UNIVERSITY OF MUMBAI

Syllabus for the M.Sc. Part - II
[Sem III and IV]

Program: M.Sc.

Course: Life Sciences
Specialisation:
Biological Macromolecules

M.Sc. Part – II Life Sciences Syllabus
Restructured for Credit Based and Grading System
To be implemented from the Academic year 2017-2018

SEMESTER III

Course Code	UNIT	TOPIC HEADINGS	Credits	L / Week
PSLSCBMT301 (Biomathematics, Research Methodology and Cell Biology Techniques)	**I**	**Biomathematics**	**4**	
	II	**Research Methodology**		
	III	**Cell and Molecular Biology Techniques**		
	IV	**Animal and Plant Tissue Culture**		
PSLSCBMT302 (Bioenergetics and Carbohydrate Metabolism)	**I**	**Bioenergetics and Carbohydrate Metabolism**	**4**	
	II	**Lipid Metabolism**		
	III	**Amino Acid Metabolism**		
	IV	**Metabolic Engineering and Systems Biology**		
PSLSCBMT303 (Biomolecular Structure)	**I**	**Chemical Bonds and Spectroscopic Techniques**	**4**	
	II	**Protein and Nucleic Acid Structure**		
	III	**Supramolecular Assemblies and DNA-protein Interactions**		
	IV	**Complex Proteins**		

PSLSCBMP301	Biomathematics, Research Methodology and Cell Biology Techniques	**2**	
PSLSCBMP302	Bioenergetics and Carbohydrate Metabolism	**2**	
PSLSCBMP303	Biomolecular Structure	**2**	

SEMESTER IV

PSLSCBMT401 (Molecular Cell Biology)	**I**	**Cell Division and Apoptosis**	**4**	
	II	**Biomembrane and Cell Matrix**		
	III	**Protein Trafficking and Targeting**		
	IV	**RNAi and Epigenetics**		

PSLSCBMT402 (Nitrogen Metabolism and Plant Biochemistry)	**I**	**Nucleotide Metabolism**	**4**	
	II	**Nitrogen Assimilation in Plants**		
	III	**Photosynthesis and Secondary Metabolism**		
	IV	**Free radicals and Antioxidant Biology**		

PSLSCBMT403 (Biomolecular Function)	**I**	**Protein folding and Engineering**	**4**	
	II	**Kinetics and Mechanism in Biological Systems**		
	III	**Metabolomics and Transcriptomics**		
	IV	**Nanobiology**		

PSLSCBMP401	Molecular Cell Biology	**2**	
PSLSCBMP402	Nitrogen Metabolism and Plant Biochemistry	**2**	
PSLSCBMP403	Biomolecular Function	**2**	

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Semester III Detailed Syllabus

Course Code	Title	Credits
PSLSCBMT301	**Biomathematics, Research Methodology and Cell Biology Techniques (60L)**	**4**
	Unit I: Biomathematics (15L) **Biomathematics**: Binomial Theorem (without infinite series), Determinants, Matrices, Rank of Matrices by Diagonalisation method Limit and derivatives, Differentiation (including differentiability), Successive Differentiation, Integration – Definite and Indefinite (ordinary, method of substitution, special trigonometric function, partial fraction) Application of integration to find area, Differential equations --homogeneous and Linear ODE's and its simple applications to biological problems.	
	Unit II: Research methodology (15L) Meaning of Research, Objectives of research, Motivation in research; Types of research – Descriptive, Analytical, Applied, Fundamental, Quantitative, Qualitative, Conceptual, Empirical and Other Types of Research; Research Approaches; Research Methods vs. Methodology; Research and Scientific Method; Research Process: Steps of research process; Criteria of Good Research; Sampling, Sample size determination, Plan for data collection, Methods of data collection, Plan for data processing and analysis; Ethical considerations during research. **Systematic review and meta analysis**	
	Unit III: Cell and Molecular Biology Techniques (15L) **Cell Biology Techniques:** Principles, Instrument overview, and Applications of flow cytometry, Fluorescence Resonance Energy Transfer (FRET); Surface Plasmon resonance. **Proteomics:** Peptide synthesis and Protein sequencing methods, detection of post-translation modification of proteins; 2-D gel electrophoresis; Mass spectrometry; X-ray diffraction methods; Static and dynamic light scattering (SLS and DLS); Capillary electrophoresis; Protein chips; Differential scanning calorimetry **Genomics:** Oligonucleotide synthesis; DNA chips/microarrays; DNA hybridization; DNA sequencing methods, strategies for genome sequencing; methods for analysis of gene expression at RNA and protein level; DNA microarrays; Site directed mutagenesis; Gene knockdown; Differential display; Serial analysis of gene expression (SAGE)	

	Unit IV: Animal and Plant Tissue Culture (15L) **Plant tissue culture:** Basic concepts in cell culture - cell culture, Cellular Totipotency, Somatic Embryogenesis In vitro culture: approaches & methodologies - preparation steps for tissue culture, surface sterilization of plant tissue material, basic procedure for aseptic tissue transfer, incubation of culture. Tissue culture methodologies: introduction - Callus Culture, Cell Suspension Culture, Protoplast culture and hybridization, Organogenesis, plant micro propagation, cryopreservation. **Animal tissue and cell culture:** In vitro culture: approaches & methodologies - preparation steps for tissue culture, basic procedure for aseptic tissue transfer, incubation of culture. Tissue culture methodologies: introduction - Source of tissue, primary culture, differentiation of cells, growth kinetics, animal cell lines and their origin and characterization Cloning & Selection of specific cell types – cloning, somatic cell fusion and HAT selection, Medium suspension fusion, selection of Hybrid clone, production of monoclonal antibodies, stem cell culture Organ Culture - Culture of embryonic organs, whole embryo culture, culture of adult organs	

Practicals:

PSLSCBMP301	**<u>Bionanalytical Techniques and Cell Dynamics</u> (60L)** 1. pka values of Ala or Gly by Titration Curve 2. Determination of melting temperature (Tm) of DNA 3. Spectroflourimetric analysis of proteins 4. Preparation of lipid bilayer vesicles (liposomes) using the purified lipids 5. Effect of detergents on membranes 6. Fractionation of cell organelles from animal/plant tissues and identification by marker enzymes 7. Estimation of inorganic phosphorus by Fiske and SubbaRao method 8. Protease protection assay to study protein transport and secretion	**2**	**04**

Course Code	Title	Credits
PSLSCBMT302	**Bioenergetics and Metabolism (60L)**	**4**

Unit I: **Bioenergetics and Carbohydrate Metabolism (15L)**

Bioenergetics: Concept of free energy, standard free energy, determination of ΔG for a reaction; Relationship between equilibrium constant and standard free energy change, biological standard state & standard free energy change in coupled reactions; Biological oxidation-reduction reactions; Redox potentials; Relation between standard reduction potentials & free energy change; High energy phosphate compounds – introduction, phosphate group transfer, free energy of hydrolysis of ATP and sugar phosphates alongwith reasons for high ΔG

Carbohydrate Metabolism: Glycolysis in higher organisms and microorganisms; Pentose phosphate pathway and its regulation; Gluconeogenesis, glycogenesis and glycogenolysis, glyoxylate and Gamma aminobutyrate shunt pathways; Cori cycle; Anaplerotic reactions; Entner-Doudoroff pathway; Glucuronate pathway; Metabolism of disaccharides; Hormonal regulation of carbohydrate metabolism; Inborn errors of carbohydrate metabolism

Unit II: **Lipid Metabolism (15L)**

Fatty acid catabolism: Hydrolysis of tri-acylglycerols; α-, β-, ω- oxidation of fatty acids; Oxidation of odd numbered fatty acids – fate of propionate; Role of carnitine; Degradation of complex lipids; Formation of ketone bodies; Energetics of beta oxidation

Fatty acid biosynthesis: Acetyl CoA carboxylase; Fatty acid synthase; ACP structure and function; Lipid biosynthesis; Biosynthetic pathway for tri-acylglycerols, phosphoglycerides, sphingomyelin and prostaglandins; Metabolism of cholesterol and its regulation; Biosynthesis of bile acids and steroid hormones; Alternative pathway for isoprenoid biosynthesis in chloroplast; Inborn errors of fatty acid metabolism

Unit III **Amino Acid Metabolism (15L)**

Amino acid catabolism: Proteolysis; General reactions of amino acid metabolism - Transamination, decarboxylation, oxidative & non-oxidative deamination of amino acids; Acetyl CoA, alpha ketogutarate, acetoacetyl CoA, succinate, fumarate and oxaloaccetate pathway; Urea cycle and its regulation; Ammonia excretion.

Biosynthesis of Amino Acids: Biosynthesis of aromatic amino acids and Histidine; One carbon atom transfer by folic acid (Biosynthesis of glycine, serine, cysteine, methionine, threonine.); Conversion of amino acids to specialized products; Inborn errors of protein metabolism

TCA cycle: Central role of TCA cycle in energy generation and biosynthesis of energy rich bond; Integration/regulation of carbohydrate, lipid and

	protein metabolism	
	Unit : IV **Metabolic Engineering and Systems Biology** **(15L)** **Metabolic Engineering:** Historical perspective and introduction; Importance of metabolic engineering; Paradigm shift; Information resources; Scope and future of metabolic engineering; Plant and microbial metabolic engineering; Metabolically engineered organisms; Metabolic flux analysis **Systems Biology:** Concepts and working principles of System Biology - Practical applications of System Biology in Life Sciences - Introduction to System Biology platforms Proprietary system Biology platform; Different Markup languages used in systems biology. Introduction to NGS technology.	

Practicals:

PSLSCBMP102	**Bioenergetics and Metabolism** **(60L)** 1. Determination of pyruvate by 2,4-dinitrophenyl hydrazine method 2. Isolation of cholesterol and lecithin from egg yolk 3. Measurement of free radicals by spectrophotometric method 4. Analysis of free radical scavengers and antioxidant enzymes (Assay of any one - peroxidase, catalase, phenol oxidase, ascorbic acid oxidase) 5.Determination of N- and C-terminal amino acids (demonstration) 6. Effect of metal ions on the activity of enzymes/proteins 7. Protein purification methods: A. Isolation of casein from milk B. Purification of an enzyme by ion exchange chromatography/affinity chromatography C. Use of ammonium sulphate precipitation and dialysis D. Use of gel filtration E. SDS-PAGE 8. Polyacrylamide gel electrophoresis under non denaturing conditions A. Silver staining B. Activity staining of enzymes C. Determination of effect of acrylamide concentration on the mobility of proteins	**2**	**04**

Course Code	Title	Credits
PSLSCBMT103	**Biomolecular Structure (60L)**	**4**

Unit I: **Chemical Bonds and Spectroscopic Techniques (15L)**

Inter atomic interactions, ionic, covalent and metallic bonds; Importance of weak, non-covalent bonded interactions in biomolecules, such as van der Waals forces and hydrogen bonding; Energies and geometrics of these interactions and their roles in structure and conformation of biomolecules. **Spectroscopic techniques:** Principle, methodology and applications of Fluorescence, Infrared, Raman, ESR, Atomic absorption spectroscopy; NMR; Use of lasers for spectroscopy.

Optical Activity: Importance of chirality in biomolecules; Principles and applications of ORD and CD

Unit II: Protein and Nucleic Acid Structures (15L)

Structure and Stability of Proteins: Myoglobin, Hemoglobin, Lysozyme, Ribonuclease A, Carboxypeptidase and Chymotrypsin; Conformation of proteins by Ramachandran plot; N and C terminal analysis of proteins

Covalent modification of proteins: Phosphorylation, adenylation, methylation, ribosylation

DNA structure: A/B/Z/D forms of double helical structure of DNA; Triple helix; DNA supercoiling and topoisomerases

Unit III: Supramolecular Assemblies and Complex proteins (15L)

Viruses: Viral assembly; Capsid; Capsomere, eg., TMV, HIV, Adenovirus

Prokaryotes and Eukaryotes: Ribosomal assembly; Biosynthesis and processing of rRNA; Macromolecular interactions in regulating translation. **Nucleic Acid Binding Motifs in Proteins:** Leucine zipper; Zinc fingers; Helix-turn-helix; Beta barrel; OB fold and their role in regulation of gene expression

Unit IV: Complex Proteins (15L)

Metalloproteins: General principles of metal coordination; Heme- and non-heme proteins.

Transport proteins: Oxygen transport proteins from vertebrate and invertebrate (haemoglobin, hemocyanin, cytochrome C)

Bacterial two-component signalling systems and their role in regulating sugar transport, catabolite repression, phosphotransferase system, chemosensory mechanisms and sensory modulation of C-N metabolism.

Practicals:

PSLSCBMP103	**Biomolecular Structure (60L)**	**2**	**04**

Semester IV Detail Syllabus

Course Code	Title	Credits
PSLSCBMT201	**Molecular Cell Biology (60L)**	**4**
Unit I: **Cell Division and Apoptosis (15L)** **Cell division and cell cycle:** Meiosis: its regulation, steps in cell cycle, and control of cell cycle. Cell-cell fusion in normal and abnormal cells. **Apoptosis**: Factors inducing apoptosis; Genes and proteins involved in apoptosis; Receptors with death domains and their signalling pathways; Role of apoptosis in development and disease. **Carcinogenesis**: Characteristics of cancerous cells; Agents promoting carcinogenesis; molecular basis of cancer therapy, Tumor markers - AFP, CEA, hCG; Telomere replication; Telomerase and its role in cancer and aging		
Unit III: **Biomembrane and Cell Matrix (15L)** **Biomembranes:** Structure and assembly; Orientation of membrane proteins, their solubilisation with detergents and enzymes; Membrane reconstitution; Liposomes and their application in biology and medicine **Nuclear pore complex:** Structure; Assembly and disassembly; RNA transport; Role in macromolecular exchange and regulation; nuclear import–export cycle **Molecules of the matrix:** Proteins of the microfilament, microtubules and intermediary filaments; Structure, properties and assembly of actin and tubulin, examples and roles of these filaments in cell structure and function, eg., dynamics and roles of kinesin and dynein; Organization of proteins on microvillus. **Extracellular Matrix:** Structure; Cell-cell/cell-matrix interactions; Intracellular transport – cilia and flagella		
Unit III: **Protein Trafficking and Targeting (15L)** N-glycosylation in the ER and Golgi (quality control, UPR, ERAD and proteosomal degradation Intracellular and membrane protein trafficking and targeting; Secretory pathways in prokaryotes and eukaryotes; Endocytic pathways; Signal sequences; Co-translational transport (protease protection assay); Targeting of mitochondrial, chloroplast, peroxisomal and nuclear proteins; Vesicle biogenesis and ER to Golgi transport; ER translocation of polypeptides (soluble and transmembrane); ER chaperons; SNAPs and SNAREs; Methods of studying Protein Transport; Disorders of protein transport		
Unit IV: **RNAi and Epigenetics (15L)** **Regulatory RNAs:** Historical background; RNA interference as regulatory mechanism in eukaryotes; Slicer and dicer; Synthesis and function of RNAi molecules in plants; Gene silencing mechanisms; RNAi-based gene therapy;		

Chromatin remodelling in human disease and diagnosis **Epigenetics:** Background, chromosomal inheritance taking fission yeast as an example; DNA methyltransferases, DNA methylation maintenance; Histone modification and regulation of chromatin structure; Bivalent histones; Histone demethylation; Epigenetic therapy; Epigenetic regulation of gene expression	

Practicals:

PSLSCP201	**<u>Molecular Cell Biology</u>** **(60L)** 1. Nucleic acid isolation and blotting A. Isolation of RNA from *E. Coli* B. Spectrophotometric characterization of RNA C. Capillary blotting (Southern/Northern) of nucleic acids from agarose gels D. Preparation of cDNA and RT-PCR 2. Isolation of DNA and demonstration of apoptosis of DNA laddering 3. MTT assay for cell viability and growth 4. UV damage and repair mechanism in *Escherichia coli* or *Serratia marcescens* 5. Determination of Molar absorption coefficient of tyrosine 6. Measurement of DNA by DPA method 7. Assay of alanine and aspartate aminotransferases 8. Measurement of activity of plant nitrate assimilation enzymes A. Isolation of nitrate reductase from plants B. Effect of environmental factors and hormones (CO_2, light, pH, growth hormones) 9. Plant pigments A. Extraction of plant pigments from spinach B. Separation by column chromatography C. Determination of absorption spectra of plant pigments	**2**	**04**

Course Code	Title	Credits

PSLSCBMT202	Nitrogen Metabolism and Plant Biochemistry (60L)	4

Unit II: **Nucleotide Metabolism** **(15L)**

Nucleotide Metabolism: Role of nucleases and phosphodiesterases in the degradation of nucleic acids; Biosynthesis and degradation of purines and pyrimidine nucleotides and their regulation; Thymine biosynthesis; Role of foluc acid in nucleotide biosynthesis; Purine salvage pathway; Role of ribonucleotide reductase; Biosynthesis of deoxyribonucleotides and polynucleotides; Inhibitors of nucleic acid biosynthesis; Inherited disorders of nucleotide metabolism; Anticancer drugs.

Unit II: **Nitrogen Assimilation in Plants** **(15L)**

Nitrogen Fixation: Nitrogenase complex; Electron transport chain and mechanism of action of nitrogenase; Structure of 'NIF' genes and its regulation; Hydrogen uptake and bacterial hydrogenases

Nitrate assimilation in plants: Structural features of nitrate reductase and nitrite reductase, incorporation of ammonia into organic compounds, regulation of nitrate assimilation; Ammonium assimilating enzymes – glutamine synthetase, glutamate synthase and GDH

Unit III: **Photosynthesis and Secondary Metabolism** **(15L)**

Photosynthesis: Light harvesting complexes; plant mitochondrial electron transport and ATP synthesis; alternate oxidase; Carbon fixation by C_3, C_4 and CAM pathways; Photoprotective mechanisms; Photorespiration; Bioluminescence.

Special features of secondary plant metabolism, terpenes (classification, biosynthesis), lignin, tannins, pigments, phytochrome, waxes, alkaloids; Biosynthesis of nicotine; Functions of alkaloids;

Unit IV: **Free radicals and Antioxidant Biology** **(15L)**

Free radicals: Introduction & Chemistry of Reactive Oxygen/Nitrogen Species (ROS/RNS); Sources of ROS/RNS; Cellular damage by ROS/RNS; Disease states and free radicals; Transition metals as catalyst; ROS and Signal Transduction; Oxidative stress; Beneficial Aspects of Oxidative Metabolism. Oxidative damage markers Methods of Detecting ROS/RNS; Detection of free radicals in biological systems; EPR spectroscopy principles and determination

Antioxidants: Diet-Derived Antioxidants; Enzymatic and non-enzymatic components of antioxidative defense mechanism (catalase, peroxidase, superoxide dismutases, vitamins E and C, uric acid, glutathione, metal chelators); Chemical scavengers; Antioxidant therapy

Practicals:

PSLSCBMP202	**PRACTICAL VII: Nitrogen Metabolism and Plant Biochemistry (60L)** 1. Analysis of DNA A. Estimation of DNA and RNA by UV absorption method B. Determination of purity of nucleic acids C. Conformational analysis of plasmid DNA by agarose gel electrophoresis 2. Enzyme inhibition A. Inhibition of enzyme activity B. Determination of Ki values 3. Immobilization studies: A. Preparation of urease entrapped in alginate beads and determination of percent entrapment B. Study of the kinetics of the rate of urea hydrolysis by urease entrapped alginate beads C. Study of reusability and storage stability of urease entrapped alginate beads D. Immobilization of urease by covalent attachment to solid support 4. 2-D Gel electrophoresis (Demonstration) 5. Study of nanoparticles A. Synthesis of Silver nanoparticles B. Spectroscopic characterisation	**2**	**04**

Course Code	Title	Credits
PSLSCBMT203	**Biomolecular Function (60L)**	**4**
Unit I: Protein folding and Engineering (15L) **Protein Folding:** Folding pathways; Intermediates of protein folding; Compact Intermediates; Hierarchical and non-heirarchical folding mechanisms; Molten globule structure; Role of chaperons, heat shock proteins and enzymes in protein folding **Protein Engineering** Design and construction of novel proteins and enzymes; Conformation of proteins in general and enzymes in particular; Effect of amino acids on structure of proteins; Energy status of a protein		

molecule, Structure- function relations of enzymes Basic concepts for design of a new protein/enzyme molecule; Specific examples of enzyme engineering – Dihydrofolatereductase	
Unit II: Kinetics and Mechanism in Biological Systems (15L) **Enzyme Kinetics:** Enzyme catalysis and factors contributing to high catalytic rates; Molecular aspects of catalysis for specific enzyme substrate complexes (Lysozyme, carbonic anhydrase, carboxypeptidase and chymotrypsin); Multisite binding of ligands to proteins; Bohr's effect; Models of Allostery - MWC and KNF models Hill's equation coefficient **Immobilised enzymes:** Methods and applications	
Unit III: Metabolomics and Transcriptomics (15L) **Metabolomics:** Modern Concept of metabolomics; Detection and characterization of metabolites; metabolite library; Metabolite isolation and analysis by Mass Spectrometry, NMR, LIF, LC-UV; Metabolomics databases and resource (e.g. MetaboLights) **Plant metabolomics:** Plant stress responses, nutrigenomics, and metabolite dynamics; Metabolite profiling in phenotyping and breeding (*Arabidopsis* ecotypes, rice) **Transcriptomics:** basic concepts and technology, data normalization, clustering (Hierarchical, k-means, SOM), detection of over expression and under expression (PCA). Modeling using Boolean Networks. EST, Unigene.	
Unit IV: Nanobiology (15L) **Introduction:** Nanoscience; Nanobiotechnology; Nanodevices; Applications in various fields viz. Physical and Chemical, Materials and Life Sciences **Application:** Gold bonding proteins; Nanopharmaceuticals such as liposomal formulations; Membrane nanodiscs; Biosensors; Nanowires **Synthesis of nanostructure:** Physical, chemical and biological methods **Properties and Characterization of nanomaterials:** Optical (UV-Vis / Fluorescence), X-ray diffraction; Imaging and size (Electron microscopy, Light scattering , Zeta potential),; Surface and composition (ECSA, EDAX, AFM/STM),	

Practicals:

PSLSCBMP203	**Biomolecular Function (60L)** 1.	**2**	**04**