SYLLABUS FOR TWO YEAR M.SC COURSE IN BIOPHYSICS AND MOLECULAR BIOLOGY (Revised 2016)

Semester I

Code	Course Title	No. of lectures	Marks	Remarks
BMB 1.1	Mathematical Methods	25	25	Theory
BMB 1.2	Biomolecules: Sequence, Structure and Interaction	25	25	Theory
BMB 1.3	Physico-chemical Methods I	25	25	Theory
BMB 1.4	Bio-organic Chemistry & Enzymology	25	25	Theory
BMB 1.5	Molecular Biology I	25	25	Theory
BMB 1.6	Cell Biology I	25	25	Theory
BMB 1.7	Linux Fundamentals, Analysis of Sequence and Structures	4 Weeks	30	Practical
BMB 1.8	Numerical & Statistical Analysis	5 Weeks	40	Practical
BMB 1.9	Experiments in Biochemistry	5 Weeks	30	Practical

Semester II

Code	Course Title	No. Of Lectures	Marks	Remarks
BMB 2.1	Bioenergetics and Intermediary Metabolism	25	25	Theory
BMB 2.2	Physico-chemical Methods II	25	25	Theory
BMB 2.3	Techniques in Structural Biology	25	25	Theory
BMB 2.4	Microbes and Viruses	25	25	Theory
BMB 2.5	Molecular Biology II	25	25	Theory
BMB 2.6	Cell Biology II	25	25	Theory
BMB 2.7	Plant Tissue Culture and Molecular Biology	4 weeks	30	Practical
BMB 2.8	Biophysical Techniques	4 weeks	30	Practical
BMB 2.9	Recombinant DNA Technology	6 weeks	40	Practical

Semester III

Code	Course Title	No. Of Lectures	Marks	Remarks
BMB 3.1	Developmental Biology	30	30	Theory
BMB 3.2	Cell Biology III	25	25	Theory
BMB 3.3	Immunology	20	20	Theory
BMB 3.4	Evolution, Ecology and Environment	25	25	Theory
BMB 3.5	Genetics	25	25	Theory
BMB 3.6	Experiments in Cell Biology	4 weeks	25	Practical
BMB 3.7	Experiments in Developmental Biology	6 weeks	25	Practical
BMB 3.8	Bioinformatic Techniques	4 weeks	25	Practical
BMB 3.9	Project	10 weeks	50	Practical

Semester IV

Students have to choose any one of the elective theory courses (some of the courses may not be on offer every year)

Code	Course Title	No. of Lectures	Marks	Remarks
BMB 4.1	Systems Biology	50	50	Theory
BMB 4.2a	Stem Cell & Regeneration Biology	25	25	Theory (elective)
BMB 4.2b	Cancer Biology	25	25	Theory (elective)
BMB 4.2c	Plant Molecular Biology	25	25	Theory (elective)
BMB 4.2d	Computational Biology	25	25	Theory (elective)
BMB 4.2e	Neurobiology	25	25	Theory (elective)
BMB 4.2f	Population Genetics	25	25	Theory (elective)
BMB 4.2g	Introduction to Molecular Modeling and Simulation	25	25	Theory (elective)
BMB 4.3	M.Sc. Thesis	20 weeks	100	Practical
BMB 4.4	Student Seminar on selected topics		25	Practical
BMB 4.5	Grand Viva		50	Practical

BMB 1.1 Mathematical Methods

Multivariable Calculus

Partial Derivatives, chain rule, differentials, geometric interpretation, gradient, electrostatics, plane polar coordinates, cylindrical, spherical coordinates, vectors: cylindrical, spherical bases

Infinite series

Basic ideas, Taylor series, convergence, multi-variable series

Vector Spaces

Axioms , examples of vector spaces , linear independence, norms, bases and scalar products , Gram-Schmidt orthogonalization, Cauchy-Schwartz inequality, infinite dimensions

Operators and Matrices

The idea of an operator , definition of an operator , examples of operators, matrix multiplication, inverses, rotations, areas, volumes, determinants, matrices as operators , eigen values and eigenvectors, change of basis

Complex algebra

Complex numbers, applications of Euler's formula

Differential Equations

Linear constant-coefficient , forced oscillations , series solutions , some general methods, The Heat Equation , Separation of Variables , Oscillating Temperatures, Spatial Temperature Distributions, Specified Heat Flow , Electrostatics

Fourier Series and Transform

Examples, computing Fourier Series , choice of basis, Fourier transform, convolution theorem, time-series analysis.

Recommended text

Nearing, James (2010) Mathematical Tools for Physics, Dover Publications

BMB 1.2 Biomolecules: Sequences, Structures and Interactions

Introduction to sequence analysis

Biomolecules within a cell; Diversity of sequnce, structure and function of these biomolecules, Sequence encoded in genome – does it bear any significance? Similarity and homology, orthologus and paralogous

Retrieval of biological information from widely used Resources (like NCBI); Resources of Sequence, structure, function of biomolecules. How can one use this information for a newly derived genome?

Theoretical foundations of molecular structure

Matter at microscopic scale, wave-particle duality, wave function and its interpretation, measurement in quantum mechanics and its mathematical representation, wave equation, solution of wave equations for model cases, basic idea of atomic and molecular orbitals, covalent bonding and hybridisation

Molecular forces

Coulomb potential, image forces, charge-dipole interactions, induced dipoles, polarizability

Dispersion, hydrophobic and hydration interactions, hydrogen bonding

Steric repulsion, stabilizing interactions in proteins, nucleic acids, lipids and membranes

Conformations

Polymer chains and configurational partition functions, statistics of random coils, persistence length, Flory theory and theta solvents, Probability distributions and physics of random coil polymers

Backbone rotations in proteins: secondary structure, thermodynamics of helix-coil transition, Protein folding and Cooperativity

Watson Crick model of DNA- base, sugar, phophodiester bond, sugar puckering envelop and twist form. Base-stacking, B and non-B form of DNA, Flexibility and Bending of DNA, Nucleosome and Chromatin model, Supercoiled DNA, Thermodynamics and kinetics of DNA- Cot Curve, RNA structures (t-RNA, micro-RNA)

Interaction

Role of water within a cell
Protein-protein, Protein-Nucelic acids interaction and their role in cellular functions.

Textbooks

Tinoco. I. et al. (2014) Physical Chemistry: Principles and Applications in Biological Sciences. Pearson Education

Jackson, M. B. (2006) Molecular and Cellular Biophysics. Cambridge University Press

Calladine, C. Drew, H. (2004) Understanding DNA. Academic Press.

BMB 1.3 Physico-chemical Methods I

Describing Macromolecules: Size, shape and frictional coefficient of macromolecules, bound water, molecular weight, Perrin's equation, shape factor, partial specific volume.

Chromatography: TLC, Paper, Size exclusion, Ion exchange, Affinity, HPLC, Capilary electrophoresis.

Gel electrophoreses: Separation of DNA, RNA: Protein SDS PAGE, Native PAGE, Isoelectric focusing, 2-D gel electrophoresis. Southern blot, Northern Blot, Western blot, DNA sequencing, DNase footprinting, EMSA.

Transport properties; Stoke's law, Diffusion.

Viscosity: Intrinsic and specific viscosity; Ostwald viscometer; Applications in biology.

Sedimentation and ultracentrifugation: flow equation, sucrose, CsCl, alkaline sucrose gradients, Applications.

MALDI-TOF and its applications.

Thermodynamics kinetics and their applications.

Suggested texts:

1. Physical Chemistry – Principles and applications in Biological Sciences – Tinoco
2. Physical Chemistry for Biosciences – Raymond Chang
3. Physical Biochemistry – David Freifelder

BMB 1.4 Bio-organic Chemistry and Enzymology (25 lectures)

Stereochemistry (2), Basic reaction mechanisms (2),Hydrogen bonds in organic compounds and their importance in biochemistry (1), Amino acids and peptides (1); Carbohydrates (2); Lipids (2).

Enzymes – nature and classification (1); Enzyme specificity, diversity and different factors influencing enzyme activities (1); Enzyme-substrate reaction kinetics (1); Enzyme inhibition kinetics (2), Isoenzymes (1); Multienzyme complexes (1); Multisubstrate enzymatic reactions (1); Stereochemistry of enzymatic reactions (2); Enzyme regulations – allosteric modifications, feedback inhibition, covalent modification and proteolytic activation (5)

Suggested texts:

Lehninger: Principles of Biochemistry

Stryer: Biochemistry

Segel: Biochemical Calculations

BMB 1.5 Molecular Biology I

Replication: DNA as a genetic material, Replicons – Prokaryotic enzymes involved in DNA replication: DNA polymerases, helicases, nucleases, DNA binding and unwinding proteins; topoisomerases; replication origin and replication fork, Initiation, elongation and termination, Semiconservative and semicontinuous replication.

Prokaryotic Transcription: polymerase subunits, different sigma factors. Initiation, elongation and termination. Transcriptional Regulation using *lac* operon and lambda as model systems.

Prokaryotic Translation: Structures of tRNA and Ribosome, Genetic code, detailed mechanism of translation.

Recommended text

1. Gene IX – Benjamin Lewin
2. Molecular Biology of Gene – James Watson
3. Molecular Biology – Weaver

BMB 1.6 Cell Biology I

The origin and evolution of the cell and its organelles: Differences between prokaryotes and eukaryotes, RNA world, endosymbiotic theory of evolution of the mitochondria and chloroplast, evolution of electron transport chains, evolution of the genetic code and the phylogenetic tree of evolution.

Membrane structure and function: Structure of model membrane, lipid bilayer and membrane proteins, fluid mosaic model of random diffusion of membrane components, structure and function of lipid rafts and caveolae; ion channels and ion pumps. Electrical properties of membranes. Membrane transport: Passive diffusion, osmosis, Facilitated diffusion, primary and secondary active transport, uniport, symport and antiport. Patch clamp technique and FACS.

Structure and function of the nucleus and molecular mechanisms underlying transport of molecules between nucleus and cytosol.

Structure and function of mitochondria and chloroplasts, their genetic systems and protein sorting into these organelles.

Structure, function and protein transport into peroxisomes.

Recommended reading:

Molecular Biology of the Cell- Bruce Alberts;

The Cell: A molecular approach- Cooper.

BMB 1.7 Linux Fundamentals, Sequence and Structure Analysis

Introduction to the structure of a Linux based OS, shell command interpreters, configuring shell environment, basic shell commands, handling file systems, editing files, file permissions, file redirection and pipes

Sequence databases, sequence manipulation and analysis, structure databases, manipulation of structure and analysis, molecular graphics tools, derived databases and their applications

BMB 1.8 Numerical & statistical Analysis

Numerical differentiation and integration algorithms, Differential equations, Euler method, Runge-Kutta method, Data fitting – Least squares, Euclidean fit, Correlations, Principal components, numerical solution of partial differential equations, using Octave for numerical problems.

Introduction to Fortran/Python for scientific computing, programs and compilers, variables, data types, declarations, expressions, input and output, selection and looping, file operations, arrays, subprograms

Basic statistics with R

[Each module has been allotted three hours of teaching and practice. If needed, a fraction of the schedule may be used as a theory class for clarification of the concepts]

Module 1: Introduction to R. Downloading and installing the program with on-line help. Objects and data. Working methodology of R. Use of R as a calculator.

Module 2: Reading data from a file, saving data. Generation of regular and random sequences. Creating and converting objects. Concatenation of vectors. Types of data. Features of data distribution.

Module 3: Data frames, matrices, functions, operators and loops. Sample spaces, conditional probability and Bayes' theorem.

Module 4: Graphics with R. graphical functions. Low level plotting commands. Packages.

Module 5: Random variables, Discrete random variables. Discrete uniform distribution, Binomial distribution, Poisson's distribution. Functions of random variables.

Module 6: Continuous random variables. Gaussian distribution. Standard Normal distribution.

Module 7: Central limit theorem. t-distribution. Pairwise t-tests.

Module 8: Confidence interval estimation for z-test, t-test.

Module 9: Hypothesis testing. Type I and Type II error.

Module 10: Chi-square distribution. Contingency chi-square. Tests of independence, tests for homogeneity.

Module 11: Hypothesis testing continued with z-distribution, t-distribution and chi-square distributions.

Module 12: Regression analysis. Residual analysis. Multiple linear regression.

Module 13: Analysis of variance. One-way analysis of variance. F statistics.

Module 14: Two-way analysis of variance. Interaction.

Module 15: Power analysis and sample size calculation. Theory of experimental design.

BMB 1.9 Experiments in Biochemistry

pH titration of amino acids and determination of pK values

Preparation of serum from human blood

Estimation of serum protein using BSA as the standard

Separation of serum proteins by PAGE

Assay of acid phosphatase, alkaline phosphatase and lactate dehydrogenase (following both forward and reverse reactions) in serum

pH – activity relationship of acid phosphatase

Determination of kinetic constants (K_m and V_{max}) of acid phosphatase in the absence and presence of inhibitors

Effect of temperature on denaturation and activity of acid phosphatase

Suggested text:

Plummer: Practical Biochemistry

BMB 2.1: Bioenergetics & Intermediary Metabolism

The ATP cycle and glycolysis ; Pentose phosphate pathway and Entner-Doudoroff pathway ; Citric acid cycle, anaplerotic pathways ; Electron transport chain, oxidative phosphorylation and regulation of ATP generation ; Anaerobic respiration and fermentations ; Oxidative degradation of fatty acids and amino acids , Correlation between carbohydrates, amino acids and fatty acid degradation, anabolic pathways ; Metabolism of nitrogen compounds, nitrogen fixation, nitrogen cycle as the source of cellular biosynthetic intermediates , CO_2 fixation; Energy transduction in chemolithotrophs and phototrophs

Suggested texts:

Lehninger: Principles of Biochemistry

Stryer: Biochemistry

Voit and Voit: Fundamental of Biochemistry

BMB 2.2 Physicochemical Methods II

Molecular spectroscopy – quantum mechanical principles

Absorption and Fluorescence, UV-Vis Spectroscopy: Definition of light, molecular basis of light absorption by molecules like DNA, RNA, protein and other biomolecules, Calculation of λ_{max} for linear conjugated molecules with example, Calculation of λ_{max} for circular conjugated molecules with example, Biomolecules that absorb light in UV-visible range, Working principle of a spectrophotometer, Application of UV-visible spectroscopy in bio-world, Fluorescence Spectroscopy: Jablonski Diagram, Stokes shift, Biomolecules that have fluorescence, DNA/RNA/ Protein/Other fluorophores in biology, Protein Fluorescence, Instrumentation for fluorescence spectroscopy, Fluorescence quenching, Polarization and anisotropy, Effect of solvent on fluorescence emission, Fluorescence Resonance Energy Transfer.

Vibrational spectroscopy (Infrared and Raman Spectroscopy)

Molecular vibrations, Harmonic and Morse Potentials; Fundamental and overtone modes; Group frequencies; Influence of hydrogen bonding and isotopic substitution on vibrational frequencies, Physical Basis of Infrared and Raman Spectra; Resonance Raman Spectroscopy, FT-IR and Raman spectrometers and their working principles, Amide vibrational modes and side chain modes of proteins; Applications of IR and Raman to structural analyses of biological macromolecules, Typical empirical (including biomedical) applications of vibrational spectroscopy; Vibrational CD.

Recommended reading:

1. Mueller, M. (2002) Fundamentals of Quantum Chemistry. Molecular Spectroscopy and Modern Electronic Structure Computations. Kluwer Academic Publishers, New York
2. I.D. Campbell and R.A. Dwek, Biological Spectroscopy (Pub: The Benjamin/Cummings Publishing Co., Inc.)
3. DM. Freifelder, Physical Biochemistry (Pub: W.H. Freeman & Co.)
4. C.R. Cantor and P.R. Schimmel, Biophysical Chemistry, Part 2 (Pub: W.H. Freeman & Co.)
5. J.R. Lakowicz, principles of Fluorescence Spectroscopy (Pub: Springer).
6. Physical Chemistry – Principles and applications in Biological Sciences – Tinoco
7. Physical Chemistry for Biosciences – Raymond Chang

BMB 2.3 Techniques in Structural Biology

NMR Spectroscopy

Quantum model for spin 1/2 nuclei; Classical Model; FT-NMR, NMR spectrometer and pulse sequence, Chemical shift; J-coupling; Relaxation; Rates and mechanisms, Correlation time, Spin decoupling; NOE, Spin echo, Applications of NMR in macromolecules, Multi-dimensional NMR; COSY; TOCSY, Protein NMR; General Principles; Resonance Assignment.

X-Ray Crystallography

Crystals; Types of lattices and symmetry, Scattering by atoms and molecules; Scattering in terms of Fourier transforms, Interference from sets of atoms and Bragg's Law, Reciprocal lattice and systematic absences, Electron density calculations and phase problem; Solutions to phase problem, Patterson function, Model building and Refinement.

CD & ORD

Chiral Molecules and Optical Activity ; Physical basis of Circular Dichroism (CD) and Optical Rotatory Dispersion (ORD), CD and ORD instruments; Parameters of optical activity; Advantages of CD relative to ORD; Different ranges of CD (visible, near, far and vacuum-UV), CD spectra of interacting chromophores, Electronic transitions of the peptide group; CD spectral signatures for different conformations of proteins ; Multicomponent analysis, Conformational analysis of DNA via CD spectroscopy, Induced circular dichroism with typical applications to studies of biomolecular interactions.

Recommended Text

1. Chary, K. V. R. & Govil, G. (2008) NMR in Biological Systems. From Molecules to Human. Springer
2. Drenth, J. (2010) Principles of Protein X-ray Crystallography, Springer

BMB 2.4 Microbes and Viruses

Microbial Physiology: Structure and function of cell wall, flagella, pili, capsule, outer membrane and its components. Stress Response

Introduction to Virology: definition, properties and origin of viruses, virus architecture and nomenclature, plaque assay, one step growth curve and T4 morphogenesis, Hershey Chase experiment, replication cycle of bacteriophage phiX174, lambda, T-even and odd phages. Basic virological methods and basics of virus entry, spread and transmission. Host resistance to viral infection: immune responses, Baltimore classification, Polioviruses and other single-stranded positive-strand RNA viruses, Rabies and other single-stranded nonsegmented negative-strand RNA viruses, Influenza virus and other single-stranded non-segmented negative strand viruses, SV40, Adeno virus, Herpesviruses (nuclear large double-stranded DNA viruses), Poxviruses (cytoplasmic large double-stranded DNA viruses), HIV and other retroviruses, Prion diseases, Interferon and their functional activity.

Plant viruses: Nomenclature, Matthew's Classification, Expression strategy, RNA Viruses, Tobacco mosaic Virus, Cauliflower Mosaic Virus, Brome Mosaic Virus, DNA Virus, Viruses as vectors.

Host-pathogen interaction: Forms of symbiotic relationship- mutualism, commensalism, parasitism. Mechanisms of pathogenesis of bacterial infections- Transmission, adherence, invasion, colonization, evasion of host defenses, damage and disease to host tissue, exit from the body, survival in the environmemt.

Recommended Text

1. Modrow, S. Et al. (2013) Molecular Virology. Springer

BMB 2.5

Molecular Biology II

DNA replication (mainly eukaryotic), Mutation and repair, DNA recombination, Regulation of gene expression: An overview, Tools to study molecular biology, Mechanism of eukaryotic transcription and methods to study transcription, Transcriptional Regulation: Transcription factors and machinery- Transcription activators and repressors; molecular mechanism of transcription via mediators, chromatin remodeling and DNA methylation, Post-transcriptional regulation: RNA processing- capping, polyadenylation splicing , mRNA stability, export, decay, miRNA, siRNA, RNA editing, Translational regulation: Translational proof-reading, translational inhibitors, Post- translational modification of proteins.

Suggested Texts:

1. Gene IX – Benjamin Lewin
2. Molecular Biology of Gene – James Watson
3. Molecular Biology - Weaver

BMB 2.6 Cell Biology-II

Structure and function of Endoplasmic reticulum, Golgi apparatus, Endosomes and Lysosomes.

Intracellular Vesicular Traffic: Molecular mechanisms of membrane transport and the maintenance of compartmental diversity. Transport from ER to golgi apparatus, transport from the trans golgi network to lysosomes, transport into the cell from the plasma membrane (endocytosis), transport from the trans golgi network to the cell exterior (exocytosis).

The Cytoskeleton structure and function: Self assembly and dynamic structure of cytoskeletal filaments, regulation of cytoskeletal filaments, molecular motors, cytoskeleton and cell behavior, muscle contraction

Cell junctions, cell adhesion and the extracellular matrix: Cadherins and cell-cell adhesion, tight junctions and the organization of epithelia, passageways from cell-cell: gap junctions and plasmodesmata, the basal lamina, integrins and cell matrix adhesions.

Overview on the general principles of cell-cell signaling

Discussions on representative recent papers.

Recommended reading:

Molecular Biology of the Cell- Bruce Alberts;

The Cell: A molecular approach- Cooper.

BMB 2.7

Plant tissue culture and molecular biology

Principles of Plant tissue culture- concept of totipotency- protocols for callus cuture-Principles of strerilization-economic exploitation of plant tissue culture.

Washing glass goods- preparation of cotton plugs- preparationof agar-sucrose medium- preparation of HgCl2 solution for seed sterilization- autoclaving- preparation of stabs.

Sterilization of seeds and Imbibition overnight.

Aseptic inoculation of seeds.

Preparation of Murashige and Skoog media- Preparation of stock solution of hormones-sterilization.

Inoculation of explants (leaf sections taken from aseptically germinated seeds) in MS medium for callus induction.

Observation of callus growth at an interval of 3 days over a period of one month .

Isolation of genomic DNA from seedlings by Edwards method and visualization by agarose gel electrophoresis, checking the quality of extracted DNA by spectrophotometry .

Demonstration of RAPD

Isolation of RNA and checking the quality of extracted RNA.

Reverse transcription PCR

Study of polyphenols from Plantago ovate by HPLC method

Study of poly amines by TLC and analysis

BMB 2.8 Biophysics

1. Verification of Lambert Beer's law by using spectrophotometer.
2. Determination of DNA melting curve by spectrophotometry.
3. Fluorescence quenching of protein (BSA) by $CuSO_4$.
4. Interaction of Ethidium bromide with DNA using fluorescence spectroscopy.
5. FTIR characterization of BSA.
6. Determination of melting curve of BSA by DSC.
7. Determination of intrinsic viscosity of DNA solution under the influence of alkali by Ostwald Viscometer.
8. Determination of Cot value of calf thymus DNA by hydroxyl apatite column.

BMB 2.9 Recombinant DNA technology

1. Glassware cleaning and sterilization:
2. Preparation of media and buffer,
3. Aseptic transfer of bacteria,
4. Maintenance of pure bacterial strain by streaking, stabbing, and by Preparation of glycerol stock.
5. Determination of bacterial growth curve by OD; microscopic count and viability assay.
6. Plasmid DNA preparation: mini and large scale,
7. Agarose gel electrophoresis of DNA and identification of various structural forms of plasmid.
8. Estimation of the purity of the isolated Plasmid DNA spectrophotometrically
9. Digestion of DNA by restriction enzyme;
10. Purification of DNA from gel
11. Preparation of competent cells by CaCl2 method.
12. Ligation and transformation of ligated DNA to E. coli of competent cells
13. Expression of a recombinant Protein in E.coli and one step purification of the protein by Affinity column.
14. Estimation of the purity of the isolated protein by SDS-PAGE.

BMB 3.1 Developmental Biology

1. Introduction

History of Developmental Biology; Techniques in Developmental Biology and model organism.

2. Spermatogenesis and Oogenesis

Spermatogenesis in mammals, structure of sperm, regulation of sperm locomotion. Types of eggs, oogenesis in amphibians and mammals.

3. Fertilization

Cellular and Biochemical process during fertilization and strategies for monospermy and conservation of species specificity. Acrosome reaction and signal transduction. Egg activation.

4. Cleavage

Types of cleavage and blastulation in seaurchin, frog, bird and mammals. Gene expression during early development and mid blastula transition.

5. Gastrulation

Gastrulation in seaurchin frog and chick. Specifying body axes in amphibian and bird. Nieukoop center, primary organizer and mesoderm induction. Early development and axis specification of Drosophila, Hox complex in mammals and fly.

6. Cell-cell communication; Cell interaction

Induction and competence. Cell surface receptor and signal transduction pathways.

Temporal and positional specificity in neural induction and neural competence in vertebrates. Molecular signaling by inducers and hierarchy in antero-posterior polarity of neural tube. Animal cap model and experiments in Xenopus.

7. Limb development

Organogenesis, morphogenetic fields and limb.

BMB 3.2: Cell Biology III

Cell division and cell cycle: Cell division cycle general strategies of the cell cycle, Mitosis and meiosis, cytokinesis, their regulation, steps in cell cycle and control of cell cycle.

Cell signaling:

1. Hormones and their receptors.
2. Signaling through G-protein coupled receptors (The cAMP Signaling Pathway: Second messengers and Protein Phosphorylation).
3. Signaling through protein tyrosine kinase receptors: Activation of phospholipase C and calcium signal transduction (Role of second messengers, PI 3-Kinase/Akt and mTOR pathways and their role in cell proliferation and cell death).
4. Non-protein tyrosine kinase receptors (JAK-STAT signaling) and signaling via TNF-α and its receptor involving the MAP kinase signaling pathway and the NF-□B signaling pathways and its role in inflammation, cell proliferation and cell death.
5. Toll-like receptor signaling and their role in early innate immune response.
6. Insulin signaling pathway and regulation of blood glucose levels.
7. Integrin signaling: cell migration, proliferation and survival.
8. Downregulation of cell signaling: receptor desensitization and receptor downregulation.
9. Discussions on recent papers to get acquainted with experimental approaches to study cell signaling.
10. An overview on mathematical approaches to study signaling networks.

<u>Recommended Text</u>

Molecular Biology of the Cell- Bruce Alberts;

The Cell: A molecular approach- Cooper;

Berridge, M.J. (2012) Cell Signalling Biology, doi:10.1042/csb0001001 and

Handbook of Cell Signaling by Bradshaw Volumes I, II and III

BMB 3.3

Immunology

Nature of immune systems; cellular basis of immunity; T cells and B cells; theory of clonalselection; self tolerance; functional properties of antibodies; valence and affinity of antibodies; antigenantibody interaction; immunological techniques and applications (ELISA, RIA etc.). Fine structure of antibodies; hyper variable regions; generation of diversity of antibody and T cell receptor molecules; structure of MHC molecules; Immunoglobin super family; effector mechanisms; complement systems and hypersensitivity reactions; cell mediated immunity; subsets of T cells and their roles in cell mediated immunity; thymic education; immune response genes; acquired immunity; Freund's adjuvant; autoimmunity acquired immune deficiency.

Recommended Text: Roit: Essential Immunology

BMB 3.4: Evolution, Ecology & Environment

Macro & Micro Evolution

Macro Cosmos:

Origin of Cosmos, Big Bang Hypothesis- evolution of elementary particles-atoms-molecules-macromolecules Evolution of Cosmos- Galaxy, Stars, planets, Solar Systems- Earth Environment of Primitive Earth Abiotic synthesis of biological building block Origin of the genetic code- Evolution of Proteins & Genes

Microcosmos:

Similarities and dissimilarities of living organisms, Darwinian theory of Evolution, Post Darwinian Concepts, Evidence of evolution Genome, Proteomes , Paleontology ,Genetics

Measurement of the rates of evolution. Extinction.

Ecology:

Habitat, ecosystem, ecological niche, symbiosis, commensalism , mutualism , antagonism,

Terrestrial Habitats: soils, soil horizon , bedrock. Aquatic Habitats: freshwater, marine and estuarine habitats; Primaryproductivity, eutrophic lakes, Marine ecosystems: Ross ice shelf, marine algae, deepsea trenches, hydrothermal vents, plate tectonics.

Biogeochemical cycles: carbon cycle, nitrogen cycle, nitrogen fixation, nitrification and denitrification. Community ecology : meme social behavoiur, models. Population dynamics: dispersal of organisms, dormancy, age structure in populations, fate of a cohort, presentation of demographic data, population pyramids, survivorship curves, evolutionary strategies, r and k strategies.

Environment

Environmental segments: lithosphere, hydrosphere, hydrosphere, biosphere and atmosphere.

Air pollution: air pollutants and their effects, greenhouse gases and the global temperature, acid rain, photochemical smog, suspended particulate matter(SPM) health hazard ozone depletion. Air pollution control.

Water Pollution: organic wastes , BOD, COD, inorganic wastes sewage and agricultural run offs, radioactive wastes, toxic trace elements . Water treatment plants

Concept of zero growth and sustainable development. COP1 to COP21, Environmental mitigation.

Recommended texts:

Ridley The problem of evolution, Van Demark and Batzing, The microbes, Chapman and Reis Ecology, Fundamentals of Ecology Dash, Text Book of Ecology Odum.

BMB 3.5 Genetics

Principles of Human Genetics and Genomics:

1. Introduction to genomics:

2. Monogenic versus multifactorial inheritance:
2.1. Gene, Locus, Allele, Allele Frequency
2.2. Mendelian pedigree patterns
2.3. Complications to the basic Mendelian pedigree patterns- Part 1 : Co-dominance, Mitochondrial inheritance, Ascertainment bias, Heterogeniety (Allelic, Locus, Clinical heterogeniety)
2.4. Complications to the basic Mendelian pedigree patterns- Part 2 : Lyonization, Pseudoautosomal segregation, Anticipation, Imprinting
2.5. Mosaics and Chimeras

3. Genetics of multifactorial traits:
3.1. Polygenic threshold theory
3.2. Factors affecting gene frequencies
3.3. Hardy-Weinberg equilibrium, Test of HWE

4. Comparative genomics and genome evolution:
4.1. Comparative genomics
4.2. Gene and genome evolution
4.3. Genetic distance and phylogenetic analysis

BMB 3.6 Cell Biology Practical

Basic techniques for mammalian cell culture

1. Growing adherent cells and trypsinizing and subculturing cells from a monolayer. Passaging cells in suspension culture.

2. Freezing cells grown from monolayer and suspension cultures and thawing and recovering frozen cells.

3. Determining cell number using a hemocytometer.

4. Determining cell viability using Trypan blue staining and other cytotoxicity assays such as MTT assay, Alamar blue assay, LDH assay.

5. Discuss methods used to transfect mammalian cells. Transfect cells with green fluorescent protein and visualize cells under the fluorescence microscope.

6. Preparing cells for fluorescence microscopy and staining for a specific protein to visualize under the fluorescence microscope.

7. Discuss staining methods to visualize localization of proteins to a particular cellular compartment.

8. Distribution of mammalian cells in different phases of cell cycle using flow cytometer.

BMB 3.7 Experiments in Developmental Biology

Staging of chick embryos:

a. Window preparation: A procedure to study chick embryos from 48 hrs to 10 days.

Preparation of skeletal specimen to study limb and axial skeleton examination during development: Whole mount staining of cartilage and bone: A procedure for whole mount alcian staining of the cartilaginous skeleton/ alizarin red S staining of bony skeleton of chicken, rodent embryos.

Preparation of skeletal specimen to study dermal skeleton in fish during regeneration:

Whole mount staining of normal and regenerating teleost (Zebrafish) fins. A procedure to study dermal skeleton by using alizarin red S staining.

Histological preparation of embryos to study different developing organs:

a. Dissection, fixation, paraffin embedding, sectioning and hematoxylin/eosin staining of embryos. Procedure to study organogenesis by routine histological preparation.

Time course study of regeneration of zebrafish caudal fin: Procedure to study regenerating fin by microscopy and studying histological sections.

BMB 3.8 Bioinformatic Techniques

Protein 3D structure modelling, analysis of gene expression data, Pathway analysis, Use of current biological database.

Markov chain package in R

Module 1: Wilcoxon signed ranks test, Mann-Whitney U-test

Module 2: Friedman test, Kruskal-Wallis H test

Module 3: Chi-square test, Fisher exact test, Pearson's rank-order correlation

Module 4: Point biserial correlation, Runs test

Module 5: Hidden Markov model. Three basic problems. Forward and backward iterations. Viterbi algorithm. Baum-Welch algorithm.

Module 6: Profile HMM, match state, insert state and delete state. Feature-based profile HMM. Jumping profile HMM.

Module 7: Pair HMM for aligned sequence pairs. Generalised pair HMM.

Module 8: Context sensitive HMM. Profile context sensitive HMM.

Module 9: Principal component analysis. Support vector machines.

Module 10: Packages in R for Principal component analysis. prcomp() and princomp() functions.

Module 11: CRAN packages for support vector machines.

Module 12: Package cluster. Hierarchical cluster analysis, Finite mixture models.

Module 13: k-means cluster analysis

Module 10: Introduction to meta analysis

BMB 3.9 Project

Each student would be placed in a reputed laboratory throughout India under a research scientist/ faculty member for doing summer training during approximately 10 weeks.

BMB 4.1 Systems Biology

Students have to attend a set of lectures on the application of different theoretical, biophysical, biochemical and cell biological tools to solve specific problems and obtain an integrated picture of the functioning of a biological system. Model systems like hemoglobin or serum albumin, transcriptional and translational machineries, cellular networks in prokaryotes and eukaryotes will be discussed. Ecological systems would also be addressed.

Recommended text

1. Journal articles on which the lectures will be based will be suggested as and when required

BMB 4.2a Stem Cell & Regeneration Biology (Elective)

Stem Cells: Their definition, Classification and Sources.

A. Embryonic stem cells

B. Embryonic germ cells

C. Fetal stem cells

D. Umbilical cord stem cells

E. Adult stem cells; Hematopoietic stem cells, Mesenchymal stem cells, Gut stem cells,

Liver stem cells, Bone and cartilage stem cells, Epidermal stem cell, Neuronal stem cell,

Pancreatic stem cell, Eye stem cell

Stem cells and their developmental potential

Definition of terms- stem cell, progenitor cell, transit amplifying cells, ES cell, EG cell, Adult stem cell or tissue stem cell – constitutive and facultative. developmental capacity- totipotent, pluripotent and multipotent, bipotent and unipotent.

Developmental potential of the cells of early embryo. Commitment and pluripotentiality, primordial germ cells, ES stem cells, Molecular control of pluripotency, multipotent tissue stem cell.

Differentiation of human embryonic stem cells. Therapeutic cloning

Hurdles to improve the efficiency of therapeutic cloning.

Differentiating human stem cells to neurons.

Stem cell therapies in animal models.

Regeneration, aging and senescence.

Epimorphic regeneration in amphibians and teleost. Regeneration of Limb and Central nervous system.

Morphallaxis regeneration in Hydra.

Compensatory regeneration in mammalian liver.

Environmental and epigenetic causes of aging

BMB 4.2b Cancer Biology (Elective)

Introductory lecture, The Nature of Cancer, Hallmarks of cancer.

Traits of Cancer, Tumor Viruses, Cellular Oncogenes, Growth Factors and Their Receptors, Cytoplasmic Signaling Circuitry Programs, Tumor Suppressor Genes like pRb and Control of the Cell Cycle Clock, p53.

Apoptosis: Master Guardian and Executioner.

Molecular mechanism of Cell Immortalization and Tumorigenesis, Multistep Tumorigenesis

Invasion and Metastasis

Biology of Angiogenesis

Telomerase

Cancer Immunology

Suggested Texts:

1. Biology of Cancer – Weinberg
2. Molecular Biology of Cell – Bruce Alberts

BMB 4.2c Plant Molecular Biology (Elective)

1. Arabidopsis as a model plant- introduction-A brief history of Arabidopsis research-The Arabidopsis Transformation Story-The importance of mutant screens-The Genetic map of Arabidopsis-Community infrastructure and shared resources- The Genome sequence and beyond-conclusion.

2. Genome organization, protein synthesis and processing in plants- Nuclear Plastid and Mitochondrial genome organization. Protein synthesis- nuclear encoded proteins- initiation-elongation and release- chloroplast and mitochondrial protein synthesis. Protein sorting-Targeting to plastids- investigating chloroplast Protein import- Precursors of chloroplast proteins-structure and specificity of transit peptides- Targeting of proteins to the stroma- Targeting to the envelope membranes and the intermembrane spece- Targeting to the thylakoid. The secretory and vacuolar pathways- secretion- sorting to the vacuole- mitochondria- microbodies.

3. Regulation of Gene Expression: Introduction- regulatory mechanisms- control of transcription-measurement of transcriptional activity- enabling transcription-activating transcription- post transcriptional control of gene expression- other regulatory mechanisms-Promoter- Reporter Gene Fusions- luciferase- B Glucunonidase- Aquorin- Green Fluorescent Protein- Signal Transduction pathways- primary sensors- secondary messengers.

4. Regulatory mechanisms- some selected examples

   The perception of Ethylene – etr1 : An Ethylene Sensor

   Ctr1: One of the messengers

   Responses to pathogens : Induced genes-The Plant cell wall – The hypersensitive response and the isolation of resistant genes.

5. Molecular Control of Development – Introduction- Experimental methods in the study of development Map based cloning Gene Tagging : Transposons Gene Tagging TDNA Isolation of Tagged genes- Reverse Genetics

6. Gene Regulation in Plant Development, Fertilization and Seed Development Fertilization Gametophytic Incompatibility Sporophytic incompatibility Barriers to interspecies pollination Embryogenesis embryo maturation. Fruit development and ripening introduction Climacteric and nonclimacteric fruit- Rpening in tomato. Germination introduction-Hormones and germination mobilization of reserves in cereal grains regulation of gene expression by GA. Floral Development homoerotic mutations in floral development Molecular Analysis of homoerotic genes.

7. Cell culture, Transformation and Gene technology Introduction Protoplast and tissue culture Protoplast isolation Transient expression assays DMGT and stable transformation Plant regeneration Agrobacterium mediated transformation Viral vectors .

8. Promoter Analysis and controlling gene expression in transgenic plants knocking out gene activity by antisense expression and cosuppression biochemical function of gene products.

9. Engineering Potentially useful agronomic traits Herbicide tolerance Resistance to insects Engineering viral resistance Resistance to fungal and bacterial pathogens manipulating plant products Carbohydrates Fats and oils Engineering Plants to synthesize novel products.

10. Functions of Secondary metabolites in plants overview Role in Plant microbe interaction Role in Plant insect interaction Role in Plant vertebrate interaction Role in Plant Plant interaction Hairy Root Culture.

11. Growth and Development Overview Embryogenesis The origin of Polarity Meristematic tissues: foundations for indeterminate growth- RAM-SAM vegetative Organogenesis Senescence and Programmed cell death.

12. Auxin Signal transduction pathways developmental effects of auxin

13. Brassinosteroids: Regulators of cell expansion and development.

14. The control of flowering Floral meristems shoot apex and phase changes Circadian rythms photoperiodism vernalization florigen.

15. Responses and adaptations to abiotic stress Developmental and physiological mechanisms that protect against environmental extremes.

16. Photosynthesis, light harvesting complexes mechanism of ETS, photoprotective mechanism CO2 fixation C3, C4 and CAM pathways

17. Respiration and photorespiration citric acid cycle plant mitochondrial ETS and ATP synthesis photorespiratory pathways

18. Nitrogen metabolism : nitrate and ammonium assimilation aminoacid biosynthesis.

Suggested Texts:

1. Plant Physiology – Taiz & Zeiger
2. Plant Biochemistry & Molecular Biology – Lea & Leegood
3. Plant Biochemistry - Heldt

BMB 4.2d Computational Biology (Elective)

An integrated view of biology – from atoms to ecosystems

A discussion on mathematical tools to study the theory of networks and its application to understand different level of biological systems; Systems Biochemistry - alternate approaches; Structural and Kinetic Modeling,;Basics of kinetic modeling- its advantage and disadvantage in studying biological systems; Structural modeling in metabolism.

Dynamical systems, definition and examples; Phase plane analysis; Nullclines; Stability analysis; Bifurcation analysis; Signal transduction; Ultrasensitivity; Gene regulatory networks; Stochastic modelling; Difficulties to model whole cell physiology; Basics of ecological modelling; Recent papers on Systems Biology to discuss the current efforts relating genotype to phenotype

Recommended texts

Robeva, R. S. Et al. (2008) An invitation to Biomathematics. Academic press

BMB 4.2e Neurobiology (Elective)

The Nervous Systems, Electrical Signals of Nerve Cells, Channels and Transporters, Synaptic Transmission: Electrical Synapses, Neurotransmitters and Their Receptors, Pain, Vision, The Auditory System, The Chemical Senses: The Olfactory System, The Taste System

An overview of the structure and function of neurons. Basic electrophysiology of cells, Active membrane properties. Initiation and propagation of action potentials, Modulation of action potential discharge by active conductances, Passive and active dendritic processing. Synapses. Morphology and neurochemistry of synapses and dendritic spines. Synaptic transmission. Synaptic learning. Overview of processing by single neurons. Synaptic interactions. Adaptation. Local vs global dendritic processing. Coding by firing rate. Coding by firing pattern. Population coding. Sensory processing. Principles of sensory transduction.Transduction and early processing of somatic and visual stimuli. Processing of visual stimuli by cortical neurons. Reducing the complexity of biological neurons. McCulloch Pitts neurons. Firing rate models. Linear threshold neurons. Spiking neurons. Neuromorphic analog VLSI Emulation of biophysics by analog electronic circuits. Silicon neurons, and silicon cortex. Models of signal processing by neuronal networks Introduction to the softwares GENESIS and NEURON. Imaging in neuroscience.Introduction to the Human Brain Project.

Suggested text: Neuroscience – Dale Purves

BMB 4.2f Population Genetics (Elective)

Introduction, Gene pool, gene frequency, random mating, Hardy-Wienberg equilibrium (HWE) for autosomal bi-allelic loci, conditions for HWE, stability of HWE, equilibrium for sex-linked loci.

Genotypic selection, fitness coefficient, selection of recessive genotype, fixation of gene, time scale for fixation, selection of dominant genotype.

Heterozygotic advantage, sickle cell anemia, heterozygotic depression, pest control, comparison of the nature of fixed points for the two cases from non-linear analysis.

Other modes of selection, gene selection, frequency dependent selection, density dependent selection, kin selection, mutation, rates of mutation, Haldane's calculation, balance between selection and mutation, migration of genes.

Maximum principle for selection, Haldane's cost of natural selection, Probability of fixation of a mutant gene, Kolmogorov backward equation, average fitness and genetic load: mutation, segregation, incompatibility and meiotic loads.

Evolution at more than one locus, Linkage disequilibrium, selection and linkage disequilibrium, subdivision in a population, Wahlund principle.

Inbreeding: decrease of heterozygosity with inbreeding, Wright coefficient *f*, computation of *f*, from pedigree, Identity by descent, equivalence between the two definitions, effect of inbreeding on the variance.

Fixation indices $F_{IS,}$ F_{ST}, F_{IT}. Population structure: continent island, two-island and infinite islands models, stepping stone model.

Genetic drift: Binomial distribution, Markov chain, Diffusion approximation, Change in mean and variance in gene frequency due to random gentic drift, effective population size- estimation of heterozygosity.

Equilibrium between mutation and genetic drift, equilibrium between selection and genetic drift, infinite alleles model, infinite sites model.

Coalescence: effective population size in coalescent model, coalescence with migration, coalescence with mutation, average coalescence time for a single allele and for all alleles.

Molecular evolution, neutral theory, measure of divergence and polymorphism, DNA sequence divergence, DNA sequence evolution, HKA test, MK test, Tajima's D, gametic hitchhiking, gametic disequilibrium, evolution of mitochondrial and chloroplast DNA, molecular phylogenetics.

Quantitative genetics, correlation between relatives, genetic model for quantitative traits, covariance between relatives, evolution of quantitative traits, trait loci, Mapping QTL.

BMB 4.2g Introduction to Molcular Modeling and Simulation

The Born-Oppenheimer approximation; Valence bond and molecular orbital approaches in quantum chemistry, semi-empirical and ab-initio methods

Molecular mechanics; Force fields; Bonded and Non-bonded interactions; optimization: principle and techniques

Monte carlo methods; Introduction to molecular dynamics simulation techniques; Calculation of thermodynamic properties of biomolecular systems

Recommended Text

Schlick, Tamar (2010) Molecular Modeling and Simulation: An Interdisciplinary Guide. Springer

BMB 4.3 M.Sc. Thesis

Each student has to complete a comprehensive research work under the guidance of a supervisor (a faculty member decided by the Departmental committee taking into account the choices given by the students and their previous performances). The thesis would be evaluated by an external expert followed by a seminar and viva-voce examination.

Allocation of marks will be as follows:

Internal assessment by the supervisor: 50%

External Expert: 25%

Seminar + Viva-voce: 25%

BMB 4.4 Student's seminar on selected topics

Each student has to attend lectures on selected topics which will be decided by the Departmental committee. At the end of the semester, each student will be assigned a topic (based on the previously mentioned lectures) and (s)he has to give a seminar and it would be evaluated by a panel of experts (at least three internal and one external).

BMB 4.5 Grand Viva

Each student will be evaluated with regard to overall comprehension at the end of the 2year course in a viva-voce test which will be conducted by a panel of not less than 3 Internal and 2 External examiners.