Syllabus of the Entrance Examination for Ph.D. (Biotechnology) Programme

PART A: Research Methodology

Research and Types of research: Meaning of Research- Objectives of Research- Motivation in Research. Research methods vs Methodology. Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical. Research Process. Criteria of good Research. Research Formulation – Defining and formulating the research problem - Selecting the problem - Necessity of defining the problem - Importance of literature review in defining a problem – Literature review – Primary and secondary sources – reviews, treatise, monographs-patents – web as a source – searching the web - Critical literature review – Identifying gap areas from literature review - Development of working hypothesis. Data Collection and analysis: Execution of the research - Observation and Collection of data - Methods of data collection – Modeling, Mathematical Models for research, Sampling Methods- Data processing and Analysis strategies. Data Analysis with Statistical Packages – Hypothesis-testing, Generalization-and Interpretation

PART B: Biotechnology

Biomolecular structure and function

a) Covalent structure of Amino acids, proteins, nucleic acids, carbohydrates and lipids.

b) Forces that stabilize biomolecules: electrostatic and van der Waal‟s interaction, hydrogen bonding. Interactions with solvents, Hydrophobic effect.

c) Protein Structure and Structural characteristics of alpha-helix, beta-sheet and gamma-turn. Ramachandran plot. Protein domains and domain architecture. Quaternary structure of proteins.

d) Conformation of Nucleic acids: Structural characteristics of A, B and Z-DNA. 3D structure of t-RNA, ribozymes and riboswitches

e) Basic Thermodynamics: Laws of thermodynamics. Concepts of ΔG, ΔH and ΔS.

f) Physical properties of water and their role in biology. Concepts of pH, ionic strength and buffers.

g) Chemical kinetics: Concepts of order and molecularity of a chemical reaction. Derivation of first and second order rate equation, measurement of rate constants. Concept of activation energy.

h) Enzymology: Introduction to enzymes. Types of enzymatic reaction mechanisms, Michaelis-Menten kinetics. Competitive, Non-competitive and Un-competitive inhibition. Bi-substrate reaction kinetics. Allostery.

Methods in Biotechnology

a) Concepts of precision and accuracy in experimental measurements. Concept of signal to noise ratio.

b) Biostatistics: Measures of Central Tendency. Fundamental ideas of probability and probability distributions: Binomial, Poisson and Gaussian distributions. Concept of the Central Limit Theorem. Hypothesis testing: Use of Student's t tests. Correlation and regression. Basic concepts of design of Experiments.

c) Biochemical Methods: Chromatography: Ion exchange, Gel Filtration and Affinity chromatography. Electrophoresis: Native and SDS-PAGE. Isoelectric focusing. 2D PAGE and its applications.

d) UV/Vis spectrophotometry. Beer-Lambert‟s law and its use in determination of protein/ nucleic acid concentration.

e) Fluorescence Spectroscopy: Basic concepts of excitation and emission. Quenching, Stern-Volmer Plots. Theory and applications of FRET and fluorescence lifetime measurements.

f) Fundamentals of CD, IR and Raman spectroscopy and their use in the study of biomolecular conformation.

g) Centrifugation: Basic concepts of centrifugation. Calculation of g_value from RPM. Density gradient centrifugation. Sedimentation velocity and Sedimentation equilibrium. Separation of sub-cellular components and macromolecules using high speed and ultracentrifugation.

h) Microscopy: Bright field, phase contrast, fluorescence, confocal, and electron microscopy.

i) Fundamentals of X-ray, NMR and cryo-electron microscopy for determination of biomolecular structure.

Cellular processes

a) DNA replication, repair and recombination (Unit of replication, enzymes involved, replication origin and replication fork, fidelity of replication, extrachromosomal replicons, DNA damage and repair mechanisms, homologous and site-specific recombination).

b) Transcription of various types of RNAs and their processing and modifications. Transcription factors and machinery including RNA polymerases, formation of initiation complex, elongation and termination of transcription. Regulation of transcription: activators (enhancers) and repressors, Locus control regions. Structure and function of different types of RNA and mRNPs. RNA transport, localization and function.

c) Protein synthesis, processing and transport of proteins: Ribosome, mRNA structure, genetic code, aminoacylation of tRNA, aminoacyl tRNA synthetase. Mechanism of translation: Initiation, elongation and termination factors and translational proof-reading. Regulation of Translation-global vs mRNA-specific. Translation inhibitors, Post- translational modifications of proteins. Protein trafficking and transport.

d) Control of gene expression at transcription and translation level: Regulation of gene expression in viruses, prokaryotes and eukaryotes, role of chromatin, chromatin remodelling and gene silencing, Epigenetic regulation.

e) Host-pathogen interaction: Recognition and entry processes of different pathogens like bacteria, viruses and protozoans into animal and plant host cells, alteration of host cell behavior by pathogens, virus-induced cell transformation, pathogen-induced diseases in animals and plants, cell-cell fusion in both normal and abnormal cells.

f) Cell signaling: Hormones and their receptors, cell surface receptor, signaling through Gprotein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component systems, light signaling in plants, bacterial chemotaxis and quorum sensing.

g) Cellular communication: General principles of cell communication, cell adhesion and roles of different adhesion molecules, tight junctions, communicating junctions, extracellular matrix, integrins, neurotransmission and its regulation. Regulation of hematopoiesis, differentiation and development.

h) Innate and adaptive immune system: Cells and molecules involved in innate and adaptive immunity, antigens, antigenicity and immunogenicity. B and T cell epitopes, structure and function of antibody molecules. generation of antibody diversity, monoclonal antibodies, antibody engineering, antigen-antibody interactions, MHC molecules, antigen processing and presentation, activation and differentiation of B and T cells, B and T cell receptors, humoral and cell-mediated immune responses, primary and secondary immune modulation, the complement system, Toll-like

receptors, cell- mediated effector functions, inflammation, hypersensitivity and autoimmunity, immune response during bacterial (tuberculosis), parasitic (malaria) and viral (HIV) infections, congenital and acquired immunodeficiencies, vaccines.

Genetics, Phylogeny & Evolution

a) Chromosomal inheritance: Principles of Mendelian inheritance, codominance, incomplete dominance, gene interactions, pleiotropy, genomic imprinting, linkage and cross-over, sex-linked inheritance, Population Genetics and Hardy-Weinberg equilibrium.

b) Extrachromosomal inheritance: Maternal inheritance (mitochondria and chloroplast)

c) Gene concept: Allele, multiple alleles, pseudoalleles.

d) Genetic analysis: Linkage maps, mapping with molecular markers, tetrad analysis, gene transfer in bacteria: transformation, conjugation, transduction, sex-duction, fine structure analysis of gene.

e) Mutation: Spontaneous, induced, lethal, conditional, reversion, mutagenic suppression, germinal and somatic mutation, insertion, deletion, duplication, translocation, transposition, ploidy.

f) DNA finger printing and its applications, DNA bar coding, marker assisted selection and QTL mapping.

g) Species concept in archaea, bacteria and eukarya.

h) Phylogenetic analysis and evolutionary relationship among taxa, MLST.

Bioinformatics & Computational Biology

a) **Major Bioinformatics Resources:** Sequence databases, Gene Expression database: GEO, SAGE, 3D Structure Database: PDB, NDB, Knowledge driven Databases & utility, Pattern Sequence: InterPro, Prosite, Pfam, ProDom, Gene Ontology

b) **Database Searches:** Keyword-based searches using tools like ENTREZ and SRS Sequence-based searches: BLAST and FASTA

c) **Sequence Analysis, Basic concepts:** Sequence similarity, identity and similarity, definitions of homologues, orthologues, paralogues, Tandem and Interspersed repeats, repeat finding.

d) Scoring Matrix, Pairwise sequence alignments, Multiple sequence alignments (MSA), Application in Taxonomy and phylogeny, Comparative genomics.

e) **Structural Biology**: 3-D structure visualization and simulation, Basic concepts in molecular modeling: different types of computer representations of molecules. External coordinates and Internal Coordinates, Molecular Mechanics, Force fields etc.

f) **Proteins**: Secondary structure elucidation using Peptide bond, phi, psi and chi torsion angles, Ramachandran map, anatomy of proteins – Hierarchical 11 organization of protein structure –like CATH,SCOP, FSSP .

g) DNA & RNA secondary and tertiary structures, t-RNA tertiary structure

h) **Classification and comparison of protein 3D structures**: Secondary structure prediction: Algorithms viz. Chou Fasman, GOR methods, Tertiary Structure prediction: Fundamentals of the methods for 3D structure prediction (sequence similarity/identity of target proteins of known structure, fundamental principles of protein folding etc.) Homology/comparative Modeling, fold recognition, threading approaches, and ab initio structure prediction methods. CASP. Computational design of Promoters, Proteins & Enzymes.

i) **Application in drug design:** Chemical databases like NCI /PUBCHEM. Fundamentals of Receptor-ligand interactions. Structure-based drug design: Identification and Analysis of Binding sites and virtual screening. Ligand based drug design: Structure Activity Relationship – QSARs & Pharmacophore etc. In silico predictions of drug activity and ADMET.