Central University of Punjab, Bathinda

Ph.D Programme in Biochemistry and microbiology
School of Basic and Applied Sciences,

Part – I

General Aptitude, current Knowledge, Basic Maths, Computers, ETC

Part – II

1. **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.

2. **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.

3. **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.

4. **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 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.

5. **Microbiology.**

Prokaryotic structure and function: Cell structure and function, Classifications.

Viruses: Structure of major viruses, Viral replication.

Eukaryotic microorganisms: Fungi, Protozoa, Algae, etc.

Growth and nutrition: Phases in bacterial growth, Growth Curve, Calculation of G-time, Physical and environmental requirements of growth, Microbial nutritional requirements, Types of culture media.

Microbial Genetics: DNA replication, Transcription and translation, Operon, Horizontal Gene Transfer.

Applied Microbiology: Environmental microbiology, Microbial ecology, Aquatic Microbiology, Food, Dairy and Agricultural Microbiology, Industrial Microbiology.

Microbial diseases: Major bacterial diseases of animals and plants, Airborne, Food-borne, Soil-borne, Nosocomial and Sexually Transmitted/Contagious Diseases, Principles of disease and epidemiology, Host-Microbe relationship, Viral pathogenesis, Major viral diseases of plants and animals.

Control of microorganisms: Physical and Chemical methods, Antimicrobial drugs, Antibiotic assays, Drug resistance in bacteria.

Emerging infectious diseases and their control: Avian Influenza A/H5N1, A/H1N1 Swine Influenza, SARS, AIDS, Japanese encephalitis, Malaria and Tuberculosis, West Nile, Mechanisms of emergence and reemergence.

6. **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.

7. **Animal Physiology.**

Digestive system: Digestion, absorption, energy balance, BMR.

Cardiovascular System: Comparative anatomy of heart structure, Myogenic heart, specialized tissue, ECG – its principle and significance, Cardiac cycle, Heart as a pump, blood pressure, neural and chemical regulation of all above, Blood corpuscles, Blood cell synthesis and Bone marrow, Haemopoiesis and formed elements, Plasma function, Blood volume, Blood volume and its regulation, Blood groups, Haemoglobin, Immunity, Haemostasis.

Respiratory system: Comparison of respiration in different species, Anatomical considerations, Transport of gases, Exchange of gases, Waste elimination, Neural and chemical regulation of respiration.

Excretory system: Comparative physiology of excretion, Kidney, Urine formation, Urine concentration, Waste elimination, Micturition, Regulation of water balance, Blood Volume, Blood pressure, Electrolyte balance, Acid-base balance.

Reproduction and Endocrinology: Endocrine glands, Basic mechanism of hormone action, Hormones and diseases, Reproductive processes, Neuroendocrine regulation.

Nervous system: Neurons, action potential, Gross neuroanatomy of the brain and spinal cord, Central and peripheral nervous system, Neural control of muscle tone and posture.

Sense organs: Vision, Hearing and Tactile response.

Thermoregulation and Stress adaptation: Comfort zone, Body temperature – physical, chemical, Neural regulation, Acclimatization.

8. **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.

9. **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.

10. Immunology.

Immune system: Recognition of self and nonself, Humoral immunity-immunoglogulins, basic structure, classes and subclasses, structural and functional relationships, nature of antigen, antigen-antibody reaction, estimation of affinity constants.

Molecular mechanisms of antibody diversity: Organization of genes coding for constant and variable regions of heavy chains and light chains. Mechanisms of antibody diversity, class switching.

Cellular immunity: Lymphocytes, cytokines, interferons, Interlukins, antigen recognition-membrane receptors for antigens.

Complement system: Complement components, their structure and functions and mechanisms of complement activation by classical, alternative and lectin pathway.

Major histocompatibility system: Structure and functions of Major Histocompatibility Complex (MHC) and Human Leukocyte Antigen (HLA) system, polymorphism, distribution variation and function. Association of MHC with disease and superantigen, recognition of antigens by T and B-cells, antigen processing, role of MHC molecules in antigen presentation and co stimulatory signals, tumor immunology

Hypersensitivity: Types, features and mechanisms of immediate and delayed hypersensitivity reactions, immunity to microbes, immunity to tumors, AIDS and immunodeficiencies, hybridoma technology and vaccine, natural, synthetic and genetic, development of vaccine for diseases like AIDS, cancer and malaria.

Monoclonal antibodies: Production, characterization and applications in diagnosis, therapy and basic research, immunotoxins, concept of making immunotoxins.

Diagnostic immunology: Methods for immunoglobulin determination-quantitative and qualitative antigen and antibody reactions, agglutination-precipitation, immunoflourescence, immunoblotting and assessment of human allergic diseases.

11. 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.

12. Cancer Biology.

Biology and classification of cancer: Classification , Phenotype of a cancer cell , Causes of cancer –DNA tumor viruses, RNA tumor viruses, Cell cycle and its control-role of protein kinases, Checkpoints, Kinase inhibitor and cellular response, Different forms of cancers, Diet and cancer screening and early detection, Tumor markers, Molecular tools for early diagnosis of cancer.

Genetic basis of cancer: Oncogenes, Tumor suppressor genes, Aberrations in signaling pathways, Oncogenic mutations in growth promoting proteins, Mutations causing loss of growth-inhibition and cell cycle control, Role of carcinogens and DNA repair in cancer.

Oncogenesis and Apoptosis: Intracellular proteolytic cascade, Cascade of caspase proteins, Adapter proteins, Bcl-2, IAP family proteins, Extra cellular control of cell division, Tumor necrosis factor and related death signals.

Metastasis: Heterogeneity of metastatic phenotype, Metastatic cascade, Basement membrane disruption, Three step theory of invasion, Proteinase and tumor cell division.

Cancer therapy: Different forms of therapy, Chemotherapy, Radiation therapy, Detection of cancers, Prediction of aggressiveness of cancer, Advances in cancer detection, Use of signal targets towards therapy of cancer, Gene therapy.

13. Molecular Stress Physiology.

Environmental Stresses: Definition, Significance, Types, Stress-as perceived by plants and animals.

Physiological responses of plants under stressful conditions: Choice between fight for flight, acquired vs induced tolerance

Responses of plants towards biotic factors: Plant defense system, Genetic basis, understanding R genes, Systemic plant defense responses.

Responses towards abiotic factors: Stresses involving water deficit, High and low temperature stress, Salinity stress, Drought stress, Anoxia and Heavy metal stress, Role of osmotic adjustments towards tolerance, Altitude Stress, understanding of genetic basis.

Signaling under stress conditions: Perception, Transduction and response trigger, Induction of specific gene expression, Stress proteins, Convergence and divergence of signaling pathways, ABA as stress hormone, ABA the phenomenon of cross adaptation.

Genetic engineering and production of plants for improved stress tolerance: Physiological approach, Mutant approach, Wild relatives approach, Contrasting genotypes approach, Getting clue from sub - relative approach, contrasting genotypes approach, Getting clue from sub-lethal stress application, Lower organisms etc insect, nematodes, virus, bacteria, phytoplasma and fungus resistant plants, Success of plant breeding vs modern genetic modifications, Raising of stress tolerant genotypes through genetic engineering.

High throughput analysis techniques in stress biology: Transriptome analysis, Proteome analysis, Microarray, SAGE etc.

14. 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.