diseases; Methods of disease prevention; Detailed study of bacteria pathogenic to finfish and shellfish with emphasis on morphology, epidemiology, pathogenesis, treatment and control:
Flavobacterium, Flexibacter, Edwardsiella, Pseudomonas, Vibrio, Aeromonas, Renibacterium, streptococcus, Yersinia, Mycobacteria and Nocardia.

3 **(15)**

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

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

Practicals **(45)**

1 Examination of moribund fish; Sampling techniques for microbiological investigation

2 Methods for examination and analysing fish for health certification/diagnosis of disease condition, techniques for sample collection and processing for bacteriological agents

3 Isolation of various bacterial pathogens; microbial identification; molecular techniques for disease diagnosis

Reference Books

1 Microbiology Handbook: fish and seafood, Edited by Rhea Fernandes
2 Fish diseases and disorders: Vol 3 : viral, bacterial and fungal infections by Woo and Bruno
3 Fish Pathology by R.J. Roberts
4 Diseases of carps and other cyprinid fishes by D. Hoole, D. Buck, P. Burgess and I. Welby.
5 Textbook of fish health by George Post.
6 Principle diseases of marine fish and shellfish by Carl J. Sindermann.
7 Fish disease diagnosis and by Edward C. Noga
8 Fish diseases and disorders by J. F. Leatherland and PKT Wook
9 Environment stress and fish diseases by Gary A. Wedemeyer, Fred P. Meyer and Lynnwood Smith
10 Molecular diagnosis of Salmm disease by Carey E. Cunningham
11 Health maintenance and principal microbial diseases of cultured fishes by John a. Plumb
12 Principal diseases of marine fish and shellfish by carl J. Sindermann
13 Bacteria from Fish and Other Aquatic Animals: A Practical Identification Manual (Cabi Publishing) by Nicky B. Buller and John A. Plumb
14 Diagnostic Microbiology (W.B. Saunders Company, 2000) de la Maza, L.M., Pezzlo, M.T., and Baron, E.J.
15 Color Atlas of Diagnostic Microbiology, Mosby, 1997
16 Manual of Diagnostic Microbiology by Wadher and Boosreddy
17 Diagnostic Microbiology by Fingold
18 Manual of Practical Microbiology and Parasitology by Chakraborty and Pal

MMO 403 - Polar Microbiology
Course credits: 4 – Four credits theory

	Theory	**(Contact Hours)**
1	Polar environments (Arctic region, Antarctic region and the Southern Ocean), polar econiches (marine: permafrost, sea ice, glaciers, lakes); microbial ecology, strategies to isolate and characterize polar microorganisms.	**(15)**
2	Factors influencing microorganisms in polar environments, microbial diversity with examples (archaea – *Cenarchaeum symbiosum*, bacteria - *Pseudoalteromonas haloplanktis, Marinomonas primoryensis, Pseudomonas putida*, cyanobacteria – *Oscillatoria*, fungi including yeast - *Glaciozyma antarctica*, and diatoms - *Fragilariopsis cylindrus,*), cellular, structural and physiological characteristics, community interactions and food webs, geochemical cycling. Biotechnological importance of polar microorganisms (psychroenzymes, anti-freeze proteins, novel antibiotics and other bioactive compounds).	**(15)**
3	The effects of global warming and ocean acidification on polar ecosystems, effects of iron fertilization on productivity and carbon export in the High-Nutrient-Low-Chlorophyll (HNLC) regions of the Southern Ocean and its impact on the Antarctic region.	**(15)**
4	Case study: Microbiological studies at Arctic and Antarctic stations.	**(15)**

Reference Books

1 Polar Microbiology: Life in a Deep Freeze. By Miller, R.V. and Whyte, L.G. (eds.) 2012, ASM Press, Washington, DC.
2 Polar Microbiology: The Ecology, Biodiversity and Bioremediation Potential of Microorganisms in Extremely Cold Environments. By Bej, Aislabie and Atlas (eds.) 2010.
3 Impacts of global warming on polar ecosystems. By Duarte, C.M. (ed.) 2008.
4 Polar ocean ecosystems in a changing world. By Smetacek, V. and Nicol, S. 2005, *Nature Insight Reviews*, 437: 362-368.
5 Ecological and Biogeochemical Response of Antarctic Ecosystems to Iron Fertilization and Implications on Global Carbon Cycle. By Bathmann, U. 2005, *Ocean and Polar Research*, 27(2): 231-235.
6 Diversity and ecology of psychrophilic microorganisms. By Margesin, R. and Miteva, V. 2011, *Research in Microbiology*, 162: 346-361.

MMO 406 - Marine Mycology
Course credits: 4 – Three credits theory and one credit practical

Theory **(Contact Hours)**

I Fungal diversity and distribution (15)

1 **Fungi**

Phylogeny and detailed classification

2 **Econiches of Marine Fungi**

(a) Polyhaline Coastal Environment – salt marsh, mangrove, estuarine and Oceans

(b) Hypersaline environment – solar salterns, Salt Lake, Dead Sea

(c) Deep Sea – Hydrothermal vents

3 **Extremophilic Fungi**

Halophiles, Xerophiles, Oligotrophs, Barophiles, Psychrophiles, Thermophiles

II Techniques to study marine and extremophilic fungi (05)

(a) Isolation – Sample collection and isolation procedures

(b) Identification - Morphotyping; Secondary metabolites; Molecular finger printing: FAME, Karyotyping, Gene sequencing and RAPD analysis.

III Physiology and Genetics (10)

1 **Growth and development**

(a) Growth cycle

(b) Fungal hormones- attractants, morphogenesis and differentiation

(c) Secondary metabolites: pigments, mycotoxins

2 Fungal genetics

Cross over and tetrad analysis, gene conversion, mating type switching; Deuteromycotina: parasexuality, cytoplasmic inheritance

IV Fungal associations and diseases (05)

1 **Mycoses**

Diseases of fish and bivalves by *Saprolegnia, Aphanomyces, Branchiomyces, Ichthyophonus*

2 **Fungal associations**

Saprophytes, parasites and symbionts on higher forms of marine life

V Bioprospecting and bioremediation (10)

1 Industrially important enzymes

2 Natural products – nutraceuticals, antimicrobials, antitumour agents

3 Secondary metabolites – pigments

4 Biodegradation and bioremediation

Practicals **(45)**

1 Study of representative fungal cultures: (a) Colony and (b) Morphological characteristics
2 Cooke R. C. and Whipps J. M. Ecophysiology of fungi. Blackwell Scientific Publications, Oxford.
3 Isolation of fungi from mangroves
4 Identification of fungi
5 Extraction of fungal DNA and gel electrophoresis
6 Screening for enzyme production
7 Application of fungi in bioremediation

Reference Books

1 Alexopoulus C. J., Mims C. W. and Blackwell M. Introductory Mycology. John Wiley & Sons (Asia) Pvt. Ltd.
2 Mehrotra R. S. and Aneja K. R. An Introduction to Mycology. Wiley Eastern Limited.
3 Deacon J. W. Introduction to Modern Mycology (Vol: 7) J.F Wilkinson (Ed)
4 Kendricks. The Fifth Kingdom
5 Davis B. D., Dulbecco R., Eisen H. N. and Ginsberg H. S. Microbiology. Harper and Row
6 Onions A.H.S., Allsop D. and Eggins H.O.W. Smith's Introduction to Industrial Mycology. Edward Arnold (publ.) Ltd. London
7 Gilman J. C. A manual of Soil Fungi. Iowa State Press. Iowa.
Domsch KH, Gams W, Anderson TH. Compendium of Soil Fungi, Eching, IHW-Verlag

MMO 408 - Marine Microbiology Field trip
Course credits: 2 - Two credits practical

Practical		Contact hours
1	**Visit to National Centre for Antarctic and Ocean Research [NCAOR] and National Institute of Oceanography [NIO]**	**(10)**
	Instruments /equipment to be observed such as the : Biosafety systems, anaerobic culturing systems, pressure cultivation chambers, Mass Q-TOF, LC/MS system, DNA sequencer, Flow cytometer, FlowCAM, Mass spectroscopy, NMR, IR and X-ray diffraction. Ice cores and samplers	
2	**Marine field trip**	**(58)**
2.1	Pre-session for marine sampling protocols; demarcation of marine trajectory (field stations) and discussion of experimental protocols	
2.2	Preparation of experimental requirements: glassware, media and reagents A. For estuarine sampling using mechanized water vessel. i) Collection of marine samples, hands-on experience for use of samplers (Niskin, Hydro-Bios) and grabs (van Veen grab), refractometers and marking of lat-long (net GIS). ii) Maintenance and transfer of samples. iii) Post-field trip session: culturing for marine microbes. B. For sampling in the coastal and intertidal regions i) Sampling and culturing for microbial flora associated with marine fauna	
2.3	Recording of experimental observations and inferences pertaining to A(iii) and B(ii)	
3	**Visit to marine-related industries**	
3.1	Study of aquaculture practices	**(10)**
3.2	Seafood processing	**(03)**
4	**Report writing**	**(04)**
5	**Presentation and group discussion**	**(05)**