UNIVERSITY OF PUNE

M. Sc. (MICROBIOLOGY)

REVISED SYLLABUS FOR POST GRADUATE COURSE IN MICROBIOLOGY

M. Sc. Part I – w. e. f. June 2008

M. Sc. Part II – w. e. f. June 2009

GENERAL INSTRUCTIONS

1. Eligibility: B. Sc. with Microbiology as principle subject and performance at entrance examination (as per the requirement of the center).

2. Distribution of University and Departmental Courses:

	University Courses	Departmental Courses
Semester - I	MB – 501, 502, 503 MB – 511, 512	**---**
Semester - II	MB – 601, 602, 603 MB – 611, 612	**---**
Semester – III	MB – 701, 702, 703	MB – 711, 712
Semester - IV	MB – 801, 802, 803	MB – 811, 812

3. Examination of practical courses of Semester - I i.e. MB - 511 and MB - 512 and practical courses of Semester - II i.e. MB - 611 and MB - 612 shall be examined at the end of respective Semester. The practical examination for Semester – I will be after theory examination. These four practical courses will be treated as University courses and will be examined by the examiners appointed by University of Pune, Pune.

4. Practical courses of Semester - III i.e. MB - 711 and MB - 712 and practical courses of Semester - IV i.e. MB – 811 and MB – 812 (Dissertation in place of practical course) shall be examined at the end of academic year i.e. in the month of April / May of the respective academic year. These four Practical courses will be treated as Departmental courses and examination will be conducted by the concerned department.

5. Practical for course no. MB - 711 and MB - 712 will be conducted throughout the academic year while students can carry out the dissertation work throughout the year.

6. The format for dissertation will be similar to the research thesis style; incorporating chapters on: Introduction, Materials and Methods, Results and Discussion and References / Bibliography. The dissertation will be submitted in a typewritten and bound form. Copy of each dissertation will be submitted to the respective department and the center will store it permanently.

7. Each Laboratory course will occupy six hours / week.

8. Dissertation will occupy equivalent to two laboratory courses i.e. 12 hours a week.

9. Dissertation will be compulsory to all students. Students will carry out dissertation work individually or in the group of not more than three students.

10. Concerned department shall provide all required infrastructure to carry out dissertation work.

11. Every student will write a review article every semester, based on original and recently published research papers.

12. Every student will give one oral presentation each semester, which will be evaluated by the faculty. Marks for review and the oral presentation will be suitably incorporated in the internal assessment of the practical courses.

13. Question paper for each theory course will include at least one problem based on research reports (Mathematical / Data Interpretation / Comment type) related to concerned course.

M. Sc. (Microbiology) Curriculum

Semester I:

Theory Course I	- MB-501	Microbial Diversity and Taxonomy
Theory Course II	- MB-502	Quantitative Biology
Theory Course III	- MB-503	Cell Organization and Biochemistry
Practical Course I	- MB-511	Microbial Diversity and Systematics
Practical Course II	- MB-512	Cell Biology and Biochemistry

Semester II:

Theory Course I	- MB-601	Instrumentation and Molecular Biophysics
Theory Course II	- MB-602	Evolution, Ecology and Environmental Microbiology
Theory Course III	- MB-603	Microbial Metabolism
Practical Course I	- MB-611	Ecology and Environmental Microbiology
Practical Course II	- MB-612	Enzymology and Microbial Metabolism

Semester III:

Theory Course I	- MB-701	Immunology
Theory Course II	- MB-702	Molecular Biology I
Theory Course III	- MB-703	Virology
Practical Course I	- MB-711	Biotechnology and Scientific Communication
Practical Course II	- MB-712	Molecular Biology and Immunology

Semester IV:

Theory Course I	- MB-801	Pharmaceutical and Medical Microbiology
Theory Course II	- MB-802	Molecular Biology II
Theory Course III	- MB-803	Microbial Biotechnology
Practical Course I	- MB-811	Research Methodology – I (Dissertation)
Practical Course II	- MB-812	Research Methodology – II (Dissertation)

SEMESTER – I

Theory Course I – MB-501: Microbial Diversity and Taxonomy

A. Taxonomy (22)

1. Methods in Taxonomy of Bacteria, Archaea and Fungi:
    1. Morphological Methods
    2. Chemotaxonomy
    3. Genetic Methods
    4. Methodology of rRNA sequencing (teach as per practical / experimental methods)
2. Methodology of identification of unknown pure cultures: Strategy and methods

B. Diversity (16)

The expanse of microbial diversity, estimates of total number of species, measures and indices of diversity.

Newer approaches for exploring unculturable bacteria from environmental samples like sewage

Culture independent molecular methods, Methods of extracting total bacterial DNA from a habitat.

C. Bioinformatics (10)

Sequence alignment, scoring matrices, local and global alignment, dynamic methods, Needleman and Wunsch algorithm, Smith-Waterman algorithm, database search for homologous sequences, BLAST and FASTA versions.

References:

Taxonomy

1. Barnett, H. L. and Hunter, B. B. 1960. *Illustrated Genera of Imperfect Fungi*. Burgess Publishing Co., Minnesota.
2. Breed and Buchanan. *Bergey's Manual of Determinative Bacteriology*. 8th Edition, 1974.
3. Breed and Buchanan. *Bergey's Manual of Determinative Bacteriology*. 9th Edition, 1982.
4. Breed and Buchanan. *Bergey's Manual of Systematic Bacteriology*. 2nd Edition, (Volumes. 1 – 5) (2001 – 2003).
5. Lodder J. (1974). *The Yeasts: A Taxonomic Study*, North Holland Publishing Co. Amsterdam.
6. Sykes, G. and F. A. Skinner (Eds). *Actinomycetales: Characteristics and Practical Importance*. Society for Applied Bacteriology Symposium Series No. 2, Academic Press. 1973.

Diversity

1. Amann R. Ludwig W. and Schleifer K. (1995). *Phylogenetic Identification and In situ detection of Individual Microbial Cells Without Cultivation*, Microbiological Reviews **59,** 143-169.
2. Cook T. (2002) *Microbial Biodiversity: Saving Bacteria to save ourselves*, Harvard Science Review, 26-28.

3. Hugenholtz P. (2002) *Exploring Prokaryotic Diversity in the Genomic Era*, Genome Biology, **3(2)**, 0003.1-0003.8.
4. Keller M. and Zengler K. (2004) *Tapping in to Microbial Diversity.* Nature Reviews **2**, 141-150.
5. Pace N. (1997) *A Molecular View of Microbial Diversity and the Biosphere*, Science, **276**, 734-740.
6. Woese C. (1987), *Bacterial Evolution*. Microbiological Reviews, 221-271.

Bioinformatics

1. Baldi, P. and Brunak, S. (2001) *Bioinformatics: The machine learning approach.* Bradford Book, MIT Press, Cambridge.
2. Baxevanis, A. D. and Ouellette, B. F. F. (2001) *Bioinformatics: A practical guide to the analysis of genes and proteins.* Second Edition. John Wiley & Sons, New York.
3. Ewens Warren J. and Gregory R. Grant. (2004) *Statistical Methods in Bioinformatics, An Introduction*, Springer, New York.
4. Lacroix, Z. and Critchlow, T. (Eds.) 2003. *Bioinformatics. Managing Scientific Data.* Morgan Kaufmann Publishers.
5. Misener, S. and Krawetz, S. A. (Eds.). 2000. *Methods in Molecular Biology*, Volume 132. Bioinformatics: Methods and Protocols. Humana Press, New Jersey.
6. Mount, D. W. (2001) *Bioinformatics: sequence and genome analysis.* Cold Spring Harbor Laboratory Press, New York.
7. Zoe L. and Terence C. (2004) *Bioinformatics: Managing Scientific Data*, Morgan Kaufmann Publishers, New Delhi.

Theory Course II – MB – 502: Quantitative Biology

A) Biostatistics **(28)**

Quantitative methods in biology, sampling methods, scales and variables, data organization, tabulation, graphical representation

Concepts, examples and problems for each of the following:

a. Descriptive statistics: Frequency and probability distributions, graphical representation of distributions, measures of central tendency, measures of dispersion, skew ness, kurtosis. Introduction to Normal, Binomial and Poisson distributions and their applications. Distribution of sample means, standard error and confidence interval.
b. Regression and correlation, curve fitting and choice of models.
c. Introduction to multivariate analysis: multiple regressions, ordination, principal component analysis.
d. Survey design
e. Factorial design, ANOVA and F test.
f. Probability: Laws of probability, independence and randomness
g. Hypothesis testing: comparison of two sample means: t-tests, non-parametric tests. The concepts of null hypothesis, significance level, type I and type II errors, one tailed and two tailed tests.
h. Categorical data and proportion data: Chi square test and test for goodness of fit.

B) Modeling in Biology

1. Concept and applications of modeling: **(10)**
   a. Population models: Exponential, logistic and chemostat models.
   b. Models in population genetics, models based on Hardy-Weinberg equation.
   c. Introduction to the concept of stochastic models.
   d. Epidemiological models

2. Use of Computers in Biology **(10)**
   a. Concept and applications of databases
   b. Concept and applications of internet
   c. Computer simulation of biological systems, writing simple simulation programs for growth models, population interactions and pathway regulation.

References:

1. Brown D. & P. Rothery (1993) *Models in Ecology*, Wiley
2. Cochran W.G. – *Sampling Techniques,*Wiley eastern Ltd, New Delhi.
3. Feller W. – *Introduction to probability theory and its applications,* Asia Publishing House, Mumbai.
4. Goon, Gupta and Dasgupta – *Fundamentals of statistics*, World Press , Kolkata.
5. Gupta S.P.- *Statistical methods,* Sultanchand & Sons.
6. Haefner James W. (1996) *Modeling Biological Systems : Principles and Applications*, Kluwer Academic Publications
7. Irfan Ali Khan and Atiya Khanum, *Fundamentals of Biostatistics*. 2nd Ed. Ukaaz Publications, Hydrabad.
8. John Maynard Smith (1974) *Models in Ecology*, Cambridge University Press.
9. Lindgren B.W.- *Statistical Theory,* Macmillan Publishing Co. Inc.

10. Montgomery D.C. – *Design and analysis of experiments,* John Wiley & Sons.
11. Mood A.M., Graybill F. and Bose D.C.- *Introduction to the theory of statistics,* McGraw Hill Publishing Co.
12. Murthy M.N. – S*ampling methods,* Indian Statistical Institute, Kolkata.
13. Paulos John A. (1990) *Innumeracy: Mathematical Illiteracy and its consequences,* Vintage Books Paperback.
14. Wayne Daniel (2007) *Biostatistics A foundation for Analysis in the health sciences,* Edition 7, Wiley- India edition.

Theory Course III – MB – 503: Cell Organization and Biochemistry

A) Introduction to Bioorganic Chemistry (10)

a. Chemical reactivity: Concept and factors affecting reactivity (Inductive effect, Resonance / Mesomeric effect, Conjugation and Hyper-conjugation, Tantomerism, etc.)
b. Bonding other than covalent – H-bonds, Van der Wall's interaction, charge transfer complexes, ionic bonding, Ion-dipole, Host-guest interactions
c. Reactions of organic molecules: A brief overview of important reactions in organic chemistry e.g. Substitution, Addition, Elimination, Rearrangement, Oxidation, Reduction, etc.
d. Stereochemistry: Three dimensional shape of molecules, conformation and configuration, structure and biological activity
e. Bioorganic mechanisms of enzyme catalyzed reactions: stereochemical aspect of inhibition by penicillin
f. Concept of pH of weak acids and weak bases, Henderson-Hasselbalch equation, concept of buffer, strength of buffer, buffer value, important biological buffers (with the help of numerical problems)

B) Chemical Composition of Living Systems

Protein Chemistry: (3)

Structural features of amino acids, classification of amino acids, amino acids as buffers, chemical reactions of amino acids, peptide linkage, partial double bond nature of peptides, determination of primary structure of polypeptide (N-terminal, C-terminal determination, method of sequencing of peptides), structural classification of proteins, primary, secondary, tertiary, quaternary structures of proteins, protein detection and estimation.

Carbohydrate Chemistry: (3)

Mono, di, oligosaccharides and polysaccharides, with examples, asymmetric centre in sugars, D-series, L-series, dextro, leavo-rotatory, reducing and non-reducing sugars, sugar anomers, sugar epimers, sugar derivatives such as sugar alcohols, amino sugars, sugar acids, deoxy sugars, estimation of carbohydrates

Nucleic acid Chemistry: (3)

Structure of bases, nucleosides, nucleotides, phospho-diester linkages, 5' phosphate, 3'hydroxyl polarity of nucleic acids, tautomeric forms of bases and their implication in pairing of bases, structure of DNA (A, B and Z forms), Tm value, structure of t-RNA, r-RNA, and m-RNA, estimation of nucleic acids

Lipid Chemistry: (3)

Classification of lipids according to chemical structure, fatty acids, saturated, unsaturated, branched, nomenclature, system structure and function of triglycerides, phospholipids, sphingolipids, terpenes, prostaglandins, waxes, steroids, detection and estimation of lipids

Vitamins: (2)

Structure and function of fat soluble vitamins as vitamins A, D, E and K

C) Ultrastructure and Organization of Eukaryotic Cell (12)

Structural organization of: Cytoskeleton (structural proteins – microfilaments, actins, etc.); nucleus, Mitochondria and chloroplasts and their genetic organization, Endoplasmic Reticulum, Golgi apparatus, Protein trafficking; Events in cell cycle, Regulation of cell cycle.

Localization of macromolecules using electron microscopy, Immuno-electron microscopy, Confocal microscopy

D) Development And Differentiation (6)

Introduction to Developmental Biology, Conserved nature of development, Importance of its regulation, Concepts of commitment, determination and differentiation, dedifferentiation, re-differentiation and trans-differentiation, teratogenesis, morphogen gradients in developmental regulation, Hox code, MPF, homeostasis, cell proliferation and cell death, apoptosis, gastrulation and cellular movements involved in it, organizer and its importance giving examples of invertebrates (*Drosophilla*) and vertebrate (*Xenopus*) model systems, pattern formation in body axis, antero-posterior and dorso-ventral polarity

E) Communication And Coordination (6)

Cell signaling and communication in *Dictyostlium,* Myxobacteria, quorum sensing. Biofilms and their application

References:

Introduction to Bioorganic Chemistry

1. Clayden, Greeves, Warren and Wothers, *Organic Chemistry*, Oxford Press
2. Jerry March, *Advanced Organic Chemistry*, John Wiley

Ultrastructure and Organization of Eukaryotic Cell

1. Alberts Bruce (1985) *Molecular Biology of Cell.* Garland Pub.
2. Conn Eric, Stumpf Paul K., Bruuening George, Doi Roy H., (1987) *Outlines of Biochemistry Edition* , John Wieley and Sons, New Delhi.
3. De Robertis E. D. P. and De Robertis E. M. F. (1987), Cellular and Molecular Biology Lea and Febiger, Philadelphia.
4. Schlegel Hans G. (1995) General Microbiology, Edition 7, CUP, Cambridge.
5. Stanier R. Y., Adelberg E. A., Ingraham J. L., (1976) *General Microbiology*, 4th edition, Mac Millan Press, London.
6. Stephen W. Paddock, *Confocal Microscopy*, from Methods and Protocols Vol. 122, Methods in Molecular Biology, Humana Press, Press Inc., Totowa, NJ

Development and Differentiation

1. Gibert Scott F. (2003). *Developmental Biology*. 7th Ed. Sinauer Associates Inc. Mass. USA.
2. Muller W.A. (1997) Developmental Biology, Springler – Verlag, New York, Inc.
3. Wolpert Lewis. (1998). *Principles of Development*. Oxford University Press. Oxford.

Chemical Composition of Living Systems

1. Berg Jeremy, Tymoczko John, Stryer Lubert (2001) *Biochemistry.* 6th Edition, W. H. Freeman, New York.
2. Conn Eric, Stumpf Paul K., Bruuening George, Doi Roy H., (1987) *Outlines of Biochemistry.* 5th Edition , John Wieley and Sons, New Delhi.
3. Dawes Edwin A. (1972). *Quantitative Problems in Biochemistry*, Churchill Livingston, Edimberg.
4. Laskin A. I. and Lechevalier H. A. (1977), *CRC Handbook of Microbiology*, Vol. 1, Bacteria, CRC Press Ohio.

5. Metzler David E. (2001) *Biochemistry: The Chemical Reactions of Living Cells*, Volume 1 & 2, Academic Press California.
6. Nelson D. L. and Cox M. M. (2002) *Lehninger's Principles of Biochemistry*, Mac Millan Worth Pub. Co. New Delhi
7. Peberdy John F. (1980), *Developmental Microbiology*, Blackie, London.
8. Segel Irvin H. (1997). *Biochemical Calculations*. 2nd Ed. John Wiley and Sons, New York.
9. White Abraham, Handler Philip, Smith Emil, Hill Rober, Lehman J. (1983) Principles of Biochemistry, Edition 6, Tata Mc-Graw Hill Companies, Inc.
10. White David (2000) *Physiology and Biochemistry of Prokaryotes*. 2nd Ed. Oxford University Press, New York.

Communication and Coordination:

1. Hamilton W. Allan, (1987) *Biofilms: Microbial Interactions and Metabolic activities*, in Ecology of Microbial Communities, (Eds. M. Fletcher, T. R. G. Gray and J. G. Jones) Cambridge University Press, Cambridge.
2. Petersm J. E. (1969) Isolation, cultivation and maintenance of *Myxobacteria*, Methods in Microbiology (Eds. Norris J. R. and W. Ribbons) Vol. 3B, Academic Press London, 185-210.
3. Toole 'O' George, H. B. Kaplan, R. Kolter,(2000) *Biofilm formation as microbial development* Annual Review of Microbiology, Vol. 54 49-79

Practical Course I – MB – 511: Microbial Diversity and Systematics

1. Isolation, identification and characterization of actinomycetes
2. Isolation, identification and characterization of yeast
3. Isolation, identification and characterization of molds
4. Isolation and characterization of anaerobic microorganisms
5. Isolation and characterization of thermophilic microorganisms
6. Isolation and characterization of cyanobacteria
7. Isolation and characterization of halophiles

(*One isolate from all the groups 1 to 7 and identification upto genus level)*

8. Molecular Taxonomy:
    a. Isolation, purification and estimation of chromosomal DNA of bacteria
    b. Isolation, purification and estimation of RNA from Yeast
    c. Sequence matching using BLAST, RDP.

Practical Course II – MB – 512: Cell Biology and Biochemistry

1. Good laboratory practices: Laboratory safety, hazard from chemicals, handling of chemicals, disposal of chemicals and cultures, recording of scientific experiments. Standardization of laboratory procedures, calibration and validation instruments, preparing / designing SOP for the same, maintenance of instruments
2. Buffer: Determination of pKa of a monoprotic weak organic acid; Preparation of buffers using KH_2PO_4 and K_2HPO_4, acetic acid and sodium acetate, K_2HPO_4 and H_3PO_4
3. Chromatography: Separation of sugar and amino acids by paper and thin layer chromatography
4. Colorimetry and spectrophotometry: Estimation of sugar and total carbohydrate, estimation of protein by Lowry, Bradford and UV Spectrophotometry
5. Computer applications: Plotting graphs, Statistical analysis using Excel, simulation of population growth in batch and continuous culture
6. Electrophoresis: Agarose gel electrophoresis, PAGE and SDS-PAGE of proteins
7. Determination of sugars (qualitative) in cell walls of actinomycetes
8. Isolation and characterization of bacterial pigment
9. Detection, isolation and characterization of PHB granules in bacteria
10. Determination of saponification value and iodine number of fat

SEMESTER – II

Theory course I – MB – 601: Instrumentation and Molecular Biophysics

A) Instrumentation: Principles and applications of: (24)

1. Chromatographic techniques: Basic concepts, Gel filtration chromatography, Ion-exchange chromatography, Affinity chromatography, Gas Liquid Chromatography, High Performance Liquid Chromatography
2. Electrophoresis: Basic concepts, Gel Electrophoresis – agarose and acrylamide (Native, denaturing: gradient), Isoelectric focusing
3. Centrifugation: Basic concepts, Ultra centrifugation, Density gradient centrifugation, Differential centrifugation, Isopycnic centrifugation
4. Spectroscopy: Basic concepts, UV/Visible spectroscopy, Circular Dichroism (CD) and Optical Rotatory Dispersion (ORD), Fluorescence spectroscopy, Infrared spectroscopy, FTIR
5. Radiography: Tracer elements in Biology, Radioisotopes and their characteristics, Autoradiography, Pulse chase experiment, Čerenkov radiation, Liquid scintillation counting, Phosphor imaging

B) Molecular Biophysics

1. Properties of amino acids and peptides: **(5)**
   Physical and chemical properties of amino acids, Theoretical and experimental methods for determination of size of proteins, Physical nature of non-covalent interactions, Conformational properties of proteins, Ramachandran plot, Secondary, super-secondary, tertiary and quaternary structures of proteins, Classification of three dimensional structures of proteins (motifs and fold domains)
2. Protein structure / properties determination:

a. *Experimental techniques:* **(15)**

i. X-ray crystallography: Isolation and purification of proteins, crystallization of proteins, instrumentation, acquisition of the diffraction pattern, basic principles of x-ray diffraction, Phase determination

ii. NMR spectroscopy: Basic Principles of NMR, Chemical shift, Intensity, Line width, Relaxation parameters, Spin-spin coupling, Nuclear Overhauser Effect, NMR Applications in Biology

iii. Mass spectroscopy: Principles of operation and types of spectrometers, ionization, Ion transport and ion detection, Ion fragmentation, Combination with chromatographic methods, Biological applications, MALDI-TOF

b. *Theoretical methods* (Concept and introduction)*:* **(4)**
   Lim's stereochemical method, Chou-Fasman method, Garnier-Osguthorpe-Robson (GOR) method, Neural networks, Homology based methods

References:

Instrumentation

1. Berg, J. M., Tymoczko, J. L. and Stryer, L. (2006) *Biochemistry.* 6th Edition. Freeman, New York.
2. Cotterill, R. M. J. (2002) *Biophysics: An Introduction.* John Wiley & Sons, England.
3. Drenth, J. (2007) *Principles of protein X-ray crystallography.* 3rd Ed. Springer, Germany.

4. Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry.* 3rd Ed. Brooks/Cole, Publishing Company, California.
5. Keeler, J. (2002) *Understanding NMR Spectroscopy.* John Wiley & Sons, England.
6. Mount, D. W. (2001) *Bioinformatics: sequence and genome analysis.* Cold Spring Harbor Laboratory Press, New York.
7. Nölting, B. (2006) *Methods in modern biophysics.* Second Edition. Springer, Germany.
8. Pattabhi, V. and Gautham, N. (2002) *Biophysics.* Kluwer Academic Publishers, New York and Narosa Publishing House, Delhi.
9. Wilson Keith and Walker John (2005) *Principles and Techniques of Biochemistry and Molecular Biology*, 6th Ed. Cambridge University Press, New York.

Molecular Biophysics

1. Cavanagh John *et.al.* (1995) *Proteins NMR Spectroscopy: Principles and Practice,* Academic Press
2. Daune M. & W. J. Duffin (1999) *Molecular Biophysics: Structures in Motion,* Oxford University Press.
3. Nalting B. & B. Nalting (2003) *Methods in Modern Biophysics* Springer Verlag
4. Voit E. O. (2000) *Computational Analysis of Biochemical Systems* Cambridge University Press.

Other books:

1. Narayanan, P. (2000) *Essentials of Biophysics*. New Age International Publication, New Delhi
2. Stephenson, F. H. (2003) *Calculations in molecular biology and biotechnology: A guide to mathematics in the laboratory.* Academic Press, Elsevier Science, London. (For numerical problems in instrumentation)

Theory course II – MB – 602: Evolution, Ecology and Environmental Microbiology

A) Evolution: **(15)**

History and development of evolutionary theory
Neo-Darwinism: Spontaneous mutation controversy, evolution of rates of mutation, types of selection, levels of selection, group selection and selfish gene.
Sociobiology, kin selection, evolutionary stability of cooperation, sociality and multi-cellularity in microorganisms , Game theory, Evolution and stability of sex, sexual selection, parasite theory of sex and sexual selection. Co-evolutionary strategies, host-parasite co-evolution, Neutral evolution and molecular clocks, phylogeny and molecular distances, Molecular evolution: origin of life, the origin of new genes and proteins. Evolution of life histories, ageing, evolutionary trade offs, r and k selection, Evolutionary origin of biochemical disorders: The case of insulin resistance.
Speciation in sexual and asexual organisms, origin and stability of diversity, diversity of secondary metabolites

B) Ecology: **(15)**

1. Community ecology: community structure, benevolent interactions (control within the microbial communities of rhizosphere), antagonistic interactions, (competition, antibiosis, predation etc.). Rhizosphere, rhizoplane, siderophore, flavonide from plants, lectines, octapine, nipotine, indole acetic acid.
2. Mycorrhiza: Host-fungus specificity, host fungus interactions, rhizosphere environment and recognition phenomenon, interaction of mycorrhizal fungi with non-host plants, functional capability.
3. Marine ecosystem: Environment of marine bacteria, bacterial growth in sea and its regulation by environmental conditions, modeling of growth and distribution of marine micro plankton, mechanism of dissolved, organic matter production (DOM), strategies of organic matter utilization and microbial utilization of organic matter in sea.

C) Wastewater Treatment and solid waste management: **(18)**

1. Wastewater treatment system (unit process): Physical screening, flow equalization, mixing, flocculation, flotation, sedimentation, granular medium filtration, adsorption, Bioremediation and phytoremediation
2. Chemical precipitation, gas transfer, disinfection, dechlorination
3. Biological: (aerobic and anaerobic, suspended and attached growth processes.) Working treatment systems and their analysis (reactions and kinetics, mass balance analysis, reactor types, hydraulic character of reactors, selection of reactor type,) Critical operating parameters like DO, hydraulic retention time, mean cell residence time, F/M ratio etc. Malfunctioning of treatment systems due to shock loading, hydraulic loading etc. and remedial measures adapted.
4. Effluent and sludge disposal, control and reuse. Water pollution control, Regulation and limit for disposals in the lakes, rivers, oceans, and land. Direct and indirect reuse of treated effluents and solid wastes.
5. Current industrial wastewater treatment and disposal processes (Sugar and distillery, Textile, dyestuff, dairy, paper and pulp manufacturing industries)
6. Approaches to solid waste management using composting, vermiculture and biomethanation methods and their suitability to environment

References:

Evolution:

1. Ridley Mark (2004). *Evolution*. Blackwell Science Ltd.
2. Strickberger M. W. (2000). *Evolution*. Jones & Bartelette Publications.

Ecology

1. Macan, T. T. (1974). *Freshwater Ecology*. Longman Group Ltd., London,.
2. Meadows, P. S. and J. I. Campbell. (1978). *An introduction to Marine Science*. Blackie & Son Ltd., Glasgow.
3. Richards, B.N. (1987). *Microbiology of Terrestrial Ecosystems*. Longman Scientific & Technical, New York.

Waste Water Treatment:

1. Tchobanoglous G. and F. L. Burton. (1991). *Wastewater Engineering, Treatment, Disposal and Reuse*. 3rd Ed., Metcalf and Eddy (Eds). Tata Mac Graw Hill Publishing Co. Ltd. New Delhi.

Theory course III - MB – 603: Microbial metabolism

A) Bioenergetics: (6)

Laws of thermodynamics, entropy, enthalpy, free energy, free energy and equilibrium constant, Gibbs free energy equation, determination of free energy of hydrolytic and biological oxidation reduction reactions, under standard and non-standard conditions, high energy compounds, coupled reactions, determination of feasibility of reactions.

B) Enzymes: (10)

Purifications of enzyme, purification chart, kinetics of single substrate enzyme catalyzed reaction. Kinetics of reversible inhibitions enzyme catalyzed reactions, King Altman approach to derive – two substrate enzyme catalyzed reactions, types of two substrate enzyme catalyzed reactions, concept of allosterism, positive and negative co-operativity, models of allosteric enzymes (Monad, Wyamann and Changuax and Koshland, Nemethy and Filmer model), kinetics of allosteric enzyme, Hill plot, examples of allosteric enzymes and their significance in allosteric regulation.

C) Aerobic Respiration: (6)

Mitochondrial electron transport chain, structure and function of ATPase (bacterial and mitochondrial), generation and maintenance of proton motive force, oxidative phosphorylation, inhibitors and un-couplers of electron transport chain and oxidative phosphorylation, Atkinson's energy charge, phosphorylation potential and its significance, Energy generation in all groups of chemolithotrophs.

D) Anaerobic Respiration: (4)

Concept of anaerobic respiration, oxidized sulfur compounds, and nitrate as electron acceptor with respect to electron transport chain and energy generation, Biochemistry of methanogenesis, Biochemistry of ammonia oxidation

F) Nitrogen Metabolism: (10)

a. Biochemistry of biological nitrogen fixation, properties of nitrogenase and its regulation, ammonia assimilation with respect to glutamine synthetase, glutamate dehydrogenase, glutamate synthetase, their properties and regulation
b. Biosynthesis of five families of amino acids and histidine, Biosynthesis of purine and pyrimidine bases

G) Photosynthesis: (6)

Energy consideration in photosynthesis, light and dark reaction, electron carriers in photosynthesis, Organization of photosystem I and II, cyclic and non-cyclic flow of electrons, Z scheme, Hill reaction, photolysis of water. Bacterial photosynthesis: scope, electron carriers, Photosynthetic reaction center, cyclic flow of electrons, bacterial photophosphorylation in various groups of phototrophic bacteria, electron donors other than water in anoxygenic photosynthetic bacteria.

F) Membrane Transport: (6)

The composition and architecture of membranes, Membrane dynamics, Solute transport across membranes: Passive diffusion, active transport using P and F type ATPases, Ion mediated transport, transport of ions across membranes (ion pumps), Model membranes; Liposomes

References:

1. Berg Jeremy, Tymoczko John, Stryer Lubert (2001) *Biochemistry* 4th Ed, W. H. Freeman, New York.
2. Conn Eric, Stumpf Paul K., Bruuening George, Doi Roy H., (1987) *Outlines of Biochemistry* 5th Ed , John Wiley and Sons, New Delhi.
3. Dawes Edwin A. (1972) *Quantitative Problems in Biochemistry*, Churchill Livingston, Edinburgh.
4. Hall D. D. and Rao K. K. (1996) *Photosynthesis* 5th Ed., Cambridge University Press.
5. Mandelstam Joel and McQuillen Kenneth (1976) *Biochemistry of Bacterial Growth*, Blackwell Scientific Publication London.
6. Metzler David E. (2001) *Biochemistry: The chemical Reactions of Living Cells*, Volume 1&2, Academic Press California.
7. Moat Albert G. and Foster John W. (1988) *Microbial Physiology* 2nd Ed. John Wiley and Sons New York.
8. Nelson D. L. and Cox M. M. (2005) *Lehninger's Principles of Biochemistry*, Fourth edition, W. H. Freeman & Co. New York.
9. Palmer Trevor (2001) *Enzymes: Biochemistry, Biotechnology and Clinical chemistry*, Horwood Pub. Co. Chinchester, England.
10. Segel Irvin H. (1997) *Biochemical Calculations* 2nd Ed., John Wiley and Sons, New York.
11. Voet Donald and Voet Judith G. (1995) *Biochemistry*, 2nd Ed.. John Wiley and sons New York.
12. White Abraham, Handler Philip, Smith Emil, Hill Rober, Lehman J. (1983) Principles of Biochemistry, Edition 6, Tata Mc-Graw Hill Companies, Inc.
13. White David (2000) *Physiology and Biochemistry of Prokaryotes.* 2nd Ed. Oxford University Press, New York.
14. Zubay Geoffrey (1998) *Biochemistry*, 4th Ed., W. C. Brown, New York.

Practical course I – MB – 611: Ecology and Environmental Microbiology

1. Determination of DO, COD and BOD
2. Determination of TS and MLSS
3. Simulated Waste decomposition using aerobic microorganisms.
4. Isolation, of cellulose degraders
5. Isolation of chitinase degraders
6. Isolation of pesticide degraders.
7. Estimation of microbial species diversity in microecosystem
8. Effect of stress Temperature, pH, salt concentration, nitrate, phosphate) on microbial species diversity.
9. Isolation of Aflatoxin producing organism
10. Detection of Aflatoxin in food / culture

Practical course II – MB – 612: Enzymology and Microbial Metabolism

1. Calibration of analytical instruments – Colorimeter and Spectrophotometer by estimation of biomolecules and statistical analysis of data generated.
2. Determination of molar extinction coefficient of biological molecule
3. Purification of enzyme from natural source by (any one method): Ammonium sulfate precipitation, Organic solvent precipitation, Gel filtration
4. Determination of Km and Vm values of Invertase
5. Determination of Km and Vm values of Amylase
6. Electrophoretic Techniques: Protein electrophoresis by PAGE and SDS PAGE
7. Isolation and characterization of (as nitrogen fixers) of *Azospirillum* and detection of IAA by *Azospirillum*
8. Detection of siderophore production by *Azospirillum* and *Pseudomonas*
9. Isolation and characterization of chemolithotrophic microorganisms
10. Interpretation of Ramchandran Plot