Semester II

1. Research Methodology (Compulsory)

What is a PhD thesis, psychological and social factors during PhD, student's role in thesis work, supervisor's role in thesis work, overview of research planning, time management, fair scientific practices.

Ethics in natural sciences, avoiding research that cause unjustified risk to people, jeopardizing the environment or convert public resources into private profits, striving for objectivity (in the research process and in presentation of results), handling uncertainties.

Literature survey, critical use of existing knowledge, finding out a research problem, scientific publishing, classification of conferences and journals, judging whether a material is publishable, refereeing process, criticizing own and others work.

How to give seminars, how to use various softwares, how to use various instruments, how to interact with people, how to apply for jobs, plagiarism in science – what to do and not to do.

As a concrete example, each student will be asked to produce a "prototype thesis" in a given area under a "prototype supervisor". The student will apply the knowledge, ethics and best scientific practices to produce the thesis. Students will be evaluated based on the thesis and its defence.

2. Advanced Level Optional Courses (to choose any 2 from each Group - A, B and C)

A. Advanced Biophysical techniques (OPT1)

(i) Macromolecular crystallography

Structure factors, Atomic scattering factor, temperature factor, structure factor calculation, Phase problem and electron density calculation. Advanced phasing techniques (like MAD/SAD). Phasing by MR, Model building and refinement. Fiber Diffraction.

High throughput crystallography; Cryo-crystallography and its application in trapping reaction intermediates; X-ray crystallography to elucidate structure-function relationship for some important biological pathways; crystallography of large macromolecular assembly.

Crystallization techniques, handling protein crystals using cryo techniques, diffraction data collection, electron density map interpretation, crystallographic data analysis.

(ii) Chromatography and Mass Spectrometry

Chromatography: General principles of chromatography, common types of chromatography[1], factors affecting chromatographic separation and considerations for choosing mode of chromatography, applications.

Mass Spectrometry: General principles, ion source[2], types of mass analyzers[3], ion fragmentation and rearrangements, mass spectrometry of protein and peptides, mass spectrometry of small molecules, imaging mass spectrometry, applications.

[1]normal phase, reverse phase, HILIC, ion exchange, size exclusion, affinity, GC and chiral.
[2]ESI, APCI, MALDI, EI, DESI, LAESI, FAB, SIMS, NIIMS.
[3]quadrupole, TOF, ion trap, orbitrap, ICR.

(iii) Spectroscopic techniques

Nanosecond to Femtosecond Laser Spectroscopic Techniques and their application to the various prototype and diverse bio-molecules of different sizes related to Biophysical Sciences. The spectroscopic methods we will cover are the following: (i) Time Resolved Fluorescence and Absorption (ii) Circular Dichroism.

(iv) Imaging techniques

Concepts in Microscopy and imaging: Basic Principle of Optics, Family of Microscope , Optical Microscope Aberrations, Polarized light and its interaction with matter, Detection system image formation and image analysis, Point spread function, Principle of TEM &SEM: development, architecture, vacuum system, power supply, Sample preparation techniques and Application

Single molecule detection (SMD) by fluorescence: Single molecule fluorescence spectroscopy/Microscopy, Technical Challenges, Methods in single molecule detection, Total Internal reflection (TIR) spectroscopy, Types (PTIR, OTIR), Data Processing, analysis and interpretation. Principle of trapping, Design Considerations, Trapping force, Microscope, Objective, Position detection.

B. Topics in Cell Biology (OPT2)

(i) Cell cycle

Regulation of cell cycle by cyclin-Cdk, Regulation of Initiation of eukaryotic DNA replication, Replication Licensing, Cell cycle checkpoints, Protein degradation by ubiquitination during cell cycle progression.

(ii) Mechanobiology

Cytoskeleton and nucleoskeleton, mechanics of cell-cell adhesion and migration, gross cell mechanics, experimental set ups to study biomechanics, disease models.

(iii) Chromatin and epigenetics

Methods to study chromatin structure, Epigenetics and gene regulation, DNA repair mechanisms in chromatin context, Chromatin dynamics in Stem cell differentiation and cancer, Chromatin as drug target.

(iv) Intracellular trafficking

Protein translocation, protein trafficking (endocytosis, exocytosis, transcytosis), de novo organelle biogenesis, protein quality control (role of internal vesicles), lysosomal biogenesis and degradation.

(v) Neuroscience

Paring Back, Critical Periods, SENSATION AND PERCEPTION: Vision, Hearing, Taste and Smell, Touch and Pain, LEARNING AND MEMORY, MOVEMENT, SLEEP: The Stuff of Sleep, Sleep Disorders, How is Sleep Regulated? STRESS: The Immediate Response, Chronic Stress, AGING: Aging Neurons, Intellectual Capacity, CHALLENGES & ADVANCES: Pain, Epilepsy, Major Depression, Manic-Depressive Illness, Addiction, Learning Disorders, Stroke, Neurological Trauma, Anxiety Disorders, Neurological AIDS, Spinal Cord Injury.

C. Topics in Modern Biology (OPT3)

(i) Membrane Biophysics and Structural Dynamics of Membrane Proteins

Models of biomembranes, Hydrophobic effect, Membrane organization and dynamics, Phase transition of membranes, Model membranes: micelles, reverse micelles, liposomes and Nanodiscs, Membrane proteins & cell surface glycoconjugates, Membrane Dynamics: Edidin & Frye experiment, heterocaryons, Diffusion of membrane components, Membrane domains and lipid rafts: membrane biophysics to cell biology, Hydrophobic mismatch, Membrane asymmetry and lipid polymorphism, Membrane cholesterol and its relevance in health and disease
Techniques in membrane biology
Structures of membrane proteins, How membranes shape protein structures? Lipid-protein interactions, Ion channels and Transporters, G-protein coupled receptors (GPCR).
Books:
1. Biomembranes : A Molecular approach by R.B. Gennis, Springer-Verlag.
2. Membrane Structural Biology – with biochemical and biophysical foundations by Mary Luckey, 2nd edition, 2014, Cambridge University Press.

(ii) Introduction to Space Bioengineering and Medicine
Manned and unmanned space missions; space as an extreme environment, microgravity, space radiation; physiological and biological effects of microgravity and space radiation on human, plants and microbes; Effect of microgravity at the level of genes and cells; Ground based facilities to simulate microgravity and cosmic radiation; space bioreactor, simulated microgravity reactor; space medicine: current status and future challenges; Bioengineering solution for long duration space flight and international space station (ISS), biological hazards in ISS and its remediation; In-situ resource utilization; space agriculture, space as a solution for earth based biomedical and bioengineering challenges; Challenges in human MARS exploration and its bioengineering solutions, concepts of terraforming; concept of space synthetic biology; space medicine and biotechnology on Indian context.

(iii) Drug Discovery: Modern Day Approach
Pre 20th century drug discovery. Drug discovery pipeline, drug targets and target validation. Methods of lead identification and optimization. Early prediction of ADMET (Absorption, Distribution, Metabolism Excretion and Toxicity). QSAR (Quantitative Structure Activity Relationship) predictions. Lipinski rule of 5. Polar surface area. Blood brain barrier crossing model. Predicting toxicity. Introduction to drug docking and pharmacophore modeling.

(iv) Nanobiomaterials :
Principles of bio-inspired nanomaterials, common biologically active molecules as suitable ligand for nanomaterials synthesis, separation procedure of different biological components from organic-mass and bio-mass, principles and function of gel electrophoresis & qPCR, concept of antigen and antibody, antigen specific aptamers, what is cancer? Different pathogens, surface modification of nanomaterials for highly specific targeting, biomarker detection and quantification for early stage detection, different therapeutic methods: photon, photodynamic, micro pH and photothermal therapy and their advantages over chemo and radiation therapy. PET scan, Magnetic separation, complete blood count (CBC), blood protein testing, tumor marker testing along with spectroscopic (UV-vis, Fluorescence and Raman techniques) and imaging techniques (TEM and AFM). Bi-metallic nanomaterials with programmable crystal defects for bacterial cytoskeleton targeting.

Semester III (Summer Semester)

Project (PRO)
Each student chooses one topic from an offered list and carries out an extensive review of literature and experiments with specific scientific aims under the supervision of a faculty. The student submits

a dissertation describing the literature survey and reporting the experimental findings which will be evaluated by two faculties. Finally, the student presents and defends the work in an open forum.