M.Sc. COURSE FOR

PLANT MOLECULAR BIOLOGY AND BIOTECHNOLOGY

M.Sc. Part I

Theory Papers	*Marks*
I. Basics of Molecular Biology	60
II. Molecular Cell Biology	60
III Biochemistry and Metabolomics	60
IV. Molecular Basis of Plant Growth and Development	60
V. Genetics and Gene Regulation	60
Theory Courses (I-V)	300
Practicals on above papers (I-V)	200
	500

M.Sc. Part-II

VI. Structure and Function of Eukaryotic Genome	60
VII. Molecular Basis of Differentiation and Morphogenesis	60
VIII. Plant Biotechnology	60
Dissertation	200
Theory papers (VI-VIII)	180
Practicals on above papers (VI-VIII)	120
	500

Paper I. BASICS OF MOLECULAR BIOLOGY

- **Matter, Universe and Origin of Life --** Basic concepts of energy; Solar radiation, H_2S and CH_4 as source of energy; Origin of universe; Principles of evolution; Molecular evolution and formation of large molecules; Origin of life from molecules to the eukaryotic cell; Nature of chemical bonds; Electromagnetic spectrum; Interaction of matter and radiation.

- **Basic Physical Chemistry** -- Chemical reactions; Ion transport; Thermodynamics; Entropy, enthalpy and free energy; Redox reactions.

- **Molecules of Life** -- Structure and diversity of sugars, amino acids, carbohydrates, lipids and proteins; Nucleic acids, the self-replicating molecules.

- **Bioenergetics** -- Mechanism of phosphorylation coupled to electron transport; Storage and utilization of energy.

- **Principles and Tools of Recombinant DNA Technology** -- Restriction enzymes and nucleic acid modifying enzymes; Choice of vectors; Plasmids, phages, cosmids, plant viruses, synthetic DNA vectors; cDNA and genomic libraries; Isolation of specific genes from bacteria and higher plants; PCR and its applications.

- **Physicochemical and Separation Techniques --** Principles and applications of spectrometry, centrifugation, chromatography, electrophoresis, radioactivity measurements.

- **Biostatistics and Bioinformatics** -- Measures of variability; Standard deviation, standard error, variance, probability; Relational data models and database management systems; Logics and techniques of constructing relational databases; Biological databases and data mining techniques; Web based programs for data analysis and presentation.

Paper II. MOLECULAR CELL BIOLOGY

- **Investigating the Cell** -- Cell theory; Microscope and its modifications; Light (phase contrast and interference), fluorescence, confocal, electron (TEM and SEM), electron tunneling and atomic force microscopy; Techniques for deciphering structure of macromolecules.

- **Cell Wall –** Cell wall composition and architecture; Biogenesis and assembly; Dynamic aspects of cell wall during growth and differentiation.

- **Membrane Structure and Function** – Structural models; Composition and dynamics; Transport of ions and macromolecules; Pumps, carriers and channels; Sensory physiology; Endo- and exocytosis; Membrane carbohydrates and their significance in cellular recognition.

- **Cellular Junctions and Intercellular Communication –** Cellular junctions and adhesions; Structure and functional significance of plasmodesmata.

- **Mitochondria** – Structure; Organization of respiratory chain complexes; ATP synthase; Structure-function relationship; Alternate oxidase system; Mitochondrial DNA and male sterility; Biogenesis of mitochondria; Origin and evolution.

- **Chloroplast and Photosynthetic Systems** – Structure; Organization of photosynthetic components in bacteria and plants; Structure-function relationship; Chloroplast DNA and its significance; Chloroplast biogenesis; Origin and evolution; Secondary association of chloroplasts.

- **Nucleus** – Structure and function of nuclear envelope, lamina and nucleolus; Macromolecular trafficking; Chromatin organization and packaging; Cell cycle and control mechanisms.

- **Ribosomes and Protein Synthesis** –Organization and biogenesis of ribosomes; Ribosome structure and its significance in protein synthesis.

- **Cytoskeleton and Cellular Motility -** Organization and role of microtubules and microfilaments; Cell shape and motility; Actin-binding proteins and their significance; Muscle organization and function; Molecular motors; Intermediate filaments.

- **Endo-membrane System -** Structure and function of microbodies, Golgi apparatus, lysosomes and endoplasmic reticulum; Membrane maturation and specialization.

Paper III. BIOCHEMISTRY AND METABOLOMICS

- **Carbon Assimilation --** Light absorption and energy conversion; Calvin Cycle; Hatch-Slack pathway; Reductive pentose phosphate pathway; Carbon dioxide uptake and assimilation; Photorespiration; Glycolate metabolism.

- **Biological Oxidation and Release of Energy --** Glycolytic pathway; Kreb's cycle; High energy compounds; Oxidative phosphorylation; Chemiosmotic hypothesis; Pentose phosphate shunt pathway.

- **Metabolism of Macromolecules --** Biosynthesis and inter-conversion of carbohydrates; Biosynthesis, inter-conversion and degradation of lipids; Metabolism of nucleotides, amino acids and vitamins.

- **Nitrogen, Sulphur and Phosphorus Metabolism --** General aspects of nitrogen economy; Nitrate reduction; Pathways of ammonia assimilation; Reductive amination; Trans-amination; Regulation of nitrogen assimilation; Uptake, transport and assimilation of sulphate and phosphate.

- **Nitrogen Fixation** -- Symbiotic and non-symbiotic nitrogen fixation; Role of lectins; *nod* genes; *nif* genes; Structure, function and regulation of nitrogenase; Leghaemoglobin; Nodulins; Regulation and enhancement of nitrogen fixation.

- **Long-distance Transport Mechanisms –** Turgor and stomatal movements; solute movement; source-sink relationship; water relations.

- **Secondary Metabolism --** Importance of Secondary Metabolites; Biosynthesis of phenolic compounds, isoprenoids, alkaloids and flavonoids.

Paper IV. MOLECULAR BASIS OF PLANT GROWTH AND DEVELOPMENT

- **General Aspects** – Novel features of plant growth and development; Concept of plasticity in plant development; Analysing plant growth.

- **Seed Germination and Seedling Growth** – Mobilization of food reserves during seed germination; tropisms; hormonal control of seed germination and seedling growth.

- **Shoot, Leaf and Root Development –** Organization of shoot apical meristem (SAM); Control of cell division and cell to cell communication; Molecular analysis of SAM; Leaf development and differentiation; Organization of root apical meristem (RAM); Root hair and trichome development; Cell fate and lineages.

- **Floral Induction and Development –** Photoperiodism and its significance; Vernalization and hormonal control; Inflorescence and floral determination; Molecular genetics of floral development and floral organ differentiation; Sex determination.

- **Seed Development and Dormancy –** Embryo and endosperm development; Cell lineages during late embryo development; Molecular and genetic determinants; Seed maturation and dormancy.

- **Senescence and Programmed Cell Death (PCD) –** Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants.

- **Signal Transduction –** Basic concepts; Receptors and G-proteins; Cyclic AMP cascade; Phospholipid and Ca^{2+}-calmodulin cascade; MAP kinase cascade; Two-component sensor-regulator system; Sucrose sensing mechanism.

- **Biosynthesis of Plant Hormones and Elicitors – S**tructure and metabolism of auxins, gibberellins, cytokinins, abscisic acid, ethylene, brassinosteroids, salicylic acid, jasmonates and related compounds.

- **Molecular Mechanism of Hormone Action –** Hormone signal perception, transduction and gene regulation; Role of mutants in understanding hormone action.

- **Light Control of Plant Development –** Discovery of phytochromes and cryptochromes, their structure, biochemical properties and cellular distribution; Molecular mechanisms of light perception, signal transduction and gene regulation; Biological clocks and their genetic and molecular determinants.

Paper V. GENETICS AND GENE REGULATION

- **Historical and General Aspects --** Basic discoveries in molecular genetics; Mendelian laws; Linkage analysis and gene mapping; Chromosome theory of heredity; Model organisms for genetic studies.

- **Genome Organization and its Replication –** Conjugation, transduction and transformation; Gene mapping in bacteria; Bacterial and cyanobacterial genomes; Replication of bacterial and eukaryotic genomes; Control of replication; Diversity in DNA polymerases; Replication of plasmids; Control of plasmid copy number.

- **Regulation of Transcription in Prokaryotes --** Discovery of RNA and its synthesis; Operon concept; Promoters and terminators; Positive and negative control of transcription; Repression and activation; RNA polymerases, Accessory factors; Sigma factors; Control of termination, Synthetic promoters.

- **Genetic Code and Translation** -- Deciphering the genetic code; Codon bias; tRNAs; ribosomes; Initiation and termination of translation; Translational and post-translational controls; Attenuation; Suppressor tRNAs.

- **Bacteriophages and Viruses** -- Control of gene expression in bacteriophage lambda, T-phages; RNA phages; Eukaryotic viruses; Contribution of phages in understanding gene regulation.

- **Mobile Genetic Elements** -- Structure and function of transposable elements; Mechanisms of transposition; Special features of retrotransposons.

- **Genetic Integrity and Diversity** -- Recombination; Mutagenesis; Repair and retrieval systems.

Paper VI. STRUCTURE AND FUNCTION OF EUKARYOTIC GENOME

- **Organization of Genome in Eukaryotes** -- Genes and gene number; Law of constancy and C-value paradox; Numerical and structural changes in chromosomes with reference to centromeres and telomeres; Gene amplification; Distribution of repeat and transposable elements and their function.

- **Molecular Mapping** -- Molecular polymorphism, RFLP, RAPD, STS, AFLP, SNP markers; Construction of genetic and physical map; Gene mapping and cloning; QTL mapping and cloning.

- **Genomes and Comparative Genomics** -- High throughput genome sequencing; *Arabidopsis*, rice and human genomes; Genome annotation; Synteny; Gene search and comparison tools.

- **Regulation of Gene Expression** -- Gene architecture; Promoter architecture; Regulatory sequences, enhancers and mechanism of their action; RNA polymerases and general transcription factors; Heterogeneous nuclear RNA; Cap structure and function; Polyadenylation; Britten-Davidson model; Transcription factors, DNA-binding and activation domains, activation of latent activators, co-activators; Chromatin remodeling and gene activation.

- **Split Gene Concept and RNA Processing** -- Introns and exons - size, distribution and evolution; RNA splicing; Catalytic RNA; Alternative splicing; RNA stability.

- **Functional Genomics and Proteomics** -- Approaches to analyze differential expression of genes - ESTs, SAGE, microarrays and their applications; Gene tagging; Gene trapping; Gene silencing; Knockout mutants; Approaches to proteome analysis; Dynamic modulation of protein structure and function; Structure to function–virtual organism.

Paper VII. MOLECULAR BASIS OF DIFFERENTIATION AND MORPHOGENESIS

- **Developmental Differences between Animals and Plants** – Comparison and consequences; Model systems.

- **Cellular Movements and Body Plan** –Laying of body axis planes; Differentiation of germ layers; Cellular polarity, cell wall and cell size and their importance in model plants like *Fucus* and *Volvox*; Concept of positional information and intercalation.

- **Embryonic Pattern Formation** – Maternal gene effects; Zygotic gene effects; Homeotic gene effects in *Drosophila*; Embryogenesis and early pattern formation in plants.

- **Post-embryonic Development** – Regeneration and totipotency; Organ differentiation and development; Cell lineages and developmental control genes in *Caenorhabditis* and maize.

- **Differentiation of Specialized Tissues** – Stem cell differentiation; Blood cell formation; Fibroblasts and their differentiation; Cellular basis of immunity; Differentiation of cancerous cells and role of proto-oncogenes.

- **Generation of Specialized Cell Types** – Phase changes in *Salmonella*; Mating cell types in yeast; Surface antigen changes in Trypanosomes; Immunoglobulin diversity and production; Heterocyst differentiation in *Anabaena;* Sex determination in *Drosophila*.

- **Special Aspects of Plant Development and Differentiation** – Pollen germination and pollen tube guidance; Phloem differentiation; Sex determination in plants; Self-incompatibility and its genetic control; Heterosis and apomixis.

Paper VIII. PLANT BIOTECHNOLOGY

- **Plant Tissue Culture** – Historical perspective; Totipotency; Organogenesis, somatic embryogenesis, their regulation and application; Artificial seed production; Micropropagation; Somaclonal variation; Androgenesis and its applications in genetics and plant breeding; Germplasm conservation and cryopreservation.

- **Protoplast Culture and Somatic Hybridization –** Protoplast isolation, culture and usage; Somatic hybridization - methods and applications; Cybrids and somatic cell genetics.

- **Agrobiology –** *Agrobacterium*-plant interaction; Virulence; Ti and Ri plasmids; Opines and their significance; T-DNA transfer; Disarming the Ti plasmid.

- **Genetic Transformation –** *Agrobacterium*-mediated gene delivery; Cointegrate and binary vectors and their utility; Direct gene transfer - PEG-mediated, electroporation, particle bombardment and alternative methods; Screenable and selectable markers; Characterization of transgenics; Chloroplast transformation; Marker-free methodologies; Gene targeting.

- **Marker Assisted Selection (MAS) –** Quantitative and qualitative traits; MAS for genes of agronomic importance, e.g. insect resistance, grain quality and grain yield.

- **Strategies for Introducing Biotic and Abiotic Stress Resistance/Tolerance** – Bacterial resistance; Viral resistance; Fungal resistance; Insects and pathogens resistance; Herbicide resistance; Drought, salinity, thermal stress, flooding and submergence tolerance.

- **Genetic Engineering for Plant Architecture and Metabolism** – Seed storage proteins; Protein engineering; Vitamins and other value addition compounds; Source-sink relationships for yield increase; Post-harvest bioengineering; Plant architecture; Flowering behaviour

- **Plants as Biofactories** – Concept of biofactories; Fermentation and production of industrial enzymes, vitamins and antibiotics and other biomolecules; Cell cultures for secondary metabolite production; Production of pharmaceutically important compounds; Bioenergy generation.

- **Environmental Biotechnology –** Soil reclamation and phytoremediation; Metal and pollutant detoxification.

- **Biosafety, Intellectual Property Rights and Ethical Issues –** Intellectual property rights (IPR); Patents, trade secrets, copyright, trademarks; Plant genetic resources; GATT & TRIPPS; Patenting of biological material; Plant breeders rights (PBRs) and farmers rights; Biosafety and containment practices**.**