MSc in Molecular Life Sciences - Course Contents

First Semester

Cells and genomes
Universal features of cells, diversity of genomes

Cell as a unit of life and functional morphology of the cell

Structure and functions of following cellular compartments :
Cell membranes, mitochondria, lysosomes and peroxisomes, endoplasmic reticulum, Golgi apparatus, nucleus and associate structures, cytoskeleton and molecular motors. Cellular hierarchy

Biomolecules and transport across biological membranes

Molecular architecture of living matter: Nucleic acids, proteins, lipids and carbohydrates.
Structure and composition of biological membranes: Fluid Mosaic model; transport across biological membranes, kinetics and mechanisms of transport, Na+/K+/ATPase pump, Ca++/ATPase, H+/ATPase, gap junctions and group translocation

Cell to cell communications and cell signaling

Neural communication

- Generation and transmission of nerve impulses, Neurotransmitters, Synapses and neuromuscular junction

Communication via chemical messengers

- Peptide and steroid hormones, biogenic amines, eicosanoids and growth factors
- Endocrine, paracrine and autocrine effects
- Signaling through G-protein coupled cell-surface receptors
- Signaling through enzyme-linked cell surface receptors
- Signaling through cytoplasmic and nuclear receptors
- Signaling in plants

Energy homeostasis in the cell

- Enzymes : Biological catalysis, kinetics, regulatory enzymes;
- Bioenergetics and metabolism : Bioenergetics and thermodynamics, Phosphoryl group transfer and ATP, the concept of free energy and biological oxidation-reduction reactions (the redox potential);
- Intermediary metabolism and its regulation : Carbohydrate metabolism, lipid metabolism and protein metabolism ;
- Oxidative Phosphorylation; Hormonal regulation and integration of mammalian metabolism

Cell in its social context

- Cell junctions, Cell adhesion molecules
- Extracellular matrix
- Cytoskeleton

Isolating and visualizing cells

- Isolation of cells from tissues
- Light and phase contrast microscopy in visualising cells
- Locating specific molecules within a cell using antibodies and fluorescence

Protein, DNA and RNA based techniques

- Structure and properties of nucleic acids
- Extraction of nucleic acids
- Quantification of nucleic acids
- Restriction endonucleases and their uses
- Nucleic acid manipulating enzymes and their uses
- Immobilization of nucleic acids
- Nucleic acid labeling
- DNA probes and hybridization of nucleic acids
- Electrophoresis (Agarose gels, polyacrylamide gels, 2D-electrophoresis, PFGE etc.)
- Polymerase Chain Reaction (PCR) base techniques (PCR, RT-PCR, Real time PCR etc.)
- Applications of PCR (RAPD, AFLP, PCR-RFLP, SSCP etc.)
- DNA sequencing

Enzymology:

- Basic principle of enzyme catalyzed reactions
- Enzyme kinetics
- Enzyme activation, inhibition, induction, repression and inactivation (proteolytic activation, covalent modification, allosteric modification, etc.)
- Classification of enzymes and isoenzymes
- multi enzyme complexes, protective enzymes
- Application of enzymes in industries
- medical applications of enzymes
- Immobilized enzymes
- Purification of enzymes.
- Basic principles of enzyme assay methods
- Measurement of enzyme activity and measurement of biochemicals in body fluids & fermentation samples using enzymes

Second Semester

Biological information storage, processing and transfer in the cell

- DNA Replication: Enzymology of DNA replication, accuracy and fidelity of replication, DNA damage and repair mechanisms.
- Transcription in prokaryotes and eukaryotes; Eukaryotic transcription factors and their role on regulation of gene expression; tissue specific transcription factors; the role of chromosome structure, remodeling, acetylation/decaetylation and methylation of histone proteins on gene transcription and mechanisms of genomic imprinting.
- Prokaryotic and eukaryotic translation, alternate splicing, post translational modifications, Protein targeting and folding.
- RNAs including non-coding RNAs.
- DNA variations.

Protein Sorting and Intracellular Vesicular traffic

- Compartmentalization of Cells.
- Transport of molecules between the nucleus and the cytosol.
- Transport of proteins into mitochondria and chloroplasts.
- Peroxisomes.
- Endoplasmic reticulum.
- Transport from ER through the Golgi Apparatus.
- Transport from the Golgi network to lysosomes.

Gameotogenesis, Fertilization, Implantation and early development of the embryo

Gonadal structures, male and female gametogenesis
Fertilization, compaction, blastocysts formation, implantation
Formation of the early embryo – plan of the embryo
Mechanisms underlying formation of multicellular organisms
Signal transduction mechanisms in embryo development (eg: Wnt, Hedgehog etc)

Cell division, cell cycle and programmed cell death

- An overview of the cell cycle, Components of the cell cycle control system including Cyclins and cyclin dependent kinases, M phase Mitosis and meiosis, Cytokinesis, Intracellular control of cell cycle events
- Programmed cell death
- Extracellular control of cell division, cell growth and apoptosis

Molecular basis of abnormal cell growth and metastasis

- Hallmarks of cancer
- Molecular basis of cancer
- Role of oncogenes, tumour suppressor genes and DNA repair enzymes in cancer
- *P*53 as an example of tumour suppressor gene and its molecular basis of action
- Role of *BRCA1* and *BRCA2* in breast cancer

Protein, DNA and RNA based techniques

- DNA synthesis (eg. oligonucleotide synthesis)
- Recombinant DNA techniques
- Cloning vectors (plasmids/phages)
- Construction and screening of DNA libraries (genomic and cDNA)
- DNA cloning and transformation
- Analysis of recombinant clones
- Genetic engineering
- Cloning and expression of recombinant proteins
- Purification of recombinant proteins
- Site directed mutagenesis

Bioinformatics

- Introduction to Bioinformatics and basic sequence analysis (DNA and Proteins)
- Databases (DNA databases, protein databases, protein structure databases etc.)
- DNA and amino acid sequence alignment methods (pair wise and multiple alignments)
- Search sequences over the databases
- Prediction of protein secondary structure, function and subcellular localization
- Protein structure prediction/analysis
- Phylogenetics

Research methodology and biostatistics

- Hypothesis driven and inductive research
- Null hypothesis, Statistical significance
- Literature review
- General and specific objectives
- Validation and quality assurance of methodology
- Analysis of numerical data - parametric and non parametric tests
- descriptive statistics, comparison of two groups, comparison of three groups or more regression and correlation

Ethical issues in scientific research and ethical, legal and social implications of genetic, genomic and reproductive technologies

- Ethical issues in animal and human experimentation, Informed consent and confidentiality
- Ethical, legal and social implications of genetic research, genetic testing, assisted reproductive technology, reproductive and therapeutic cloning

One of the following Optional Modules

Plant Molecular Biology

- Plant Genome (nuclear, chloroplast and mitochondrial genome);
- Regulation & tissue specific expression of plant genes,
- Effect of cell intrinsic information (cell lineage and position) on cell fate;
- Molecular Biology of plant development (Gene regulation of embryogenesis, leaf development, flower development, self-incompatibility);
- Effect of cell intrinsic information on development in response to light, Gravitrophism,
  Thigmomorphogenesis,nutrients;
- Molecular basis of stress responses (abiotic and biotic)
- Molecular Markers: Marker assisted selection, Gene mapping
- Genetic engineering of plants: Techniques for plant transformation, Genetic modification in agriculture (taught under genetically modified organisms/ foods in the core units)

Molecular Medicine

- Historical aspects,
- Chromosomal aberrations leading to diseases, autosomal dominant, autosomal recessive,
- Sex linked recessive inheritance of monogenic diseases,
- Polygenic diseases and genomic approach to complex diseases,
- Diseases due to tri-nucleotide expansion with examples,
- Applications of molecular techniques in disease diagnosis,
- Recombinant technology in vaccine and therapeutic development,
- Gene therapy,
- Pre natal and pre implantation diagnosis,
- Epigenomics and its implications for molecular medicine,
- Gene environment interaction,
- Genome wide association studies,
- Copy number variation and human health,
- Systems biology and systems medicine,
- Overview of pharmacogenetics and pharmacogenomics,
- Antioxidants in health and disease (stem cells and cancer are covered under the core units)

Third Semester

Research Project