



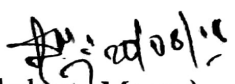
UNIVERSITY OF CALCUTTA

Notification No. CSR/ 80 /18

It is notified for information of all concerned that the Syndicate in its meeting held on 13.07.2018 (vide Item No.11) approved the Syllabus of Two-Year (Four-Semester) M.Sc. Course of Study in Biophysics, Molecular Biology and Bioinformatics under CBCS in the Post-Graduate Departments of the University and in the affiliated Colleges offering Post-Graduate Courses under this University, as laid down in the accompanying pamphlet.

The above shall be effective from the academic session 2018-2019.

SENATE HOUSE
KOLKATA-700073
The 20th August, 2018


(Debabrata Manna)
Deputy Registrar (Acting)

Syllabus

M.Sc. in Biophysics and Molecular Biology

University of Calcutta

2018

Orientation of courses in four semesters for M.Sc. in Biophysics and Molecular Biology

1st Semester

		<i>Marks</i>	<i>Credits</i>
BMB 101	Molecular biology I	25	2
BMB 102	Cell biology I	25	2
BMB 103	Biomolecules I	25	2
BMB 104	Physico-chemical methods I	25	2
BMB 105	Bio-organic chemistry & enzymology	25	2
BMB 106	Physico-mathematical methods	50	4
BMB 107	Introduction to computers and programming (Practical)	25	2
BMB 108	Bioinformatic tools and techniques (Practical)	25	2
BMB 109	Experiments in biochemistry (Practical)	25	2
		175 (Theoretical) + 75(Practical) = 250	14 (Theoretical) + 6 (Practical) = 20

2nd semester

		<i>Marks</i>	<i>Credits</i>
BMB 201	Molecular biology II	25	2
BMB 202	Cell biology II	25	2
BMB 203	Biomolecules II	50	4
BMB 204	Physico-chemical methods II	50	4
BMB 205	Bioenergetics and intermediary metabolism	25	2
BMB 206	Experiments in cell biology (Practical)	25	2
BMB 207	Plant tissue culture and molecular biology (Practical)	25	2
BMB 208	Recombinant DNA technology (Practical)	25	2
		175 (Theoretical) +75(Practical) = 250	14 (Theoretical) + 6 (Practical) = 20

3rd Semester

		<i>Marks</i>	<i>Credits</i>
BMB 301	Molecular biology III	25	2
BMB 302	Cell biology III	25	2
BMB 303	Immunology	25	2
BMB 304	Developmental biology	25	2
CBCCA	Choice Based Credit Course A	50	4
CBCCB	Choice Based Credit Course B	50	4
BMB 307	Experiments in developmental and systems biology (Practical)	25	2
BMB 308	Biophysical techniques (Practical)	25	2
		200 (Theoretical) + 50 (Practical) = 250	16 (Theoretical) + 4 (Practical) = 20

4th Semester

		<i>Marks</i>	<i>Credits</i>
<i>Core courses</i>			
BMB 401	Systems biology	50	4
BMB 402	Evolution and ecology	25	2
BMB 403	Genetics and genomics	25	2
BMB 404 a	Stem cell and regeneration biology (Elective)	25	2
BMB 404 b	Neurobiology (Elective)	25	2
BMB 404 c	Cancer biology (Elective)	25	2
BMB 404 d	Plant molecular biology (Elective)	25	2
BMB 404 e	Population genetics (Elective)	25	2
BMB 404 f	Molecular modeling and simulation (Elective)	25	2
BMB 405	Summer project (Practical)	25	2
BMB 406	M.Sc. thesis (Practical)	100	8
		125 (Theoretical) + 125 (Practical) = 250	10 (Theoretical) + 10 (Practical) = 20

Total Marks/Credits	675 (Theoretical) + 325 (Practical) = 1000	54 (Theoretical) + 26 (Practical) = 80
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Detailed Syllabus for two years M.Sc Course in Biophysics and Molecular Biology, 2018

First Semester

BMB 101: Molecular biology I

Methods for genetic transfers: transformation, conjugation, transduction and sex-duction, mapping genes by interrupted mating.

Prokaryotic Replication: DNA as a genetic material, Replicons – Prokaryotic enzymes involved in DNA replication: replication origin and replication fork, initiation, elongation and termination. Semi-conservative and semi-continuous replication.

Overview of Gene Expression: Prokaryotic transcription, RNA polymerase, promoters, initiation, elongation and termination; Major shifts in transcription.

Prokaryotic translation: Structures of tRNA and ribosome, genetic code, mechanism of translation (initiation, elongation and termination).

Fine control of bacterial transcription: *lac*, *Trp* and *lambda* operons as models.

Recommended texts

1. Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. (2018) Lewin's GENES XII. Jones and Bartlett Learning.
2. Watson, J. D. et al. (2017) Molecular Biology of Gene. 7th edition. Pearson.
3. Weaver, R. (2011) Molecular Biology. 5th edition. McGraw-Hill Education.

BMB 102: Cell biology I

Evolution of cells, cell architecture; differences between prokaryotes and eukaryotes.

Membrane structure and function: Structure of model membrane, lipid bilayer and membrane proteins, fluid mosaic model, 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.

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.

Cellular Thermodynamics: Isolated, closed, open systems and cell. Order, disorder and cell. Thermodynamic parameters and cellular activities. Cellular equilibrium.

Recommended texts

1. Alberts, B. et al. (2014) *Molecular Biology of the Cell*. 6th edition. W. W. Norton & Co.
2. Cooper, G. M. and Hausman, R. E. (2015) *The Cell: A Molecular Approach*. 7th edition. Sinauer Associates.
3. Lodish, H. et al. (2016) *Molecular Cell Biology*. 8th edition. W. H. Freeman & Co.
4. Phillips, R. et al. (2012) *Physical Biology of the Cell*. 2nd edition. Garland Science.

BMB 103: Biomolecules I

Introduction to sequence analysis

Revolution in biological information; protein and nucleic acid primary structures; sequence variations; models of sequence evolution; alignment algorithms; searching sequence databases; phylogenetic methods; retrieval of biological information from widely used resources (e.g. NCBI); resources of sequence, structure, function of biomolecules; examples of application.

Theoretical foundations of molecular structure

The emergence of quantum theory; the Schrodinger equation; interpretation of wave function; the uncertainty principle; motion in one dimension; motion in multiple dimensions; rotational motion; vibration; hydrogenic atoms; many electron atoms; valence bond and molecular orbital theories; Huckel theory; elementary concepts of semi-empirical, ab-initio and density functional methods.

Molecular forces

Coulomb potential, image forces, charge-dipole interactions, induced dipoles, polarizability; dispersion; steric repulsion; hydrogen bonding; hydrophobic and hydration interactions.

Conformations

Chemical constituents of proteins; primary structure; geometry of the peptide bond and protein backbone; backbone rotations in proteins; secondary structure - alpha helix, beta-sheets, polyproline helix and other structures; tertiary structure.

Chemical constituents of nucleic acids; primary structure - base, sugar, phosphodiester bond, sugar puckering envelop and twist form; secondary structure - Watson-Crick model; base-stacking, B and non-B form of DNA, Flexibility and Bending of DNA.

Recommended texts

1. Tinoco, I. et al. (2014) *Physical Chemistry: Principles and Applications in Biological Sciences*. Pearson Education
2. Atkins, P. and de Paula, J. (2010) *Physical Chemistry for the Life Sciences*. 2nd edition. Oxford University Press.
3. Jackson, M. B. (2006) *Molecular and Cellular Biophysics*. Cambridge University Press
4. Finkelstein, A. V. and Ptitsyn, O. B. (2016) *Protein Physics: A Course of Lectures*. 2nd edition. Academic Press
5. Calladine, C. and Drew, H. (2004) *Understanding DNA*. Academic Press.
6. Mount, D. W. (2004) *Bioinformatics: Sequence and Genome Analysis*. 2nd edition. CSHL Press

BMB 104: Physico-chemical methods I

Molecular spectroscopy – quantum mechanical principles

Electronic spectroscopy

UV-Vis Spectroscopy: Parameters of absorption spectra; 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; molecular basis of light absorption by DNA, RNA, protein and other biomolecules; working principle of UV-Vis absorption spectrophotometer; application of UV-visible spectroscopy in bio-world.

Fluorescence Spectroscopy: Jablonski diagram; Stokes shift; fluorescence emission parameters; biomolecules that have fluorescence; intrinsic protein fluorescence from aromatic amino acids; other natural fluorophores like flavins, chlorophyll, Y-base of t-RNA, vitamin A, green fluorescence protein (GFP) and its mutants; extrinsic fluorescence probes; protein fluorescence; instrumentation for fluorescence spectroscopy; fluorescence quenching; polarization and anisotropy, effect of solvent on fluorescence emission, fluorescence resonance energy transfer (FRET).

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.

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 texts

1. Lakowicz, J. R. (2006) Principles of Fluorescence Spectroscopy. 3rd edition. Springer.
2. Cantor, C. R. and Schimmel, P. R. (1980) Biophysical Chemistry. Part II. 1st edition. W. H. Freeman & Co.
3. Banwell, C N. and McCash, E. M. (1994) Fundamentals of Molecular Spectroscopy. 4th Edition, McGraw-Hill.
4. Hollas, J. M. (2004) Modern Spectroscopy. 4th Edition. Wiley.
5. Campbell, I. D. & Dwek R. A. (1984) Biological Spectroscopy. Addison-Wesley.
6. Tinoco. I. et al. (2014) Physical Chemistry: Principles and Applications in Biological Sciences. Pearson Education.

BMB 105: Bio-organic chemistry and enzymology

Stereochemistry; basic reaction mechanisms; hydrogen bonds in organic compounds and their importance in biochemistry, amino acids and peptides; carbohydrates; lipids.

Enzymes – nature and classification; enzyme specificity, diversity and different factors influencing enzyme activities; enzyme-substrate reaction kinetics; enzyme inhibition kinetics, isoenzymes; multienzyme complexes; multisubstrate enzymatic reactions; stereochemistry of enzymatic reactions; enzyme regulations – allosteric modifications, feedback inhibition, covalent modification and proteolytic activation.

Recommended texts

1. Nelson, D. M. and Cox, M. M. (2017) *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co.
2. Berg, J. M. et al. (2015) *Biochemistry*. 8th edition. W. H. Freeman & Co.
3. Voet, D. and Voet, J. G. (2010) *Biochemistry*. 4th edition. Wiley.
4. Voet, D., Voet, J. G. and Pratt, C. W. (2016) *Fundamentals of Biochemistry: Life at the Molecular Level*. 5th edition. Wiley.
5. Segel, I. H. (2010) *Biochemical Calculations*. 2nd edition. Wiley.

BMB 106: Physico-mathematical methods

Calculus and classical mechanics

Recapitulation of classical mechanics: vectors and coordinate systems; momentum, force and energy, linear and rotational motion, system of particles; continuum mechanics; elasticity; theory of fluids

Taylor series, convergence, multivariable series.

Vector and metric spaces

Axioms, examples of vector spaces, linear independence, norms, bases and scalar products, Gram-Schmidt orthogonalization, infinite dimensions, metric spaces; applications.

Operators and matrices

The idea of an operator, definition of an operator, examples of operators; gradient, divergence and curl operators, application in electrostatics and electrodynamics.

Matrices as operators, matrix multiplication, inverses, rotations, areas, volumes, determinants, eigenvalues and eigenvectors, change of basis, matrix normalization.

Fourier analysis

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

Differential equations

ODEs; states of a process; analysis of phase space; integral curves; geometric significance of a differential equation; example - logistic equation; effect of feedback; predator-prey model.

Statistics

Measures of central tendency and dispersal; probability distributions (Binomial, Poisson and normal); Sampling distribution; Difference between parametric and non-parametric statistics; Confidence Interval; Errors; Levels of significance; Regression and Correlation; t-test; Analysis of variance; chi-square test; Basic introduction to multivariate statistics.

Recommended texts

1. Newman, J. (2008) *Physics of the Life Sciences*. Springer.
2. Nearing, J. (2010) *Mathematical Tools for Physics*, Dover Publications.
3. Phillips, R. et al. (2011) *Physical Biology of the Cell*. 2nd edition. Garland Science.

BMB 107: Introduction to computers and programming

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.

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

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.

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

Graphics with R; graphical functions. Low level plotting commands. Packages.

Random variables; discrete random variables. Discrete uniform distribution. Binomial distribution; Poisson's distribution. Functions of random variables.

Continuous random variables. Gaussian distribution. Standard Normal distribution. Central limit theorem. t-distribution. Pairwise t-tests. Confidence interval estimation for z-test, t-test. Hypothesis testing. Type I and Type II error. Chi-square distribution. Contingency chi-square. Tests of independence, tests for homogeneity. Hypothesis testing continued with z-distribution, t-distribution and chi-square distributions.

Regression analysis. Residual analysis. Multiple linear regression. Analysis of variance. One-way analysis of variance. F statistics. Two-way analysis of variance. Interaction. Power analysis and sample size calculation. Theory of experimental design.

Recommended texts

1. Cobbaut, P. (2012) Linux Fundamentals. Netsec BVBA, Paul Cobbaut.
2. Eaton, J. W. et al. (2018) GNU Octave: Free Your Numbers. John W. Eaton.
3. Bloomfield, V. (2009) Computer Simulation and Data Analysis in Molecular Biology and Biophysics. Springer.

BMB 108: Bioinformatics tools and techniques

Introduction to Python for bioinformatics: Programs and compilers, variables, data types, declarations, expressions, input and output, selection and looping, file operations, arrays, subprograms.

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

Recommended texts

1. Model, M. L. (2009) Bioinformatics Programming using Python. O'Reilly.
2. Stevens, T. J. and Boucher, W. (2015) Python Programming for Biology. Bioinformatics and Beyond. Cambridge University Press.

BMB 109: 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

Recommended texts

1. Plummer, D. T. (1987) Introduction to Practical Biochemistry. 3rd edition. McGraw-Hill Publishing Co.
2. Holtzauer, M. (2006) Basic Methods for the Biochemical Lab. 1st English edition. Springer.

Second Semester

BMB 201: Molecular biology II

DNA replication (viral, prokaryotic and eukaryotic), DNA recombination (regular and advanced), Somatic recombination of Immunoglobulin genes, Mutation, DNA Repair (Prokaryotic, Eukaryotic and Parasitic). Transposons (Prokaryotic and Eukaryotic) and Retrotransposons.

Methods to study DNA replication recombination and repair (Radioactive and nonradioactive Tracers, Autoradiography, Southern Blots, DNA Fingerprinting and DNA Typing, In Situ Hybridization, DNA Sequencing and Physical Mapping).

Recommended texts

1. Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. (2018) Lewin's GENES XII. Jones and Bartlett Learning.
2. Watson, J. D. et al. (2017) Molecular Biology of Gene. 7th edition. Pearson.
3. Weaver, R. (2011) Molecular Biology. 5th edition. McGraw-Hill Education.

BMB 202: 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.

Recommended texts

1. Alberts, B. et al. (2014) *Molecular Biology of the Cell*. 6th edition. W. W. Norton & Co.
2. Cooper, G. M. and Hausman, R. E. (2015) *The Cell: A Molecular Approach*. 7th edition. Sinauer Associates.
3. Lodish, H. et al. (2016) *Molecular Cell Biology*. 8th edition. W. H. Freeman.
4. Phillips, R. et al. (2012) *Physical Biology of the Cell*. 2nd edition. Garland Science.

BMB 203: Biomolecules II

Biomolecular structure, folding and interactions

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

Thermodynamics of helix-coil transition, thermodynamics and kinetics of DNA- Cot Curve, Thermodynamics of biomolecular interactions.

Protein tertiary structure; domains and folds, protein folding and cooperativity, quaternary structure and allosteric interactions. Protein-protein and protein-nucleic acid interaction

Nucleosome and chromatin model; supercoiled DNA; RNA quaternary structure; tRNA structure and folding.

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.

Microscopy

Design and fundamental principles of light and fluorescence microscopes; the fundamental principles of transmission and scanning electron microscopy; sample preparation for microscope, diffraction-limited resolution of light microscopy; point spread function and its utility.

Structure and function of a confocal laser scanning microscope; the principle and use of deconvolution in fluorescence microscopy.

Recommended texts

1. Jackson, M. B. (2006) Molecular and Cellular Biophysics. Cambridge University Press
2. Chary, K. V. R. & Govil, G. (2008) NMR in Biological Systems. From Molecules to Human. Springer.
3. Drenth, J. (2010) Principles of Protein X-ray Crystallography, Springer.

BMB 204: Physico-chemical methods II

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, capillary electrophoresis and their applications.

Gel electrophoresis: Separation of DNA, RNA: Protein SDS PAGE, Native PAGE, Isoelectric focusing, 2-D gel electrophoresis and their applications in Biology.

Transport properties; Stokes' law, diffusion. Viscosity: Intrinsic and specific viscosity; Ostwald viscometer; applications. Sedimentation and ultracentrifugation: flow equation, sucrose, CsCl, alkaline sucrose gradients and Applications.

MALDI-TOF and its applications. Principle and applications of FACS

Tools of statistical mechanics to study some biological problems.

Recommended texts

1. Tinoco. I. et al. (2014) Physical Chemistry: Principles and Applications in Biological Sciences. Pearson Education
2. Chang, R. (2005) Physical Chemistry for Biosciences. University Science Books.
3. Cantor, C. R. and Schimmel, P. R. (1980) Biophysical Chemistry. Part III. 1st edition. W. H. Freeman & Co.

BMB 205: Bioenergetics and 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 fermentation; 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 , CO₂ fixation; Energy transduction in chemolithotrophs and phototrophs

Recommended texts

1. Nelson, D. M. and Cox, M. M. (2017) *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co.
2. Berg, J. M. et al. (2015) *Biochemistry*. 8th edition. W. H. Freeman & Co.
3. Voet, D. and Voet, J. G. (2010) *Biochemistry*. 4th edition. Wiley.
4. Voet, D., Voet, J. G. and Pratt, C. W. (2016) *Fundamentals of Biochemistry: Life at the Molecular Level*. 5th edition. Wiley.

BMB 206: Experiments in cell biology

Basic techniques for mammalian cell culture

Growing adherent cells and trypsinizing and subculturing cells from a monolayer; Passaging cells in suspension culture; Freezing cells grown from monolayer and suspension cultures and thawing and recovering frozen cells; Determining cell number using a hemocytometer; Determining cell viability using Trypan blue staining and other cytotoxicity assays such as MTT assay, Alamar blue assay, LDH assay; Discuss methods used to transfect mammalian cells. Transfect cells with green fluorescent protein and visualize cells under the fluorescence microscope; Preparing cells for fluorescence microscopy and staining for a specific protein to visualize under the fluorescence microscope; Discuss staining methods to visualize localization of proteins to a particular cellular compartment; Distribution of mammalian cells in different phases of cell cycle using flow cytometer.

Recommended texts

1. Celis, J. E. (1997) Cell Biology: A Laboratory Handbook. 2nd edition. Academic Press.

BMB 207: Plant tissue culture and molecular biology

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

Preparation of agar-sucrose medium- preparation of HgCl_2 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 ovata* by HPLC method

Study of polyamines by TLC.

Recommended texts

1. Smith, R. H. (2013) Plant Tissue Culture: Techniques and Experiments. 3rd Edition. Academic Press.

BMB 208: Recombinant DNA technology

Glassware cleaning and sterilization, Preparation of media and buffer, Aseptic transfer of bacteria, Maintenance of pure bacterial strain by streaking, stabbing, and by Preparation of glycerol stock. Determination of bacterial growth curve by OD; microscopic count and viability assay.

Plasmid DNA preparation, Agarose gel electrophoresis of DNA and identification of various structural forms of plasmid, Estimation of the purity of the isolated Plasmid DNA spectrophotometrically, Digestion of DNA by restriction enzyme; Purification of DNA from gel

Preparation of competent cells by CaCl₂ method. Ligation and transformation of ligated DNA to E. coli of competent cells, measurement of Transformation efficiency.

Expression of a recombinant Protein in E.coli and one step purification of the protein by Affinity column. Estimation of the purity of the isolated protein by SDS-PAGE.

Recommended texts

1. Green, M. R. and Sambrook, J. (2012) Molecular Cloning: A Laboratory Manual. 4th edition. CSHL Press.

Third Semester

BMB 301: Molecular biology III

Transcription in Eukaryotes: RNA Polymerases, Promoters, Enhancers and Silencers, Transcription Factors, Mediator Complex, Activators, Interaction among Activators, Chromatin remodeling; Regulation of Transcription and Epigenetic regulation.

RNA Processing: Splicing, Capping and Polyadenylation, Post-Transcriptional Control of Gene Expression, RNA Editing, mRNA Stability, siRNA, miRNA, Translation Repression, mRNA Degradation

Translation in Eukaryotes: Ribosomes, Initiation, elongation and termination. Translational regulation, Post-translational modifications and mechanisms of protein degradation.

Overview of regulation of viral gene expression (both plant and animal) in connection to host-pathogen interaction.

Methods to study gene expression: Mapping and Quantifying Transcripts (Northern Blots, Primer Extension, Run-Off Transcription, Cassette Transcription), Measuring Transcription Rates *in vivo* (Nuclear Run-On, Reporter Gene Transcription, Measuring Protein Accumulation *in Vivo*), Assaying DNA–Protein Interactions (Filter Binding, Gel Mobility Shift, DNase Footprinting, Chromatin Immunoprecipitation), Assaying Protein–Protein Interactions.

Recommended texts

1. Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. (2018) Lewin's GENES XII. Jones and Bartlett Learning.
2. Watson, J. D. et al. (2017) Molecular Biology of Gene. 7th edition. Pearson.
3. Weaver, R. (2011) Molecular Biology. 5th edition. McGraw-Hill Education.

BMB 302: 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

Hormones and their receptors.

Signaling through G-protein coupled receptors (The cAMP Signaling Pathway: Second messengers and Protein Phosphorylation).

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).

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- κ B signaling pathways and its role in inflammation, cell proliferation and cell death.

Toll-like receptor signaling and their role in early innate immune response.

Insulin signaling pathway and regulation of blood glucose levels.

Integrin signaling: cell migration, proliferation and survival.

Downregulation of cell signaling: receptor desensitization and receptor downregulation.

An overview on mathematical approaches to study signaling networks.

Recommended texts

1. Alberts, B. et al. (2014) Molecular Biology of the Cell. 6th edition. W. W. Norton & Co.
2. Cooper, G. M. and Hausman, R. E. (2015) The Cell: A Molecular Approach. 7th edition. Sinauer Associates.
3. Lodish, H. et al. (2016) Molecular Cell Biology. 8th edition. W. H. Freeman.
4. Berridge, M.J. (2014) Cell Signalling Biology. Portland Press.
5. Bradshaw, R. A. and Dennis, E. A. (2003) Handbook of Cell Signaling. Vol. I, II and III. Academic Press.

BMB 303: Immunology

Nature of immune systems; cellular basis of immunity; T cells and B cells; theory of clonal selection; self tolerance; functional properties of antibodies; valence and affinity of antibodies; antigen-antibody 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; Immunoglobulin 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 texts

1. Delves, P. J. et al. (2017) Roitt's Essential Immunology. 13th edition. Wiley Blackwell.
2. Owen, J. A et al. (2013) Kuby Immunology. 7th edition. W. H. Freeman.

BMB 304: Developmental biology

History of developmental biology. Techniques in developmental biology and model organism.

Spermatogenesis and Oogenesis

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

Fertilization

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

Cleavage

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

Gastrulation

Gastrulation in sea urchin 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.

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*.

Limb development

Organogenesis, morphogenetic fields and limb.

Recommended texts

1. Wolpert, L., Tickle, C. and Arias, A. M. (2015) Principles of Development. 5th edition. Oxford University Press.
2. Gilbert, S. F. and Barresi, M. J. F. (2016) Developmental Biology. 11th edition. Sinauer.
3. Wolpert, L. (2011) Developmental Biology: A Very Short Introduction. Oxford University Press.

CBCC A: Choice Based Credit Course A ~ 50 marks; 4 credits.

CBCC B: Choice Based Credit Course B ~ 50 marks; 4 credits.

[Details of CBCC offered by the department: Page 40]

BMB 307: Experiments in developmental and systems 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.

Recommended texts

1. Westerfield, M. (2000). The Zebrafish Book. A Guide for the Laboratory Use of Zebrafish (*Danio rerio*). 4th edition. University of Oregon Press.

BMB 308: Biophysical techniques

Determination of DNA (B DNA/ G-quadruplex) melting curve by spectrophotometry.

Enhancement of fluorescence activity of Ethidium Bromide upon interaction with double stranded DNA.

Fluorescence quenching of protein (BSA) by Acrylamide, and study of the effect of micro-environment on intrinsic fluorescence.

FTIR characterization of BSA.

Denaturation curve of BSA by DSC.

Fluorescence studies of protein-ligand binding: Binding of ANS a fluorescence probe with BSA. Estimation of binding parameters via Scatchard plot analysis. FRET studies (Trp to ANS FRET)

Studying the effect of solvent polarity on ANS fluorescence by examining emission spectra of ANS in varying concentrations of ethanol-water mixtures.

Recommended texts

1. Holtzhauer, M. (2006) Basic Methods for the Biochemical Lab. 1st English edition. Springer.
2. Nadeau, J. L. (2015) Introduction to Experimental Biophysics. CRC Press.

Fourth Semester

BMB 401 Systems biology

An integrated view of biology – from atoms to ecosystems

Experimental techniques used in small and large scale data generation for systems biology study.

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 advantages and disadvantages 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.

Apart from the coursework, 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 texts

1. Klipp, E. et.al. (2009) Systems Biology: A Textbook. 1st edition. Wiley-Blackwell.
2. Voit, E. O. (2012) A First Course in Systems Biology. 1st edition. Garland Science.
3. Phillips, R. et al. (2011) Physical Biology of the Cell. 2nd edition. Garland Science.

BMB 402: Evolution and ecology

Emergence of evolutionary thoughts

Lamarck; Darwin – concepts of variation, adaptation, struggle, fitness and natural selection; Mendelism; spontaneity of mutations; the evolutionary synthesis.

Origin of cells and unicellular evolution

Environment of primitive earth; origin of basic biological molecules; abiotic synthesis of organic monomers and polymers; hypotheses of Oparin and Haldane; experiment of Miller (1953); origin of the genetic code; evolution of proteins and genes, the first cell; evolution of prokaryotes; origin of eukaryotic cells; evolution of unicellular eukaryotes; anaerobic metabolism, photosynthesis and aerobic metabolism.

Paleontology and evolutionary history

The evolutionary time scale; eras, periods and epoch; major events in the evolutionary time scale; origins of unicellular and multicellular organisms; major groups of plants and animals; stages in primate evolution including Homo.

Molecular evolution

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.

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.

Behavioural ecology

Approaches and methods in study of behavior; proximate and ultimate causation; altruism and evolution - group selection, kin selection, reciprocal altruism; neural basis of learning, memory, cognition, sleep and arousal; biological clocks; development of behavior; social communication; social dominance; use of space and territoriality; mating systems, parental investment and reproductive success; parental care; aggressive behavior; habitat selection and optimality in foraging; migration, orientation and navigation; domestication and behavioral changes.

Ecology and environment

Physical environment; biotic environment; biotic and abiotic interactions.

Concept of habitat and niche; niche width and overlap; fundamental and realized niche; resource partitioning; character displacement.

Characteristics of a population; population growth curves; population regulation; life history strategies (r

and K selection); concept of metapopulation – demes and dispersal, interdemic extinctions, age structured populations.

Species interactions; types of interactions, interspecific competition, herbivory, carnivory, pollination, symbiosis.

Community ecology; nature of communities; community structure and attributes; levels of species diversity and its measurement; edges and ecotones.

Ecological succession; types; mechanisms; changes involved in succession; concept of climax.

Ecosystem ecology; ecosystem structure; ecosystem function; energy flow and mineral cycling (C,N,P); primary production and decomposition; structure and function of some Indian ecosystems: terrestrial (forest, grassland) and aquatic (freshwater, marine, estuarine).

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 runoffs, radioactive wastes, toxic trace elements . Water treatment plants.

Recommended texts

1. Ridley, M. (1985) *The Problems of Evolution*. 1st edition. Oxford University Press.
2. Ridley M. (2008) *Evolution*. Oxford University Press.
3. Barton, N. H. et al. (2007) *Evolution*. CSHL Press.
4. Futuyama, D. J. (2013) *Evolution*. 3rd edition. Sinauer Associates.
5. Stillman, B., Stewart, D. and Witkowski, J (2009) *Evolution: The Molecular Landscape*. CSHL Press
6. Chapman, J. L. and Reis, M. J. (1998) *Ecology: Principles and Applications*. 2nd edition. Cambridge University Press.
7. Odum, E. (2005) *Fundamentals of Ecology*. 5th edition. Cengage.
8. Dash, M. C. and Dash, S. P. (2009) *Fundamentals of Ecology*. 3rd edition. McGraw-Hill Education.

BMB 403: Genetics and genomics

Introduction to genomics; monogenic versus multifactorial inheritance

Gene, locus, allele, allele frequency; Mendelian pedigree patterns

Complications to the basic Mendelian pedigree patterns - Part 1: Co-dominance; mitochondrial inheritance; ascertainment bias; heterogeneity (allelic, locus, clinical heterogeneity)

Complications to the basic Mendelian pedigree patterns - Part 2: Lyonization, pseudoautosomal segregation; anticipation; imprinting; mosaics and chimeras

Genetics of multifactorial traits; polygenic threshold theory; factors affecting gene frequencies; Hardy-Weinberg equilibrium, Test of HWE

Comparative genomics and genome evolution; comparative genomics; gene and genome evolution; genetic distance and phylogenetic analysis

Recommended texts

1. Meneely, P. (2014) Genetic Analysis: Genes, Genomes and Networks in Eukaryotes. 2nd edition. Oxford University Press.
2. Hawley, R. S. and Walker, M. (2003) Advanced Genetic Analysis: Finding Meaning in a Genome. 1st edition. Wiley-Blackwell.
3. Korf, B. R. and Irons, M. B. (2013) Human Genetics and Genomics. 4th edition. Wiley-Blackwell.

BMB 404a: 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

Recommended texts

1. Stocum, D. (2006) Regenerative Biology and Medicine. 1st Edition. Academic Press.
2. Carlson, B. M. (2007) Principles of Regenerative Biology. 1st edition. Academic Press.
3. Lanza, R. et al. (2009) Essentials of Stem Cell Biology. 2nd edition. Academic Press.

BMB 404b: 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.

Recommended texts

1. Kandel, E. et al. (2012) Principles of Neural Science. 5th edition. McGraw-Hill Education.
2. Purves, D. et al. (2017) Neuroscience. 6th edition. Sinauer Associates.
3. Gerstner, W. and Kistler, W. M. (2002) Spiking Neuron Models. Cambridge University Press.

BMB 404c Cancer Biology (Elective)

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

Recommended texts

1. Weinberg, R. A. (2013) The Biology of Cancer. 2nd edition. Garland Science.
2. Alberts, B. et al. (2014) Molecular Biology of the Cell. 6th edition. W. W. Norton & Co.

BMB 404d: Plant molecular biology (Elective)

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.

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 space- Targeting to the thylakoid. The secretory and vacuolar pathways- secretion- sorting to the vacuole- mitochondria- microbodies.

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 Glucuronidase- Aquorin- Green Fluorescent Protein- Signal Transduction pathways- primary sensors- secondary messengers.

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.

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.

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- Ripening 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.

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.

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

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.

Growth and Development: Overview; embryogenesis; the origin of polarity; meristematic tissues: foundations for indeterminate growth - RAM-SAM; vegetative organogenesis; senescence and programmed cell death.

Auxin signal transduction pathways; developmental effects of auxin.

Brassinosteroids: Regulators of cell expansion and development.

The control of flowering; floral meristems; shoot apex and phase changes; circadian rhythms; photoperiodism; vernalization; florigen.

Recommended texts

1. Taiz, L et al. (2018) Plant Physiology and Development. 6th edition. Oxford University Press.
2. Lea, P. and Leegood, R. C. (1999) Plant Biochemistry and Molecular Biology. 2nd edition. Wiley.
3. Heldt, H.-W. and Piechulla, B. (2010) Plant Biochemistry. 4th edition. Academic Press.

BMB 404e: Population genetics (Elective)

Introduction, Gene pool, gene frequency, random mating, Hardy-Weinberg 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 genetic 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.

Recommended texts

1. Crow, J. F. and Kimura, M. (2009) An Introduction to Population Genetics Theory. The Blackburn Press.

BMB 404f: Molecular modelling and simulation (Elective)

The Born-Oppenheimer approximation; valence bond and molecular orbital approaches in quantum chemistry, semi-empirical and ab-initio methods; introduction to density functional theory

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

Biomolecular 3D structure modeling, theory and application of docking

Recommended texts

1. Schlick, T. (2010) *Molecular Modeling and Simulation: An Interdisciplinary Guide*. Springer.
2. Leach, A. (2009) *Molecular Modelling: Principles and Applications*. 2nd edition. Pearson Education.
3. Smit, B. and Frenkel, D. (2001) *Understanding Molecular Simulations*. 2nd edition. Academic Press.

BMB 405: Summer project

Each student would be placed in a reputed laboratory under a research scientist/ faculty member as summer trainee for approximately 6/8 weeks duration after the second semester. They are suppose to complete their project during the fourth semester and submit report followed by a project defence.

BMB 406: 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%

Seminar + Report + Viva-voce: 50%

**CBCC offered by Department of Biophysics, Molecular Biology and
Bioinformatics**

Biology by the numbers

The building blocks of life

Four classes of biological macromolecules. Polymeric codes in proteins and nucleic acids.

Biological spatial scales

Cells and structures; diversity of shapes, sizes and functions; organelles; macromolecular assemblies; viruses

Multicellularity; biofilms; slime molds; tissues and networks of cells; differentiation of cells; formation of organs and organisms; development - *C. elegans* as a model; colonies of organisms

Biological time scales

Diversity of time scales in biology; cell cycle and the standard clock

Transcription; translation and replication time scales

Clocks and oscillators; segmentation in development; circadian clocks

Checkpoint and cell cycle; genetic network

Chemical kinetics and enzyme turnover; diffusive transport; motor transport

The art of quantitative modeling in biology

Recommended text

1. Phillips, R. et al. (2012) Physical Biology of the Cell. 2nd edition. Garland Science.