CURRICULUM AND SYLLABUS

Integrated MSc-PhD Programme

On

CHEMICAL AND MOLECULAR BIOLOGY

to be offered by IIT Kharagpur jointly with the Indian Association for the Cultivation of Science, Kolkata

Curriculum

Semester : 1	Minimum Semester Credit Required : **24** Cumulative Semester Credit Required : **24**		
Subject Type	**Subject Name**	**L-T-P**	**Credit**
DEPTH	MOLECULES OF LIFE AND THE FUNDAMENTALS OF LIVING SYSTEMS	2-0-0	2
DEPTH	CELL AND DEVELOPMENTAL BIOLOGY	3-1-0	4
DEPTH	BIOPHYSICAL & BIOCHEMICAL METHODS	3-1-0	4
DEPTH	NUCLEIC ACIDS: STRUCTURE & FUNCTION	3-0-0	3
DEPTH	CARBOHYDRATES & LIPIDS: STRUCTURE & FUNCTION	3-0-0	3
DEPTH	COMPUTATIONAL BIOLOGY & BIOINFORMATICS	3-1-0	4
DEPTH	CHEMICAL BIOLOGY LAB	0-0-6	4
Semester : 2	Minimum Semester Credit Required : **22** Cumulative Semester Credit Required : **46**		
Subject Type	**Subject Name**	**L-T-P**	**Credit**
DEPTH	RECOMBINANT DNA TECHNOLOGY	3-1-0	4
DEPTH	STRUCTURE DETERMINATION OF BIOMOLECULES	3-1-0	4
DEPTH	ADVANCES IN PROTEIN STRUCTURE & FUNCTION	3-1-0	4
DEPTH	MOLECULAR MICROBIOLOGY	3-0-0	3
DEPTH	INFECTION & IMMUNITY	3-0-0	3
DEPTH	CELL BIOLOGY LAB	0-0-3	2
DEPTH	RECOMBINANT DNA TECHNOLOGY LAB	0-0-3	2
Semester : 3	Minimum Semester Credit Required : **21** Cumulative Semester Credit Required : **67**		
Subject Type	**Subject Name**	**L-T-P**	**Credit**
DEPTH	PROJECT	0-0-18	12
Elective-I		3-0-0	3
Elective-II		3-0-0	3
Elective-III		3-0-0	3
Semester : 4	Minimum Semester Credit Required : **23** Cumulative Semester Credit Required : **90**		
Subject Type	**Subject Name**	**L-T-P**	**Credit**
DEPTH	PROJECT	0-0-24	16
DEPTH	VIVA VOCE	0-0-0	2
Elective-IV		3-0-0	3
DEPTH	SEMINAR	0-0-3	2

Electives I, II and III

	NANOSCALE ENGINEERING OF BIOLOGICAL SYSTEMS
AG60091	**MODERN GENETICS**
BT60003	**IMMUNOTECHNOLOGY**
CY60019	**ELECTROANALYSIS AND SENSOR**
	BIOSYNTHESIS OF SECONDARY METABOLITES
	PROTEOMICS
MM61511	**BIOSTATISTICS**
	FUNCTIONAL MATERIALS IN BIOLOGY
BS60001	**PHARMACOKINETICS AND PHARMACOGENOMICS**
CY60005	**DRUG DESIGN AND DEVELOPMENT**
CY60115	**BIOTRANSFORMATION IN ORGANIC CHEMISTRY**
CY71003	**CHEMISTRY OF NATURAL PRODUCTS**
MM61509	**MEMS & BIOSENSORS**

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Elective IV

MM61316	**BIOMATERIALS**
	BIOLOGICAL IMAGING: *IN VIVO* AND *IN VITRO*
	DRUG DELIVERY AND GENE THERAPY
BT41022	**NEUROPHYSIOLOGY**
MM60006	**STEM CELL BIOLOGY AND THERAPY**
MM71514	**MOLECULAR IMAGING**
MM72335	**CANCER BIOLOGY**

Syllabus

CORE COURSES

MOLECULES OF LIFE AND THE FUNDAMENTALS OF LIVING SYSTEMS [2-0-0] 2

Structures and functions of DNA, RNA and proteins, and the relations between these molecules; DNA replication, transcription and translation; Enzymes; Carbohydrates and glycobiology; Lipids, biological membranes and transport; Principles of metabolic regulation, glycolysis and citric acid cycle.
Introduction to cells and genomes; Internal organization of the cell, membrane structure, intracellular compartments and the cytoskeleton; Cell cycle and programmed cell death.

Books/References:

- The Molecules of Life (2013) First Edition, by Kuriyan et al., Garland Science publishers.
- Lehninger Principles of Biochemistry (2012) Sixth edition, By Nelson & Cox, W.H. Freeman publisher
- Molecular Cell Biology (2013) Seventh Edition, by Lodish et al., Macmillan publishers.

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CELL AND DEVELOPMENTAL BIOLOGY [3-1-0] 4

Prokaryotic and eukaryotic cell organizations; intracellular compartments and transport: membrane bound organelles, protein sorting, and vesicular transport, secretory pathways, endocytosis pathways, phagocytosis and pinocytosis; cell communication: general principles of cell signaling, G-protein linked receptors and enzyme linked receptors; cytoskeleton: intermediate filaments, microtubules, and actin filaments, microtubule polymerization dynamics, dynamic instability and treadmilling, actin polymerization dynamics, cell crawling, contractile structures, actomyosin complex, muscle contraction, neurons, axons, dendrites, growth cone, inward transport and outward transport; motor proteins; the structure of eukaryotic chromosome; Overview of the cell cycle, mitosis, meiosis, and cytokinesis, animal cells and yeast cells division; cell cycle control: cell cycle check point, metaphase/anaphase transition, control of cell numbers in multi-cellular organisms and programmed cell death, cancer, anti-mitotic drugs; cytoskeletal diseases: microtubule dependent drugs and actin targeted drugs.
Life cycle, evolution of pattern formation; Embryonic development – fertilization, early development, genetics of axis specification in Drosophila; Later embryonic development – central nervous system, development of the tetrapod limb; Metamorphosis, regeneration and aging.

Books/References:

- Alberts et al., Molecular Biology of the Cell, Garland Publishing, Inc., 2002, 4th ed.
- Lodish et al., Molecular Cell Biology, W.H. Freeman & Company, New York, 2007, 6th edition.

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BIOPHYSICAL & BIOCHEMICAL METHODS [3-1-0] 4

Overview of modern biophysical and biochemical experimental techniques; Spectroscopy theory - Electromagnetic and quantum theory of radiation, wave particle duality, Light matter interaction, Transition dipole moment, Jablonsky diagram, Bear Lambert's Law. Spectroscopy - UV-visible, IR, fluorescence spectroscopy and circular dichroism (CD); Microscopy & Imaging - optical microscopy, confocal fluorescence microscopy, atomic force microscopy; Molecular interaction - fluorescence resonance energy transfer (FRET), surface plasmon resonance (SPR), isothermal titration calorimetry (ITC); Mass Spectrometry. Application in characterization of Bio molecules.
Analytical and preparative chromatographic separation techniques - general concepts, dynamics of zone migration, multi-component adsorption, chromatographic dispersion, linear and non-linear chromatography; liquid chromatographic techniques - size exclusion, ion exchange, affinity and reverse phase chromatography;

Books/References:

- Biophysical Techniques (2012) by Iain D. Campbell, Oxford University Press.
- Interpretation of Mass Spectra (1993) edited by Fred McLafferty, University Science Books.
- Chromatographic methods (1996) by Braithwaite & Smith, Kluwer publisher.

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NUCLEIC ACIDS: STRUCTURE & FUNCTION [3-0-0] 3

Historical overview; Structure and properties of RNA and DNA;DNA separation methods, chemical synthesis of DNA; the molecular basis of DNA replication, transcription and their regulation in prokaryotes and eukaryotes; Chromatin structure; DNA repair, excision repair, mismatch repair, post-replication repair, homologous recombination and non-homologous recombination; RNA structure and function; Ribozymes; experimental methods for studying DNA and RNA, recombinant DNA techniques, mutagenesis, protein-nucleic acids interaction.

Books/References:

- Lehninger Principles of Biochemistry (2012) Sixth edition, By Nelson & Cox, W.H. Freeman publisher.
- Nucleic Acids in Chemistry and Biology (2006) Third Edition, by G. Michael Blackburn, Royal Society of Chemistry Publishing.

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CARBOHYDRATES & LIPIDS: STRUCTURE & FUNCTION [3-0-0] 3

Carbohydrate – Classification, structure, general properties and functions of polysaccharides and complex carbohydrates; amino sugars, proteoglycans and glycoproteins. Lipids – Classification, structure, properties and functions of fatty acids, essential fatty acids, fats, phospholipids, sphingolipids, cerebrocides, steroids, bile acids, prostaglandins, lipoamino acids, lipoproteins proteolipids, phosphatidopeptides, lipopolysaccharides.

Metabolism
Carbohydrates –Glycolysis, various forms of fermentations in micro-organisms, citric acid cycle,its function in energy generation and biosynthesis of energy rich bond, pentose

phosphate pathway and its regulation. Gluconeogenesis, glycogenesis and glycogenolysis, glyoxylate and Gammaaminobutyrate shunt pathways, Cori cycle, anaplerotic reactions, Entner-Doudoroff pathway, glucuronate pathway. Metabolism of disaccharides. Hormonal regulation of carbohydrate metabolism Energetics of metabolic cycle. Lipids–Introduction, 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. Fatty acid biosynthesis, AcetylCoA 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. Energetics of fatty acid cycle.

Books/References:

- Lehninger Principles of Biochemistry (2012) Sixth edition, By Nelson & Cox, W.H. Freeman publisher.
- Essentials of Glycobiology (2009) Second edition, Edited by Ajit Varki et. al., Cold Spring Harbor Laboratory Press.

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COMPUTATIONAL BIOLOGY AND BIOINFORMATICS

Functions: Plotting functions, Sketching simple functions, Maximum and minimum points. Vectors and Co-ordinate systems. Differentiation: Introduce change in concentration, length-scale etc. as derivatives. Relate slope and derivative. Integration: Integration as area under a curve. Integrating simple expressions. Use of Integration techniques in biology. Differential Equations: Ordinary/partial differential equations. Fourier transformation. Applications in biology. Stochasticity in biology: Introduction to probability and distribution functions, Gaussian and Poisson distribution, Examples from biology, Stochastic modeling of biopolymers, molecular motors. Descriptive statistics: Measurement scales, continuous and discrete data, Histograms, Mean, variance, standard deviation, Errors, fitting a function to experimental data, linear and non-linear fits.

Biological Databases: Organisation, searching and retrieval of information, accessing global bioinformatics resources using internet links. Introduction to Unix operating system and network communication. Nucleic acids sequence assembly, restriction mapping, finding simple sites and transcriptional signals, coding region identification, RNA secondary structure prediction. Similarity and Homology, dotmatrix methods, dynamic programming methods, scoring systems, multiple sequence alignments, evolutionary relationships, genome analysis. Protein physical properties, structural properties – secondary structure prediction, hydrophobicity patterns, detection of motifs, structural database (PDB). Genome databases, Cambridge structure database, data mining tools and techniques, Structural Bioinformatics, Topics from the current literature will be discussed.

Books/References:

- Mathematics for Biological Scientists, M. Aitken, B. Broadhursts, S. Haldky, Garland Science (2009)
- Physical Biology of the Cell, R Phillips, J Kondev, J. Theriot, Garland Science (2009).
- Bioinformatics: Tools and Applications by David Edwards, Jason Stajich and David Hansen

- Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins by Andreas D. Baxevanis and B.F. Francis Ouellette

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CHEMICAL BIOLOGY LAB [0-0-6] 4

Synthesis of peptides and assay molecules; Interaction of small molecules with macromolecules by fluorescence, CD, NMR, mass-spectrometry etc.; Small molecule-small molecule interactions; Protein conformation study by CD spectroscopy; Estimation of nucleic acids, amino acids and proteins; Chromatographic methods for protein purification; Liposomes and micelles as delivery vehicles; Synthesis and characterization of nanoparticles and their interaction with biomolecules.

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RECOMBINANT DNA TECHNOLOGY [3-1-0] 4

Tools of recombinant DNA: restriction endonucleases and other enzymes, plasmid, bacteriophage, cosmid and other vectors. c-DNA and genomic library, Gene isolation, cloning and expression, DNA sequencing, oligonucleotide synthesis, Southern and Northern hybridization, FISH, PCR, RAPD, RFLP, DNA fingerprinting and their applications for diagnosis of disease, site-directed mutagenesis, Gene silencing, Gene transfer technologies, Gene therapy; Molecular basis of genetic diseases, genetic counseling. Functional genomics: DNA chipsand microarray gene screen technology; transgenic animals and gene knockout techniques, cell culture based techniques. Practical: DNA isolation and purification, restriction enzyme analysis, southern hybridization, DNA sequencing, PCR, RAPD, gene cloning, identification of recombinant clone and expression of protein in bacteria and eukaryotic cells.

Books/References

- Recombinant DNA: Genes and Genomes - A Short Course by James D. Watson et al; Cold Spring Harbor Laboratory Press
- Principles of Gene Manipulation and Genomics by Primrose SB and Twyman R; Wiley-Blackwell
  Gene cloning and DNA analysis by Brown TA; Wiley-Blackwell
- Molecular Cloning: A Laboratory Manual by Sambrook J, Fritsch EF and Maniatis T; Cold Spring Harbor Laboratory Press

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STRUCTURE DETERMINATION OF BIOMOLECULES [3-1-0] 4

Introduction to quantum spin states; Energy levels and transitions; Basic one-dimensional NMR experiment; Vector model; Product operators; Multi-dimensional NMR experiments; Relaxation; Fourier transformation and data processing; Spectrometer basics; Application to biological problems.

Diffraction theory - waves, interference and complex numbers; Atoms, crystals and reciprocal space; X-ray sources: from generators to synchrotrons; Crystallization, data collection, processing, complications; The phase problem: introduction to phasing methods; Introduction to fitting, refinement and validation.

Books/References:

- Understanding NMR Spectroscopy (2010) 2nd edition by James Keeler, Wiler Publishers.
- Protein NMR Spectroscopy: Principles and Practice, 2nd edn. Cavanagh J, Fairbrother WJ, Palmer AG, Rance M and Skelton JJ ,New York: Academic Press.
- Crystallography made crystal clear (2006) 3rd edition by Gale Rhodes, Elsevier Publishers.

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ADVANCES IN PROTEIN STRUCTURE & FUNCTION [3-1-0] 4

Primary, secondary, tertiary and quaternary structures; Motifs, supersecondary structures and fold types; forces that stabilize protein fold, folding pathways, mutagenesis studies; Protein dynamics – timescales of motions, computation and experimental methods to study protein dynamics; intrinsically disordered proteins and their functions.
Directed protein evolution – phage display, cell surface display, cell free display systems; Alternative scaffolds, combinatorial enzyme engineering; Protein engineering using non-canonical amino acids; Knowledge based protein design; Selected case studies.

Books/References:

- Introduction to Protein Science: Architecture, Function, and Genomics (2010) by Arthur M Lesk, Oxford University Press.
- Introduction to Protein Structure (1998) by Branden & Tooze by Garland Publishing.
- Protein Engineering and Design (2010) by Sheldon Park and Jennifer Cochran, CRC Press.
- Protein Engineering Handbook. (2006) by Stefan Lutz and Uwe Bornscheuer, Wiley-VCH.

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MOLECULAR MICROBIOLOGY [3-0-0] 3

Introduction to molecular microbiology; Health/economic significance of microorganisms; vertical and horizontal transfer of genetic materials in microbes; Transformation, conjugation and transduction; Culture-based and culture-independent molecular detection of microorganisms. Morphology and cellular architectures of microorganisms; Molecular basis of bacterial growth and division; Solute transport in bacteria: ABC transporters, amino acid transport, drug export systems etc.; Microbial interactions: environmental and quorum sensing. Microbe-host interactions. Biofilm formation and its implication, bacterial adhesion to host and pathogenesis; targeting strategies against cell wall biosynthesis, and other fundamental processes of bacteria; Mechanism of antibiotic action and resistance; Multidrug resistance, progress and challenges; Structure, function and virulence of viruses, and others microorganisms including fungus, protozoa and parasites. Comparative and environmental genomics.

Textbooks:

1. Stanier, RY., et al., General Microbiology, 5th ed. Macmillan Press.
2. Atlas, RM., Principles of Microbiology, 2nd ed.,1997, McGraw-Hill
3. Prescott, LM., Microbiology, 6th ed. 2005, McGraw-Hill.

References

1. Slonczewski JL and Foster JW, Microbiology: An Evolving Science, 3rd ed

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INFECTION & IMMUNITY [3-0-0] 3

An overview of immune system; Infectious organisms: viruses, bacteria, fungi, protozoa, helminths, prion etc.; Virulence factors and host susceptibility, entry and exit of pathogens; How pathogens escape innate and adaptive immune systems; Control of infectious diseases: vaccination, chemotherapy and public health measures
Viral pathogenicity and antiviral agents; Case studies: HIV, influenza, swine flu etc., and recent viral outbreaks: Zika, Ebola, Chikungunya, bird flu etc.; bacterial diseases (Tuberculosis, Diphtheria, Staphylococcal infection etc) and immunity; Fungal (systemic and opportunistic infections) and protozoal (Malaria, Leishmaniasis etc.) diseases and immunity; Cancer immunology

Textbooks:

1. Janeway's Immunobiology, Author: Kenneth Murphy
2. Infection and Immunity by John Playfair and Gregory Bancroft, 4th edition, Oxford University Press

References:

1. Nigel Dimmock *et al*., Introduction to modern virology, John Wiley & Sons

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CELL BIOLOGY LAB [0-0-3] 2

Visualization of plant and animal cells using Light microscopy, dehydration and fixation of tissues for microscopic analysis, sub-cellular isolation of organelles; staining of Nucleus and visualization of mitotic chromosomes; Cell division and Cell-cell adhesion studies by microscopy and flow-cytometry, mammalian cell culture techniques, Transfection and subsequent culture of mammalian and insect cells for heterologous expression of proteins.

Media preparation and sterilization, Bacterial growth curve (using E. coli strain), Determination of antibiotic sensitivity of selected bacteria, Gram staining- Gram positive and negative staining procedures.

RECOMBINANT DNA TECHNOLOGY LAB [0-0-3] 2

Extraction and purification of genomic and Plasmid DNA; Restriction enzyme digestion of DNA and analysis by agarose gel electrophoresis; Elution of DNA from agarose gel; Labelling of DNA, Southern blotting. Extraction and analysis of total RNA; Preparation and

transformation of competent cells, Identification of recombinant clones, Polymerase chain reaction, DNA Sequencing

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ELECTIVES I, II AND III

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Nanoscale Engineering of Biological Systems

Syllabus:

Introduction to Nanotechnology; Nanoparticles and Colloids; Materials Science aspects of nanoparticles and their properties (optical, electronic, etc.); Nanomaterials fabrication and characterization; Classification of nanodevices; Carbon nanotubes: types, properties and synthesis by arc discharge, laser ablation, chemical vapor deposition techniques. MEMS & NEMS: MEMS fabrication and limitations, Introduction to NEMS- fabrication processes and applications. Nanomedicine: Medical use of Nanomaterials; Targeted drug delivery systems; Cancer treatment; Applications of Nanomaterials in Medical imaging. Bio molecular nanotechnology: Nanorobots and their application; Nano-bio sensors (including DNA and protein sensors; glucose sensors); Nanoparticles for gene delivery systems; Optical biosensors and their application.

Textbooks:

1. N. Malsch, Biomedical nanotechnology, CRC press

References:

R. A. Freitas Jr., Nanotechnology: Science, Innovation, and Opportunity, Nanomedicine: Basic Capabilities, Vol. 1, American Scientific Publishers, 1999.

PHARMACOKINETICS AND PHARMACOGENOMICS [3-0-0] 3

Pharmacokinetics: Concepts of bioavailability, absorption of drug, volume of distribution, clearance and drug elimination. Metabolism of drug and half-life of bio-pharmaceuticals. Routes of drug administration, bioavailability, advantages and disadvantages. Kinetics of drug action: Concepts of Potency, efficacy, therapeutic index, safety margin. Dosage optimization based on pharmacokinetic modeling. Drug-drug interactions, transport of drug across biological membranes. Physiological and hormonal variables relevant to drug absorption. Effect of food on drug absorption, distribution and metabolism. Clinical Pharmacokinetics case studies with different drug types: antibiotics, cardiovascular agents, immunosuppressants.

Pharmacogenomics: Genes encoding drug metabolizing enzymes, drug transporting proteins, and drug receptors (targets). Contribution of genetic variability in drug absorption, distribution and metabolism. Clinical consequences of pharmacogenomics in drug interactions. Clinical approaches of drug selection based on genotypes. Pharmacogenomics and adverse drug reactions. Importance of pharmacogenomics in drug discovery and development.

Books/References

- Physical Pharmacy. by David Attwood and Alexander T. Florence, 2nd edition

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FUNCTIONAL MATERIALS IN BIOLOGY [3-0-0] 3

Introduction to Biomaterials, Biomineralization, Molecular Self-assembly, Nanomaterials, Synthetic and naturally derived biomaterials, Organic and inorganic polymers, proteins, polysaccharydes, composite biomaterials, nanobiomaterials, Clinical applications, Decellularization, Hydrogels, Tissue engineering, Regenerative medicine, Biodegradable materials.

Books/References:

- Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons. Biomaterials Science: An Introduction to Materials in Medicine, Academic Press, 2004, USA.
- J.B. Park and J.D. Bronzino. Biomaterials: Principles and Applications. CRC Press. 2002. ISBN: 0849314917.
- T. M. Wright, and S. B. Goodman. Implant Wear in Total Joint Replacement: Clinical and Biologic Issues, Material and Design Considerations. American Academy of Orthopaedic Surgeons, 2001.
- L Ambrosio. Biomedical composites, Woodhead Publishing Limited, UK, 2009

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BIOTRANSFORMATION IN ORGANIC CHEMISTRY [3-0-0] 3

General methods for new biocatalyst discovery; Screening and assay methods; Isolation, purification and immobilization techniques; Classification and nomenclature (IUBMB); Catalytic role of enzymes (enzyme kinetics and various kinds of inhibition); Potentials and limitations; Enzymes in functional group transformation; White biotechnology; Few industrial process using enzymes for production of drugs, fine chemicals and chiral intermediates; Combinatorial biocatalysis; Bio-mimetic catalysts (catalytic antibodies, artificial enzymes,

molecular imprinted polymeric catalyst) and their applications; DNA and RNA based catalysis; Recombinant DNA technology in enzyme engineering.

Reference Books/References:

- Biotra Enzyme catalysis in organic synthesis (Vol I-III); Eds by K. Drauz and H. Waldmann. Willey-VCH.
- Enzyme Biotransformations in organic chemistry. K. Faber . Springer.

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CHEMISTRY OF NATURAL PRODUCTS [3-1-0] 4

Chemistry of selected natural products; Special emphasis on the structural elucidation, synthesis and biological activity of steroids, terpenes, alkaloids, pheromones, prostaglandins, macrolides and polyether antibiotics; Polyphenols and their antioxidant property; Selected topics from the current literature.

Books/References:

- The Chemistry of Natural Products, R.H. Thomson
- Natural Products Chemistry, Kōji Nakanishi
- Chemistry of Natural Products, Sujata V. Bhat, Bhimsen A. Nagasampagi, Meenakshi Sivakumar
- Natural Product Chemistry at a Glance, Stephen P. Stanforth

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DRUG DESIGN AND DEVELOPMENT [3-0-0] 3

Approaches to Drug Design: Enzyme Inhibition, Molecular Recognition, Receptor Based Molecular Modelling, QSAR, Agonist and Antagonist. Examples of Designed Drugs: Antihypertensive, Antiviral, Anticancer and Antibiotic. Combinatorial Library and High-throughput Screening.

Books/References

- The Organic Chemistry of Drug Design and Drug Action, by R. B. Silverman
- An Introduction to Medicinal Chemistry by G. L. Patrick

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MEMS & BIOSENSORS [3-1-0] 4

Fundamental of MEMS: Introduction to MEMS principles and fabrication technologies, fundamental of MEMS structures, MEMS materials, MEMS design, fabrication, packaging, Fundamental mechanical, electrical, optical, biochemical and fluidic characteristics of the basic microstructures. Bio-MEMS for clinical detection: Fundamentals of micro and nano fabrication of biochips and lab-on-a-chips, molecular recognition and bio-immobilization principles and procedures, on-chip biochemical detection methods, introduction to micro/nano fluidics, basic components of lab-on-a-chips and its integration. Biosensors and Biochips: Fundamentals of biosensors, fundamentals of electrochemistry and electrochemical biosensors, micro-fluidic devices and systems, MEMS sensors and actuators for medical instrumentation and fundamental of bioelectronics for bio-signal conditioning and processing.

Books/References:

- Alice Cunningham, Introduction to Bioanalytical Sensors, John Wiley& Sons.

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PROTEOMICS [3-0-0] 3

Proteomics: a basic overview; Theory of mass spectrometry; Protein/peptide separation techniques; Protein mass spectrometry, Bioinformatics tools; Biological applications including quantitative proteomics; Protein post translational modification; Mapping Protein-protein Interaction; Topology and Network motifs; Hydrogen/deuterium exchange mass spectrometry for high throughput protein structure determination; Identification of protein targets and biomarkers; Protein arrays; Structural genomics and structural proteomics; Two-dimensional gel electrophoresis; Peptide structural characterization by tandem mass spectrometry; Protein identification using computational tools.

Books/References:

- Proteomics, C. David O'Connor, B. David Hames
- Principles of Proteomics, Richard Twyman
- Proteomics, Timothy Palzkill
- Proteomics: from protein sequence to function, Stephen R. Pennington, M. J. Dunn

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BIOSYNTHESIS OF SECONDARY METABOLITES [3-0-0] 3

Biosynthesis of antibiotics: erythromycin and other polyketides, streptomycin, puromycin, penicillins, cephalosporins, clavulanic acid and tetracycline; biosynthesis of alkaloids, terpenes, flavonoids and lignin.

Books/References:

- Chemical Review, 1997, Issue 7
- Natural Product Reports 2013, 21-107
- The Chemistry of β-Lactams by Michael I. Page

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BIOSTATISTICS [3-0-0] 3

Measurements and descriptive statistics in medical research and practice: Data types and scales of measurement: continuous vs. enumeration data, Sampling distributions - normal distribution (continuous data), binomial distribution (proportions, based on enumeration data), Measures of central tendency-mean, median, mode Measures of variability-standard deviation and standard error, Probability and odds Confidence limits on the mean Disease incidence and prevalence, Sensitivity, specificity, positive and negative predictive values Risk measures-relative risk, attributable risk, odds ratios, risk factors, Survival curves. Sampling : Concept of a source population, Random sampling, Estimation of population statistics, Standard error of a sample mean and of a proportion, and their differences, Confidence intervals Regression and Correlation: Simple, Partial and Multiple Correlation, Simple Linear / Nonlinear Regression, Logistic Regression for dichotomous variable.Statistical Inference and Hypothesis Testing: Hypothesis generation, Null hypothesis, Type I and II errors, Statistical Power, Interpretation of P-values and confidence intervals, Statistical and clinical significance. Comparing 2 or more groups: Comparing means of two populations with the t-test (continuous data), Comparing proportions of responders in two populations (enumeration data), Chi square with corrections (goodness of fit, test of independence). One - Way ANOVA: Ftest,Treatments and Factors.

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IMMUNOTECHNOLOGY [3-0-0] 3

Characteristics of animal cells and their implication on process design Nutritional requirements and serum free culture of mammalian cells Kinetics of growth and product formation. Reactor systems for large-scale production using animal cells. Production of Polyclonal antibodies with different types of antigens: antigen preparation and modification, adjuvants does and rute of antigen administration, collection of sera, purification of antibodies. Hybridoma technology – production and applications of monoclonal antibodies for diagnosis and therapy. Production of virus vaccines, specific vaccines. Production of cellular chemicals like Interferons, Interleukin etc. Immunoassay procedures.

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ELECTROANALYSIS AND SENSORS [3-0-0] 3

Basics of electroanalytical chemistry- modified electrodes and their application. Fundamentals of electrochemical sensosr. Electroanalytical chemistry in neuroscience. Electrochemistry of redox proteins. Design of third generation electrochemical sensors. Electrochemical DNA sensors. Electrochemical Impedance spectroscopy and their application. Electrochemical immunoassay: redox and enzyme labeled immunoassay. Electrochemiluminescence and immunoassay; Electrochemical quartz crystal microbalance and its applications. Design of in vivo sensor and measurement of biological molecules like glucose, insulin and cholesterol. Electrochemical sensor for food analysis.

Books:

F. Scholz, Electroanalytical methods, Springer, 2002.P. Monk, Fundamentals of electroanalytical chemistry, Wiley, 2001.A.P.F.

Turner I. Karube, I. G. Wilson, Biosensors- Fundamentals and applications.

Oxford University Press, New York, 1987.

MODERN GENETICS [3-1-0] 4

Genetics of inheritance: Mendelian principles and its modifications, genetic recombination. Transposable elements in plants. Outlines of DNA replication, damage and repair. Molecular genetics of gene expression: Plant nuclear genome structure. Outlines of transcription and translation mechanism in eukaryotes. Mechanisms of introns splicing, evolution of introns. RNA editing and guide RNA. Role of special transcription factors in gene expression. Histones and DNA methylation, genome imprinting. Riboswitch-dependent plant gene regulation. RNA interference: early history, cellular mechanism, difference in RNAi mechanisms in plants and animals. Genetic analysis of plant developmental processes.

Elective IV

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DRUG DELIVERY AND GENE THERAPY [3-0-0] 3

Introduction to drug delivery; Drug delivery: the basic concepts/principles; Polymers in controlled drug delivery; Controlled drug delivery systems; Traditional oral drug delivery; Nanotechnology in drug delivery; Implant drug delivery; Transdermal drug delivery; Nasal and pulmonary drug delivery.

Human Disease Targeted for Gene therapy, Antigene and Antisense Therapy, Vector and other Delivery Systems for Gene therapy, Viruses as vector, on viral DNA Delivery systems, Synthetic particles and nanotechnology for drug Targeting and Gene therapy, *Ex vivo* vs *In vivo* Gene Therapy. Genetically modified stem cells in experimental gene therapy.

Books/References:

- Drug Delivery Systems by Vasant V. Ranade; John B. Cannon CRC Press.
- Controlled Drug Delivery: Fundamentals and Applications, Joseph Robinson, Vincent H. L. Lee Taylor & Francis
- Molecular Biotechnology: Principles and Applications of Recombinant DNA: Bernard R Glick & Jack Pasternak

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NEUROPHYSIOLOGY [3-1-0] 4

Nerve-Muscle Physiology: Neuron structure and function; Regeneration of nerve; Axoplasmic flow and transport mechanism in the axons; Nature of nervefibre excitation and interpretation of action potential; Significance of different nerve fibre types. Structural architecture of Neuro-Muscular Junction (NMJ); Neuro-muscular transmission - Electrical and Biochemical events; Drugs acting at NMJ. Protein components and contraction mechanism of muscles. B. Nervous System : Interpretative function of cerebral cortex. Aging and its effect on brain, Regulatory function of cerebellum and structure activity relationship (neural circuitory) of cerebellum, Vestibular apparatus, hypothalamus and its functions, basal ganglia, thalamo cortical projections. Non-specific sensory mechanism- Sleep and wakefulness. Behavioral functions of the brain - emotion, memory, learning and consciousness, Pharmacology and chemical transmission autonomic nervous system. C. Special Sense: Sensory modalities, Sensory receptors, Sensory circuits, and Sensory perception. Taste system , Olfactory system, Visual Sense and Auditory Senses

Books/References

- Guyton and Hall Textbook of Medical Physiology, 12th Ed. by John E. Hall
- Ganong's Review of Medical Physiology, 24th Edition by Kim E. Barrett, Susan M. Barman, Scott Boitano , Heddwen Brooks
- Physiology: Best and Taylor's Physiological Basis of Medical Practice By John B. Best
- Neuroscience: Exploring the Brain 4th Ed, Mark F. Bear, Barry W. Connors, Michael A. Paradiso
- The Cognitive Neurosciences III (Bradford Books/References), Michael S. Gazzaniga (Editor)
- Neuroscience, 4th Ed. by Dale Purves

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CANCER BIOLOGY (3-0-0) 3

Oncogenes and cancer, tumor suppressor genes, growth factors and signal transduction, signal transduction mechanism, cell cycle and apoptosis, angiogenesis, different important bio-markers and targets for targeting cancer e.g.: epidermal growth factors and its receptors, vascular epidermal growth factor and its receptors, PI3-K and AKT and others, different compounds for cancer therapy, monoclonal antibodies, small tyrosine kinase inhibitors and others. Combination therapy with antibody or small tyrosine kinase inhibitors in combination with chemotherapeutics drugs alone or with radiation. Ionizing radiation: a genetic switch for cancer therapy.

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STEM CELL BIOLOGY AND THERAPY [3-0-0] 3

Introduction to different types of stem cells; their importance, sources, availability and present status in clinics and research: What does a stem cell mean? History of stem cell research. Explanation of totipotency, pluripotency and multipotency. Introduction to the different types of stem cells. What is the difference between embryonic and adult stem cell. Importance of stem cells. Embryonic Stem (ES) Cells, Adult Stem (AS) Cells, Induced Pluripotent Stem Cells (iPSCs): Differences between embryonic and adult stem cells. Fate of early embryonic cells. Ethical concerns with ES cells. Adult stem cells: Mesenchymal and hematopoietic stem cells. Sources and biology of different types of adult stem cells. Availability of adult stem cells and their current clinical use. What are iPSCs? Possible techniques of inducing pluripotency, nuclear transfer, cell-culture-induced reprogramming etc.

Cell signaling pathways: Introduction, cellular communications, different types of involved in MSC proliferation and differentiation: Introduction to cell signaling pathways. Communication between cells, electrical and chemical mechanisms. Basic concepts of cell signaling mechanisms - concepts of cell stimuli, receptors, tranducers, amplifiers, messengers, sensors and effectors, cellular responses. Examples of the various components of signaling pathways. Cell signaling pathways involved in paracrine secretions of MSCs. Major cell signaling pathways involved in proliferation and differentiation of MSCs (example: TGF-beta/BMP, Wnt, FGF, Notch, Hedgehog etc.)

Small RNAs and stem cells: What are small RNAs? Biogenesis of microRNAs. miRNAs and their mechanism of action. Target predictions and analysis. Role of miRNAs in regulation of ES cells. Role of miRNAs in regulation of MSCs. miRNAs and their role in certain pathological conditions

Immunomodulatory properties of mesenchymal stem cells: Characteristics of MSCs. Mechanisms of immunomodulation by MSCs. Interaction of MSCs with T cells, B cells and NK cells. Induction of immune tolerance in host. MSCs and Induce Immune Tolerance in the Host Applications of immunomodulatory properties of MSCs: Graft vs. Host Disease (GVH), autoimmune diseases, organ transplantation. Future directions.

Homing of mesenchymal stem cells to injured tissues: Homing capacity of MSCs. Therapeutic effects of the ability to home. Mechanisms of Leukocyte Trafficking to sites of inflammation. Potential ligand/ receptors for MSC homing. Chemokines.

Cancer and stem cells: Introduction. Relationship between normal and cancer stem cells, Prospective isolation of cancer stem cells. Origin of cancer stem cells. Solid tumor stem cells – tumor stem cells in CNS and other organ systems. Signaling pathways in cancer stem cells. Signaling pathways in cancer stem cells. Clinical implications.

Experimental tools for stem cell research: In vitro differentiation of MSCs to different cell types. Basics of cell sorting. Flow cytometry. Polymerase Chain Reactions (PCR), Western Blotting, Transformation, Transfection. Molecular Cloning. Introduction to Biomicrofluidics
Adult Stem Cells and their niches: The niche concept. Components of stem cell niches. Molecular pathways associated with functions of niche. Extracellular matrix and inter-cellular interactions. Stem cell niche dynamism and aging, malignany stem cell niches. Application of biomaterials in modulation of stem cells: Physicochemical effects on MSC fate. Physicomechanical control of MSC fate. Micro- and NanoStructural Control of MSCs Fate.

Stem Cell Therapy: Applications, current status and future prospects: MSCs in cardiovascular diseases. MSCs in Graft vs. Host diseases, MSCs for liver diseases, bone repair, diabetes. Reprogramming of somatic cells to pluripotency. Generation of iPSCs. Directed reprogramming of cells. Future prospects.

Ethical considerations and regulatory affairs governing present day stem cell therapy: Regulatory challenges. Regulations and guidelines. Perspectives in different countries (US, EU, China, India). Harmonization.

Books/References:

- The Cell Biology of Stem Cells. Edited by Eran Meshorer and Kathrin Plath. In Advances in Experimental Medicine and Biology, Volume 695. Year - 2010
- Essentials of Mesenchymal Stem Cell Biology and Its Clinical Translation. (Ed) Robert Chunhua Zhao. Publisher: Springer Science+Business Media. Year – 2013
- Lobo, N.A., et al., The biology of cancer stem cells. Annu Rev Cell Dev Biol, 2007. 23: p. 675-99.

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MOLECULAR IMAGING [3-1-0] 4

Introduction to Molecular Imaging: Biostructures of Interest in Molecular Imaging (MI): Cells & Tissues, Information molecules & other bio-molecules of interest in MI. Implication of molecular imaging in radiology, medicine, surgery and biomaterial research. Processes Involved in MI: Optical properties of cell, tissues & molecules. Interference, diffraction, polarization, birefringence phenomena, Luminescence, fluorescence, flurophores, chromophores. Molecular probes, contrast agents in MI. Spectroscopy in MI, Auto-fluorescence Imaging, Raman Spectroscopy. IR- Thermography. Optical Coherence Tomography (OCT). Con-focal Microscopy. Atomic Force Microscopy. E- SEM and EDAX. Microbubble enhanced USG. Plasmon Resonance Spectroscopy. PET-CT. Applications of MI in Biomedical & Biomaterial Sciences: Application of OCT in ophthalmology. Application Confocal Microscopy & applications. Applications of IR –imaging. Applications of micro-bubble enhanced USG. Applications of MALDI-ToF, Raman & IR Spectroscopy.

Books/References:

- Bioimaging, Authors: Douglas E Chandler and Robert W Roberson, Publisher: Jones and Bartlett
- Methods in cellular imaging, Author: Periasamy Ammasi
- PET: Molecular imaging and its biological applications, Author: Michael E. Phelps, Publisher: Springer.
- Functional Magnetic Resonance Imaging, Authors: Scott A. Huettel, Allen W. Song, Gregory Mccarthy, Publisher: Sinauer Associates Inc

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BIOLOGICAL IMAGING: *IN VIVO* AND *IN VITRO* [3-0-0] 3

Introduction to biological imaging: Biostructures of interest in Biological Imaging (BI): Cells and Tissues, Information molecules and other biomolecules of interest in BI, Implication of molecular imaging in structural and functional characterization of biological object.
Imaging techniques: Fundamentals of macro and micro imaging, Optical properties of cell, tissues and molecules, Interference, diffraction, polarization, birefringence phenomena, Luminescence, Basics of fluorescence and their labeling procedure to acquire biological signals, fluorophores, chromophores, Molecular probes, contrast agents in molecular imaging.
Macro-imaging: Basics and techniques of X-ray, CT, USG, PET, MRI, X-ray fluoroscopy, digital X-ray, Micro-bubble enhanced USG, Plasmon Resonance Spectroscopy, PET-CT, basic biological properties of fMRI signal, Applications of molecular imaging in Biomedical and Biomaterial Sciences.
Micro-imaging: Basics of light microscopy (compound microscope, polarization, DIC & Phase contrast) imaging systems and its applications in biology, Auto-fluorescence Imaging, Detector of flurescence microscopy, Cellular Response to Laser Radiation in Fluorescence Microscopes, IR- Thermography, Optical Coherence Tomography (OCT), Laser scanning Confocal Microscopy and its applications to living cells and tissues, Atomic Force Microscopy and its use for elastography, ESEM and EDAX, Introduction Raman spectroscopy, Fusion imaging techniques: Raman-OCT, Raman-confocal, Laser Doppler imaging.

Books/References:

- Bioimaging, Authors: Douglas E Chandler and Robert W Roberson, Publisher: Jones and Bartlett
- Methods in cellular imaging, Author: Periasamy Ammasi
- PET: Molecular imaging and its biological applications, Author: Michael E. Phelps, Publisher: Springer.
- Functional Magnetic Resonance Imaging, Authors: Scott A. Huettel, Allen W. Song, Gregory Mccarthy, Publisher: Sinauer Associates Inc

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BIOMATERIALS [3-1-0] 4

Introduction to Materials, General structure and properties. Classification of common materials and applications. Chemical Bonding, Crystalline, Amorphous. Melting, Solidification, Nucleation, Phase diagrams. Metal and alloys in Medical application: Stainless steel, cobalt based alloys, titanium based alloys (including shape memory alloys). Ceramics and glasses-bioceramics: Type of Ceramics and their classification, Calcinations, Annealing, Sintering, Nearly inert ceramics, bio-reactive glasses and glass ceramics, Calcium phosphate ceramics. Introductions to polymers: Definition, classification, Polymerization. Rubber, plastics, fibers and resins and structure-properties relationship. Biodegradable

polymers; Natural polymers, Composites, Pyrolitic carbon, Carbon nano tubes. Bulk Proper, Surface properties and modification of surface properties. Basic principles of engineering manufacturing, methods and applications of common manufacturing processes, milling, grinding, finishing, rolling, forging, Concept of biomimetic synthesis, Preparation of fiber and wire, Fabrication of Porous Materials, Direct moulding Technique, Different advanced fabrication technique.

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