# Central University of Punjab, Bathinda

**Ph.D Programme in Plant Sciences**
**School of Basic and Applied Sciences,**

**Part – I**

**General Aptitude**

General studies (General science and Mathematics) and General Knowledge.

**Statistics and Computer Applications.**

**Statistics:** Difference between parametric and non-parametric statistics, Univariant and multivariant analysis, Confidence interval, Errors, Levels of significance, Hypothesis testing.

**Descriptive statistics:** Measures of central tendency and dispersal, Histograms, Probability distributions (Binomial, Poisson and Normal), Sampling distribution, Kurtosis and Skewness.

**Fundamentals of computers:** Parts of computers, Hardware, BIOS, Operating systems, Binary system, Logic gates and Boolean Algebra.

**World Wide Web:** Origin and concepts, Latency and bandwidth, Searching the internet, Advanced web-search using Boolean logic, Cloud computing.

**Part – II**

**Cell Biology.**

**Introduction to the Cell:** The evolution of the cell, From molecules to first cell, From prokaryotes to eukaryotes, Prokaryotic and eukaryotic genomes, From single cell to multicellular organism.

**Membrane Structure and function:** Models of membrane structure, Membrane proteins, Membrane carbohydrates, Membrane transport of small molecules, Membrane transport of macromolecules and particles.

**Chromosomal DNA, its packaging and organization:** The cell nucleus, Morphology and functional elements of eukaryotic chromosomes. The complex global structure of chromosomes and function implications, lampbrush chromosomes, ploytene chromosomes, heterochromatin, centromeres, telomere.

**Structural organization and function of intracellular organelles:** The lysosomes, Ribosomes, The peroxisomes, The golgi apparatus, The endoplasmic reticulum, Mitochondria and chloroplast, Structure of Mitochondria and choroplast, Oxidation of glucose and fatty acids, Electron transport oxidative phosphorylation, Chloroplast and photosynthesis.

**Protein secretion and sorting:** Organelle biogenesis and protein secretion, synthesis and targeting, of mitochondria, chloroplast, peroxisomal proteins, translational modification in the ER. Intracellular traffic, vesicular traffic in the secretary pathway, protein sorting in the Golgi, traffic in the endocytic pathway, exocytosis.

**The cytoskeleton:**The nature of cytoskeleton, Intermediate filaments, Microtubules, Acti on filaments, Cilia and centrioles, Organization of the cytoskeleton.

**Cell growth and division:** Overview of the Cell cycle and its control, The molecular mechanisms for regulating mitotic and meiotic events, Amitosis, Cell cycle control, Check-points in cell cycle regulation.

**Cell communication and cell signaling:** Cell adhesions, Cell junctions and the extra cellular matrix, Cell- cell adhesion and communication, Cell matrix adhesion, Collagen the fibrous protein of the matrix, Non-collagen component of the extra cellular matrix, Cell to cell signaling, Overview of the extra cellular signaling , Identification of cell surface receptors, G--Protein coupled receptors and their effectors, Second messengers, Enzyme-linked cell surface receptors, Interaction and regulation of signaling pathways.

**General Biochemistry.**

**Principles of biophysical chemistry** pH, Buffer, Reaction kinetics, Thermodynamics, Colligative properties, Structure of atoms, Molecules and chemical bonds.

**Composition, structure and function of Biomolecules:** Carbohydrates, Lipids, Proteins, Nucleic acids and Vitamins.

**Stabilizing interactions:** Van der Waals, Electrostatic, Hydrogen bonding, Hydrophobic interaction, etc.

**Metabolic Pathways:** Carbohydrates, Lipids, Amino Acids, Nucleotides, Hormones and Vitamins.

**Bioenergetics:** Glycolysis, Oxidative Phosphorylation, Coupled reaction, Group transfer, Biological energy transducers.

**Enzymology:** Principles of catalysis, Enzymes and Enzyme kinetics, Enzyme regulation, Mechanism of enzyme catalysis, Isozymes.

**Proteins Chemistry:** Ramachandran plot, Secondary, Tertiary and Quaternary structure, Domains, Motif and Folds.

**Nucleic acids:** A-, B-, Z-,DNA, t-RNA, micro-RNA, Stability of protein and Nucleic acid structures.

**Genetics.**

**Introduction and scope of genetics**

**DNA as genetic material:** The vehicle of Inheritance, Chemical structure and base composition of nucleic acid, Double helical structure, Basic structure of DNA and RNA, Different types of DNA molecules, forces stabilizing nucleic acid structure, super coiled DNA, properties of DNA, denaturation and renaturation of DNA and Cot curves.

**DNA replication:** Messelson and Stahl Experiment, Carins Experiment, Okazaki Experiment, Basic mechanism of DNA replication.

**Cell division and Cell cycle:** Mitosis, Meiosis, Chromosomal basis of inheritance.

**Basic Principles of Mendelian Inheritance:** Segregation and Independent Assortment, Alleles and Multiple Alleles, Human pedigrees and inheritance.

**Linkage analysis and gene mapping:** Coupling and repulsion phases, Crossing over and recombination**.**

**Gene Interaction:** Sex determination and Sex linked inheritance, Sex determination in humans, *Drosophila* and other animals, Sex determination in plants, Sexlinked genes and dosage compensation of X linked genes. Human genetics: pedigree analysis.

**Gene Concept:** Fine Structure of gene and gene concept, Fine structure of rII gene – Benzer's experiments, Complementation analysis and fine structure of gene, Complementation and recombination, Concept of gene.

**Extra-chromosomal inheritance:** Chloroplast and Mitochondrial inheritance, Yeast, *Chlamydomonas/ Neurospora* and higher plants.

**Mutations:** Spontaneous and induced mutations, Somatic vs germinal mutation.

**Chromosomal aberrations**: Main type of changes– deletions duplications,Inversions, translocations,Change in chromosome number: trisomy and polyploidy. Evolutionary history of bread wheat, Aneuploids–nullisomics, monosomics, and trisomics, Somatic aneuploids, Changes in chromosome structure, Properties of chromosomes for detection of structural changes.

**Population genetics:** Application of Mendel's laws to whole population, Hardy-Weinberg principle, inbreeding depression and heterosis, inheritance of quantitative traits.

**Biosystematics & Biodiversity.**

**General Introduction to systematics:** Taxonomy, Classification and Biological nomenclature; Tree of life, Basic Latin used in systematics, Concepts of species and hierarchical taxa, Speciation, The species problem, Biological nomenclature, Classical and quantititative methods of taxonomy.

**Overview of plant and algal systematics:** Overview of ICBN rules, Major classes and orders, Major families of commercially important plants.

**Overview of animal systematics:** Overview of ICZN rules, Major phyla and classes.

**Overview of microbial (Bacterial, Fungal and Viral) systematics:** Overview of microbial systematics, Major human, domestic animal and plant pathogens.

**Natural history of Indian subcontinent:** Major habitat types of the subcontinent, Geographic origins and migrations of species, Common Indian mammals, birds, Seasonality and phenology of the subcontinent, Biogeography, Major terrestrial biomes, Theory of island biogeography and biogeographical zones of India.

**Overview of Biodiversity:** Evolutionary Significant Units, Importance of Biodiversity, Patterns of Biodiversity, Endemism and Hotspots, Continental drift and dispersal routes, Geologic time scale, Role of extinctions and additions, Measuring Biodiversity: Realism Vs. Nominalism, Species richness, species evenness, Simpson's diversity index, Biodiversity acts, Conservation of biodiversity.

**Molecular Biology**.

**Structure, Conformation, Denaturation, Renaturation of Nucleic acids:** A carrier of genetic information, Chemical structure of DNA and base composition,Watson-Crick model, Supercoiled DNA, Different forms of RNA : mRNA, tRNA, rRNA and other Types of RNA. Organelle DNA: mitochondria and chloroplast DNA.

**Chromosome Structure, Chromatin and the Nucleosome:** Genome Sequence and Chromosome Diversity, Chromosome Duplication and segregation, The nucleosome, Chromatin structure: euchromatin, heterochromatin, Constitutive and facultative heterochromatin, Regulation of chromatin structure and nucleosome assembly, Nucleolus.

**Gene & Genome organization:** Split Genes, Overlapping genes, Transposons & retrotransposons, Gene clusters, Histones, Non-histones, Nucleosome, Chromatin, Chromosome structure in prokaryotes & eukaryotes.

**Basic Processes, Replication of DNA:** Prokaryotic and eukaryotic DNA replication, Mechanism of DNA replication, Enzymes and accessory proteins involved in DNA replication, Replication errors, DNA damage and their repair.

**Transcription and mRNA processing:** Prokaryotic &, eukaryotic transcription, general and specific transcription factors, Regulatory elements and mechanisms of transcription regulation, Transcriptional and posttranscriptional gene silencing : Initiation, Elongation & Termination of transcription, Capping, Polyadenylation, Splicing, editing, mRNA stability, RNA interference, Microarray.

**Translation:** Genetic code, Prokaryotic & eukaryotic translation, the translation machinery, mechanisms of initiation, elongation and termination, regulation of translation, co-and post- translational modifications of proteins, Epigenetics.

**Ecology and Environment.**

**The Environment:** Physical environment, biotic environment, biotic and abiotic interactions.

**Habitat and Niche:** Concept of habitat and niche, niche width and overlap, fundamental and realized niche, resource partitioning and character displacement.

**Ecological succession:** Types, mechanisms, changes involved in succession, concept of climax.

**Ecosystem:** Structure and function, energy flow and mineral cycling (CNP), primary production and decomposition, structure and function of some Indian ecosystems: terrestrial (forest, grassland) and aquatic (fresh water, marine, eustarine).

**Population ecology:** Characteristics of a population, population growth curves, population regulation, life history strategies (*r* and *K* selection), concept of metapopulation – demes and dispersal, interdemic extinctions, age structured populations.

**Species interactions:** Types of interactions, interspecific competition, herbivory, carnivory, pollination and symbiosis.

**Community ecology:** Nature of communities, community structure and attributes, levels of species diversity and its measurement, edges and ecotones.

**Environmental pollution:** Global environmental change, ozone depletion, biodiversity-status, monitoring and documentation, major drivers of biodiversity change, biodiversity management approaches, Carbon credit.

**Plant Physiology.**

**Water relations:** Properties of water, Properties of solutions, Cell water potential, Soil-plant-atmosphere continuum.

**Photosynthesis:** Light harvesting complexes, Mechanisms of electron transport, Photoprotective mechanisms, $CO_2$ fixation, C3 , C4 and CAM pathways.

**Respiration and Photorespiration:** Citric acid cycle. Plant mitochondrial electron transport and ATP synthesis, Alternate oxidase, Photorespiratory pathway.

**Nitrogen metabolism:** Nitrate and ammonium assimilation, Amino acid biosynthesis.

**Solute transport and photoassimilate translocation:** Uptake, transport and translocation of water, ions, Solutes and macromolecules from soil, Through cells, Across membranes, Through xylem and phloem, Transpiration, Mechanisms of loading and unloading of photoassimilates.

**Phyto hormone:** Biosynthesis, storage, breakdown and transport, physiological effects and mechanisms of action.

**Secondary metabolites:** Biosynthesis of terpenes, Phenols and nitrogenous compounds and their roles.

**Seed physiology:** Germination pattern, Dormancy.

**Sensory photobiology:** Structure, function and mechanisms of action of phytochromes, cryptochromes and phototropins, Stomatal movement, Photoperiodism and Biological clocks.

**Stress physiology:** Responses of plants to biotic (pathogen and insects) and abiotic (water, temperature and salt) stresses, Mechanisms of resistance to biotic stress and tolerance to abiotic stress.

**Computational Biology and Bioinformatics.**

**Biological Databases:** Nucleotide Sequence Databases, GenBank, DDBJ, EMBL, Sequence Flatfile and submission process, Protein sequence databases, UniProt in detail, Mapping databases, Genomic databases, Data mining.

**Analysis for nucleotide sequences:** Gene Prediction methods and programs, Markov and Hidden Markov models in gene prediction, Promoter analysis, RNA secondary structure thermodynamics, Dynamic programming and genetic algorithms for secondary structure prediction, refining multiple sequence alignment based on RNA secondary

structure predictions, Vienna RNAfold, Evolution and origins of sequence polymorphisms, SNP discovery methods and databases, Genotyping, International haplotype map project, 1000 genomes project.

**Analysis for protein sequences:** Predicting features of individual residues, Predicting function, Neural Networks, Protein structure prediction, Protein structure databases, PDB in detail, 3D visualization softwares, Pathway and molecular interaction databases, Prediction algorithms for pathways and Molecular Interactions, Integrating gene expression data with pathway information.

**Inferring relationships:** Global Vs. local sequence alignments, Dotplots, Scoring matrices, Pairwise sequence alignment, BLAST, Position-Specific scoring and PSI-BLAST, MegaBLAST, BL2SEQ, BLAT, FASTA Vs BLAST, Protein multiple sequence alignments, Multiple structural alignments, Shotgun sequencing, Sequence assembly and finishing.

**Phylogenetic Analysis:** Basics of phylogenetics, Nucleotide substitution models and selection, Distance-matrix-based methods, Neighbor-Joining, Fitch-Margoliash, Outgroups, UPGMA, Minimum Evolution, Maximum Parsimony, Maximum Likelihood, Bayesian Inference, Searching for trees, Rooting trees, Bootstrapping, Likelihood ratio tests.

**Genomics:** Comparative Genomics, Genomic alignments, Gene predictions in genomic alignments, Genome-wide association study, Phylogenetic footprinting, Gene annotation, Gene expression analysis using DNA Microarray, Annotation of array probes, Image processing, Normalizing expression measurements.

**Proteomics:** Major proteomic approaches, Protein analysis by MALDI and SELDI methods, Time of Flight MS in protein analysis, Protein Identification by Mascot, Peptide Mass Fingerprinting, Comparative proteomics, Two-Dimensional Polyacrylamide Gel Electrophoresis.

**Evolution and Developmental Biology**.

**Emergence of evolutionary thoughts:** Lamarckism, Darwinism, Concepts of variation, adaptation, struggle, fitness and natural selection, Mendelism, Spontaneity of mutations, Theories of phyletic gradualism Vs. punctuated equilibria, Modern evolutionary synthesis.

**Origin of life and unicellular evolution:** Origin of basic biological molecules, Abiotic synthesis of organic monomers and polymers, Concept of Oparin and Haldane, Experiment of Miller (1953), The first cell, Evolution of prokaryotes, Origin of eukaryotic cells, Evolution of unicellular eukaryotes, Anaerobic metabolism, Photosynthesis and aerobic metabolism.

**Paleontology and evolutionary history:** The evolutionary time scale, Eras, periods and epoch, Major events in the evolutionary time scale, Origins of unicellular and multicellular organisms, Stages in primate evolution including *Homo sapiens*.

**Molecular Evolution:** Concepts of neutral evolution, Molecular divergence and molecular clocks, Molecular tools in phylogeny, Classification and identification; Origin of new genes and proteins; Gene duplication and divergence.

**Evolutionary Mechanisms:** Populations, gene pool and gene frequency, Hardy-Weinberg law, Concepts and rate of change in gene frequency through natural selection, migration and random genetic drift, Adaptive radiation and modifications, Isolating mechanisms, Speciation, allopatricity and sympatricity, Convergent evolution, Significance of sex in evolution, Co-evolution.

**Basic concepts of development:** Totipotency, Commitment, Specification, Induction, Competence, Determination and Differentiation, Morphogenetic gradients, Cell fate and cell lineages, Stem cells, Genomic equivalence and the cytoplasmic determinants, Imprinting, Mutants and transgenics in analysis of development.

**Gametogenesis, fertilization and early development:** Production of gametes, Cell surface molecules in sperm-egg recognition in animals; Embryo-sac development and double fertilization in plants, Zygote formation, cleavage, blastula formation, embryonic fields, gastrulation and formation of germ layers in animals, Embryogenesis and establishment of symmetry in plants, Seed formation.

**Programmed cell death:** Hypersensitive response, functions, relevance with diseases, apoptosis, Caspases, Importance of PCD in plant development, role of PCD, model of PCD.

**Bioethics and Biosafety.**

**Social and Ethical issues.**

**Bioethics:** Genetically Modified Organisms and their release in to the environment. Special procedures for r-DNA based products, Animal rights, Perspectives and methodology.

**Medical ethics:** Healthcare rationing, Organ transplantation, Abortion, Euthanasia, *In-Vitro* fertilization, Stem cell cloning, Artificial life.

**Biosafety:** Good Lab Practices, Biosafety for human health and environment, Gene pollution, Biological invasion, Risk Assessment of GMOs, Biological warfare, CDC Biosafety levels.

**Intellectual Property Rights (IPR) and patenting.** History of Patent Law, Copyright, Trademark, Fair use, Open Access Publishing, Gene Patents and Ethical Issues, Plant breeder's rights, Indigenous Intellectual Property, Criticism of Intellectual Property, Plagiarism.

**Genetic Engineering**

**Plant cell and tissue culture**: Somatic embryogenesis and synthetic seeds, Gene expression programme during somatic embryogenesis.

**Production of androgenic and gynogenetic haploids:** Dihaploid breeding.

**Organogenesis and embryogenesis:** Production of virus-free plants and micropropagation, Clonal multiplication, shoot tip culture.

**Manipulations with cells in culture:** Somaclonal variations, Production of secondary metabolites.

**Protoplast culture and Somatic hybridization.**

**Cryopreservation of germplasm.**

**DNA delivery and expression tools:** Vectorless and vector mediated methods of plant transformation, *Agrobacterium* mediated gene transfer, Natural pathogen mode of infection, vir gene functions, Ti/Ri plasmids, Auxin and cytokinin biosynthetic genes and mutants, Binary vector systems advantages, Features and basic protocol for construction of binary vector and DNA delivery into plant cell,

Components and basic protocol, Advantages and disadvantages in comparison with *Agrobacterium* mediated methods.

**Special vectors and transformation systems:** Transposon tagging, enhancer / promoter / gene trap, Transactivation, Over expression and under expression, Gene silencing, Virus induced gene silencing, Gene replacement, Gene targeting.

**Transgenic plants for biotic and abiotic stress tolerance:** Genetic modification of plants against environmental abuses, Herbicide resistance, Shelf life, Pest resistance, Resistance towards diseases, Stress tolerance, Nutritional quality.

**Molecular markers and construction of maps:** Molecular breeding, DNA fingerprinting, Genomics.

**Future prospects:** Genetically modified crops.