ANNEXURE VI

Syllabus for Two Years MSc Program
in
Botany/Zoology/Microbiology

(Effective from Academic Session: 2019-20)

Offered by

Department of Biological Sciences

ALIAH UNIVERSITY

II-A/27, Action Area II, New Town
Kolkata 700160

Syllabus for MSc Botany

Department of Biological Sciences, Aliah University, Kolkata
Draft Syllabus for MSc Botany
(As part of Integrated BSc-MSc Biological Sciences with Lateral Entry at MSc)

Specialization: Plant Biochemistry and Metabolism

Sem	Code	Paper Name	LTPC**	Marks/ Credit
VII/I	BB401	Systematics and Evolution	60	50/4
	BB403	#Molecular Plant Pathology	60	50/4
	BB405	Cell Biology	60	50/4
	BB407	Principles of Biochemistry	60	50/4
	BB491	Practical I (Systematics and Plant Pathology)	60	50/4
	BB493	Practical II (Cell Biology and Biochemistry)	60	50/4
			Total	300/24
VIII/II	BB402	#Plant Biochemistry and Metabolism	60	50/4
	BB404	Development Biology of Plants	60	50/4
	BB406	Biophysics and Bioethics	60	50/4
	BB408	Biostatistics and Bioinformatics	60	50/4
	BB492	Practical III (Plant Biochemistry and Developmental Biology)	60	50/4
	BB494	Practical IV (Biophysics and Bioinformatics)	60	50/4
			Total	300/24
IX/III	BB501	#Plant Physiology	60	50/4
	BB503	Microbial Technology	60	50/4
	BB505	Genetics and Genomics	60	50/4
	BB507	Molecular Biology	60	50/4
	BB591	Practical V (Physiology and Microbial Technology)	60	50/4
	BB593	Practical VI (Genetics and Molecular Biology)	60	50/4
			Total	300/24
X/IV	BB502	Genetic Engineering and Plant Biotechnology	60	50/4
	BB504	Ecology and Conservation	60	50/4
	BB592	Practical VII (Plant Biotech and Ecology)	60	50/4
	BB562	Project Work/Dissertation	120	100/8
	BB572	Comprehensive Viva	30	25/2
	BB582	Field trip/Industrial visit	30	25/2
			Total	**300/24**

**Lecture Taken Per Course
Specialized paper

Semester VII/I
BB 401: Systematics and Evolution

Unit I: Concepts of Plant Taxonomy
Concept and objective of plant taxonomy, and its relevance to plant conservation; Plant Nomenclature – ICBN, Principles, Rules, Recommendations and special provisions; Type concept, Valid publication and rejection of names; application of code with problems; nomenclature of cultivated and hybrid plants; Biocode and Phylocode.

Unit II: **Taxonomic Literature**
Types, definition and Examples- Dictionaries, Indices, Monographs, Manuals, Floras, Journals, and taxonomic websites; Genbank. Use of Herbaria; role of Botanic Gardens in the 21st Century.

Unit III: **Biosystematics**
Definition, methods, importance, categories and relationship with traditional taxonomy. Major areas of biosystematic studies: *Palynology* - morphology, chemistry of exine, bearing on phylogeny, reconstruction of vegetation structure; *Embryology*- Diversity in structures of gametophytes, endosperm formation developing embryo; ovule morphology; *Molecular Systematics*: Plant genomes: nuclear, mitochondrial, chloroplast; Molecular markers; Generating molecular data: restriction site mapping, gene sequencing; Analysis of molecular data: alignment of sequences, methods of phylogeny reconstruction; *Remote sensing* and *GIS*. Analysis of data; commonly available software, construction of dendrograms

Unit IV: Taxonomic hierarchy
Concept of taxonomic hierarchy, delimitation of taxa and attribution of rank. Species concept. Recent systems of Angiosperm classification including APGII (2003); Indian flora. Endemism- in Indian perspective;Migration, dispersal and discontinuous. Distribution of plants. Numerical Taxonomy / Phenetics and Cladistics: Principles, Methods. Meats and Dements.

Unit V: Phylogenic studies of economically important taxa
Concise accounts of the phylogeny and economic importance of the following taxa: Magnoliales, Amentiferae, Umbelliferae, Tubiflorae, Campanulales, Helobiae, Pandanales, Poaceae and Orchidales.

Unit VI: **Biodiversity**
Components, levels and values; IUCN categories, Effects of Rio de Genero world summit, Conservation Hotspots, India as a Megadiversity country; Methods of *in situ* and *ex situ* conservation. Biodiversity protected areas in India.

Unit VII: Basic concepts of evolution
Origin of basic biological molecules; Abiotic synthesis of organic monomers and polymers; Concept of Oparin and Haldane; Experiment of Miller (1953); The first cell; Evolution of prokaryotes; Origin of eukaryotic cells; Evolution of unicellular eukaryotes; Anaerobic metabolism, photosynthesis and aerobic metabolism

Unit VIII: **Evolutionary time scale**
Eras, periods and epoch; Major events in the evolutionary time scale; Origins of unicellular and multi cellular organisms; Major groups of plants

Unit IX: Tools of evolutionary studies
Concepts of neutral evolution, molecular divergence and molecular clocks; Molecular tools in phylogeny, classification and identification; Protein and nucleotide sequence analysis; origin of new genes and proteins; Gene duplication and divergence

Unit X: Population genetics
Populations, Gene pool, Gene frequency; Hardy-Weinberg Law; concepts and rate of change in gene frequency through natural selection, migration and random genetic drift; Adaptive radiation; Isolating mechanisms; Speciation; Allopatricity and Sympatricity; Convergent evolution; Sexual selection; Co-evolution.

Suggested Reading

1. Taxonomy of Vascular Plants - G.H. Lawrence
2. Flora of India (all vols.) - Botanical Survey of India
3. The Identification of Flowering Plant Families - P.H. Davis & J. Cullen
4. The Evolution and Classification of Flowering Plants - A. Cronquist
5. The Families of Flowering Plants (3rdEdn.) - J. Hutchinson
6. Plant Systematics - S.B. Jones & L.E. Luchsinger

7. Biodiversity – Principles and Conservation - U. Kumar & M.J. Asija
8. Molecular systematics and Plant Evolution.- P.M. Hollingsworth, R.M. Bateman and R.J. Gornall ,Taylor and Francis, London. .
9. Judd WS, Campbell CS, Kellogg EA, Stevens PA and Donoghue MJ (2002). Plant Systematics: A Phylogenetic Approach. Sinauer Associaes, Inc., Massachusetts.
10. Nei M and Kumar S (2000). Molecular Evolution and Phylogenetics. Oxford University Press, New York.

BB 403: Molecular Plant Pathology

Unit I: Recognition and Specificity between Host and Pathogen
Penetration, infection, invasion of host tissue, relationship between pathogen and host factor(s); Molecular recognition and specificity of host and pathogen in disease resistance; Molecular detection of plant pathogens in soil, water and plant tissues

Unit II: Plant responses to biotic and abiotic stress
Mechanism of biotic and abiotic stress tolerance; Hypersensitive response (HR) and Systemic Acquired Resistance (SAR).

Unit III: Plant defense enzymes
Occurrence, properties, isolation, purification, biochemical and immunological characterization, induction, possible functions

Unit IV: Phytoalexins
Isoflavonoid and terpenoid phytoalexins: Biosynthesis; Role in plant defence and application in human health and control of diseases; Detoxification mechanisms; Elicitors of phytoalexins; Manipulation of phytoalexin synthesis in plants; Induced immunity in plants.

Unit V: Genetic manipulation of industrially important fungi
Strain improvement, recombinant DNA technology, choice of vectors for cloning, stabilization of transformants, application in genetic improvement of edible mushroom and biocontrol fungi.

Unit VI: **Resistance genes**
Gene-for-gene concept in plant-microbe interaction; Signal exchange and transduction mechanism for activation of plant defence against microbial attack; Signalling in plant disease resistance

Unit VII: **Genetic engineering of plants for disease resistance**
Organization of genes controlling disease resistance, methods of gene transfer, strategies for development of transgenics

Unit VIII: **Mycorrhizae**
Molecular tools for identification and detection; PCR cloning of genes from AM fungi; RAPD and ITS analysis of Orchid mycorrhizal fungi; Genomic fingerprinting of ectomycorrhizal fungi; Analysis of gene expression in AM fungi.

Unit IX: Biocontrol agents
Commercialization of biocontrol fungi, entomopathogenic fungi and plant growth promoting rhizobacteria

Suggested Readings

1. Molecular Plant Pathology - M. Dicinson. Bios Scientific Publishers, Taylor and Francis group , London and New York
2. Molecular and cellular biology of filamentous fungi-Nick Talbot, Oxford University Press.
3. Plant Pathology- G. N. Agrios, Elsevier Publications.
4. Plant Pathology - Mehrotra and Agarwal, Tata McGrow Hill
5. Handbook of Phytoalexin Metabolism and Action – M. Daniel and R. P. Purkayastha Eds. Marcel Dekker, Inc. New York
6. Molecular approaches for Plant Fungal Disease Management – H.P.singh, P.chowdappa, B.N.Chakraborty, A.R. Podile Eds.Westville Publishing House, New Delhi
7. Molecular Plant Pathology: A practical approach, Vol. I & II- S.J. Gurr, M. J. Mc Phersson and D. J. Bowles, Eds., Oxford University Press.

BB 405: Cell Biology

Unit I: Structure of Cell
Plasma membrane: Structure and transport of small molecules; Cell Wall: Eukaryotic cell wall, Extracellular matrix; Cytoskeleton: Structure and organization of actin filaments, association of actin filaments with plasma membrane, cell surface protrusions, intermediate filaments, microtubules. Mitochondria, chloroplasts, lysosomes and peroxisomes; Nucleus: Nuclear envelope, nuclear pore complex, nucleolus and nuclear lamina; Chromatin; Endoplasmic Reticulum and Golgi Apparatus.

Unit II: **Cell signaling**
Hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component systems, light signaling in plants, bacterial chemotaxis and quorum sensing.

Unit III: **Cellular communication**
Regulation of hematopoiesis, general principles of cell communication, cell adhesion and roles of different adhesion molecules, gap junctions, extracellular matrix, integrins, neurotransmission and its regulation.

Unit IV: **Cell cycle and cancer**
Cell cycle and its regulation, Genetic rearrangements in progenitor cells, oncogenes, tumor suppressor genes, cancer and the cell cycle, virus-induced cancer, metastasis, angiogenesis, interaction of cancer cells with normal cells, apoptosis, autophagy, therapeutic interventions of uncontrolled cell growth.

Suggested Readings

1. Cell and Molecular Biology: Concepts and Experiments, 6th edition (2009), Gerald Karp, Wiley. ISBN-978-0470483374.
2. The World of the Cell, 7th edition (2008), Becker, Kleinsmith, Hardin and Bertoni. Benjamin Cummings, ISBN-13: 978-0805393934.
3. The Cell: A Molecular Approach, 6th edition (2013), Cooper and Hausman; Sinauer Associates, Inc. ISBN-13:978-1605351551.
4. Essential Cell Biology, 7th edition (2009), Alberts, Bray, Hopkin, Johnson, Lewis, Raff, Roberts and Walter. Garland Science. ISBN-13:978-0815341291.
5. Molecular Cell Biology, 7th edition (2012), Lodish, Berk, Kaiser, Krieger, Bretscher, Ploegh, Amon and Scott. W. H. Freeman. ISBN-13: 978-1429234139.

BB 407: Principles of Biochemistry

Unit I: Introduction
Chemical basis of life; Water, structure of liquid water, water as ideal biological solvent; Principles of biophysical chemistry- pH, buffer, reaction kinetics, colligative properties; Henderson-Hasselbalch equation. Biomolecular hierarchy; Macromolecules; Molecular assemblies; Stablizing interactions- Van der Waals, electrostatic, hydrogen bonding, hydrophobic interaction etc. Thermodynamics- Laws of thermodynamics, free energy, entropy, high energy bonds.

Unit II: Carbohydrates
Sugars; monosaccharides- aldoses and ketoses, trioses, tetroses, pentoses, and hexoses. Stereoisomerism of monosaccharides- epimers, anomers, mutarotation. Furanose and pyranose forms of glucose and fructose, Haworth projection formulae for glucose; chair and boat forms of glucose, Sugar derivatives, glucosamine, galactosamine, muramic acid, N- acetyl neuraminic acid. Disaccharides: concept of reducing and non-reducing sugars, occurrence and Haworth projections of maltose, lactose, and sucrose. Polysaccharides: Structure and functions; Storage Polysaccharides- starch and glycogen; Structural Polysaccharides- cellulose, peptidoglycan and chitin. Suitability in the context of their different functions- cellular structure; energy storage; signaling; Glycosylation of other biomolecules - glycoproteins and glycolipids.

Unit III: Amino acids and Proteins
Amino acids- Concept, Properties, Classification, and reactions (N / C terminal reactions). Titration curve of amino acid and its Significance. Natural modifications of amino acids in proteins hydrolysine, cystine and hydroxyproline, Non protein amino acids: Gramicidin, beta-alanine, D-alanine and D- glutamic acid. Peptide bond formation; Protein structure- Levels, primary structure and its importance. The alpha helix, the beta pleated sheet and their occurrence in proteins, Tertiary and quaternary structures of proteins. Conformation of proteins: Ramachandran plot, domains,

motifs and folds; End group analysis and protein sequencing. Forces stabilizing protein structure, unfolding and refolding. Structure-function relationships in model proteins like ribonuclease A; myoglobin; hemoglobin; chymotrypsin etc.; Tools to characterize expressed protein. Biological Roles of Proteins. Amino acid and Protein metabolism

Unit IV: Nucleic acid

Nucleoside, Nucleotide, Nucleic acids- Structure, diversity and functions; DNA: Double helical structure; A-DNA, B-DNA & Z-DNA (structure, occurrence and differences). The RNA world- Structure, types and roles of RNA. Nucleic acid Sequencing. Nucleic acid Synthesis and Metabolism

Unit V: Lipids

Fatty acids structure and functions. Storage and structural lipids. Lipids in the formation of membranes (lipid micelles, monolayers, bilayers). Saponification Structural lipids. Lipid functions: cell signals, cofactors, pigments. Principles and pathways of lipid metabolism

Unit VI: Enzymes

Principles of catalysis, enzymes- properties and classification; Mechanism of enzyme action: active site, transition state complex and activation energy; Lock and key hypothesis, and Induced Fit hypothesis. Enzyme kinetics- Significance of hyperbolic, double reciprocal plots of enzyme activity, Km, and allosteric mechanism; Isozymes; Effect of pH and temperature on enzyme activity. Enzyme activators and inhibitors; competitive and non-competitive inhibitors. Structure and function of Vitamins and coenzymes. Immobilized enzymes and their applications

Suggested Readings

1. Campbell, MK (2012) Biochemistry, 7th ed., Published by Cengage Learning
2. Campbell, PN and Smith AD (2011) Biochemistry Illustrated, 4th ed., Published by Churchill Livingstone
3. Tymoczko JL, Berg JM and Stryer L (2012) Biochemistry: A short course, 2nd ed., W. H. Freeman
4. Berg JM, Tymoczko JL and Stryer L (2012) Biochemistry, W. H. Freeman and Company
5. Nelson DL and Cox MM (2008) Lehninger Principles of Biochemistry, 5th Edition., W.H. Freeman and Company,
6. Voet, D. and Voet J.G (2005) Biochemistry 3rd edition, John Wiley and Sons.
7. Segel Irvin H (1997) Biochemical Calculations, 2nd Ed., John Wiley and Sons, New York.
8. Palmer, T (2001) Enzymes: Biochemistry, Biotechnology & Clinical chemistry, Horwood Pub. Co., Englan.

BB 491: Practical I (Systematics and Plant Pathology)

Unit I: Molecular plant pathology-

1. Histopathological studies of fungal diseases of economically important crops.
2. Artificial inoculation of plants with pathogen(s) and disease assessment.
3. Comparison of soluble protein content between healthy and artificially inoculated plants.
4. Comparison of total and orthodihydroxy phenol content between healthy and artificially inoculated plants.
5. Extraction and assay of Phenylalanine ammonia lyase (PAL) activity in plants following infection.
6. Extraction and assay of peroxidase activity in plants following infection
7. Isolation of fungal/plant DNA and its quantification by spectrophotometric method.

Unit II: Systematics and Evolution-

1. Seasonal collection of local flora, processing, Herbarium preparation.
2. Phenology of some common weeds.
3. Seed, endosperm, embryo and seedling morphology.
4. Identification of plants by matching.
5. Working out of different angiospermic plants (fresh and dry), their identifications using literature and preparation of artificial keys.
6. Phytosociological studies; Biological Spectrum; Determination of Diversity Indices (Shannon-Wiener, Species Richness & β-diversity).
7. Use of GPS and demonstration on the use of at least one remote-sensing software
8. Familiarity with Taxonomic Literature (e.g. Index Kewensis, Wall-Cat., Icones, Bibliographies, Dictionaries, Keys, Floras, etc.).
9. Preparation of temporary and permanent pollen slides, description of common palynomorphs, preparation of identification keys.
10. Field trip within and near-by areas; compilation of field notes and preparation of herbarium sheets of commonly available plants.

**From above 17 practicals, any 10 practicals (equivalent to 30H) will be taken*

BB 493: Practical II (Cell Biology and Biochemistry)

Unit I: Cell Biology

1. Isolation of mitochondria and their visualization with Janus green B
2. *In situ* visualization of microfilaments and microtubules by fluorescent labeling.
3. *In silico* analysis (sequence comparison) of mitochondrial and chloroplast genes for identification of the loci for interspecific discrimination.
4. Immunostaining of nuclei, chloroplast and/or mitochondria.

Unit II: Basic and standardization Methods

1. Preparation of Acid & Alkali solutions and acid-base titration.
2. Concept of pH. Measuring pH of different solutions
3. Preparation of buffers: Acetate, Phosphate and Tris buffers.

Unit III: Estimation of micromolecules

1. Estimation of inorganic phosphate
2. Estimation of sugar (glucose)
3. Estimation of Amino acid (Tyrosine)
4. Estimation of Base (Guanine)

Unit IV: Estimation of macromolecules

1. Determination of Blue Value of Starch
2. Estimation of Proteins
3. Estimation of nucleic acids (DNA)

Unit V: Enzyme kinetics

1. Determination of Units and specific activity of an enzyme
2. Determination of Km and Vmax of an enzyme

(From above 16 practicals, any 10 practicals (equivalent to 30H) will be taken)

Semester VIII/II

BB 402: Plant Biochemistry and Metabolism

Unit I: Metabolic compartments of a plant cell

Ultra-structure, composition and functions of various sub-cellular compartments, with special emphasis on cell wall, cell membrane, vacuoles, plastids, and peroxisomes

Unit II: Carbohydrate metabolism

Photosynthesis: general concept of light reaction, action spectra for photosynthetic activity, light-harvesting antennas and photochemical reaction centres, mechanism of light reaction; organizational structure of photosynthetic apparatus and light-absorbing antenna systems; mechanism of electron transport, proton transport, and ATP synthesis; repair and regulation of the photosynthetic machinery; genetics, assembly, and evolution of photosynthetic systems; mechanism and regulation of Calvin-Benson cycle; C_2 oxidative photosynthetic carbon cycle; Inorganic carbon-concentrating mechanisms- C_4-carbon cycle and crassulacean acid metabolism (CAM); accumulation and partitioning of photosynthates (starch and sucrose)- biosynthesis and signalling of sucrose, formation and mobilization of starch.
Respiration: overview of plant respiration; Glycolysis; Oxidative phosphate pentose pathway; Kreb's cycle; Mitochondrial electron transport and ATP synthesis.

Unit III: Lipid metabolism

Fats and oils as storehouse of energy; structural and functional lipids; fatty acid biosynthesis; glycerolipids synthesis; membrane lipids as precursors of cell-signalling molecules; biochemistry of storage lipids in germinating seeds

Unit IV: Assimilation of mineral nutrients

Physical and biological nitrogen fixation, Ammonification, Nitrification, Denitrification. Biochemistry and genetics of nitrogen fixation and Ammonium assimilation; Amino acid biosynthesis and degradation; sulfur assimilation; phosphate assimilation; energetics of nutrient assimilation.

Unit V: Secondary metabolites and plant defenses

Overview of secondary metabolites; Biosynthesis, structure and physiological, ecological, and biochemical significances of terpenes, phenolic phytochemicals, and nitrogen-containing compounds including alkaloids, cyanogenic glycosides,

glucosinolates and non-protein amino acids; induced plant defenses against insect herbivores; plant defenses against pathogens, phytoalexins.

Suggested readings

1. Plant Biochemistry by Hans Walter Heldt
2. Plant physiology and development, Lincoln TaizSinauer Associates
3. Biochemistry, Voet and Voet. Prentice-Hall
4. Lehninger of Principles of Biochemistry, Nelson and Cox.

BB 404: Development Biology of Plants

Unit I: Basic concepts of developmental biology

Potency, commitment, specification, induction, competence, determination and differentiation; morphogenetic gradients; cell fate and cell lineages; stem cells; genomic equivalence and the cytoplasmic determinants; imprinting; mutants and transgenics in analysis of development

Unit II: Signal transduction in plant cells

Basic concepts and components of signal transduction in eukaryotes. Receptor kinases and signal transduction cascade; signal receptors and their locations within plant cells; functions of signal transduction in plants; role of protein degradation in signal transduction; components of ubiquitination machinery; repressor proteins and their role in signal transduction; attenuation of signaling responses; cross-regulation of signal transduction; significance of signal transduction in space and time.

Unit III: Gametogenesis, fertilization and early development in plants

Production of gametes, cell surface molecules in sperm-egg; embryo sac development and double fertilization in plants; Sporophytic development of plant growth; embryogenesis, establishment of symmetry in plants: origin of polarity; identification of genes essential for embryo organization; GNOM proteins, MONOPTEROS, formation of tissue layers, differentiation of cortical and endodermal layers, intercellular movement of macromolecules during developmental processes; Biochemistry of seed development (including starch synthesis) and seed germination.

Unit IV: Ultra-structure, biogenesis and expansion of plant cell wall

Composition of primary cell wall; synthesis of various cell wall components including cellulose microfibrils, matrix polymers, hemicelluloses, and pectins; assembling of new primary cell walls during cytokinesis; development of secondary cell walls. Patterns of cell expansion; rate of cell elongation- stress relaxation, expansins, and structural changes after wall expansion

Unit V: Morphogenesis and organogenesis in plants

Meristematic tissues as foundations for indeterminate growth; Organization and development of shoot and root apical meristem; shoot and root development; leaf development and phyllotaxy; transition to flowering, floral meristems and floral development in *Arabidopsis* and *Antirrhinum.*

Unit VI: Phytochrome and light control of plant development

Photochemical and biochemical properties of phytochrome; characteristics of phytochrome-induced responses; structure and function of phytochrome proteins; genetic analyses of phytochrome function; phytochrome signaling pathways; ecological functions of phytochromes; photophysiology of blue-light responses; regulation of blue light-stimulated responses; blue-light photoreceptors. Circadian rhythms; Photoperiodism; coincidence model; SDPs and LDPs; Vernalization: influence on flowering; role of signaling in flower development; discovery of Florigen.

Unit VII: Plant hormones and their role in plant growth and development

Study of the structure, biosynthesis, transport, signal transduction pathways, effects, and functions of plant hormones including auxin, gibberellins, cytokinins, ethylene, abscisic acid, brassino-steroids

Unit VIII: Aging and senescence

Types of plant senescence; leaf senescence regulation; systematic degradation of phototoxic chlorophyll; Programmed cell death as a type of plant senescence.

Suggested readings

1. Plant Biochemistry by Hans Walter Heldt
2. Plant physiology and development, Lincoln Taiz, Eduardo Zeiger, Ian Max Møller, Angus Murphy, Sinauer Associates

3. Biochemistry, Voet and Voet. Prentice-Hall
4. Lehninger of Principles of Biochemistry, Nelson and Cox.

BB 406: Biophysics and Bioethics

Unit I: Separation Techniques
Different methods of protein precipitation: Precipitation using inorganic salts (salting out) and organic solvents, isoelectric precipitation, Dialysis, Ultrafiltration, Lyophilization

Unit II: Chromatography
Basic principles of chromatography: Partition coefficient, concept of theoretical plates, various modes of chromatography (paper, thin layer, column), preparative and analytical applications, LPLC and HPLC. Different types of chromatography: Paper Chromatography, Thin Layer Chromatography. Molecular Sieve Chromatography, Ion Exchange Chromatography, Affinity Chromatography, Gas Liquid Chromatography

Unit III: Microscopy
Principles and applications of Microscopy, Fluorescence, Phase contrast, Confocal, Scanning and Transmission and Cryo- Electron microscopy.

Unit IV: Electrophoresis
Basic Principle of electrophoresis, Paper electrophoresis, Gel electrophoresis, discontinuous gel electrophoresis, PAGE, SDS-PAGE, PFGE, Native gels, denaturing gels, 2D gel, Isoelectric Focusing of proteins, agarose gel electrophoresis, buffer systems in electrophoresis, protein and nucleic acid blotting, detection and identification (staining procedures), molecular weight determination.

Unit V: Immunological techniques
Hybridoma technology, Phage display, Development of animal models for studying diseases

Unit VI: Analysis of protein-DNA and protein-protein interactions
Gel retardation assay, DNA footprinting by DNase I and chemical methods, yeast one-hybrid assay, ChIP- chips; Yeast two hybrids, three-hybrids, split hybrids and reverse hybrids. Co-immunoprecipitations. GFP and FRET. Phage display.

Unit VII: Genome Editing
CRISPR-Cas9, Principle, Variations involved and applications

Unit VIII: Spectroscopy
Molecular spectroscopy, IR, ESR, FRET, Biomolecular fluorescence complementation assay, Mass spectrometry

Unit IX: Radioisotopes
Radioisotopes and their use in biology and diagnostics, autoradiography, radioactive labeling of biological macromolecules

Unit X: Bioethics
Philosophy and Theories of Bioethics; Clinical ethics; Research Ethics

Suggested Readings

1. Physical Biochemistry: Principles and Applications, 2nd edition (2009), David Sheehan, John Wiley. ISBN-13: 978-0470856031.
2. Cell and Molecular Biology: Concepts and Experiments, 6th edition (2009), Gerald Karp, Wiley. ISBN-978-0470483374.
3. Gene cloning and DNA analysis, 6th edition (2010), T.A. Brown. Wiley-Blackwell ISBN-13: 978-1405181730.
4. Principles of Gene Manipulation and Genomics, 7th edition (2006), S.B. Primrose and R.M. Twyman. Blackwell Scientific ISBN: 978-1405135443.
5. Human Molecular Genetics, 3rd edition (2003), Tom Strachan and Andrew Read; Garland Science Publishers, ISBN -13:978-0815341826.
6. Immunology, 6th edition, (2006), J. Kuby, W.H. Freeman and Company, New York. ISBN-13: 978-1429202114.

BB 408: Biostatistics and Bioinformatics

Unit I: Descriptive Statistics

a) Data in Biology: Development in biostatistics, samples and populations, techniques of sampling (random and stratified), sampling and non-sampling errors, variables in biology, univariate and bivariate frequency distributions
b) Measures of Central Tendency: means, mode, median and partition values.
c) Measures of Dispersion: Range, standard deviation, coefficient of variance and covariance.
d) Moments: Raw and central moments and their relationships.
e) Measures of Skewness: Pearson's coefficients of skewness; coefficient of skewness using moments. Measures of Kurtosis.

Unit II: Probability and Probability Distributions

a) Probability: Basic concepts, addition and multiplication rules of probability, conditional probability
b) Probability Distributions: Probability mass function, probability density function and distribution function. Binomial distribution, Poisson distribution, normal distribution and exponential distribution along with their properties and relationships

Unit III: Correlation and Linear Regression

a) Correlation Analysis: Scatter diagrams, Pearson's and Spearman's coefficients of correlation, coefficient of determination, standard and probable errors.
b) Regression Analysis: Method of least squares, equations of lines of regression and their applications in biostatistics.

Unit IV: Hypothesis Testing

a) Sampling distributions and standard error, null and alternate hypothesis, basic concept and illustrations of type I and type II errors, concept of confidence interval estimation.
b) Student's t-distribution: test for single mean, difference of means and paired t- test, chi-square distribution: tests for goodness of fit, independence of attributes and homogeneity, F-distribution, one-way and two-way analysis of variance (ANOVA).

Unit V: Biological databases and genome browsers

Introduction to various databases and their classification (primary and secondary databases) e.g. NCBI, DDBJ, EMBL, ENSEMBL, UCSC and their uses

Unit VI: Sequence alignment

Local and global sequence alignments (Needleman-Wunsch and Smith-Waterman algorithms), pair-wise (BLAST and FASTA algorithms) and multiple sequence alignment (Clustal W) and its importance. Theory behind BLAST- how Hidden Markov Model (HMM), BLAST score, amino acid substitution matrices, s-value and e-value, p value.

Unit VII: Phylogenetic analysis

Basic concepts of phylogenetic analysis, rooted/uprooted trees, approaches for phylogenetic tree construction (UPGMA, Neighbor joining, Maximum parsimony, Maximum likelihood).

Unit VIII: Structure predictions for nucleic acids and proteins

Approaches for the prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models, Basic approaches for protein structure predictions, comparative modeling, fold recognition/threading and *ab-initio* prediction

Unit IX: Overview of drug development

Drug life cycle, stages of drug discovery and strategic issues in drug discovery. Lead Generation; HTS, clinical trials, characterization of binding site, virtual screening, protein-ligand interactions, prediction of pharmacological properties, Lipinski's rule of five, concept of energy minimization and force fields, introduction to rational drug design using example, Introduction to drug databases

Suggested Readings:

1. Bioinformatics: Sequence and Genome analysis, 2nd edition (2004), David W. Mount, Cold Spring Harbour Laboratory Press. ISBN-13: 978-0879697129.
2. Bioinformatics: A practical guide to the analysis of genes and proteins, 3rd edition (2004), Andreas D. Baxevanis and B.F. Francis Ouellette, John Wiley and Sons. ISBN-13: 978-0471478782.
3. The Process of New Drug Discovery and Development, 2nd edition (2006), C.G. Smith and J.T. O"Donnell, Informa Healthcare, ISBN-13: 978-0849327797.
4. Cheminformatics (2003), J. Gasteiger, Thomas Engel; Wiley-VCH. ISBN: 9783527618279.

5. Molecular modeling - Principles and Applications, 2nd edition (2003), A. R. Leach, Pearson Education Limited, UK. ISBN 13: 9780582382107.
6. Cheminformatics in Drug Discovery (2006), edited by. T.I. Opera; Wiley Publishers, ISBN: 9783527604203.
7. Primer of Biostatistics, 7th edition (2011), Stanton Glantz, McGraw-Hill Medical. ISBN-13: 978-0071781503.
8. Biostatistics: A Foundation for Analysis in the Health Sciences, 10th edition (2013), Wayne W Daniel and Chad L. Cross, Wiley. ISBN-13: 978-1118302798.
9. Principles of Biostatistics, 2nd edition (2000), Marcello Pagano and KimberleeGauvrean, Thompson learning. ISBN-13: 978-0534229023.
10. Biostatistical Analysis, 5th edition (2009), Jerrold H. Zar, Pearson. ISBN-13: 978-0131008465.

BB 492: Practical III (Plant Biochemistry and Developmental Biology)

Unit I: Plant Biochemistry-

1. Determination of proteins during seed germination
2. Extraction, separation and determination of absorption spectra of plant pigments
3. Identification of Food Adulterants:
   a. Test for dilution of milk with water
   b. Test for starch in milk or milk products
   c. Test for Argemone oil in Mustard oil
   d. Test for common sugar in honey
   e. Test for khesari Dal in Besan of other Dal
   f. Test for coloured saw in turmeric powder
4. Estimation of fructose in Fruit-juice
5. Estimation of Urease activity from Horse-gram
6. Determination of cholesterol of edible oil
7. Determination of total Ascorbic acid from fruit juices by DNPH method
8. Estimation of phosphorus content by Fiske- Subbarow' method
9. Estimation of Acid phosphatase activity from Potato
10. Estimation of amylase activity in germinated seedlings
11. Enzymatic determination of oxaloacetic acid in plant sample (C4 plant)
12. Assay of glutamate dehydrogenase activity in given plant tissue
13. Estimation of proline content in plant sample
14. Determination of aspartate aminotransferase activity in given plant tissue
15. Estimation of starch content by Anthrone reagent

Unit II: Developmental Biology of plants-

1. Spectrophotometric estimation of Indole acetic acid in plant tissues
2. Determination of Gibberllic acid by half seed method
3. Microsporogenesis and development of male gametophyte (pollen) and pollinia.
4. Megasporogenesis and development of female gametophyte.
5. Observation on types of endosperm, dissection and isolation of endosperm.
6. Observation or stages of embryo development, dissection and isolation of developing embryo.
7. Effect of different concentration and combination of sucrose, boric acid on pollen germination and pollen tube growth.
8. Pollen-pistil interaction in angiosperms.
9. Seed germinability and viability test
10. Qualitative test for Unknown Secondary metabolites in plants (Alkaloids, terpenoids, flavonoids etc.)

From above 25 practicals, any 10practicals (equivalent to 30H) will be taken

BB 494: Practical IV (Biophysics and Bioinformatics)

Unit I: Biophysics

1. Effect of denaturation (heat/urea/guanidium chloride/BME) on UV absorption spectra of proteins.
2. Study of structural changes of proteins at different pH/solvent/temperature using UV spectrophotometry.
3. Analysis, identification and comparison of various spectra (UV, NMR, MS, IR) of simple organic compounds.
4. Separation of nucleotides/amino acids using TLC
5. Calculation of electrophoretic mobility

6. Study of autoradiographs

Unit II: Bioinformatics

1. Sequence alignment using BLAST and Clustal W.
2. Phylogenetic analysis using PHYLIP.
3. Microarray analysis using Bioconductor.
4. Molecular format conversion and hands-on molecular visualization program for displaying, animating and analyzing large bio-molecular systems using 3-D graphics.
5. Homology Modelling using SPDBV, model structure refinement using SPDBV and model validation using What Check and Pro Check.
6. Comparing structures, mutations, studying interactions creating electrostatic potential diagrams.
7. Virtual screening and molecular docking using AUTODOCK.

Unit III: Biostatistics

Computer-based practicals using any statistical software like 'R'. MATLAB, SPSS, Spreadsheets, etc. to understand the following concepts:

1. Graphical data representation
2. Measures of central tendency and dispersion
3. Probability and probability distributions: binomial, Poisson and normal distribution
4. Correlation and linear regression analysis
5. Student's t- test
6. Chi-square test
7. ANOVA

Semester IX/III

BB 501: Plant Physiology

Unit I: Overview of the plant structure:

Plant cells, tissue systems; independently dividing autonomous and semi-autonomous sub-cellular organelles; brief description of the plant cytoskeleton; Plant cell wall and membrane properties

Unit II: Transport and translocation of water

Physicochemical Properties and biological significance of water; Diffusion and osmosis; concept and significance of water potential; water potential in plant cells; turgor pressure and its significance. Mechanism of water absorption by roots; mechanism of water transport through xylem; transport of water from leaves to atmosphere; soil-plant-atmosphere continuum

Unit III: Transport and translocation of solutes in phloem

Active and passive transport mechanism; transport of ions across membrane barriers; membrane transport processes; membrane transport proteins; ion transport in roots

Pathways of translocation through various phloem cells; pattern of translocation; description of various materials that are translocated via phloem; rates of solute movement, pressure-flow model, and its various aspects; translocation of solutes in gymnosperms; Mechanisms of phloem loading via symplast and apoplast; phloem unloading and sink-to-source transition. Photosynthate distribution that includes allocation of sugars, and partitioning of sinks; transport of signalling molecules such as proteins and RNAs.

Unit IV: Physiological aspects of photosynthesis and respiration

Influence of leaf anatomy, leaf angle, and leaf movement on photosynthesis. Plant acclimatization of sun and shade environments; photosynthetic responses to light; photosynthetic responses to temperature; photosynthetic responses to carbon dioxide; studies on identification of various photosynthetic pathways; interlinking of photosynthesis and respiration. Respiration rates in various plant tissues and organs, role of various environmental factors that alter respiration rates.

Unit V: Mineral nutrition

Essential nutrients, deficiencies, and plant disorders; treatment of nutritional deficiencies in plants; influence of soil texture, pH, microbes and development of root systems that assist in adsorption of mineral nutrients in plant roots. Mycorrhizal fungi and its mechanism of action on nutrient uptake in root cells

Unit VI: Stress physiology

Adaptations and phenotypic plasticity; Abiotic environment and its biological impact on plants- climate change, water deficit and flooding, imbalance of soil minerals (salt stress), extreme temperature stress, high light stress;

developmental and physiological mechanisms that protect plants against environmental extremes; regulation and proteomics of stress tolerance. Seed dormancy- its mechanism, types and uses. Biochemistry of fruit ripening. Artificial seeds-preparation and uses

Suggested readings

1. Plant Biochemistry by Hans Walter Heldt
2. Plant physiology and development, Lincoln Taiz, Eduardo Zeiger, Ian Max Møller, Angus Murphy, Sinauer Associates
3. Biochemistry, Voet and Voet. Prentice-Hall
4. Lehninger of Principles of Biochemistry, Nelson and Cox.

BB 503: Microbial Technology

Unit I: Basic features of microorganisms

General characters of microorganisms- Bacteria, Algae, Fungi and Protozoa. Classification of bacteria; Bacterial growth and metabolism. Microbes in Extreme Environment – Special features of the thermophilic, methanogenic and halophilic archaea; Photosynthetic bacteria, Cyanobacteria; microbes in other extreme conditions – Deep Ocean, and space

Unit II: Role of microorganisms in agriculture, food and dairy industry

Role of microorganisms in agriculture, food and dairy industry; Isolation and selection of Agriculturally important and industrially important microorganisms; Preservation and maintenance of microbial cultures; Various Microbial metabolites and their Overproduction. Microbial enzymes for food, detergent and pharma industry

Unit III: Microbial Fermentation Technology

Microbial substrates and Media formulation; Components of microbial fermentation process; Types of fermentation processes- Solid state, Static and submerged fermentations; Types of Bioreactor: Stirred tank reactor, bubble column; Downstream processing. Fermented beverages-beer, wine and other alcoholic beverages. Production of Ethanol, Citric acid; Amino acids and vitamins; Microbial preparation of Tempeh, sauerkraut, Cheese, yogurt. Probiotics. Single cell protein

Unit IV: Production of Microbial Biomass

Production of Microbial Biomass - Baker's Yeast, Mushroom cultivation and processing; Plant growth promoting rhizobacteria (PGPR); Biopesticides - *Bacillus thuringiensis*, *Trichoderma harzianum*, *Beauveria bassiana.* Biofertilizers- *Rhizobium, Azospirillum, Azotobacter*, *Gluconacetobacter*, Azorhizobium, phosphobacteria - Mycorrhizae - Blue Green Algae and *Azolla.*

Unit V: Production of Antibiotics

Production of Antibiotics-Penicillin, Tetracycline and peptide antibiotics; Bioweapons and Bioshields; Microbial production and commercial applications of Amylases, Proteases, Lipases; Microbial transformation, Production of Insulin, Interluekin, growth hormones using rDNA technology

Unit VI: Renewable bioenergy using microorganisms

Methanogenesis, Methane production by anaerobic digestion of waste organic materials. Bioethanol and Biobutanol production by using microorganisms. Biohydrogen Generation, Microbial Fuel. Biodiesel from algae.

Unit VII: Microbiology of wastewater and solid waste treatment

Microbiology of wastewater and solid waste treatment - biological, aerobic, anaerobic, primary, secondary and tertiary treatments; Activated sludge and Anaerobic digestion process. Treatment of industrial effluents by microorganisms; Composting; Microbiology of degradation of xenobiotics; Bioremediation of insecticides, pesticides and heavy metals

Suggested Readings

1. Bacterial Metabolism - G. Gottschalk, Springer
2. Food Microbiology - M.R. Adams & M.O. Moss, RSC
3. Microorganisms in Our World - R.M. Atlas, Mosby
4. Principles of Fermentation Technology -P. FStanbury, A. Whitaker, S. J. Hall, Butterworth-Heinemann
5. Biotechnology. A Textbook of Industrial Microbiology- W. Crueger and A. Crueger, Sinauer Associates Gerald Reed.
6. Industrial Microbiology-L. E. J. R Casida, New Age Publisher
7. Advances in Enzyme Biotechnology– P.Shukla and I. Pletschke -Eds, Springer-Verlag

8. Advances in Fermentation technology-A. Pandey, C.Lasroche, C.R. Soccol and C. Dussop,Asiatech publishers Inc.
9. Industrial Biotechnology – A.S. Mathuriya, Ane Books Pvt. Ltd.

BB 505: Genetics and Genomics

Unit I: Overview of changing paradigms in genetics
A brief overview of how genetic principles took shape, leading to the concept of a blueprint of life within the cell to the physical entity of DNA. Also mention the surprises we have from the genomics such as genetic variation between individuals. There are popular videos/presentations that can be used. The purpose is to ignite the curiosity of the students.

Unit II: Concept of genetic inheritance
Concept of alleles, haploid and diploid status, phenotype and genotype: Mendel"s laws of inheritance, dominant and recessive inheritance, test, back and reciprocal crosses with two examples each.

Unit III: Physical basis of inheritance
Chromosomal theory of inheritance, concept of linkage and crossing over, cytological proof of crossing over, genetic mapping: two and three point-cross over; Distinguishing recombination and complementation; Allelic interactions-dominance relationships- complete, incomplete and co-dominance, gene-gene interaction

Unit IV: Extra nuclear inheritance
Criteria for extra nuclear inheritance**,** plastid inheritance in *Mirabilis jalapa*, kappa particles in *Paramecium*, maternal effect- snail shell coiling, cytoplasmic inheritance (mitochondria and chloroplast).

Unit V: Mutation
Concept of selection with examples from bacteria, prototrophy and auxotrophy, spontaneous and induced mutations, types of mutations- point, (non-sense, missense, frame shift, insertion, deletion), use of mutants to study gene functions, effects on the gene product- loss of the function and gain of function. Distinction between mutation and polymorphism

Unit VI: Transposable genetic elements
Prokaryotic transposable elements- IS elements, Composite transposons; Eukaryotic transposable elements- Ac-Ds system in maize; Uses of transposons.

Unit VII: Analysis of genetic inheritance in human
Gathering family history, pedigree symbols and construction of pedigrees; Patterns of inheritance for monogenic traits and risk assessment with examples for autosomal inheritance-dominant, recessive, sex-linked inheritance, sex-limited and sex-influenced traits, mitochondrial inheritance

Unit VIII: Genome Organization and Cytogenetics
Organization of Genomes in Prokaryotes and Eukaryotes, Establishing the central Dogma, Nucleosomes organization and assembly, Regulation of chromatin structure; Euchromatin, Heterochromatin- constitutive and facultative heterochromatin
Karyotyping- banding pattern and nomenclature (G and Q banding), common syndromes due to numerical chromosome changes, common syndromes due to structural alterations (translocations, duplications, deletions)

Unit IX: Introduction to chromosomal basis of sex determination
Chromosomal theory of sex determination, mechanisms of sex determination, environmental factors and sex determination in human and *Drosophila*, Barr bodies, dosage compensation

Unit X: Population genetics
Gene pool and gene frequency, Hardy Weinberg law and its application for calculating allelic and genotype frequencies

Suggested Readings

1. Principles of Genetics, 6th edition (2011), Snustad DP and Simmons MJ, John Wiley and Sons, Inc; ISBN-13: 978-0470903599
2. Human Molecular Genetics, 3rd edition (2003) by Tom Strachan and Andrew Read; Garland Science Publishers, ISBN -13: 978-0815341826.

3. Concepts of Genetics, 10th edition, (2011). William S. Klug, Michael R. Cummings, Charlotte A. Spencer, Michael A. Palladino; Pearson Education, ISBN-13: 978-0321724120.
4. Principles of Genetics, 8th edition (2005), Gardner EJ, Simmons MJ, Snustad DP. John Wiley and Sons, Inc. ; ISBN-13: 978-9971513467.
5. An introduction to Genetic Analysis, 10th edition (2010), Griffith AJF, Miller JH, Suzuki DT, Lewontin RC, Gelbert WM., W. H. Freeman and Co. New York. ISBN-13: 978-429229432.
1. Principles of Genetics, 6th edition (1998), Robert H. Tamarin Publisher: William C Brown Pub; ISBN-13: 978-0697354624.

BB 407: Molecular Biology

Unit I: Genetic material
The structure of DNA and RNA; Melting of DNA, Superhelicity, Comparative Organization and features of Microbial Genomes and Eukaryotic Genomes

Unit II: DNA replication
Arrangement of replicons in a genome, Various modes of replication, continuous, discontinuous synthesis, various replication Enzymes, Replication Fork and priming, leading and lagging strand, elongation, termination, Plasmid replication, specific features of replication in Prokaryotes and Eukaryotes, action of topoisomerases, Telomere maintenance and Chromatin Assembly, Single stranded DNA replication, Relationship between DNA replication and cell cycle, DNA copy number maintenance.

Unit III: Recombination and Repair of DNA
DNA repair and recombination, DNA Mismatch Repair, Double Strand Break Repair, Recombination as a molecular biology tool

Unit IV: Transcription
Transcription machinery of prokaryotes, various transcription enzymes and cofactors, initiation, elongation and termination, sigma factors, Transcription machinery of eukaryotes, various forms of RNA polymerase and cofactors, initiation, elongation and termination, promoters, enhancers, silencers, activators, effect of chromatin structure, regulation of transcription.

Unit V: Post-transcriptional processes
RNA processing, splicing, capping and polyadenylation, rRNA and tRNA processing, RNA Editing; RNAi and miRNAs, Antisense RNA, Post-transcriptional gene regulation

Unit VI: Operon
Gene structure, concept of Operon, Lac and Trp operon, organization and role in regulation of expression

Unit VII: Translation
The genetic code and protein structure, Mechanisms of translation in prokaryotes, Mechanisms of translation in eukaryotes, initiation complex, ribosomes and tRNA, factors, elongation and termination, *in vitro* translation systems, polycistronic/ monocistronic synthesis, Regulation of translation, RNA instability, inhibitors of translation, stringent response in bacteria

Unit VIII: Post-translational processes
Protein modification, folding, chaperones, transportation; The Signal Hypothesis, proteosome

Unit IX: Genes and behavior
Human Genome Project, Genome analysis, DNA typing, Genomics and beyond

Suggested Readings:

1. Gene IX by Benjamin Lewin, Jones and Bartlett Publishers, Sudbury, Massachusetts, 2007.
2. Molecular Biology by R.F. Weaver , 4th edition, McGraw Hill. New York. USA, 2007.
3. Molecular Biology of the Gene by J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick, 6th edition, Benjamin Cummings, San Francisco, USA, 2007.
4. Molecular Biology of the Cell by B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P. Walter, 5th edition, Garland Science, New York and London, 2007.
5. Biochemistry (5th edition) by J.M. Berg, J.L. Tymoczko, L. Stryer, W.H. Freeman and Company, New York, USA, 2008.

6. Current Protocols in Molecular Biology Edited by: Fred M. Ausubel; Roger Brent; Robert E. Kingston; David D. Moore; John A. Smith; Kevin Struhl, John Wiley and Sons, Inc. 2007

BB 591 Practical V (Plant Physiology and Microbial Technology)

Unit I: Plant Physiology

1. Isolation of chloroplasts and Estimation of chlorophylls from given plant sample
2. Determination of peroxidase activity in plant tissue
3. Determination catalase activity in plant tissue
4. Determination of protein under abiotic stress
5. Determination of pyridoxine of fruits / leaves
6. Effect of water stress on root metabolic activity
7. Determination of water potential of plant samples by Chardakov's method.
8. Quantitative estimation of accumulated chloride ion in cell sap.
9. Study of photolysis of water by demonstration of Hill reaction.
10. Quantitative estimation of dissolved oxygen due to photosynthesis by Winkler's method.
11. Effect of sodium azide on water uptake by plants.

Unit II: Microbial Technology

1. Isolation of agriculturally important microorganisms – plant growth promoting rhizobacteria (PGPR), plant growth promoting fungi (PGPF), Biocontrol agent (BCA) from soil collected from riverine, forest and agricultural field using specific media.
2. Isolation of industrially important microorganism from different sources using specific substrates.
3. Talc based formulation of PGPR
4. Mass production of biopesticides
5. Mass production of arbuscular mycorrhizal fungi
6. Solid waste management through vermicomposting

(From above 17practicals, any 10 practicals (equivalent to 30H) will be taken)

BB 593 Practical VI (Genetics and Molecular Biology)

(Wherever wet lab experiments are not possible the principles and concepts can be demonstrated through any other material or medium including videos/virtual labs etc.)

Unit I: Genetics

1. Observation of wild type and mutant phenotypes in *Drosophila.*
2. Preparation of culture media for *Drosophila* and study different stages of life cycle of *Drosophila.*
3. Verification of Mendelian laws through *Drosophila* / seeds – dominant, recessive and sex-linked
4. Preparation of Barr body.
5. Karyotyping with the help of photographs (normal and abnormal karyotypes).
6. Pedigree charts of some common characters like blood group, color blindness and PTC tasting.
7. Study of polyploidy in onion root tip by colchicine treatment.

Unit II: Molecular Biology

1. Restriction digestion analysis by agarose gel electrophoresis.
2. Restriction digestion analysis by polyacrylamide gel electrophoresis.
3. Isolation of plasmid DNA from minicultures.
4. Isolation of plasmid from maxicultures.
5. Isolation of genomic DNA.
6. Cloning of a DNA fragment

Semester X/IV

BB 502: Genetic Engineering and Plant Biotechnology

Unit I: Principles of Gene cloning

Basics of gene cloning; importance of gene cloning; introduction to plasmids- classification of plasmids, plasmid size and copy numbers, plasmid conjugation and compatibility, plasmids present in eukaryotes; introduction to bacteriophages- types of bacteriophages, lytic and lysogenic cycles, gene organization in lambda DNA (linear and circular), M13-phage; viruses as cloning vectors for eukaryotes.

Unit II: Isolation and purification of DNA from living cells

Preparation and isolation of DNA from bacteria and plant extracts; purification of plasmid DNA and bacteriophage DNA

Unit III: Molecular tools for manipulation of purified DNA

DNA manipulating enzymes (Nucleases, Ligases, Polymerases, other DNA-modifying enzymes). DNA-cutting enzymes (restriction endonucleases)- discovery, types of restriction endonucleases, sticky ends & blunt ends, mapping the positions of different restriction sites in a DNA molecule; DNA ligase- mechanism of action of ligase, efficiency of ligation, types and importance of linkers and adaptors, homopolymer tailing, blunt end ligation.

Unit IV: Methods of introduction of DNA in prokaryotes and eukaryotes, and identification of recombinants

Transformation of bacterial cells- DNA uptake by bacterial cells, preparation of competent *E. coli* cells, selection of transformed bacterial cells; identification of recombinants- insertional inactivation, pBR322. Transfection of bacterial cells with phage infection- in vitro packaging of lambda cloning vectors, identification of phage infected bacterial cells. Identification of recombinant phages- insertional inactivation of *Lac Z* gene, lambda-cl gene, selection on the basis of lambda genome size; introduction of DNA into eukaryotes

Unit V: Cloning vectors

Cloning vectors based on *E. coli* plasmids- nomenclature of plasmid cloning vectors, properties of pBR322 and pUC8. Cloning vectors based on M13 phage- construction of phage cloning vector; hybrid plasmid-M13 vectors. Cloning vectors based on lambda phage- construction and selection of lamda phage cloning vectors, insertion and replacement vectors. Cloning vectors for long DNA fragments- Cosmids. Cloning vectors for eukaryotes- Yeast episomal plasmid (YEp) vectors, artificial chromosomes (BACs, YACs), *Agrobacterium tumefaciens* plasmids (Ti plasmids, Ri plasmids), limitations of *Agrobacterium tumefaciens;* P-elements, viruses as cloning vectors in mammals. Direct gene transfer without vectors; Basic strategies of clone selection- Direct selection and gene libraries. Methods of clone identification

Unit VI: Genome sequencing and expression studies

Basics of DNA sequencing and its types. Genetic maps, physical maps, its importance in DNA sequencing. Methods of RNA transcript analysis; HRT and HART; *in vitro* mutagenesis. Gene annotations- identification of genes and their functions in a sequence. Yeast two-hybrid system. Basics of RFLP, RAPD and AFLP techniques

Unit VII: Gene cloning and DNA analysis in agriculture

Gene addition in plant genetic engineering- insect resistance gene in maize, herbicide resistant crops, glyphosate resistant crops. Gene subtraction in plant genetic engineering- Use of Antisense RNA in fruit ripening in tomato, inactivation of polygalacturonase gene, inactivation of ethylene synthesis. Potential and problems of genetically modified plants.

Unit VIII: Principles and applications of plant tissue culture

Tissue culture media, Initiation and maintenance of callus and suspension cultures; single cell clones; Totipotency: Organogenesis; somatic embryogenesis; transfer and establishment of whole plants in soil (hardening). Rapid clonal propagation and production of virus -free plants. *In vitro* pollination; embryo culture and embryo rescue. Protoplast fusion, selection of hybrid cells; symmetric and asymmetric hybrids, cybrids. Nuclear cytology of cultured plant cells and somaclonal variations. Production of haploid plants and their utilization. Cryopreservation and slow growth for germ plasm conservation

Suggested Readings

1. Brown TA. (2010). Gene Cloning and DNA Analysis. 6th edition. Blackwell Publishing, Oxford,U.K.
2. Clark DP and Pazdernik NJ. (2009). Biotechnology: Applying the Genetic Revolution. Elsevier Academic Press, USA
3. Primrose SB and Twyman RM. (2006). Principles of Gene Manipulation and Genomics, 7th edition. Blackwell Publishing, Oxford, U.K.
4. Sambrook J and Russell D. (2001). Molecular Cloning-A Laboratory Manual. 3rd edition. Cold Spring Harbor Laboratory Press

5. Wiley JM, Sherwood LM and Woolverton CJ. (2008). Prescott, Harley and Klein's Microbiology. McGraw Hill Higher Education
6. Brown TA. (2007). Genomes-3. Garland Science Publishers
7. Primrose SB and Twyman RM. (2008). Genomics: Applications in human biology. Blackwell Publishing, Oxford, U.K.

BB 504: Ecology and Conservation

Unit I: Concept of Ecology

Introduction to ecology, evolutionary ecology, environmental concepts – laws and limiting factors, ecological models. Characteristics of population, population size and exponential growth, limits of population growth, population dynamics, life history pattern, fertility rate and age structure. Competition and coexistence, intraspecific and inter-specific interactions, scramble and contest competition model, mutualism and commensalism, prey-predator interactions.

Unit II: Ecosystem

Nature of ecosystem, production, food webs, energy flow through ecosystem, bio-geochemical cycles, resilience of ecosystem, ecosystem management. The biosphere, biomes and impact of climate on biomes

Unit III: Climate change

Environmental Stresses and their management, global climatic pattern, global warming, atmospheric ozone, acid and nitrogen deposition, coping with climatic variations

Unit IV: Bioremediation

Major classes of contaminants. Uptake, biotransformation, detoxification, elimination and accumulation of toxicants. Factors influencing bioaccumulation from food and trophic transfer. Pesticides and other chemical in agriculture, industry and hygiene and their disposal. Impact of chemicals on biodiversity of microbes, animals and plants. Bioindicator and biomarkers of environmental health. Biodegradation and bioremediation of chemicals.

Unit V: Biodiversity

Biosphere: Characterization, generation and maintenance, Biosphere reserves, resources and management, Global diversity hotspots, Effect of manmade alteration of environment on Biospheres. Biodiversity assessment, conservation and management, biodiversity act and related international conventions. Sustainable development, natural resource management in changing environment. Molecular ecology, genetic analysis of single and multiple population, phylogeography, molecular approach to behavioural ecology, conservation genetics.

Conservation: Objective of Conservation, strategies of conservation, Global programmes and concept of endangered species, Modern tools and techniques to assess biodiversity.

Suggested Readings

1. Field Sampling: Principles and Practices in Environmental Analysis. 2004. Conklin, A.R. Jr. CRC Press.
2. Principles and Standards for Measuring Primary Production. 2007. Fahey, T.J. and Knapp, A.K. Oxford University Press, UK.
3. Ecological Modeling. 2008. Grant, W.E. and Swannack, T.M., Blackwell.
4. Fundamental Processes in Ecology: An Earth system Approach. 2007. Wilkinson, D.M. Oxford University Press, UK.
5. Principles of Terrestrial Ecosystem Ecology. 2011. Chaplin, F.S., Matson, P.A. and Vitousek, P.M. Springer.
6. Environmental Chemistry. 2010. Stanley and Manahan, E. CRC, Taylor & Francis. London.
7. Freshwater Ecology: A Scientific Introduction. 2004. Closs, G., Downes, B. and Boulton, A. Wiley-Blackwell publisher, Oxford.

BB 592: Practical VII (Plant Biotechnology and Ecology)

Unit I: Genetic engineering and Plant Biotechnology

1. DNA digestion by Restriction endonuclease
2. Isolation of plasmid DNA and restriction mapping
3. Preparation of culture media, autoclaving and sterilization
4. Culture of *E.coli* cells & plasmid isolation
5. Preparation of competent cells
6. Calcium chloride mediated transformation

7. Ligation of DNA
8. Restriction fragment length polymorphism
9. Random amplified polymorphic DNA
10. Estimation of DNA by Diphenylamine method
11. Isolation RNA from yeast cells.
12. Estimation of RNA BY Orcinol method.
13. Estimation of DNA and purity determination by UV absorption method.
14. Determination of melting temperature (Tm) of ds-DNA

Unit II: Ecology and Conservation

A. Habitat studies:

1. Physical and chemical characteristics of soil.
2. Physico-chemical properties of water.

B. Community/ecosystem studies:

1. Assessment of density, frequency and abundance of plants/ animals in a community using various techniques i.e. transect, quadrate etc.
2. Decomposition of various organic matters and nutrient release mechanisms/role of arthropods and other micro- and macro-fauna in decomposition.
3. Understanding ecosystem succession by studying various stages of vegetation/community assemblages development.
4. Application of molecular techniques in ecological study.
5. Insect diversity in soil.
6. Identification of aquatic organisms of different trophic levels and construction of food chain and food web.

C. Landscape studies:

1. Principles of GIS, GPS and RS technology.
2. Interpretation (visual and automated) of remote sensing information for landscape differentiation

D. Aquatic ecology studies:

1. Estimation of dissolved O2 of water
2. Estimation of free CO2 in water
3. Estimation of pH of water
4. Quantitative counting of zooplankton

(From above number of practicals, any 15 practicals (equivalent to 30H) will be taken)

BB 562: Project Work/Dissertation

The students would be required to undertake a Dissertation Project Work under the faculty based on their preference, such that total students are equally distributed amongst the faculty. The allotment of students would be done at the beginning of 3rd Semester and evaluation would be done at the end of 4th Semester. Dissertation evaluation would comprise of the following

Continuous Evaluation	: 40
Report	: 30
Presentation & Viva	: 30

Students can do part of their Project work outside Aliah University, subject to approval from concerned authority.
External members may be invited, subject to approval from concerned authority.

BB 572: Comprehensive Viva

The Viva would involve an overall assessment of students jointly by all the faculty members.
External members may be invited, subject to approval from concerned authority.

BB 582: Field trip / Industrial Visit

A mandatory visit to any of the following

a) Natural Park
b) Botanical garden
c) Zoological Park
d) Relevant industry
e) Research Labs at Institutes of National importance

Students would be required to submit a report of their visit which would be evaluated.

Syllabus for MSc Zoology

Department of Biological Sciences, Aliah University, Kolkata
Draft Syllabus for MSc Zoology
(As part of Integrated BSc-MSc Biological Sciences with Lateral Entry at MSc)

Specialization: Molecular Biology and Genetics

Sem	Code	Paper Name	LTPC**	Marks/Credit
VII/I	BZ 401	Non-Chordates and Systematics	60	50/4
	BZ 403	Ecology and Conservation	60	50/4
	BZ 405	Cell Biology	60	50/4
	BZ 407	Principles of Biochemistry	60	50/4
	BZ 491	Practical I (Non-Chordates and Ecology)	60	50/4
	BZ 493	Practical II (Cell Biology and Biochemistry)	60	50/4
			Total	300/24
VIII/II	BZ 402	Metabolism and Human Physiology	60	50/4
	BZ 404	Chordates and Animal Physiology	60	50/4
	BZ 406	Biophysics and Bioethics	60	50/4
	BZ 408	Biostatistics & Bioinformatics	60	50/4
	BZ 492	Practical III (Metabolism and Chordates)	60	50/4
	BZ 494	Practical IV (Biophysics and Bioinformatics)	60	50/4
			Total	300/24
IX/III	BZ 501	Immunology and Parasitology	60	50/4
	BZ 503	Evolution and Animal Behaviour	60	50/4
	BZ 505	#Genetics and Genomics	60	50/4
	BZ 507	#Molecular Biology	60	50/4
	BZ 591	Practical V (Immunology and Evolution)	60	50/4
	BZ 593	Practical VI (Genetics and Molecular Biology)	60	50/4
			Total	300/24
X/IV	BZ 502	Insects and Aquatic Biology	60	50/4
	BZ 504	#Developmental Genetics	60	50/4
	BZ 592	Practical VII (Aquatic Biology and Dev Bio)	60	50/4
	BZ 562	Project Work/Dissertation	120	100/8
	BZ 572	Comprehensive Viva	30	25/2
	BZ 582	Field trip/Industrial visit	30	25/2
			Total	**300/24**

**Lecture Taken Per Course
Specialized paper

Semester VII/I

BZ 401: Non Chordates and Systematics

Section A: Non-Chordates

Unit I: Lower Non-Chordata

Nutrition in Protozoa; Reproduction in Protozoa; Origin of Metazoa; Organization and affinities of Porifera; Polymorphism in Coelenterata; Colony formation in Coelenterata; Coral reefs-Definition, Formation, Types and Distribution; Salient features of parasitism in helminthes; Life cycle patterns in helminthes parasites; Outlines of the ecology of soil nematodes; Adaptive radiation in Polychaeta; Segmental organs in Annelida.

Unit II: Higher Non-Chordata

Organization, affinities and evolutionary significance of Onychophora; Parasitism in Crustacea; Larval forms in Crustacea; Mouth parts of insects; Basic concept of insect pest management; Biology and control of Lepisma; Pediculus, Cimex; Adaptive radiation in mollusca; Torsion in mollusca; Larval forms in Echinodermata; Affinities of Echinodermata; Brief outlines of the structure and affinities of minor phyla with special reference to *Ctenophora, Rotifera, Acanthocephala, Sipunculoidea* and *Echiuroidea.*

Section B: Systematics

Unit I: Fundamental of Systematics

Biological classification, Hierarchy of categories and higher taxa, Taxonomic characters: procedures and keys, Species concepts: varieties, subspecies, sibling species, race etc. International code of Zoological nomenclature.

Unit II: Kingdoms

General outline of kingdoms including Monera & Protista; Broad outline & Diversity in kingdom Animalia

Unit B3: Methodologies in systematics

Morphology based taxonomy, Numerical taxonomy, Cyto-taxonomy and chemotaxonomy, Molecular systematics, DNS fingerprinting & Molecular markers for detection/evaluation of polymorphism, RFLP, RAPD etc.

Suggested Readings

1. This is Biology: The Science of Living world, Mayr, M. (1997), Universities Press Ltd.
2. J.R.B. Alfred and Ramakrishna (2004) Collection, Preservation and Identification of animals. Zoological Survey of India Publications.
3. N.A. Campbell and J.B. Reece (2004) Biology, 7th edition, Benjamin Cummings Publ. [8th edition (2009)]
4. Ruppert and Barnes, R.D. (2006). Invertebrate Zoology, VIII Edition. Holt Saunders International Edition.
5. Barnes, R.S.K., Calow, P., Olive, P.J.W., Golding, D.W. and Spicer, J.I. (2002). The Invertebrates: A New Synthesis, III Edition, Blackwell Science.
6. Barrington, E.J.W. (1979). Invertebrate Structure and Functions. II Edition, E.L.B.S. and Nelson.

BZ 403: Ecology and Conservation

Unit I Concept of Ecology

Introduction to ecology, evolutionary ecology, environmental concepts- laws and limiting factors, ecological models. Characteristics of population, population size and exponential growth, limits of population growth, population dynamics, life history pattern, fertility rate and age structure. Competition and coexistence, intraspecific and inter-specific interactions, scramble and contest competition model, mutualism and commensalism, prey-predator interactions.

Unit II: Ecosystem

Nature of ecosystem, production, food webs, energy flow through ecosystem, bio-geochemical cycles, resilience of ecosystem, ecosystem management. The biosphere, biomes and impact of climate on biomes

Unit III: Climate change

Environmental Stresses and their management, global climatic pattern, global warming, atmospheric ozone, acid and nitrogen deposition, coping with climatic variations

Unit IV: Bioremediation

Major classes of contaminants. Uptake, biotransformation, detoxification, elimination and accumulation of toxicants. Factors influencing bioaccumulation from food and trophic transfer. Pesticides and other chemical in agriculture,

industry and hygiene and their disposal. Impact of chemicals on biodiversity of microbes, animals and plants. Bioindicator and biomarkers of environmental health. Biodegradation and bioremediation of chemicals.

Unit V: Biodiversity

Biosphere: Characterization, generation and maintenance, Biosphere reserves, resources and management, Global diversity hotspots, Effect of manmade alteration of environment on Biospheres. Biodiversity assessment, conservation and management, biodiversity act and related international conventions. Sustainable development, natural resource management in changing environment. Molecular ecology, genetic analysis of single and multiple population, phylogeography, molecular approach to behavioural ecology, conservation genetics.

Conservation: Objective of Conservation, strategies of conservation, Global programmes and concept of endangered species, Modern tools and techniques to assess biodiversity.

Suggested Readings

1. Field Sampling: Principles and Practices in Environmental Analysis. 2004. Conklin, A.R. Jr. CRC Press.
2. Principles and Standards for Measuring Primary Production. 2007. Fahey, T.J. and Knapp, A.K. Oxford University Press, UK.
3. Ecological Modeling. 2008. Grant, W.E. and Swannack, T.M., Blackwell.
4. Fundamental Processes in Ecology: An Earth system Approach. 2007. Wilkinson, D.M. Oxford University Press, UK.
5. Principles of Terrestrial Ecosystem Ecology. 2011. Chaplin, F.S., Matson, P.A. and Vitousek, P.M. Springer.
6. Environmental Chemistry. 2010. Stanley and Manahan, E. CRC, Taylor & Francis. London.
7. Freshwater Ecology: A Scientific Introduction. 2004. Closs, G., Downes, B. and Boulton, A. Wiley-Blackwell publisher, Oxford.

BZ 405: Cell Biology

Unit I: Structure of Cell

Plasma membrane: Structure and transport of small molecules; Cell Wall: Eukaryotic cell wall, Extracellular matrix; Cytoskeleton: Structure and organization of actin filaments, association of actin filaments with plasma membrane, cell surface protrusions, intermediate filaments, microtubules. Mitochondria, chloroplasts, lysosomes and peroxisomes; Nucleus: Nuclear envelope, nuclear pore complex, nucleolus and nuclear lamina; Chromatin; Endoplasmic Reticulum and Golgi Apparatus.

Unit II: **Cell signaling**

Hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component systems, light signaling in plants, bacterial chemotaxis and quorum sensing.

Unit III: **Cellular communication**

Regulation of hematopoiesis, general principles of cell communication, cell adhesion and roles of different adhesion molecules, gap junctions, extracellular matrix, integrins, neurotransmission and its regulation

Unit 4: **Cell cycle and cancer**

Cell cycle and its regulation, Genetic rearrangements in progenitor cells, oncogenes, tumor suppressor genes, cancer and the cell cycle, virus-induced cancer, metastasis, angiogenesis, interaction of cancer cells with normal cells, apoptosis, autophagy, therapeutic interventions of uncontrolled cell growth.

Suggested Readings

1. Cell and Molecular Biology: Concepts and Experiments, 6th edition (2009), Gerald Karp, Wiley. ISBN-978-0470483374.
2. The World of the Cell, 7th edition (2008), Becker, Kleinsmith, Hardin and Bertoni. Benjamin Cummings, ISBN-13: 978-0805393934.
3. The Cell: A Molecular Approach, 6th edition (2013), Cooper and Hausman; Sinauer Associates, Inc. ISBN-13:978-1605351551.
4. Essential Cell Biology, 7th edition (2009), Alberts, Bray, Hopkin, Johnson, Lewis, Raff, Roberts and Walter. Garland Science. ISBN-13:978-0815341291.
5. Molecular Cell Biology, 7th edition (2012), Lodish, Berk, Kaiser, Krieger, Bretscher, Ploegh, Amon and Scott. W. H. Freeman. ISBN-13: 978-1429234139.

BZ 407: Principles of Biochemistry

Unit I: Introduction

Chemical basis of life; Water, structure of liquid water, water as ideal biological solvent; Principles of biophysical chemistry- pH, buffer, reaction kinetics, colligative properties; Henderson-Hasselbalch equation. Biomolecular hierarchy; Macromolecules; Molecular assemblies; Stablizing interactions- Van der Waals, electrostatic, hydrogen bonding, hydrophobic interaction etc. Thermodynamics- Laws of thermodynamics, free energy, entropy, high energy bonds.

Unit II: Carbohydrates

Sugars; monosaccharides- aldoses and ketoses, trioses, tetroses, pentoses, and hexoses. Stereoisomerism of monosaccharides- epimers, anomers, muta-rotation. Furanose and pyranose forms of glucose and fructose, Haworth projection formulae for glucose; chair and boat forms of glucose, Sugar derivatives, glucosamine, galactosamine, muramic acid, N- acetyl neuraminic acid. Disaccharides: concept of reducing and non-reducing sugars, occurrence and Haworth projections of maltose, lactose, and sucrose. Polysaccharides: Structure and functions; Storage Polysaccharides- starch and glycogen; Structural Polysaccharides- cellulose, peptidoglycan and chitin. Suitability in the context of their different functions- cellular structure; energy storage; signaling; Glycosylation of other biomolecules - glycoproteins and glycolipids.

Unit III: Amino acids & Proteins

Amino acids- Concept, Properties, Classification, and reactions (N / C terminal reactions). Titration curve of amino acid and its Significance. Natural modifications of amino acids in proteins hydrolysine, cystine and hydroxyproline, Non protein amino acids: Gramicidin, beta-alanine, D-alanine and D- glutamic acid. Peptide bond formation; Protein structure- Levels, primary structure and its importance. The alpha helix, the beta pleated sheet and their occurrence in proteins, Tertiary and quaternary structures of proteins. Conformation of proteins: Ramachandran plot, domains, motifs and folds; End group analysis and protein sequencing. Forces stabilizing protein structure, unfolding and refolding. Structure-function relationships in model proteins like ribonuclease A; myoglobin; hemoglobin; chymotrypsin etc.; Tools to characterize expressed protein. Biological Roles of Proteins. Amino acid and Protein metabolism

Unit IV: Nucleic acid

Nucleoside, Nucleotide, Nucleic acids- Structure, diversity and functions; DNA: Double helical structure; A-DNA, B-DNA & Z-DNA (structure, occurrence and differences). The RNA world-Structure, types and roles of RNA. Nucleic acid Sequencing. Nucleic acid Synthesis and Metabolism

Unit V: Lipids

Fatty acids structure and functions. Storage and structural lipids. Lipids in the formation of membranes (lipid micelles, monolayers, bilayers). Saponification Structural lipids. Lipid functions: cell signals, cofactors, pigments. Principles and pathways of lipid metabolism

Unit VI: Enzymes

Principles of catalysis, enzymes- properties and classification; Mechanism of enzyme action: active site, transition state complex and activation energy; Lock and key hypothesis, and Induced Fit hypothesis. Enzyme kinetics- Significance of hyperbolic, double reciprocal plots of enzyme activity, Km, and allosteric mechanism; Isozymes; Effect of pH and temperature on enzyme activity. Enzyme activators and inhibitors. Structure and function of Vitamins and coenzymes. Enzyme immobilization and their applications

Suggested Readings

1. Campbell, MK (2012) Biochemistry, 7th ed., Published by Cengage Learning
2. Campbell, PN and Smith AD (2011) Biochemistry Illustrated, 4th ed., Published by Churchill Livingstone
3. Tymoczko JL, Berg JM and Stryer L (2012) Biochemistry: A short course, 2nd ed., W.H.Freeman
4. Berg JM, Tymoczko JL and Stryer L (2012) Biochemistry, W.H.Freeman and Company
5. Nelson DL and Cox MM (2008) Lehninger Principles of Biochemistry, 5th Edition., W.H. Freeman and Company,
6. Voet,D. and Voet J.G (2005) Biochemistry 3rd edition, John Wiley and Sons.
7. Segel Irvin H (1997) Biochemical Calculations, 2nd Ed., John Wiley and Sons, New York.
8. Palmer, T (2001) Enzymes: Biochemistry, Biotechnology & Clinical chemistry, Horwood Pub. Co., England.

BZ 491: Practical I (Non-Chordates and Ecology)

Unit I: Non-chordates & Systematics

1. Study of whole mount of Euglena, Amoeba and Paramecium, Binary fission and
2. Conjugation in Paramecium
3. Examination of pond water collected from different places for diversity in protista
4. Study of Sycon (T.S. and L.S.), *Hyalonema*, *Euplectella*, *Spongilla*
5. Study of *Obelia, Physalia, Millepora, Aurelia, Tubipora, Corallium, Alcyonium, Gorgonia, Metridium, Pennatula, Fungia, Meandrina, Madrepora.* One specimen/slide of any ctenophore
6. Study of adult Fasciola hepatica, Taenia solium and their life cycles (Slides/microphotographs)
7. Study of adult Ascaris lumbricoides and its life stages (Slides/micro-photographs)
8. To submit a Project Report on any related topic on life cycles/coral/ coral reefs.
9. Study of following specimens:
   a. Annelids - *Aphrodite, Nereis, Heteronereis, Sabella, Serpula, Chaetopterus, Pheretima, Hirudinaria*
   b. Arthropods - *Limulus*, *Palamnaeus, Palaemon, Daphnia*, *Balanus*, *Sacculina*, *Cancer*, *Eupagurus*, *Scolopendra*, *Julus*, *Bombyx*, *Periplaneta,* termites and honey bees.
   c. Onychophora – *Peripatus.*
   d. Molluscs - *Chiton, Dentalium, Pila, Doris, Helix, Unio, Ostrea, Pinctada, Sepia, Octopus, Nautilus.*
   e. Echinodermates - *Pentaceros/Asterias, Ophiura, Clypeaster, Echinus, Cucumaria* and *Antedon.*
10. Study of digestive system, septal nephridia and pharyngeal nephridia of earthworm.
11. T.S. through pharynx, gizzard, and typhlosolar intestine of earthworm.
12. Mount of mouth parts and dissection of digestive system and nervous system of *Periplaneta,*
13. To submit a Project Report on any related topic to larval forms (crustacean, mollusk and echinoderm).
14. Study of soil fauna: sampling, extraction / collection, preservation and analysis.
15. Collection, identification and preservation of various insect orders and arthropod groups (including study of permanent specimens).
16. Study of Freshwater planktons, collection, sorting, identification of samples of zooplanktons: protozoans, rotifers, crustaceans. (including study of permanent specimens)

Unit II: Ecology and Conservation

A. Habitat studies

1. Physical and chemical characteristics of soil.
2. Physico-chemical properties of water.

B. Community/ecosystem studies

1. Assessment of density, frequency and abundance of plants/ animals in a community using various techniques i.e. transect, quadrate etc.
2. Decomposition of various organic matters and nutrient release mechanisms/role of arthropods and other micro- and macro-fauna in decomposition.
3. Understanding ecosystem succession by studying various stages of vegetation/community assemblages development.
4. Application of molecular techniques in ecological study.
5. Insect diversity in soil.
6. Identification of aquatic organisms of different trophic levels and construction of food chain and food web.

C. Landscape studies:

1. Principles of GIS, GPS and RS technology.
2. Interpretation (visual and automated) of remote sensing information for landscape differentiation

D. Aquatic ecology studies:

1. Estimation of dissolved O2 of water
3. Estimation of free CO2 in water
4. Estimation of pH of water
5. Quantitative counting of zooplankton

BZ 493: Practical II (Cell Biology and Biochemistry)

Unit I: Cell Biology

1. Isolation of mitochondria and their visualization with Janus green B
2. *In situ* visualization of microfilaments and microtubules by fluorescent labeling.
3. *In silico* analysis (sequence comparison) of mitochondrial and chloroplast genes for identification of the loci for interspecific discrimination.

4. Immunostaining of nuclei, chloroplast and/or mitochondria.

Unit II: Basic and standardization Methods

1. Preparation of Acid & Alkali solutions and acid-base titration.
2. Concept of pH. Measuring pH of different solutions
3. Preparation of buffers: Acetate, Phosphate and Tris buffers.

Unit III: Estimation of micromolecules

1. Estimation of inorganic phosphate
2. Estimation of sugar (glucose)
3. Estimation of Amino acid (Tyrosine)
4. Estimation of Base (Guanine)

Unit IV: Estimation of macromolecules

1. Determination of Blue Value of Starch
2. Estimation of Proteins
3. Estimation of nucleic acids (DNA)

Unit V: Enzyme kinetics

1. Determination of Units and specific activity of an enzyme
2. Determination of Km and Vmax of an enzyme

(From above practicals, any 10 practicals will be taken)

Semester VIII/II

BZ 402: Metabolism and Human Physiology

Unit I: Basic concepts of Metabolism

Concept of catabolism and anabolism: metabolic strategies, organization, clustering of enzymes. Experimental approaches to study metabolism. Regulation of Metabolic Pathways: energy charge, phosphorylation potential etc.

Unit II: Carbohydrate metabolism

Glycolysis, glycogenolysis, gluconeogenesis, pentose phosphate pathway, glucoronic acid pathway (emphasis on regulation). The Citric acid cycle: Cyclic overview and reactions. Metabolic sources of acetyl CoA. Regulation and amphibolic nature of the cycle. Glyoxylate cycle. Dark reactions of Photosynthesis: CO_2 fixation: C3, C4 and CAM pathways.

Unit III: Lipid Metabolism

β-oxidation of unsaturated and saturated fatty acid and its regulation. Propoinyl coA metabolism, significance of ketone bodies, Biosynthesis of palmitate and its regulation. Mitochondrial and microsomal pathways of chain elongation, long term dietary changes and enzyme level. Metabolism of chloesterol: Biosynthesis of cholesterol and its regulation, lipoprotein metabolism, chylomicrons, LDL, HDL, VLDHL.

Unit IV: Amino acid metabolism

Transamination, deamination, Fate of amino acid skeleton, urea cycle, precursors for compounds other than proteins, Genetic diseases.

Unit V: Nucleotide Metabolism

Salvage and *de novo* pathways of purine and pyrimidine nucleotide biosynthesis. Formation of deoxyribonucleotides, origin of thymine

Unit VI: Physiology of Digestion

Structural organization and functions of gastrointestinal tract and associated glands; Mechanical and chemical digestion of food; Absorptions of carbohydrates, lipids, proteins, water, minerals and vitamins; Hormonal control of secretion of enzymes in Gastrointestinal tract.

Unit VII: Physiology of Respiration

Histology of trachea and lung; Mechanism of respiration, Pulmonary ventilation; Respiratory volumes and capacities; Transport of oxygen and carbon dioxide in blood; Respiratory pigments, Dissociation curves and the factors influencing it; Carbon monoxide poisoning; Control of respiration.

Unit VIII: Renal Physiology
Structure of kidney and its functional unit; Mechanism of urine formation; Regulation of water balance; Regulation of acid-base balance

Unit IX: Physiology of Heart
Structure of mammalian heart; Coronary circulation; Structure and working of conducting myocardial fibers. Origin and conduction of cardiac impulses Cardiac cycle; Cardiac output and its regulation, Frank-Starling Law of the heart, nervous and chemical regulation of heart rate. Electrocardiogram, Blood pressure and its regulation

Suggested Readings

1. *Biochemistry*, 3rd Ed. (2005), Voet Donald and Voet Judith G. John, Publisher: Wiley & sons,New York.
2. *Biochemistry* 6th Ed, (2007) Berg Jeremy, Tymoczko John, Stryer Lubert, Publisher: W. H. Freeman, New York.
3. *Lehninger's Principles of Biochemistry*, 4th edition, (2005) Nelson D. L. and Cox M. M. W. H. Freeman & Co. NY.
4. Berg, J.M., Tymoczko, J.L. and Stryer, L. (2007). *Biochemistry*, VI Edition, W.H. Freeman and Co., New York.
5. *Harper's Biochemistry*, 26th edition (2003) R.K. Murray, D.K. Granner, P.A. Mayes, V. W. Rodwell, Publisher-McGraw Hil
6. Guyton, A.C. & Hall, J.E. (2006). Textbook of Medical Physiology. XI Edition. Hercourt Asia PTE Ltd. W.B. Saunders Company.
7. Tortora, G.J. & Grabowski, S. (2006). Principles of Anatomy & Physiology. XI Edition John Wiley & sons,
8. Victor P. Eroschenko. (2008). diFiore's Atlas of Histology with Functional correlations. XII Edition. Lippincott W. & Wilkins.
9. Vander A, Sherman J. and Luciano D. (2014). Vander's Human Physiology: The Mechanism of Body Function. XIII Edition, McGraw Hills

BZ 404: Chordates and Animal Physiology

Unit I: Introduction
General characteristics and Classification of all phylum. Modern interpretation of origin of early chordate

Unit II: Integumentary system
Cell association, Glandular System

Unit III: Skeletal system
Origin of jaw and modification of jaw bones and types; functional and evolutionary significance. Jaw kinetics in relation to feeding

Unit IV: Circulation
Heart and circulation in fetal and neonatal mammal. Evolution of portal system

Unit V: Nervous system & Sense organ
Sensory receptors and classification. Organ of olfaction and taste.

Unit VI: Structural Adaptation
Structural elements of body and their properties. Mechanics of support and movement. Swimming adaptation. Cursorial adaptation. Flying mechanism.

Unit VII: Principles of animal physiology
Mechanistic and evolutionary approaches; Size and scaling of animals

Unit VIII: Physiological homeostasis
Positive and negative feedback, Controlled variable, Set point. Thermal physiology: Heat transfer mechanism between animal and environment. Supercooling, Anti-freeze compound, Behavioural thermoregulation, Pejus and Critical temperature, adaptational trend in subzero condition.

Unit IX: Physiology of behavior
Pheromones in colonial interactions, foraging and mating. Allelo-chemicals in Plant-Insect interaction

Suggested Readings

1. Young, J. Z. (2004). *The Life of Vertebrates*. III Edition. Oxford university press.
2. Pough H. *Vertebrate life,* VIII Edition, Pearson International.
3. Darlington P.J. *The Geographical Distribution of Animals*, R.E. Krieger Pub Co.
4. Tortora, G.J. & Grabowski, S. (2006). Principles of Anatomy & Physiology. XI Edition John Wiley & sons.
5. Victor P. Eroschenko. (2008). diFiore's Atlas of Histology with Functional correlations. XII Edition. Lippincott W. & Wilkins.

BZ 406: Biophysics and Bioethics

Unit I: Separation Techniques

Different methods of protein precipitation: Precipitation using inorganic salts (salting out) and organic solvents, isoelectric precipitation, Dialysis, Ultrafiltration, Lyophilization

Unit II: Chromatography

Basic principles of chromatography: Partition coefficient, concept of theoretical plates, various modes of chromatography (paper, thin layer, column), preparative and analytical applications, LPLC and HPLC. Different types of chromatography: Paper Chromatography, Thin Layer Chromatography. Molecular Sieve Chromatography, Ion Exchange Chromatography, Affinity Chromatography, Gas Liquid Chromatography

Unit III: Microscopy

Principles and applications of Microscopy, Fluorescence, Phase contrast, Confocal, Scanning and Transmission and Cryo- Electron microscopy.

Unit IV: Electrophoresis

Basic Principle of electrophoresis, Paper electrophoresis, Gel electrophoresis, discontinuous gel electrophoresis, PAGE, SDS-PAGE, PFGE, Native gels, denaturing gels, 2D gel, Isoelectric Focusing of proteins, agarose gel electrophoresis, buffer systems in electrophoresis, protein and nucleic acid blotting, detection and identification (staining procedures), molecular weight determination.

Unit V: Immunological techniques

Hybridoma technology, Phage display, Development of animal models for studying diseases

Unit VI: Analysis of protein-DNA and protein-protein interactions

Gel retardation assay, DNA foot-printing by DNase I and chemical methods, yeast one-hybrid assay, ChIP- chips. Yeast two hybrids, three-hybrids, split hybrids and reverse hybrids. Co-immunoprecipitations. GFP and FRET. Phage display.

Unit VII: Genome Editing

CRISPR-Cas9, Principle, Variations involved and applications

Unit VIII: Spectroscopy

Molecular spectroscopy, IR, ESR, FRET, Biomolecular fluorescence complementation assay, Mass spectrometry.

Unit IX: Radioisotopes

Radioisotopes and their use in biology and diagnostics, autoradiography, radioactive labeling of biological macromolecules.

Unit X: Bioethics

Philosophy and Theories of Bioethics; Clinical ethics; Research Ethics

Suggested Readings

1. Physical Biochemistry: Principles and Applications, 2nd edition (2009), David Sheehan, JohnWiley. ISBN-13: 978-0470856031.
2. Cell and Molecular Biology: Concepts and Experiments, 6th edition (2009), Gerald Karp, Wiley. ISBN-978-0470483374.
3. Gene cloning and DNA analysis, 6th edition (2010), T.A. Brown. Wiley-Blackwell ISBN-13: 978-1405181730.
4. Principles of Gene Manipulation and Genomics, 7th edition (2006), S.B. Primrose and R.M. Twyman. Blackwell Scientific ISBN: 978-1405135443.

5. Human Molecular Genetics, 3rd edition (2003), Tom Strachan and Andrew Read; Garland Science Publishers, ISBN -13:978-0815341826.
6. Immunology, 6th edition, (2006), J. Kuby, W.H. Freeman and Company, New York. ISBN-13: 978-1429202114.

BZ 408: Biostatistics & Bioinformatics

Unit I: Descriptive Statistics

a) Data in Biology: Development in biostatistics, samples and populations, techniques of sampling (random and stratified), sampling and non-sampling errors, variables in biology, univariate and bivariate frequency distributions
b) Measures of Central Tendency: means, mode, median and partition values.
c) Measures of Dispersion: Range, standard deviation, coefficient of variance and covariance.
d) Moments: Raw and central moments and their relationships.
e) Measures of Skewness: Pearson's coefficients of skewness; coefficient of skewness using moments. Measures of Kurtosis.

Unit II: Probability and Probability Distributions

a) Probability: Basic concepts, addition and multiplication rules of probability, conditional probability
b) Probability Distributions: Probability mass function, probability density function and distribution function. Binomial distribution, Poisson distribution, normal distribution and exponential distribution along with their properties and relationships.

Unit III: Correlation and Linear Regression

a) Correlation Analysis: Scatter diagrams, Pearson's and Spearman's coefficients of correlation, coefficient of determination, standard and probable errors.
b) Regression Analysis: Method of least squares, equations of lines of regression and their applications in biostatistics.

Unit IV: Hypothesis Testing

a) Sampling distributions and standard error, null and alternate hypothesis, basic concept and illustrations of type I and type II errors, concept of confidence interval estimation.
b) Student's t-distribution: test for single mean, difference of means and paired t- test, chi-square distribution: tests for goodness of fit, independence of attributes and homogeneity, F-distribution, one-way and two-way analysis of variance (ANOVA).

Unit V: Biological databases and genome browsers

Introduction to various databases and their classification (primary and secondary databases) e.g. NCBI, DDBJ, EMBL, ENSEMBL, UCSC and their uses

Unit VI: Sequence alignment

Local and global sequence alignments (Needleman-Wunsch and Smith-Waterman algorithms), pair-wise (BLAST and FASTA algorithms) and multiple sequence alignment (Clustal W) and its importance. Theory behind BLAST- how Hidden Markov Model (HMM), BLAST score, amino acid substitution matrices, s-value and e-value, p value.

Unit VII: Phylogenetic analysis

Basic concepts of phylogenetic analysis, rooted/uprooted trees, approaches for phylogenetic tree construction (UPGMA, Neighbor joining, Maximum parsimony, Maximum likelihood).

Unit VIII: Structure predictions for nucleic acids and proteins

Approaches for the prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models, Basic approaches for protein structure predictions, comparative modeling, fold recognition/threading and *ab-initio* prediction

Unit IX: Overview of drug development

Drug life cycle, stages of drug discovery and strategic issues in drug discovery. Lead Generation; HTS, clinical trials, characterization of binding site, virtual screening, protein-ligand interactions, prediction of pharmacological properties, Lipinski's rule of five, concept of energy minimization and force fields, introduction to rational drug design using example, Introduction to drug databases

Suggested Readings

1. Bioinformatics: Sequence and Genome analysis, 2nd edition (2004), David W. Mount, Cold Spring Harbour Laboratory Press. ISBN-13: 978-0879697129.
2. Bioinformatics: A practical guide to the analysis of genes and proteins, 3rd edition (2004), Andreas D. Baxevanis and B.F. Francis Ouellette, John Wiley and Sons. ISBN-13: 978-0471478782.
3. The Process of New Drug Discovery and Development, 2nd edition (2006), C.G. Smith and J.T. O"Donnell, Informa Healthcare, ISBN-13: 978-0849327797.
4. Cheminformatics (2003), J. Gasteiger, Thomas Engel; Wiley-VCH. ISBN: 9783527618279.
5. Molecular modeling - Principles and Applications, 2nd edition (2003), A. R. Leach, Pearson Education Limited, UK. ISBN 13: 9780582382107.
6. Cheminformatics in Drug Discovery (2006), edited by. T.I. Opera; Wiley Publishers, ISBN: 9783527604203.
7. Primer of Biostatistics, 7th edition (2011), Stanton Glantz, McGraw-Hill Medical. ISBN-13: 978-0071781503.
8. Biostatistics: A Foundation for Analysis in the Health Sciences, 10th edition (2013), Wayne W Daniel and Chad L. Cross, Wiley. ISBN-13: 978-1118302798.
9. Principles of Biostatistics, 2nd edition (2000), Marcello Pagano and KimberleeGauvrean, Thompson learning. ISBN-13: 978-0534229023.
10. Biostatistical Analysis, 5th edition (2009), Jerrold H. Zar, Pearson. ISBN-13: 978-0131008465.

BZ 492: Practical III (Metabolism and Chordates)

Unit I: Metabolism and Physiology

1. Determination of ABO Blood group.
2. Enumeration of red blood cells and white blood cells using haemocytometer.
3. Estimation of haemoglobin using Sahli's haemoglobinometer.
4. Preparation of haemin and haemochromogen crystals.
5. Recording of frog's heart beat under *in situ* and perfused conditions.*
6. Recording of blood pressure using a sphygmomanometer.
7. Examination of sections of mammalian oesophagus, stomach, duodenum, ileum, rectum liver, trachea, lung, kidney.
8. Estimation of total protein in given solutions by Lowry's method.
9. Detection of SGOT and SGPT or GST and GSH in serum/ tissue.
10. To study the enzymatic activity of Trypsin and Lipase.
11. Study of biological oxidation (SDH) [goat liver].
12. To perform the Acid and Alkaline phosphatase assay from serum/ tissue.
13. Dry Lab: To trace the labelled C atoms of Acetyl-CoA till they evolve as CO2 in the TCA cycle.

**Subject to UGC guidelines*

From above practicals, any 10 practicals will be taken

Unit II: Chordates & Animal Physiology

1. Study of following specimens:

Balanoglossus, Amphioxus, Petromyzon, Pristis, Hippocampus, Labeo, Icthyophis/Uraeotyphlus, Salamander, Rhacophorus Draco, Uromastix, Naja, Viper, model of Archaeopteryx, any three common birds-*(Crow, duck, Owl),* Squirrel and Bat.

2. Preparation of temporary mounts: Neurons and Blood film.
3. Preparation of haemin and haemochromogen crystals.
4. Estimation of haemoglobin using Sahli's haemoglobinometer.
5. Examination of permanent histological sections of mammalian oesophagus, stomach, duodenum, rectum, lung, kidney, thyroid, pancreas, adrenal, testis, ovary.

BZ 494: Practical IV (Biophysics and Bioinformatics)

Unit I: Biophysics

1. Effect of denaturation (heat/urea/guanidium chloride/BME) on UV absorption spectra of proteins.
2. Study of structural changes of proteins at different pH/solvent/temperature using UV spectrophotometry.
3. Analysis, identification and comparison of various spectra (UV, NMR, MS, IR) of simple organic compounds.

4. Separation of nucleotides/amino acids using TLC
5. Calculation of electrophoretic mobility
6. Study of autoradiographs

Unit II: Bioinformatics

1. Sequence alignment using BLAST and Clustal W.
2. Phylogenetic analysis using PHYLIP.
3. Microarray analysis using Bioconductor.
4. Molecular format conversion and hands-on molecular visualization program for displaying, animating and analyzing large bio-molecular systems using 3-D graphics.
5. Homology Modeling using SPDBV, model structure refinement using SPDBV and model validation using What Check and Pro Check.
6. Comparing structures, mutations, studying interactions creating electrostatic potential diagrams.
7. Virtual screening and molecular docking using AUTODOCK.

Unit III: Biostatistics

Computer-based practicals using any statistical software like 'R'. MATLAB, SPSS, Spreadsheets, etc. to understand the following concepts:

a. Graphical data representation
b. Measures of central tendency and dispersion
c. Probability and probability distributions: binomial, Poisson and normal distribution
d. Correlation and linear regression analysis
e. Student's t- test
f. Chi-square test
g. ANOVA

Semester IX/III

BZ 501: Immunology and Parasitology

Unit I: Fundamental concepts and anatomy of the immune system

Three fundamental concepts in immunology- specificity, self- and non-self- discrimination and memory. Components of innate and acquired immunity; Mechanisms of barrier to entry of microbes/pathogens; Phagocytosis; Complement and Inflammatory responses; Haematopoesis and its regulation; Organs and cells of the immune system; Lymphatic system; Lymphocyte circulation; Lymphocyte homing; Mucosal and Cutaneous associated Lymphoid tissue (MALT&CALT); Mucosal Immunity.

Unit II: Immune responses and signaling

Antigens, antigenicity and immunogenicity; non-peptide bacterial antigens and superantigens; B and T cell epitopes; haptens. Immunoglobulins- structure and function- classes & subclasses of immunoglobulins; antigenic determinants; immunoglobulin domains, concepts of variability, isotypes, allotypes and idiotypic markers. Immunoglobulin superfamily; B-cell receptor; B cell maturation; activation and differentiation; Generation of antibody diversity; T-cell maturation; activation and differentiation and T-cell receptors; Functional T Cell Subsets. Cell-mediated immune responses; ADCC; Cytokines- properties, receptors and therapeutic uses; The Complement systems- pathways for complement activation; Principles of cell signaling- MAP kinase and NF-κB; Kinetics of immune response; Cell-cell co-operation; Immune cell receptors; Cellular adhesion molecules.

Unit III: Genetic Organization

Immunoglobulin genes; VJ/VDJ rearrangements and genetic mechanisms responsible for antibody diversity, affinity maturation, allelic exclusion; Class switching; Major Histocompatibility Complex- MHC-I and MHC-II, genetic organization of H-2 and HLA. Antigen processing and presentation pathways.

Unit IV: Antigen-antibody interactions

Precipitation; agglutination and; Advanced immunological techniques- RIA; ELISA; Western blotting; ELISPOT assay; immunofluorescence; flow cytometry and immunoelectron microscopy; Surface plasma resonance; Biosensor assays for assessing ligand-receptor interaction; CMI techniques- lymphoproliferation assay; Mixed lymphocyte reaction; Cell Cytotoxicity assays; Apoptosis assay.

Unit V: Clinical Immunology

Immunity to Infection: Bacteria; viral; fungal and parasitic infections (with examples from each group); Hypersensitivity- Type I-IV; Autoimmunity; Types of autoimmune diseases; Mechanism and role of CD4+ T cells, MHC

and TCR in autoimmunity; Treatment of autoimmune diseases. Immunodeficiency-Primary and acquired immunodeficiency. Central and peripheral tolerance, and their mechanism; Mechanisms of autoimmunity.

Unit VI: Transplantation and tumor immunology
Transplantation- Immunological basis of graft rejection; Clinical transplantation and immunosuppressive therapy. Tumor immunology- Tumor antigens; Immune response to tumors and tumor evasion of the immune system, Cancer immunotherapy.

Unit VII: Vaccinology
Active and passive immunization; Live; killed; attenuated; sub unit vaccines; Vaccine technology- Role and properties of adjuvants; recombinant DNA and protein based vaccines; plant-based vaccines; reverse vaccinology; Peptide vaccines; conjugate vaccines; Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies; Catalytic antibodies and generation of immunoglobulin gene libraries

Unit VIII: Parasitology
Basic concept and overview of Host: Parasite relationship. Parasitic adaptations, interrelationships between host and parasite. Life history, Mode of infection, pathogenicity and control measures of the following parasites: *Plasmodium vivax, Entamoeba histolytica*, *Trypanosoma* spp. *Leishmenia* spp. *Fasciola hepatica*, *Ascaris lumbricoides*. Parasitic adaptation of *Fasciola*, *Taenia* and *Ascaris*. Vectors: Examples, structures associated with disease transmission and names of diseases transmitted by fleas, ticks and mosquitoes.

Suggested Readings

1. Kuby Immunology by Kindt TJ, Goldsby RA, Osborne BA, Kuby J: 6th edition. New York. WH Freeman; 2006.
2. Cellular and Molecular Immunology by Abbas AK, Lichtman AH, Pillai S: Saunders Elsevier; 2007.
3. Immunobiology: The immune system in health and disease by Janeway CA, Travers P, Walport M, Shlomchik MJ: 6th edition. New York. Garland Science Publishing; 2005.
4. Fundamental Immunology by Paul WE: 4th edition. New York. Raven Press; 2000.
5. Roitt's Essential Immunology by Delves PJ, Martin SJ, Burton DR, Roitt IM; 11th edition. Blackwell Publishing/Oxford Univ. Press; 2006.
6. Anderson RM, May RM. (1985) Helminth infections of humans: mathematical models,population dynamics, and control. *Adv Parasitol.:*1-101.
7. Cox F. E. G. (1993) *Modern Parasitology: A Textbook of Parasitology*.
8. Chatterjee (1967) K. D. *Parasitology: Protozoology & Helminthology*.
9. Gardner MJ et al (2002) Genome sequence of the human malaria parasite *Plasmodium falciparum Nature* 419:498-511.
10. Ivens AC et al. (2005) The genome of the kinetoplastid parasite, *Leishmania major. Science.* 309:436-42.

BZ 503: Evolution and Animal Behaviour

Unit I: Natural Selection and Adaptation
Ascent of Darwinism and Synthetic Darwinism. Methods of studying natural selection and Models of selection. Recognizing adaptation; Punctuated equilibrium and stasis

Unit II: Evolutionary Process
Mechanisms producing genetic diversity (mutation, migration and genetic drift). Phenotypic variation and plasticity. Molecular evolution; Speciation

Unit III: Gene Frequencies in Population
The Hardy-Weinberg principle and analysis of gene frequencies in natural population. Major factors influencing gene frequencies (migration, inbreeding), effects of selection and mutation on gene frequencies

Unit IV: Patterns and trends in evolution
Constructing evolutionary trees, measures of genetic relationship among organisms. Tools of studying human evolution. Cultural evolution

Unit V: Species and Speciation
Genetic basis of species difference and reproductive barriers. Evolution of interaction among species

Unit VI: Introduction to animal behaviour
Origin and History of animal behavior. Genes and Behaviour. Different types of behavior-Orientation, Reflexes; Instinct vs. Learnt Behaviour; Associative learning, classical and operant conditioning, Habituation, Imprinting.

Unit VII: Cooperation and conflict
Range of cooperative behavior and theories of cooperation, Kin selection. Elaborate ornaments: Fisher's hypothesis and Handicap hypothesis. Conflict over mate choice, Parental care.

Unit VIII: Foraging
Optimal foraging theory. Foraging and predation risk: defense strategies against predators. Territoriality and Group foraging.

Unit IX: Aggression
Aggressive behavior; Game theory models and strategies – Prisoners' dilemma and reciprocal altruism and evolution of sociality.

Suggested Readings

1. Evolution, Barton, N. H., Briggs, D. E.G., Eisen, J. A., Goldstein, A. E., Patel, N. H., Cold Spring Harbor Laboratory Press, New York, USA
2. Evolution, Hall, B. K. and Hallgrimsson, B., Jones and Bartlett Publisher, Sudbury,USA.
3. Evolution, Futuyma, D. J., Sinauer Associates, Inc., Sunderland, USA.
4. What Evolution Is, Mayr, E., (2001), Basic Books, New York, USA.
5. Mechanism of Animal Behaviour, Peter Marler and J. Hamilton; John Wiley & Sons, USA.
6. Animal Behaviour, David McFarland, Pitman Publishing Limited, London, UK.
7. Animal Behaviour, John Alcock, Sinauer Associate Inc., USA.
8. Perspective on Animal Behaviour, Goodenough, McGuire and Wallace, John Wiley & Sons, USA.
9. Exploring Animal Behaviour, Paul W. Sherman & John Alcock, Sinauer Associate Inc., Massachusetts, USA.
10. An Introduction to Animal Behaviour, A. Manning and M.S Dawkins, Cambridge University Press, UK.

BZ 505: #Genetics and Genomics

Unit I: Overview of changing paradigms in genetics
A brief overview of how genetic principles took shape, leading to the concept of a blueprint of life within the cell to the physical entity of DNA. Also mention the surprises we have from the genomics such as genetic variation between individuals. There are popular videos/presentations that can be used. The purpose is to ignite the curiosity of the students.

Unit II: Concept of genetic inheritance
Concept of alleles, haploid and diploid status, phenotype and genotype: Mendel's laws of inheritance, dominant and recessive inheritance, test, back and reciprocal crosses with two examples each.

Unit III: Physical basis of inheritance
Chromosomal theory of inheritance, concept of linkage and crossing over, cytological proof of crossing over, genetic mapping: two and three point-cross over. Distinguishing recombination and complementation. Allelic interactions-dominance relationships- complete, incomplete and co-dominance, gene-gene interaction.

Unit IV: Extra nuclear inheritance
Criteria for extra nuclear inheritance**,** plastid inheritance in *Mirabilis jalapa*, kappa particles in *Paramecium*, maternal effect- snail shell coiling, cytoplasmic inheritance (mitochondria and chloroplast).

Unit V: Mutation
Concept of selection with examples from bacteria, prototrophy and auxotrophy, spontaneous and induced mutations, types of mutations- point, (non-sense, missense, frame shift, insertion, deletion), use of mutants to study gene functions, effects on the gene product- loss of the function and gain of function. Distinction between mutation and polymorphism.

Unit VI: Transposable genetic elements
Prokaryotic transposable elements- IS elements, Composite transposons; Eukaryotic transposable elements- Ac-Ds system in maize; Uses of transposons.

Unit VII: Analysis of genetic inheritance in human
Gathering family history, pedigree symbols and construction of pedigrees. Patterns of inheritance for monogenic traits and risk assessment with examples for autosomal inheritance-dominant, recessive, sex-linked inheritance, sex-limited and sex-influenced traits, mitochondrial inheritance.

Unit VIII: Genome Organization and Cytogenetics
Organization of Genomes in Prokaryotes and Eukaryotes, Establishing the central Dogma, Nucleosomes organization and assembly, Regulation of chromatin structure. Euchromatin, Heterochromatin- constitutive and facultative heterochromatin.
Karyotyping- banding pattern and nomenclature (G and Q banding), common syndromes due to numerical chromosome changes, common syndromes due to structural alterations (translocations, duplications, deletions)

Unit IX: Introduction to chromosomal basis of sex determination
Chromosomal theory of sex determination, mechanisms of sex determination, environmental factors and sex determination in human and *Drosophila*, Barr bodies, dosage compensation.

Unit X: Population genetics
Gene pool and gene frequency, Hardy Weinberg law and its application for calculating allelic and genotype frequencies.

Suggested Readings

1. Principles of Genetics, 6th edition (2011), Snustad DP and Simmons MJ, John Wiley and Sons, Inc; ISBN-13: 978-0470903599
2. Human Molecular Genetics, 3rd edition (2003) by Tom Strachan and Andrew Read; Garland Science Publishers, ISBN -13: 978-0815341826.
3. Concepts of Genetics, 10th edition, (2011). William S. Klug, Michael R. Cummings, Charlotte A. Spencer, Michael A. Palladino; Pearson Education, ISBN-13: 978-0321724120.
4. Principles of Genetics, 8th edition (2005), Gardner EJ, Simmons MJ, Snustad DP. John Wiley and Sons, Inc. ISBN-13: 978-9971513467.
5. An introduction to Genetic Analysis, 10th edition (2010), Griffith AJF, Miller JH, Suzuki DT, Lewontin RC, Gelbert WM., W. H. Freeman and Co. New York. ISBN-13: 978-429229432.
6. Principles of Genetics, 6th edition (1998), Robert H. Tamarin Publisher: William C Brown Pub; ISBN-13: 978-0697354624.

BZ 507: #Molecular Biology

Unit I: Genetic material
The structure of DNA and RNA; Melting of DNA, Superhelicity, Comparative Organization and features of Microbial Genomes and Eukaryotic Genomes

Unit II: DNA replication
Arrangement of replicons in a genome, Various modes of replication, continuous, discontinuous synthesis, various replication Enzymes, Replication Fork and priming, leading and lagging strand, elongation, termination, Plasmid replication, specific features of replication in Prokaryotes and Eukaryotes, action of topoisomerases, Telomere maintenance and Chromatin Assembly, Single stranded DNA replication, Relationship between DNA replication and cell cycle, DNA copy number maintenance.

Unit III: Recombination and Repair of DNA
DNA repair and recombination, DNA Mismatch Repair, Double Strand Break Repair, Recombination as a molecular biology tool

Unit IV: Transcription
Transcription machinery of prokaryotes, various transcription enzymes and cofactors, initiation, elongation and termination, sigma factors, Transcription machinery of eukaryotes, various forms of RNA polymerase and cofactors, initiation, elongation and termination, promoters, enhancers, silencers, activators, effect of chromatin structure, regulation of transcription.

Unit V: Post-transcriptional processes
RNA processing, splicing, capping and polyadenylation, rRNA and tRNA processing, RNA Editing; RNAi and miRNAs, Antisense RNA, Post-transcriptional gene regulation

Unit VI: Operon
Gene structure, concept of Operon, Lac and Trp operon, organization and role in regulation of expression

Unit VII: Translation
The genetic code and protein structure, Mechanisms of translation in prokaryotes, Mechanisms of translation in eukaryotes, initiation complex, ribosomes and tRNA, factors, elongation and termination, *in vitro* translation systems, polycistronic/ monocistronic synthesis, Regulation of translation, RNA instability, inhibitors of translation, stringent response in bacteria

Unit VIII: Post-translational processes
Protein modification, folding, chaperones, transportation; The Signal Hypothesis, proteosome

Unit IX: Genes and behavior
Human Genome Project, Genome analysis, DNA typing, Genomics and beyond

Suggested Readings

1. Gene IX by Benjamin Lewin, Jones and Bartlett Publishers, Sudbury, Massachusetts, 2007.
2. Molecular Biology by R.F. Weaver , 4th edition, McGraw Hill. New York. USA, 2007.
3. Molecular Biology of the Gene by J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick, 6th edition, Benjamin Cummings, San Francisco, USA, 2007.
4. Molecular Biology of the Cell by B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P. Walter, 5th edition, Garland Science, New York and London, 2007.
5. Biochemistry (5th edition) by J.M. Berg, J.L. Tymoczko, L. Stryer, W.H. Freeman and Company, New York, USA, 2008.
6. Current Protocols in Molecular Biology Edited by: Fred M. Ausubel; Roger Brent; Robert E. Kingston; David D. Moore; John A. Smith; Kevin Struhl, John Wiley and Sons, Inc. 2007

BZ 591: Practical V (Immunology and Evolution)

Unit I: Immunology and Parasitology

A. Immunology Practicals

1. Selection of animals, preparation of antigens, immunization and methods of bleeding, serum separation, storage.
2. Antibody titre by ELISA.
3. Double diffusion, immuno-electrophoresis and radial Immuno diffusion.
4. Complement fixation test.
5. Isolation and purification of IgG from serum or IgY from chicken egg.
6. SDS-PAGE, Immunoblotting, Dot blot assays.
7. Agglutination test, precipitation assay.
8. Blood smear identification of leucocytes by Giemsa stain
9. Separation of leucocytes by Dextran density gradient method
10. Separation of mononuclear cells by Ficoll-Hypaque.

B. Parasitology Practicals

1. Smear preparations and staining of the gut contents of cockroach and seminal vesicle of earthworm for Protozoan parasites.
2. Collection of helminth, parasites from vertebrates (Goat and Fowl), their fixation, staining and identification.
3. Identifications (systematic position and specimen characters only) and clinical importance: Entamoeba, Plasmodium vivax, Leishmania, Ascaris (male and female), Wuchereria and Ancylostoma.

Unit II: Evolution and Animal Behaviour

1. Isolation of Genomic DNA from a bacterium and its quantification.
2. Designing primers for 16S rRNA gene sequence.
3. Amplification of 16S rRNA gene sequences by using genomic DNA as well as by colony boiling method.
4. Purification of 16S rRNA gene.
5. Sequence of 16S rRNA gene; editing the sequence, multiple alignments, construction of phylogenetic trees and interpretation of result.
6. To study the responses of woodlice to hygrostimuli.
7. To study the geotaxis behaviour of earthworm.
8. To study the orientational responses of 1st instar noctuid larvae to photo stimuli.

9. To study the median threshold concentration of sucrose solution in eliciting feeding responses of housefly.
10. To study the orientational responses of larvae to volatile and visual stimul

BZ 593: Practical VI (Genetics and Biophysics)

Unit I: Genetics

1. Observation of wild type and mutant phenotypes in *Drosophila.*
2. Preparation of culture media for *Drosophila* and study different stages of life cycle of *Drosophila.*
3. Verification of Mendelian laws through *Drosophila* / seeds – dominant, recessive and sex-linked
4. Preparation of Barr body.
5. Karyotyping with the help of photographs (normal and abnormal karyotypes).
6. Pedigree charts of some common characters like blood group, color blindness and PTC tasting.
7. Study of polyploidy in onion root tip by colchicine treatment.

Unit II: Molecular Biology

1. Restriction digestion analysis by agarose gel electrophoresis.
2. Restriction digestion analysis by polyacrylamide gel electrophoresis.
3. Isolation of plasmid DNA from minicultures.
4. Isolation of plasmid from maxicultures.
5. Isolation of genomic DNA.
6. Cloning of a DNA fragment

(*Wherever wet lab experiments are not possible the principles and concepts can be demonstrated through any other material or medium including videos/virtual labs etc.)*

Semester X/IV

BZ 502: Insects and Aquatic Biology

Unit I: Insect classification

Major order with characters and examples

Unit II: Physiology of Insects

Food and digestion, feeding potential of insects in response to food availability. Excretory mechanism of insects with special reference to Cryptonephridial mechanism. Tracheal and plastron respiration of insects.

Unit III: Immune system

Insect immune defense, Insect-plant interaction

Unit IV: Metamorphosis

Metamorphosis, diapauses and their interrelationship and regulation

Unit V: Atypical modes of reproduction

Unit VI: Stridulation

Stridulation and its biological significance; Bioluminescence

Unit VII: Aquatic Biology

Characteristics and biodiversity of Freshwater, Estuarine and Marine ecosystems. Bioresources and Bioactive compounds from estuarine and Marine resources. Metapopulation and Metacommunity approaches for fish assemblages, Coarse and Fine filter methods for conservation of aquatic bioresources.

Unit VIII: Fish Nutrition

Fish Nutrition- Stages of Nutrient Acquisition, Temporal pattern of nutrient acquisition, Integration of nutrient acquisition – compartment models, gut-reactor model, state space model, nutritional requirement of cultivable fish and prawn, nutritional bioenergetics, energy efficiency in fish production, Feeding schedules and ratio, feed performance, feed formulation, processing, storage and application, Fish growth estimation.

Unit IX: Fish Pathology and Defense mechanism

Factors of fish health and integrated health management, Infection and Immune responses to pathogens in environment – Transformation of infection into disease, cells and tissues of the immune system of fish – cellular and humoral defenses, Cells and tissues of the immune system of fish – cellular and humoral defenses, Immunomodulation- exogenous and endogenous factors.

Unit X: Aquaculture

Brief account of Sustainable technology for Aquaculture (Freshwater, Estuarine and Mariculture), Advancements in technology for finfish and shellfish culture, Modern hatcheries and management, Technology of stock improvement – cryopreservation, hybridization, polyploidy and transgenesis, xenogenesis, sex reversal and breeding. Principles and design of Raceway, cages and Pen enclosures, Recirculating systems, Intensive Fish Hub, Integrated Aquaculture.

Unit XI: Genetic conservation

Gene banking and maintaining genetic quality

Suggested Readings

1. A general text book of entomology, Imms. A. D., Chapman & Hall, UK.
2. Introduction to the study of insects, Borror, D. J., Triplehorn, C. A., and Johnson, N. F.,M Saunders College Publication, USA.
3. Principles of Insect Morphology, Snodgrass, R. E., Cornell Univ. Press, USA
4. The Insect Societies, Wilson, E. O., Harward Univ. Press, UK
5. Host Selection by Phytophagous insects, Bernays, E. A., and Chapman, R. F., Chapman and Hall, New York, USA
6. Insect Plant Biology, Schoonhoven, L. M., van Loop, J. A., & Dicke. M. Pub. Oxford Univ. Press. USA.
7. Computers in Fisheries Research, Megrey, B. A. and Moksness, E. (2009), Springer, USA.
8. Biological Invasions in Marine Ecosystems Ecological, Management and Geographic Perspectives. Rilov, G. and Jeffrey, A. C. (2009), Springer-Verlag, GERMANY.
9. Handbook of Fisheries and Aquaculture, Indian Council of Agricultural Research, ICAR, (2006), DIPA, New Delhi, INDIA

#BZ 504: Developmental Genetics

Unit I: Basic concepts of development

Potency, commitment, specification, induction, competence, determination and differentiation; morphogenetic gradients; cell fate and cell lineages; stem cells; genomic equivalence and the cytoplasmic determinants; imprinting; mutants and transgenics in analysis of development.

Unit II: Model systems

Vertebrates model organism- *Xenopus laevis*, chicken, mammals, zebrafish; invertebrate model organism- *Drosophila melanogaster*, *Caenorhabditis elegans*; Identification of developmental genes: spontaneous and induced mutation, mutant screening, developmental mutations in *Drosophila*.

Unit III: Gametogenesis, fertilization and early development:

Production of gametes; Structure of the gametes- the sperm, the egg; Cell surface molecules in sperm-egg recognition in animals; fertilization; zygote formation, cleavage, blastula formation, embryonic fields, gastrulation and formation of germ layers in animals; embryogenesis.

Unit IV: Morphogenesis and organogenesis in animals

Cell aggregation and differentiation in *Dictyostelium*; axes and pattern formation in *Drosophila*, amphibia and chick; organogenesis- vulva formation in *Caenorhabditis elegans*, eye lens induction, limb development and regeneration in vertebrates; differentiation of neurons, post embryonic development- larval formation, metamorphosis; environmental regulation of normal development; sex determination.

Unit V: Axis specification in *Drosophila*

Role of maternal genes, patterning of early embryo by zygotic genes- gap genes, pair– rule genes, segment polarity genes, homeotic selector genes- bithorax and antennapedia complex.

Unit VI: Genetics of organogenesis

Development and patterning of vertebrate limb, homeobox genes in patterning, signaling in patterning of the limb; Insect imaginal discs–organizing center in patterning of the leg and wing, the homeotic selector genes for segmental identity; insect compound eye.

Unit VII: Postembryonic development
Growth, cell proliferation, growth hormones; aging- genes involved in alteration in timing of senescence.

Unit VIII: Regeneration
Epimorphic regeneration of reptile (salamander) limb; Morphollaxis regeneration in hydra; embryonic stem cells and their applications.

Unit IX: Medical implications of developmental biology:
Genetic errors of human development- the nature of human syndromes– pleiotropy, genetic heterogeneity, phenotypic variability, mechanism of dominance; gene expression and human disease– inborn errors of nuclear RNA processing, inborn errors of translation; teratogenesis environmental assaults on human development- teratogenic agents like alcohol, retinoic acid etc.

Suggested Readings

1. Developmental Biology: Scott F Gilbert [Latest edition].
2. Essentials of Developmental Biology: JMW Slack [Latest edition]
3. Principles of Development: Louis Wolpert [Latest edition].
4. S.F. Gilbert, Developmental Biology, Sinauer Associates Inc. Massachusetts
5. Ethan Bier, 'The Coild Spring' Coild Spring Harbor Laboratory Press New York Karp G, and Berrill N.J., Development
6. B.I. Balinsky, An introduction to Embryology, Saunders College Publishing
7. Lewis Wolpert, Principles of Development, Current Biology Ltd., London, New York.

BZ 592: Practical VII (Aquatic Biology and Developmental Genetics)

Unit I: Aquatic Biology

1. **Morphology**:
   a. Study of head and its sclerites of *Dysdercus*, honeybee, grasshopper and cockroach
   b. Mounting and display of mouth parts of *Dysdercus*, housefly, honeybee, mosquito and butterfly.
   c. Wings and their venation. Different types of antennae and legs of insects.
   d. Mounting of stinging apparatus of honey bee.
2. **Taxonomy**:
   a. Identification of insects up to super families.
   b. Collection, preservation and identification of insects. Field studies ofinsects.
3. **Social Insects**:
   a. Morphological and anatomical studies of various castes of *Polistes, Apis, Camponotus, and Odontotermes*.
   2. Collection of various types of social insects and their nests. Sting apparatus of honey bee.
4. Identification of Indian common fish faunal resources from cold water, warm water, brackish water, marine water and ornamental fishes.
5. Physico- chemical parameters of freshwater bodies.
6. Biological analysis of water and estimation of primary productivity.
7. Collection of phytoplankton and zooplankton from natural resources and their identification.
8. Study of benthic macroinvertebrates in natural water bodies.
9. Study of fishing gears and nets with the help of models.
10. Simulated experiments on population enumeration.
11. Salinity tolerance in select fishes.
12. Determination of age and growth; gonadosomatic index.
13. Length-weight relationship and condition factor determination.
14. Experiments on chemoreception using different attractants and repellents.
15. Toxicity testing with zooplankton/fish.
16. Visit to a coastal/ mariculture farm and study the socio-economic status of the fisherman community

Unit II: Developmental Genetics

1. Study of life cycle of *Drosophila melanogaster.*

2. Study of embryogenesis in *Drosophila* and pattern of gene expression in embryogenesis by *in situ* hybridization technique.
3. Immunohistochemical staining to study the expression pattern of gap and pair rule gene proteins.
4. Dissection and study of larval and prepupal wing, leg and eye antennal imaginal discs of *Drosophila.*
5. Patterning of the adult wing and demonstration of the effect of cell death on the patterning of the adult wing.
6. Study of Homeotic gene mutations.
7. Influence of temperature and teratogenes on animal development.
8. Study of regeneration in *Hydra.*

BZ 562: Project Work/Dissertation

The students would be required to undertake a Dissertation Project Work under the faculty based on their preference, such that total students are equally distributed amongst the faculty. The allotment of students would be done at the beginning of 3rd Semester and evaluation would be done at the end of 4th Semester. Dissertation evaluation would comprise of the following

Continuous Evaluation	: 40	
Report		: 30
Presentation & Viva		: 30

Students can do part of their Project work outside Aliah University, subject to approval from concerned authority.
External members may be invited, subject to approval from concerned authority.

BZ 572: Comprehensive Viva

The Viva would involve an overall assessment of students jointly by all the faculty members.
External members may be invited, subject to approval from concerned authority.

BZ 582: Field trip / Industrial Visit

A mandatory visit to any of the following

f) Natural Park
g) Botanical garden
h) Zoological Park
i) Relevant industry
j) Research Labs at Institutes of National importance

Students would be required to submit a report of their visit which would be evaluated.

Syllabus for MSc Microbiology

Department of Biological Sciences, Aliah University, Kolkata
Draft Syllabus for MSc Microbiology
(As part of Integrated BSc-MSc Biological Sciences with Lateral Entry at MSc)

Specialization: Microbial Biotechnology

Sem	Code	Paper Name	LTPC**	Marks/Credit
VII/I	BM 401	Prokarya	60	50/4
	BM 403	Acellular world and Eukarya	60	50/4
	BM 405	Cell Biology	60	50/4
	BM 407	Principles of Biochemistry	60	50/4
	BM 491	Practical I (Prokarya and Eukarya)	60	50/4
	BM 493	Practical II (Cell Biology and Biochemistry)	60	50/4
			Total	300/24
VIII/II	BM 402	Microbial Physiology & Metabolism	60	50/4
	BM 404	#Microbial Genetics	60	50/4
	BM 406	Biophysics and Bioethics	60	50/4
	BM 408	Biostatistics & Bioinformatics	60	50/4
	BM 492	Practical III (Metabolism and Genetics)	60	50/4
	BM 494	Practical IV (Biophysics and Bioinformatics)	60	50/4
				300/24
IX/III	BM 501	Immunobiology	60	50/4
	BM 503	#Genetic Engineering	60	50/4
	BM 505	Microbial Pathogenicity	60	50/4
	BM 507	Molecular Biology	60	50/4
	BM 591	Practical V (Immunobiology and Genetic Engg)	60	50/4
	BM 593	Practical VI (Microbial Pathogenicity and Molecular Biology)	60	50/4
			Total	300/24
X/IV	BM 502	#Food and Industrial Microbiology	60	50/4
	BM 504	Environmental Microbiology	60	50/4
	BM 592	Practical VII (Applied Microbiology)	60	50/4
	BM 562	Project Work/Dissertation	120	100/8
	BM 572	Comprehensive Viva	30	25/2
	BM 582	Field trip/Industrial visit	30	25/2
			Total	300/24

**Lecture Taken Per Course
#Specialized paper

Semester VII/I

BM 401: Prokarya

Unit I: Evolutionary Microbiology

Origin of basic bio-molecules, Abiotic synthesis of organic monomers and polymers; concept of Oparin & Haldane; Experiment of Miller (1953); origin of first cell; Evolution of prokaryotes; Endosymbiosis and Origin of eukaryotic cells; origin of unicellular & multicellular organisms. The evolutionary time scale; eras, periods and epoch; major events in the evolutionary time scale. History and major events in the development of microbiology.

Unit II: Microbial cellular details

Cell size, shape and arrangement, Cell-wall: Composition and detailed structure of Gram-positive and Gram-negative cell walls, Archaebacterial cell wall, Gram and acid fast staining mechanisms, lipopolysaccharide (LPS), sphaeroplasts, protoplasts, and L-forms. Effect of antibiotics and enzymes on the cell wall. Cell Membrane: Structure, function and chemical composition of bacterial and archaeal cell membranes; glycocalyx, capsule, flagella, endoflagella, fimbriae and pili. Cytoplasm: Ribosomes, mesosomes, inclusion bodies, nucleoid, chromosome and plasmids Endospore: Structure, formation, stages of sporulation. Motility and taxis (Chemotaxis, Phototaxis, magnetotaxis.)

Unit III: Prokaryotic diversity

Estimates & indices of diversity. Culture dependent and independent methods for exploring diversity. Prokaryotic taxonomy - classical and modern (polyphasic). Prokaryote and eukaryote species concept. Diversity, Occurrence, characteristics and potential application of Major groups of *Bacteria* and *Archaea.* Extremophiles and their mechanism of resistance.

Unit IV: Microbiological techniques

Pure culture isolation: Streaking, serial dilution and plating methods; cultivation; principles and techniques of maintenance and preservation/stocking of pure cultures; synchronous and asynchronous culture, batch, fed batch and continuous culture; cultivation of anaerobic bacteria; assessing non-culturable bacteria.

Unit V: Nutrition and Growth

Nutritional requirements in bacteria and nutritional categories; Culture media: components of media, natural and synthetic media, chemically defined media, complex media, selective, differential, indicator, enriched and enrichment media. Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation. Chemical methods of microbial control: disinfectants, types and mode of action. Methods of prokaryotic cell division (Proteins involved; molecular aspects), Definitions of growth, logarithmic representation of bacterial populations, phases of growth, calculation of generation time and specific growth rate, measurement of microbial growth, diauxic growth curve. Environmental and nutritional factors affecting growth.

Suggested Readings

1. Tortora GJ, Funke BR and Case CL. (2008). Microbiology: An Introduction. 9th edition. Pearson Education
2. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms.14th edition. Pearson International Edition
3. Cappucino J and Sherman N. (2010). Microbiology: A Laboratory Manual. 9th edition. Pearson Education Limited
4. Wiley JM, Sherwood LM and Woolverton CJ. (2013) Prescott's Microbiology. 9thEdition. McGraw Hill International.
5. Atlas RM. (1997).Principles of Microbiology.2nd edition. W M. T. Brown Publishers.
6. Pelczar MJ, Chan ECS and Krieg NR.(1993). Microbiology.5th edition. McGraw Hill Book Company.
7. Stanier RY, Ingraham JL, Wheelis ML, and Painter PR. (2005). General Microbiology. 5th edition. McMillan.

BM 403: Acellular world and Eukarya

Unit I: Nature and Properties of Viruses

Discovery of viruses, nature and definition and distinctive properties of viruses. Theories of viral origin. Structure of viruses: capsid symmetry, enveloped and non-enveloped viruses. Types of envelope and their composition. Isolation, purification and cultivation of viruses; assay of plant, animal and bacterial viruses. Viral taxonomy: Classification and nomenclature of different groups of viruses. Concept of viroids, virusoids, satellite viruses and prions.

Unit II: Bacteriophages

Diversity, classification, one step multiplication curve. Details of lytic and lysogenic phages: lambda, T4, T7, M13, lytic cycle, lysogeny, viral replication, nucleic acid and protein synthesis - concept of early and late proteins. Regulation of transcription in lambda phage - molecular mechanism of lytic-lysogenic conversion.

Unit III: Plant and Animal Viruses
Modes of viral propagation: persistent, non-persistent, vertical and horizontal. Salient features of viral nucleic acids; diversity and classification of plant and animal viruses. Interaction of viruses with cellular receptors and entry into the cell. Multiplication, replication maturation and release strategies of different plant (TMV) and animal (Adenovirus, Retrovirus, Hepatitis viruses, Herpes virus, Influenza virus; vaccinia, Ebola virus, Encephalitis etc.) viruses. Assembly, budding, maturation and cellular trophism of HIV; molecular biology of genetic shift and drift in influenza virus. Oncogenic viruses and their roles in cancer.

Unit IV: Algae
Algal Diversity, distribution, nutrition, mode of reproduction, Life cycle patterns, ecological significance of major algal taxa. Phycotoxins, economic importance including role in agriculture and human affairs -algal pigments, biofuels, hydrogen production, important bioactive molecules, role of algae in sustainable environment.

Unit V: Fungi
Fungal Diversity, modes of reproduction, ecological significance, mycotoxins, fungal associations with algae (lichens), plants (endophytes, mycorrhizal fungi), animals and humans. Economic importance, Secondary metabolites from fungi.

Unit VI: Eukaryotic Microorganisms
Host parasite interactions. Classification of Protozoa, general biology of protozoal cell, process of reproduction in common protozoal classes, importance of protozoa in soil and water ecosystems. Important human and veterinary parasites, life cycle and biology of *Plasmodium, Entamoeba, Leishmania, Wuchereria, Fasciola, Schistosoma*.

Suggested Readings

1. Tortora GJ, Funke BR and Case CL. (2008). Microbiology: An Introduction. 9th edition. Pearson Education
2. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms.14th edition. Pearson International Edition
3. Cappucino J and Sherman N. (2010). Microbiology: A Laboratory Manual. 9th edition. Pearson Education Limited
4. Wiley JM, Sherwood LM and Woolverton CJ. (2013) Prescott's Microbiology. 9th Edition. McGraw Hill International.
5. Atlas RM. (1997).Principles of Microbiology.2nd edition. WM.T.Brown Publishers.
6. Pelczar MJ, Chan ECS and Krieg NR. (1993). Microbiology.5th edition. McGrawHill Book Company.
7. Stanier RY, Ingraham JL, Wheelis ML, and Painter PR. (2005). General Microbiology. 5th edition. McMillan.

BM 405: Cell Biology

Unit I: Structure of Cell
Plasma membrane: Structure and transport of small molecules; Cell Wall: Eukaryotic cell wall, Extracellular matrix; Cytoskeleton: Structure and organization of actin filaments, association of actin filaments with plasma membrane, cell surface protrusions, intermediate filaments, microtubules. Mitochondria, chloroplasts, lysosomes and peroxisomes; Nucleus: Nuclear envelope, nuclear pore complex, nucleolus and nuclear lamina; Chromatin; Endoplasmic Reticulum and Golgi Apparatus.

Unit II: **Cell signaling**
Hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component systems, light signaling in plants, bacterial chemotaxis and quorum sensing.

Unit III: **Cellular communication**
Regulation of hematopoiesis, general principles of cell communication, cell adhesion and roles of different adhesion molecules, gap junctions, extracellular matrix, integrins, neurotransmission and its regulation.

Unit IV: **Cell cycle and cancer**
Cell cycle and its regulation, Genetic rearrangements in progenitor cells, oncogenes, tumor suppressor genes, cancer and the cell cycle, virus-induced cancer, metastasis, angiogenesis, interaction of cancer cells with normal cells, apoptosis, autophagy, therapeutic interventions of uncontrolled cell growth.

Suggested Readings

1. Cell and Molecular Biology: Concepts and Experiments, 6th edition (2009), Gerald Karp, Wiley. ISBN-978-0470483374.
2. The World of the Cell, 7th edition (2008), Becker, Kleinsmith, Hardin and Bertoni. Benjamin Cummings, ISBN-13: 978-0805393934.
3. The Cell: A Molecular Approach, 6th edition (2013), Cooper and Hausman; Sinauer Associates, Inc. ISBN-13:978-1605351551.
4. Essential Cell Biology, 7th edition (2009), Alberts, Bray, Hopkin, Johnson, Lewis, Raff, Roberts and Walter. Garland Science. ISBN-13:978-0815341291.
5. Molecular Cell Biology, 7th edition (2012), Lodish, Berk, Kaiser, Krieger, Bretscher, Ploegh, Amon and Scott. W. H. Freeman. ISBN-13: 978-1429234139.

BM 407: Principles of Biochemistry

Unit I: Introduction

Chemical basis of life; Water, structure of liquid water, water as ideal biological solvent; Principles of biophysical chemistry- pH, buffer, reaction kinetics, colligative properties; Henderson-Hasselbalch equation. Biomolecular hierarchy; Macromolecules; Molecular assemblies; Stablizing interactions- Van der Waals, electrostatic, hydrogen bonding, hydrophobic interaction etc. Thermodynamics- Laws of thermodynamics, free energy, entropy, high energy bonds.

Unit II: Carbohydrates

Sugars; monosaccharides- aldoses and ketoses, trioses, tetroses, pentoses, and hexoses. Stereoisomerism of monosaccharides- epimers, anomers, mutarotation. Furanose and pyranose forms of glucose and fructose, Haworth projection formulae for glucose; chair and boat forms of glucose, Sugar derivatives, glucosamine, galactosamine, muramic acid, N- acetyl neuraminic acid. Disaccharides: concept of reducing and non-reducing sugars, occurrence and Haworth projections of maltose, lactose, and sucrose. Polysaccharides: Structure and functions; Storage Polysaccharides- starch and glycogen; Structural Polysaccharides- cellulose, peptidoglycan and chitin. Suitability in the context of their different functions- cellular structure; energy storage; signaling; Glycosylation of other biomolecules - glycoproteins and glycolipids.

Unit III: Amino acids & Proteins

Amino acids- Concept, Properties, Classification, and reactions (N / C terminal reactions). Titration curve of amino acid and its Significance. Natural modifications of amino acids in proteins hydrolysine, cystine and hydroxyproline, Non protein amino acids: Gramicidin, beta-alanine, D-alanine and D- glutamic acid. Peptide bond formation; Protein structure- Levels, primary structure and its importance. The alpha helix, the beta pleated sheet and their occurrence in proteins, Tertiary and quaternary structures of proteins. Conformation of proteins: Ramachandran plot, domains, motifs and folds; End group analysis and protein sequencing. Forces stabilizing protein structure, unfolding and refolding. Structure-function relationships in model proteins like ribonuclease A; myoglobin; hemoglobin; chymotrypsin etc.; Tools to characterize expressed protein. Biological Roles of Proteins. Amino acid and Protein metabolism

Unit IV: Nucleic acid

Nucleoside, Nucleotide, Nucleic acids- Structure, diversity and functions; DNA: Double helical structure; A-DNA, B-DNA & Z-DNA (structure, occurrence and differences). The RNA world-Structure, types and roles of RNA. Nucleic acid Sequencing. Nucleic acid Synthesis and Metabolism

Unit V: Lipids

Fatty acids structure and functions. Storage and structural lipids. Lipids in the formation of membranes (lipid micelles, monolayers, bilayers). Saponification Structural lipids. Lipid functions: cell signals, cofactors, pigments. Principles and pathways of lipid metabolism

Unit VI: Enzymes

Principles of catalysis, enzymes- properties and classification; Mechanism of enzyme action: active site, transition state complex and activation energy; Lock and key hypothesis, and Induced Fit hypothesis. Enzyme kinetics- Significance of hyperbolic, double reciprocal plots of enzyme activity, Km, and allosteric mechanism; Isozymes; Effect of pH and temperature on enzyme activity. Enzyme activators and inhibitors. Structure and function of Vitamins and coenzymes. Enzyme immobilization and their applications

Suggested Readings

1. Campbell, MK (2012) Biochemistry, 7th ed., Published by Cengage Learning
2. Campbell, PN and Smith AD (2011) Biochemistry Illustrated, 4th ed., Published by Churchill Livingstone

3. Tymoczko JL, Berg JM and Stryer L (2012) Biochemistry: A short course, 2nd ed., W.H.Freeman
4. Berg JM, Tymoczko JL and Stryer L (2012) Biochemistry, W.H.Freeman and Company
5. Nelson DL and Cox MM (2008) Lehninger Principles of Biochemistry, 5th Edition., W.H. Freeman and Company,
6. Voet, D. and Voet J.G (2005) Biochemistry 3rd edition, John Wiley and Sons.
7. Segel Irvin H (1997) Biochemical Calculations, 2nd Ed., John Wiley and Sons, New York.
8. Palmer, T (2001) Enzymes: Biochemistry, Biotechnology & Clinical chemistry, Horwood Pub. Co., England.

BM 491: Practical I (Prokarya and Eukarya)

1. Laboratory rules, safety and regulation, First Aid and ethics.
2. Staining: simple, negative, Gram's, flagella, and endospore.
3. Culture techniques and microbe handling: Pure culture isolation by serial dilution – plating and dilution streaking methods; slating and stabbing of cultures.
4. Culture preservation & revival: -80°C glycerol stock & Lyophilization.
5. Enrichment culture of prokaryotes: Sulpur Oxidizers and phosphate solubilizer.
6. Effect of environmental factors on microbial growth: temperature, pH, osmotic pressure.
7. Biochemical characterization of pure prokaryotic isolates.
8. Cultivation of anaerobic bacteria
9. Study of bacterial motility by hanging-drop method.
10. Identification of Algae, fungi & eukaryotic microorganisms through permanent slides.
11. Isolation and enumeration of bacteriophages (PFU) from water/sewage sample using double agar layer technique (plaque assay).
12. Determination of phage titer & multiplicity of infection.
13. Study of structural details of major bacterial, plant and animal viruses (Demonstration only).

BM: 493 Practical II (Cell Biology and Biochemistry)

Unit I: Cell Biology

1. Isolation of mitochondria and their visualization with Janus green B
2. *In situ* visualization of microfilaments and microtubules by fluorescent labeling.
3. *In silico* analysis (sequence comparison) of mitochondrial and chloroplast genes for identification of the loci for interspecific discrimination.
4. Immunostaining of nuclei, chloroplast and/or mitochondria.

Unit II: Basic and standardization Methods

1. Preparation of Acid & Alkali solutions and acid-base titration.
2. Concept of pH. Measuring pH of different solutions
3. Preparation of buffers: Acetate, Phosphate and Tris buffers.

Unit III: Estimation of micromolecules

1. Estimation of inorganic phosphate
2. Estimation of sugar (glucose)
3. Estimation of Amino acid (Tyrosine)
4. Estimation of Base (Guanine)

Unit IV: Estimation of macromolecules

1. Determination of Blue Value of Starch
2. Estimation of Proteins
3. Estimation of nucleic acids (DNA)

Unit V: Enzyme kinetics

1. Determination of Units and specific activity of an enzyme
2. Determination of Km and Vmax of an enzyme

(From above 16 practicals, any 10 practicals will be taken)

Semester VIII/II

BM 402: Microbial Physiology & Metabolism

Unit I: Microbial Photosynthesis

Major groups of photosynthetic prokaryotic microorganisms. Ultrastructure of reaction center, arrangements of light harvesting pigments, light reaction & electron flow in photosynthesis, photophosphorylation, and bioenergetics. CO_2 fixation pathways, RUBISCO-structure and molecular regulation of light and dark reactions

Unit II: Aerobic respiration

Regulation and energetics of hexose and pentose metabolism - Embden-Meyerhoff pathway, Entner-Doudroff pathway, Pentose phosphate pathway, phosphoketolase pathway, glyoxalate pathway, Krebs' cycle, oxidative and substrate level phosphorylation, reverse TCA cycle, gluconeogenesis- Pasteur effect;. Mitochondrial Electron Transport chain. Bioenergetics of ETC and oxidative phosphorylation, mechanism of oxidative phosphorylation. Inhibitors of electron Transport chain

Unit III: Anaerobic respiration and Fermentation

Electron transport & bioenergetics of anaerobic respiration (NO_3 respiration, SO_4 respiration, H_2- respiration, Halo-respiration).Fermentation – Lactic acid (homo and heterolactic) fermentations, mixed acid, propionic acid, butyric acid, acetone-butanol etc. Secondary fermentation

Unit IV: Nitrogen metabolism

Biochemistry of biological nitrogen fixation, properties of nitrogenase enzyme and its regulation, alternate and oxygen insensitive nitrogenase, nitrogenase assay. Ammonia assimilation with respect to glutamine synthetase, glutamate dehydrogenase, glutamate synthetase, their properties and regulation. Anammox reactions and Comammox organisms.

Unit V: Chemolithtrophy

Iron, Carbon, Hydrogen and Sulphur oxidation, Methanotrophy, Acetogenesis, Methanogenesis, Anammox, ATP synthesis in *Halobacterium.*

Unit VI: Biosynthesis and degradation of biomolecules

Biosynthesis (shikimate family) and degradation of amino acids; protein turn over. Biosynthesis and oxidation of saturated and unsaturated fatty acids. Biosynthesis of purine and pyrimidine bases

Suggested Readings

1. Madigan MT, and Martinko JM (2014).Brock Biology of Microorganisms.14th edition. Prentice Hall International Inc.
2. Moat AG and Foster JW. (2002). Microbial Physiology.4th edition. John Wiley & Sons
3. Reddy SR and Reddy SM. (2005). Microbial Physiology. Scientific Publishers India
4. Gottschalk G. (1986). Bacterial Metabolism.2nd edition. Springer Verlag
5. Stanier RY, Ingrahm JI, Wheelis ML and Painter PR. (1987). General Microbiology. 5th edition, McMillan Press
6. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology.9th edition. McGraw Hill Higher Education

BM 404: Microbial Genetics

Unit I: Mendelian Genetics

Genotype, Phenotype; Monohybrid, Dihybrid cross; Mendel's Laws: Dominance, recessiveness, segregation, independent assortment, autosomal & sex linked inheritance; Deviation from Mendelian inheritance; Chromosome theory of inheritance: Allele, multiple alleles, pseudoallele, complementation tests, Extensions of Mendelian genetics; Allelic interactions; Concept of Incomplete dominance and co-dominance, Epistasis, penetrance and expressivity.

Unit II: Mutations and Repair

Experimental evidence for DNA as genetic material (Experiments of Griffith, Avery and MacLeod; Hershey and Chase); Experimental evidence for RNA as genetic material (TMV).

Mutations and mutagenesis: Definition and types of Mutations; Physical and chemical mutagens; Molecular basis of mutations; Functional mutants (loss and gain of function mutants); Uses of mutations. Reversion and suppression: True revertants; Intra- and inter-genic suppression; Ames test; Mutator genes.

Genetic Analysis in Bacteria: isolating mutants, genetic characterization of mutants, complementation tests.

Repair: Reversal of UV damage in prokaryotes : photoreactivation, base excision and nucleotide excision repair , post replicational repair, mismatch repair, SOS repair, error prone repair. Mechanisms of different genetic recombination

Unit III: Plasmids

Properties of plasmids, functions encoded by plasmids, plasmid structure, types of plasmids – F plasmid, R Plasmids, colicinogenic plasmids, Ti plasmids, linear plasmids, yeast- 2μ plasmid, plasmid replication and partitioning, host range, plasmid-incompatibility, plasmid amplification, regulation of copy number, curing of plasmids.

Unit IV: Mechanisms of Genetic Exchange

Transformation - Discovery, mechanism of natural competence; Importance of natural transformation, artificially induced competence. Conjugation- Discovery, mechanism (Gram negative and Gram Positive), Hfr and F' strains; interrupted mating technique and time of entry mapping; plasmid-attracting pheromones. Transduction - Generalized transduction, specialized transduction, LFT & HFT lysates, role of transduction in bacterial evolution. Mapping by recombination and co-transduction of markers. Genetic crosses in bacteria.

Unit V: Phage Genetics

Features of T4 genetics, Genetic basis of lytic versus lysogenic switch of phage lambda

Unit VI: Transposable elements

General Properties of Transposons; Prokaryotic transposable elements – Insertion Sequences, composite and non-composite transposons, Replicative and Non replicative transposition, Mu transposon; Eukaryotic transposable elements - Yeast (Ty retrotransposon), Drosophila (P elements), Maize (Ac/Ds); Uses of transposons and transposition - transposon mutagenesis.

Suggested Readings

1. Klug WS, Cummings MR, Spencer, C, Palladino, M (2011). Concepts of Genetics, 10th Ed. Benjamin Cummings
2. Krebs J, Goldstein E, Kilpatrick S (2013). Lewin's Essential Genes, 3rd Ed., Jones and Bartlett Learning
3. Pierce BA (2011) Genetics: A Conceptual Approach, 4th Ed., Macmillan Higher Education Learning
4. Watson JD, Baker TA, Bell SP et al. (2008) Molecular Biology of the Gene, 6th Ed., Benjamin Cummings
5. Gardner EJ, Simmons MJ, Snustad DP (2008). Principles of Genetics.8th Ed. Wiley-India
6. Russell PJ. (2009). i Genetics- A Molecular Approach. 3rd Ed, Benjamin Cummings.
7. Sambrook J and Russell DW. (2001). Molecular Cloning: A Laboratory Manual. 4th Edition, Cold Spring Harbour Laboratory press
8. Maloy SR, Cronan JE and Friefelder D (2004) Microbial Genetics 2nd ED, Jones and Barlett Publishers

BM 406: Biophysics and Bioethics

Unit I: Separation Techniques

Different methods of protein precipitation: Precipitation using inorganic salts (salting out) and organic solvents, isoelectric precipitation, Dialysis, Ultrafilteration, Lyophilization

Unit II: Chromatography

Basic principles of chromatography: Partition coefficient, concept of theoretical plates, various modes of chromatography (paper, thin layer, column), preparative and analytical applications, LPLC and HPLC. Different types of chromatography: Paper Chromatography, Thin Layer Chromatography. Molecular Sieve Chromatography, Ion Exchange Chromatography, Affinity Chromatography, Gas Liquid Chromatography

Unit III: Microscopy

Principles and applications of Microscopy, Fluorescence, Phase contrast, Confocal, Scanning and Transmission and Cryo- Electron microscopy.

Unit IV: Electrophoresis

Basic Principle of electrophoresis, Paper electrophoresis, Gel electrophoresis, discontinuous gel electrophoresis, PAGE, SDS-PAGE, PFGE, Native gels, denaturing gels, 2D gel, Isoelectric Focusing of proteins, agarose gel electrophoresis, buffer systems in electrophoresis, protein and nucleic acid blotting, detection and identification (staining procedures), molecular weight determination.

Unit V: Immunological techniques
Hybridoma technology, Phage display, Development of animal models for studying diseases

Unit VI: Analysis of protein-DNA and protein-protein interactions
Gel retardation assay, DNA footprinting by DNase I and chemical methods, yeast one-hybrid assay, ChIP- chips. Yeast two hybrids, three-hybrids, split hybrids and reverse hybrids. Co-immunoprecipitations.GFP and FRET.Phage display.

Unit VII: Genome Editing
CRISPR-Cas9, Principle, Variations involved and applications

Unit VIII: Spectroscopy
Molecular spectroscopy, IR, ESR, FRET, Biomolecular fluorescence complementation assay, Mass spectrometry

Unit IX: Radioisotopes
Radioisotopes and their use in biology and diagnostics, autoradiography, radioactive labeling of biological macromolecules

Unit IX: Bioethics
Philosophy and Theories of Bioethics; Clinical ethics; Research Ethics

Suggested Readings

1. Physical Biochemistry: Principles and Applications, 2nd edition (2009), David Sheehan, JohnWiley. ISBN-13: 978-0470856031.
2. Cell and Molecular Biology: Concepts and Experiments, 6th edition (2009), Gerald Karp, Wiley. ISBN-978-0470483374.
3. Gene cloning and DNA analysis, 6th edition (2010), T.A. Brown. Wiley-Blackwell ISBN-13: 978-1405181730.
4. Principles of Gene Manipulation and Genomics, 7th edition (2006), S.B. Primrose and R.M. Twyman. Blackwell Scientific ISBN: 978-1405135443.
5. Human Molecular Genetics, 3rd edition (2003), Tom Strachan and Andrew Read; Garland Science Publishers, ISBN -13:978-0815341826.
6. Immunology, 6th edition, (2006), J. Kuby, W.H. Freeman and Company, New York. ISBN-13: 978-1429202114.

BM 408: Biostatistics & Bioinformatics

Unit I: Descriptive Statistics
a) Data in Biology: Development in biostatistics, samples and populations, techniques of sampling (random and stratified), sampling and non-sampling errors, variables in biology, univariate and bivariate frequency distributions
b) Measures of Central Tendency: means, mode, median and partition values.
c) Measures of Dispersion: Range, standard deviation, coefficient of variance and covariance.
d) Moments: Raw and central moments and their relationships.
e) Measures of Skewness: Pearson's coefficients of skewness; coefficient of skewness using moments. Measures of Kurtosis.

Unit II: Probability and Probability Distributions
a) Probability: Basic concepts, addition and multiplication rules of probability, conditional probability
b) Probability Distributions: Probability mass function, probability density function and distribution function. Binomial distribution, Poisson distribution, normal distribution and exponential distribution along with their properties and relationships.

Unit III: Correlation and Linear Regression
a) Correlation Analysis: Scatter diagrams, Pearson's and Spearman's coefficients of correlation, coefficient of determination, standard and probable errors.
b) Regression Analysis: Method of least squares, equations of lines of regression and their applications in biostatistics.

Unit IV: Hypothesis Testing
a) Sampling distributions and standard error, null and alternate hypothesis, basic concept and illustrations of type I and type II errors, concept of confidence interval estimation.

b) Student's t-distribution: test for single mean, difference of means and paired t- test, chi-square distribution: tests for goodness of fit, independence of attributes and homogeneity, F-distribution, one-way and two-way analysis of variance (ANOVA).

Unit V: Biological databases and genome browsers
Introduction to various databases and their classification (primary and secondary databases) e.g. NCBI, DDBJ, EMBL, ENSEMBL, UCSC and their uses

Unit VII: Sequence alignment
Local and global sequence alignments (Needleman-Wunsch and Smith-Waterman algorithms), pair-wise (BLAST and FASTA algorithms) and multiple sequence alignment (Clustal W) and its importance. Theory behind BLAST- how Hidden Markov Model (HMM), BLAST score, amino acid substitution matrices, s-value and e-value, p value.

Unit VIII: Phylogenetic analysis
Basic concepts of phylogenetic analysis, rooted/uprooted trees, approaches for phylogenetic tree construction (UPGMA, Neighbour joining, Maximum parsimony, Maximum likelihood).

Unit IX: Structure predictions for nucleic acids and proteins
Approaches for the prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models, Basic approaches for protein structure predictions, comparative modeling, fold recognition/threading and *ab-initio* prediction

Unit X: Overview of drug development
Drug life cycle, stages of drug discovery and strategic issues in drug discovery. Lead Generation HTS, clinical trials, characterization of binding site, virtual screening, protein-ligand interactions, prediction of pharmacological properties, Lipinski's rule of five, concept of energy minimization and force fields, introduction to rational drug design using example, Introduction to drug databases. ADMET.

Suggested Readings

1. Bioinformatics: Sequence and Genome analysis, 2nd edition (2004), David W. Mount, Cold Spring Harbour Laboratory Press. ISBN-13: 978-0879697129.
2. Bioinformatics: A practical guide to the analysis of genes and proteins, 3rd edition (2004), Andreas D. Baxevanis and B.F. Francis Ouellette, John Wiley and Sons. ISBN-13: 978-0471478782.
3. Introduction to Medicinal Chemistry, 4th edition (2009), Graham l. Patrick, Oxford University Press. ISBN-13: 978-0199234479.
4. The Process of New Drug Discovery and Development, 2nd edition (2006), C.G. Smith and J.T. O"Donnell, Informa Healthcare, ISBN-13: 978-0849327797.
5. Molecular modeling - Principles and Applications, 2nd edition (2003), A. R. Leach, Pearson Education Limited, UK. ISBN 13: 9780582382107.
6. Cheminformatics in Drug Discovery (2006), edited by. T.I. Opera; Wiley Publishers, ISBN: 9783527604203.
7. Primer of Biostatistics, 7th edition (2011), Stanton Glantz, McGraw-Hill Medical. ISBN-13: 978-0071781503.
8. Biostatistics: A Foundation for Analysis in the Health Sciences, 10th edition (2013), Wayne W Daniel and Chad L. Cross, Wiley. ISBN-13: 978-1118302798.
9. Principles of Biostatistics, 2nd edition (2000), Marcello Pagano and Kimberlee Gauvrean, Thompson learning. ISBN-13: 978-0534229023.
10. Biostatistical Analysis, 5th edition (2009), Jerrold H. Zar, Pearson. ISBN-13: 978-0131008465.

BM 492: Practical III (Metabolism and Genetics)

Unit I: Metabolism
1. Study of presence of bacteriochlorophyll(s) and other light harvesting pigment in any pigmented bacteria.
2. Utilization pattern of different carbon and nitrogen sources by*E.coli*.
3. Study of anaerobic respiration by using $NO_3$and/or SO_4as terminal electron acceptor.
4. Isolation of denitrifying bacteria from natural sample.
5. Isolation and characterization of any one type of chemolithotrophic microorganisms.

Unit II: Genetics
1. Preparation of master and replica plates.
2. Study the effect of chemical (HNO_2) and physical (UV) mutagens on bacterial cells.

3. Study of survival curve of bacteria after exposure to ultraviolet (UV) light.
4. Study of photoreactivation mechanism of DNA repair
5. Study of different conformations of plasmid DNA through Agaraose gel electrophoresis
6. Curing of plasmid
7. Demonstration of Bacterial Conjugation
8. Demonstration of bacterial transformation and transduction
9. Demonstration of AMES test.

BM 494: Practical IV (Biophysics and Bioinformatics)

Unit I: Biophysics

1. Effect of denaturation (heat/urea/guanidium chloride/BME) on UV absorption spectra of proteins.
2. Study of structural changes of proteins at different pH/solvent/temperature using UV spectrophotometry.
3. Analysis, identification and comparison of various spectra (UV, NMR, MS, IR) of simple organic compounds.
4. Separation of nucleotides/amino acids using TLC
5. Calculation of electrophoretic mobility
6. Study of autoradiographs

Unit II: Bioinformatics

1. Sequence alignment using BLAST and Clustal W.
2. Phylogenetic analysis using PHYLIP.
3. Microarray analysis using Bioconductor.
4. Molecular format conversion and hands-on molecular visualization program for displaying, animating and analyzing large bio-molecular systems using 3-D graphics.
5. Homology Modeling using SPDBV, model structure refinement using SPDBV and model validation using What Check and Pro Check.
6. Comparing structures, mutations, studying interactions creating electrostatic potential diagrams.
7. Virtual screening and molecular docking using AUTODOCK.

Unit III: Biostatistics

Computer-based practicals using any statistical software like 'R'. MATLAB, SPSS, Spreadsheets, etc. to understand the following concepts:

1. Graphical data representation
2. Measures of central tendency and dispersion
3. Probability and probability distributions: binomial, Poisson and normal distribution
4. Correlation and linear regression analysis
5. Student's t- test
6. Chi-square test
7. ANOVA

Semester IX/III

BM 501: Immunobiology

Unit I: Fundamental concepts and anatomy of the immune system

Three fundamental concepts in immunology- specificity, self- nonself discrimination and memory. Components of innate and acquired immunity; Mechanisms of barrier to entry of microbes/pathogens; Phagocytosis; Complement and Inflammatory responses; Haematopoesis and its regulation; Organs and cells of the immune system; Lymphatic system; Lymphocyte circulation; Lymphocyte homing; Mucosal and Cutaneous associated Lymphoid tissue (MALT&CALT); Mucosal Immunity.

Unit II: Immune responses and signaling

Antigens, antigenicity and immunogenicity; non-peptide bacterial antigens and superantigens; B and T cell epitopes; haptens. Immunoglobulins- structure and function- classes & subclasses of immunoglobulins; antigenic determinants; immunoglobulin domains, concepts of variability, isotypes, allotypes and idiotypic markers. Immunoglobulin superfamily; B-cell receptor; B cell maturation; activation and differentiation; Generation of antibody diversity; T-cell maturation; activation and differentiation and T-cell receptors; Functional T Cell Subsets. Cell-mediated immune responses; ADCC; Cytokines- properties, receptors and therapeutic uses; The Complement systems- pathways for

complement activation; Principles of cell signaling- MAP kinase and NF-κB; Kinetics of immune response; Cell-cell co-operation; Immune cell receptors; Cellular adhesion molecules.

Unit III: Genetic Organization
Immunoglobulin genes; VJ/VDJ rearrangements and genetic mechanisms responsible for antibody diversity, affinity maturation, allelic exclusion; Class switching; Major Histocompatibility Complex- MHC-I and MHC-II, genetic organization of H-2 and HLA. Antigen processing and presentation pathways.

Unit IV: Antigen-antibody interactions
Precipitation; agglutination and; Advanced immunological techniques- RIA; ELISA; Western blotting; ELISPOT assay; immunofluorescence; flow cytometry and immunoelectron microscopy; Surface plasmon resonance; Biosensor assays for assessing ligand-receptor interaction; CMI techniques- lymphoproliferation assay; Mixed lymphocyte reaction; Cell Cytotoxicity assays; Apoptosis assay.

Unit V: Clinical Immunology
Immunity to Infection: Bacteria; viral; fungal and parasitic infections (with examples from each group); Hypersensitivity- Type I-IV; Autoimmunity; Types of autoimmune diseases; Mechanism and role of CD4+ T cells, MHC and TCR in autoimmunity; Treatment of autoimmune diseases. Immunodeficiency-Primary and acquired immunodeficiency. Central and peripheral tolerance, and their mechanism; Mechanisms of autoimmunity.

Unit VI: Transplantation and tumor immunology
Transplantation- Immunological basis of graft rejection; Clinical transplantation and immunosuppressive therapy. Tumor immunology- Tumor antigens; Immune response to tumors and tumor evasion of the immune system, Cancer immunotherapy.

Unit VII: Vaccinology
Active and passive immunization; Live; killed; attenuated; sub unit vaccines; Vaccine technology- Role and properties of adjuvants; recombinant DNA and protein-based vaccines; plant-based vaccines; reverse vaccinology; Peptide vaccines; conjugate vaccines; Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies; Catalytic antibodies and generation of immunoglobulin gene libraries

Suggested Readings

1. Kuby Immunology by Kindt TJ, Goldsby RA, Osborne BA, Kuby J: 6th edition. New York. WH Freeman; 2006.
2. Cellular and Molecular Immunology by Abbas AK, Lichtman AH, Pillai S: Saunders Elsevier; 2007.
3. Immunobiology: The immune system in health and disease by Janeway CA, Travers P, Walport M, Shlomchik MJ: 6th edition. New York. Garland Science Publishing; 2005
4. Medical Microbiology and Immunology by Levinson W, Jawetz E: Lange publication; 2001.
5. Fundamental Immunology by Paul WE: 4th edition. New York. Raven Press; 2000.
6. Roitt's Essential Immunology by Delves PJ, Martin SJ, Burton DR, Roitt IM; 11th edition. Blackwell Publishing/Oxford Univ. Press; 2006.

BM 503 #Genetic Engineering

Unit I: Basics of DNA cloning
Tools of DNA cloning: Different enzymes and vectors used in genetic engineering. Cloning into various kinds of vectors – plasmids, phages lambda and M13, phagemids, cosmids, P1 phage, PACs, BACs and YACs. Simple cloning and cloning using linkers and adaptors. Selection and screening of clones.

Unit II: DNA fingerprinting
DNA fingerprinting and its application in forensics, in disease diagnosis and in identification of strains, RAPD fingerprinting of micro-organisms, RFLP

Unit III: Polymerase Chain Reaction
Concept of PCR and various thermophilic enzymes used in PCR. Gradient PCR versus Touchdown PCR. Designing primers. Cloning PCR products. Long PCR, Inverse PRC, RT-PCR, 5' and 3' RACE, qPCR, MOPAC, Multiplex PCR, Differential Display PCR, Ligation Chain Reaction, Overlap PCR, Rolling Circle Amplification Technology.

Unit IV: Construction of cDNA and genomic DNA libraries

Vectors used in the construction of cDNA versus genomic DNA libraries. Steps and enzymes involved in the construction of cDNA versus genomic DNA libraries. Screening libraries by colony hybridization and colony PCR. Screening expression libraries. Enriching for clones in cDNA libraries by positive selection and subtractive hybridization. Identifying genes in complex genomes by direct selection of cDNA and exon trapping

Unit V: Genome sequencing

DNA sequencing by Sanger's method – traditional and cycle sequencing. Physical mapping by restriction fragment fingerprinting of BAC clones and STS mapping. E-PCR. Whole genome shotgun sequencing. Clone-by-clone shotgun sequencing of genome – preparation of BAC/YAC library, map construction, clone selection, subclone library construction, random shotgun phase, finishing phase and sequence authentication. Genome annotation at the nucleotide level, protein level and process level. Comparative genome sequencing of micro-organisms to identify and categorize SNPs. Array CGH. Next gen sequencing technologies. Mechanism of Pyrosequencing.

Unit VI: Transcriptomics

Reporters used in protein localization and trafficking studies. Promoter analysis – deletion analysis and linker scanning analysis coupled to reporter assays, mapping transcriptional start sites by S1 nuclease mapping; Transcriptome analysis by DD-PCR and EST analysis, DNA microarrays (cDNA arrays and oligo arrays), Serial Analysis of Gene Expresion (SAGE).

Unit VII: Over-expression of recombinant proteins

Overexpression and tagging of recombinant proteins in *E.coli* driven by lac, T7 and Tet-regulatable promoters; Expression in *B. subtilis*; Overexpression systems in *S. cerevisiae*, *P. pastoris, S. pombe* and *K. lactis*; Baculovirus overexpression system; Mammalian cell overexpression system; Insertional and deletion mutagenesis; Site directed mutagenesis by conventional and PCR-based methods.

Suggested Readings

1. Molecular Biology by David P. Clarke, 1st edition; Elsevier Academic Press; 2005.
2. Molecular Cloning: A laboratory manual by Joseph Sambrook& David Russell, 3rd edition; CSHL press; 2001.
3. DNA Technology: The Awesome Skill by I. Edward Alcamo, 2nd edition; Hardcourt Academic Press; 2001.
4. Molecular Biology of the Gene by James Watson, Tania Baker, Stephen Bell, Alexander Gann, Michael Levine & Richard Losick , 6th Edition; CSHL Press; 2007.

BM 505: Microbial Pathogenicity

Unit I: Classical view of microbial pathogenicity

Define pathogenicity and virulence; Quantitative measures of virulence: minimal lethal dose (MLD), MIC, LD50, ID50, TCID50. Virulence determinants: colonization, toxins, enzymes and invasiveness. Facultative/obligate intracellular pathogens

Unit II: Molecular microbial pathogenicity

Molecular Koch's postulates, multiplicity of virulence features, coordinated regulation of virulence genes, two component signal transudation systems and environmental regulation of virulence determinants, antigenic variation; clonal and panmictic nature of microbial pathogens, type I-IV secretion systems, biofilms.

Unit III: Emerging and re-emerging pathogens

V. cholera O: 139, X-MDR *M. tuberculosis, Helicobacter pylori,* Enterohaemorrhagic *E. coli* (EHEC), *Cryptosporidium parvum*, Lyme disease, SARS virus, Bird flu, prions, AIDS, Dengue Hemorrhagic Fever, and *Chlamydiae*, opportunistic fungal pathogens. Mechanisms of emergence of new pathogens: microbial change and adaptation, horizontal gene transfer (HGT), pathogenicity islands (PAI), role of integrons.

Unit IV: Transmission, pathogenesis, symptoms and control of common bacterial, viral, fungal and protozoan diseases

Unit V: Molecular microbial epidemiology

Objectives of microbial epidemiology. Biochemical and Immunological tools - biotyping, serotyping, phage typing, FAME, Curie Point PyMS, protein profiling, multilocus enzyme electrophoresis (MLEE); Molecular typing: RFLP (ribotyping, IS based), RAPD, 16S-23S IGS, ARDRA, rep (REP, ERIC, BOX)-PCR, PFGE, AFLP, MLST, MVLST, VNTR, SNP, Microarray and whole genome sequence; GIS

Unit VI: Antimicrobials and their mode of action

Antibacterial agents: Different modes with one examples: Inhibitor of nucleic acid synthesis; Inhibitor of cell wall synthesis; Inhibitor of cell membrane function; Inhibitor of protein synthesis; Inhibitor of metabolism.
Antifungal agents; Antiviral agents; Antibiotic resistance

Unit VII: Antimicrobial resistance

Multidrug resistance, strategies involved, with examples: extended spectrum β-lactamases (ESBL), XMDR *M. tuberculosis*, Mecithillin-resistant *S. aureus* (MRSA).

Suggested Readings

1. Jawetz, Melnick, &Adelberg's Medical Microbiology by Brooks GF, Butel JS, Morse SA, Melnick JL, Jawetz E, Adelberg EA . 23rd edition. Lange Publication. 2004.
2. Cellular Microbiology by Cossart P, Boquet P, Normark S, Rappuoli R eds. 2nd edition. American Society for Microbiology Press. 2005.
3. Bacterial Pathogenesis: A molecular approach by Salyers AA and Whitt DD eds. American Society for Microbiology Press, Washington, DC USA. 2002.
4. Pathogenomics: Genome analysis of pathogenic microbes by Hacker J and Dorbindt U. ed. Wiley-VCH. 2006.
5. Molecular Microbiology: Diagnostic Principles and Practice by Persing DH, Tenover FC, Versalovic J, Tang Y, Unger ER, Relman DA, White TJ eds. American Society for Microbiology Press, 2004.
6. Infectious Disease Epidemiology: Theory and Practice by Nelson KE, Williams CM, Graham NMH eds. An Aspen Publication. 2001.

BM 507: Molecular Biology

Unit I: Genetic material

The structure of DNA and RNA; Melting of DNA, Superhelicity, Comparative Organization and features of Microbial Genomes and Eukaryotic Genomes

Unit II: DNA replication

Arrangement of replicons in a genome, Various modes of replication, continuous, discontinuous synthesis, various replication Enzymes, Replication Fork and priming, leading and lagging strand, elongation, termination, Plasmid replication, specific features of replication in Prokaryotes and Eukaryotes, action of topoisomerases, Telomere maintenance and Chromatin Assembly, Single stranded DNA replication, Relationship between DNA replication and cell cycle, DNA copy number maintenance.

Unit III: Recombination and Repair of DNA

DNA repair and recombination, DNA Mismatch Repair, Double Strand Break Repair, Recombination as a molecular biology tool

Unit IV: Transcription

Transcription machinery of prokaryotes, various transcription enzymes and cofactors, initiation, elongation and termination, sigma factors, Transcription machinery of eukaryotes, various forms of RNA polymerase and cofactors, initiation, elongation and termination, promoters, enhancers, silencers, activators, effect of chromatin structure, regulation of transcription.

Unit V: Post-transcriptional processes

RNA processing, splicing, capping and polyadenylation, rRNA and tRNA processing, RNA Editing; RNAi and miRNAs, Antisense RNA, Post-transcriptional gene regulation

Unit VI: Operon

Gene structure, concept of Operon, Lac and Trp operon, organization and role in regulation of expression

Unit VII: Translation

The genetic code and protein structure, Mechanisms of translation in prokaryotes, Mechanisms of translation in eukaryotes, initiation complex, ribosomes and tRNA, factors, elongation and termination, *in vitro* translation systems, polycistronic/ monocistronic synthesis, Regulation of translation, RNA instability, inhibitors of translation, stringent response in bacteria

Unit VIII: Post-translational processes

Protein modification, folding, chaperones, transportation; The Signal Hypothesis, proteosome

Unit IX: Genes and behavior

Human Genome Project, Genome analysis, DNA typing, Genomics and beyond

Suggested Readings

1. Gene IX by Benjamin Lewin, Jones and Bartlett Publishers, Sudbury, Massachusetts, 2007.
2. Molecular Biology by R.F. Weaver, 4th edition, McGraw Hill. New York. USA, 2007.
3. Molecular Biology of the Gene by J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick, 6th edition, Benjamin Cummings, San Francisco, USA, 2007.
4. Molecular Biology of the Cell by B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P. Walter, 5th edition, Garland Science, New York and London, 2007.
5. Biochemistry (5th edition) by J.M. Berg, J.L. Tymoczko, L. Stryer, W.H. Freeman and Company, New York, USA, 2008.
6. Current Protocols in Molecular Biology Edited by: Fred M. Ausubel; Roger Brent; Robert E. Kingston; David D. Moore; John A. Smith; Kevin Struhl, John Wiley and Sons, Inc. 2007

BM 591 Practical V (Immunobiology and Genetic Engg)

Unit I: Immunobiology

1. To perform immunoelectrophoresis.
2. To perform radial immunodiffusion assay.
3. To perform rocket immunoelectrophoresis.
4. To study quantitative precipitation assay
5. To perform dot- & Indirect ELISA.
6. To perform agglutination test
7. To perform western blotting.
8. To study morphological and staining characteristics of lymphocytes, neutrophils, monocytes, eosinophils, and basophils.

Unit II: Genetic Engineering

1. Amplification of DNA by PCR
2. RAPD analysis
3. Overexpression of proteins and analysis by SDS-PAGE
4. Purification of recombinant protein
5. Western Blotting analysis
6. Preparation of competent cells and determination of transformation efficiency
7. Alpha-complementation

BM 593 Practical VI (Microbial Pathogenicity and Molecular Biology)

Unit I: Microbial Pathogenicity

1. To study cultural and microscopic characteristics of selected pathogenic fungi *viz*. *Microsporum* sp., *Candida albicans*, and *Aspergillus* sp.
2. Isolation of bacteria from vegetables and fruits.
3. Biochemical and physiological tests for detection of pathogens in fruits and vegetables, eg; Arginine hydrolysis for *Pseudomonas*.
4. Isolation of soilborne pathogens from plant tissue and soil.
5. Effects of processing methods in vegetables;
6. Bacterial counts in blanched vegetables.
7. Bacterial counts in unblanched vegetables.
8. Bacterial counts in frozen vegetables.

Unit II: Molecular Biology

1. Isolation of plasmid DNA from minicultures.
2. Isolation of plasmid from maxicultures.
3. Isolation of genomic DNA.
4. Estimation of purity & concentration of DNA.
5. Restriction digestion analysis by agarose gel electrophoresis.
6. Restriction digestion analysis by polyacrylamide gel electrophoresis.
7. Cloning of a DNA fragment
8. Isolation of total protein and estimation by Bradford method.

Semester X/IV

BM 502 #Food and Industrial Microbiology

Unit I: Microbiology of Foods
Vegetables, fruits, milk, fermented and non-fermented milk products, fresh meats, poultry and non-dairy fermented foods.

Unit II: Food Preservation
Microbial spoilage of foods; Food preservation: Chemical, physical and biological methods.
Fermentation processes: Production of milk and milk products, plant-based products, fish products, meat products and food beverages. Food-borne diseases

Unit III: Bioreactor Types and Operation
Control batch reactors, fed-batch reactors, CSTR reactors, various types of bioreactors for microbial, animal, plant cell culture, fluidized bed reactor, bubble column, air lift fermenter, packed bed, trickle bed etc. parallel and series bioreactor. Impellers, stirrer, glands and bearings, packed gland seal, mechanical seal, magnetic drives, baffles, different types of spargers, computer based advance controllers for bioreactors.

Unit IV: Bioreactor Design
Introduction, general design information, design of bioreactors, basic function of a bioreactor design, mass and energy balance, materials of construction for bioprocess plant, mechanical design of process equipment, utilities for biotechnology production plants.

Unit V: Applications of Process Technology
Production of cell biomass and some primary metabolites, e.g. ethanol, acetone-butanol, citric acid, dextran and amino acids. Microbial production of industrial enzymes: glucose isomerase, cellulase & lipases. Applications of bioconversion, transformation of steroids and sterols. Transformation of non-steroidal compounds, antibiotics and pesticides. Bioenergy-fuel from biomass, production and economics of biofuels. Metal recovery and microbial desulfurization of coal

Suggested Readings

1. Modern Industrial Microbiology & Biotechnology by N. Okafer, Scientific Publishers, Enfield, USA., 2007.
2. Industrial Microbiology: An Introduction by Waites, Morgan, Rockey&Highton, Blackwell Science, 2001.
3. Modern Food Microbiology, 4th edition by J.M. Jay, Springer, 2006.
4. Fundamental Food Microbiology, 3rd edition by B. Ray., CRC press, 2006.
5. Food Microbiology: Fundamentals and Frontiers, 2nd edition by Michael P. Doyle, Larry R. Beuchat, Thomas J. Montville, ASM press, 2001.
6. Bioprocess Technology- fundamentals and applications, S O Enfors& L Hagstrom (1992), RIT, Stockholm.

BM 504: Environmental Microbiology

Unit I: Microorganisms and their Habitats
Structure and function of ecosystems. Terrestrial environment: soil profile and soil microflora – rhizospheric and non-rhizospheric. Aquatic environment: microflora of fresh water ecosystems and marine habitats (benthic and pelagic microflora). Atmosphere: Aeromicroflora and dispersal of microbes, phyloplane microflora. Animal environment: Microbes in/on human body & animal (ruminants) body. Extreme habitats and their inhabitants

Unit II: Microbial Interactions
Microbe interactions: Mutualism, synergism, commensalism, competition, amensalism, arasitism, predation. Microbe-Plant interaction: Symbiotic and non-symbiotic interactions. Microbe-animal interaction: Microbes in ruminants, nematophagus fungi and symbiotic luminescent bacteria.

Unit III: Waste Management and Water Treatment
Solid waste management: sources and types of solid waste, methods of solid waste disposal (composting and sanitary landfill). Liquid waste management: Composition and strength of sewage (BOD and COD), primary, secondary (oxidation ponds, trickling filter, activated sludge process and septic tank) and tertiary sewage treatment. Potability of water: treatment and safety of drinking (potable) water, methods to detect potability of water samples: (a) standard qualitative procedure: presumptive test/MPN test, confirmed and completed tests for faecal coliforms (b) Membrane filter technique and (c) Presence/absence tests.

Unit IV: Microorganisms in bioremediation and mineral recovery

Principles and degradation of common pesticides, organic (hydrocarbons, oil spills) and inorganic (metals) matter, biosurfactants and their uses; Bioleaching of copper, gold and uranium

Unit V: Microbial biofertilizer and insecticides

Types of microbial bio-fertilizers and microbes used (symbiotic N_2 fixers, Non-symbiotic N_2 fixers, Phosphate solubilizers and mycorrhizal biofertilizers), characteristics of inoculant, production of inoculant biomass, formulation & packaging technology and field application.

General account of microbes used as bio-insecticides and their advantages over synthetic pesticides, *Bacillus thuringiensis* – production and field applications; Viruses – cultivation and field applications.

Suggested Readings

1. Atlas RM and Bartha R. (2000). Microbial Ecology: Fundamentals & Applications. 4th edition. Benjamin/Cummings Science Publishing, USA
2. Madigan MT, Martinko JM and Parker J. (2014). Brock Biology of Microorganisms.14th edition. Pearson/ Benjamin Cummings
3. Maier RM, Pepper IL and Gerba CP. (2009). Environmental Microbiology. 2nd edition, Academic Press
4. Okafor, N (2011). Environmental Microbiology of Aquatic & Waste systems. 1st edition, Springer, New York
5. Singh A, Kuhad, RC & Ward OP (2009). Advances in Applied Bioremediation. Volume 17, Springer-Verlag, Berlin Hedeilberg
6. Coyne MS. (2001). Soil Microbiology: An Exploratory Approach. Delmar Thomson Learning.
7. Lynch JM & Hobbie JE. (1988). Microorganisms in Action: Concepts & Application in Microbial Ecology. Blackwell Scientific Publication, U.K.
8. Martin A. (1977). An Introduction to Soil Microbiology. 2nd edition. John Wiley & Sons Inc. New York & London.
9. Stolp H. (1988). Microbial Ecology: Organisms Habitats Activities. Cambridge University Press, Cambridge, England.
10. Subba Rao NS. (1999). Soil Microbiology.4th edition. Oxford & IBH Publishing Co. New Delhi.
11. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology.9th edition. McGraw Hill Higher Education.

BM 592: Practical VII (Applied Microbiology)

Unit I: Food and Industrial Microbiology

1. To make wine from different juices by fermentation.
2. To study microbiology of vegetables, fruits, milk and milk products.
3. To test the quality of milk.
4. To demonstrate production of curd and cheese.
5. To study production of wine from grape juice.
6. Microbial Growth kinetics-Determination of specific growth rate (mmax), saturation constant (KS) and growth yield (YX/S) in batch culture.
7. Determination of K_{La} by sulphite oxidation method.
8. Determination of K_{La} in a bioreactor by dynamic method.
9. Determination of thermal death rate constant and decimal reduction time for *E. coli*.
10. Disruption of microbial cells (Baker's yeast) for the release of the intracellular protein.
11. Bio-transformation of sucrose into high fructose syrup by immobilized cell ofSaccharomyces cerevisiae

Unit II: Environmental microbiology

1. Analysis of soil - pH, moisture content, water holding capacity, percolation, capillary action.
2. Analysis of BOD, TOC of waste water.
3. Study of microflora of soil, fresh water (pond) and air.
4. Study of microflora of waste water and drinking water.
5. Assessment of microbiological quality of water (Presumptive test, Confirmatory test, Completed test for coliform; IMVIC reactions)
6. Study the presence of microbial activity by detecting (qualitatively) enzymes (dehydrogenase, amylase, phosphatase, and urease) in soil.
7. Isolation of Rhizobium from root nodules.
8. Isolation of phosphate solubilizing bacteria.
9. Isolation of heavy metal resistant bacteria,
10. Isolation of cellulolytic bacteria from soil sample,

11. Isolation of hydrocarbon(s) or pesticides(s) degrading bacteria.
12. Metabolic fingerprinting of microbes by BIOLOG.
13. Preparation of total DNA from soil and water, and amplification of 16S rDNA

BM 562: Project Work/Dissertation

The students would be required to undertake a Dissertation Project Work under the faculty based on their preference, such that total students are equally distributed amongst the faculty. The allotment of students would be done at the beginning of 3rd Semester and evaluation would be done at the end of 4th Semester. Dissertation evaluation would comprise of the following

Continuous Evaluation	: 40
Report	: 30
Presentation & Viva	: 30

Students can do part of their Project work outside Aliah University, subject to approval from concerned authority. External members may be invited, subject to approval from concerned authority.

BM 572: Comprehensive Viva

The Viva would involve an overall assessment of students jointly by all the faculty members.
External members may be invited, subject to approval from concerned authority.

BM 582: Field trip / Industrial Visit

A mandatory visit to any of the following

k) Natural Park
l) Botanical garden
m) Zoological Park
n) Relevant industry
o) Research Labs at Institutes of National importance

Students would be required to submit a report of their visit which would be evaluated.