Syllabus for Biophysics (SCPH04)

Note:

i. There will be one Question Paper which will have 100 questions.

ii. All questions will be compulsory.

iii. The Question Paper will have two Parts i.e. Part A and Part B

iv. Part A will have 50 questions based on Research Methodology

v. Part B will have 50 questions based on Subject-Specific Knowledge.

1. Introductory Biology

- **Origin of Life:** Brief history & mechanism of evolution. Theories of evolution & Inheritance.
- **Unity of Life:** Definition and characteristic of life, conservation and genetic variation, Genetic diversity and specification, molecular basis of living organisms, chemical Organization of the cell, inorganic and organic constituents, micro and macromolecules in The cell.
- **Cellular Organization**: Structures and functions of cell wall, plasma membrane, Protoplasm and its colloidal nature, nucleus, chloroplast, mitochondria, endoplasmic Reticulum, ribosomes, lysosomes, Golgi apparatus, centrioles, cilia, flagella and Microtubules, microfilaments, intermediate filaments, cytoskeleton, cell shape and Motility.
- **Cell cycles:** Mitosis and meiosis, regulation, cellular excitability, cellular motility, Cellular secretion, cellular immunity, cellular ageing and cell death, cellular respiration, Cell permeability and endocytosis. Nucleo-cytoplasmic interactions, role of cell surface And microtubules.
- **Diversity of Life:** Prokaryotic and Eukaryotic Cells, Introduction to micro-organisms like Viruses, bacteria and protozoa, algae & fungi, their metabolism and genetic Recombination.
- **Plants:** Plant diversification, Brief account of anatomical, embryological and Morphological aspects. Life cycle of representative genera.

- **Animals:** Diversification in animal kingdom, anatomical and embryological aspects, Life cycle of representative genera, types of cells and their organization and function in Tissues-muscle, epithelial, neuronal, skeletal, bone, adipose and blood, Organs and their Functions – liver, kidney, heart, lung, brain, pancreas etc.
- **Concepts of Genetics:** Mendel's Laws of Inheritance, Chromosome Theory of Inheritance, Gene Expression, Concepts of Linkage and Crossing Over, Gene Mapping, Organellar Genome, Sex-linked Inheritance, Determination of Sex, Chromosome Structure & Organization, Chromosomal Aberrations.

2. Introductory Physics & Chemistry

- **Mechanics:** Motion, Flow and forces, acceleration, law of motion, gravitation, projectile Motion, circular motion, rotational dynamics, friction, fluid statics and dynamics.
- **Heat & Thermodynamics:** Concept of temperature, laws of thermodynamics, enthalpy And thermos chemistry: exothermic and endothermic reactions, free energy, entropy, Gibb's equation, kinetic theory of gases, elements of statistical physics: canonical and Grand canonical ensembles, partition function, Maxwell-Boltzmann distribution of kinetic Energy of molecules and related applications, chemical kinetics: rate and order of Reactions, theory of kinetics.
- **Electricity & Magnetism:** Charge and matter in the electric field, electric potential, Gauss's law, capacitors and dielectrics, current, resistance and conductance, Electromotive force and circuits, ohm's law, magnetic field, Ampere's law, Faraday's Law, inductance, magnetic properties of matter, electromagnetic oscillations, Electromagnetic waves.
- **Optics:** Nature and propagation of light, reflection, refraction, interference, diffraction, Polarization, quantum theory of light.
- **Atomic & Molecular Physics:** Electronic structure of atoms and molecules, quantum Mechanical principles, de Broglie's concept, Heisenberg's principles, Schrödinger's Equation, particle in a box problem, quantization of angular and spin momenta, solution For hydrogenic atoms, electronic conduction, semiconductors, p-n junctions, solid state Devices.
- **Nature of Chemical Bonding:** Atomic orbitals, electronic configuration of atoms, Concept & theories of valency: Valency Bond theory, hybridization of atomic orbitals,

Molecular Orbital Theory, Bond order.

- **Electrochemistry:** Electrolytic cells, Arrhenius theory of ionic conduction, electrolysis, Ion atmosphere, ionic diffusion, electro chemicals, Donnan equilibrium, Nernst equation. Organic Chemistry: Aliphatic, aromatic, heterocyclic compounds, isomeric compounds, Addition reactions, electrophilic & nucleophilic substitutions and their mechanisms, Stereochemistry, optical isomers, biologically relevant organic molecules.

3. Mathematics and Statistics for Life Sciences

- **Refreshing Basic Mathematics:** Algebra, e.g. equations, matrices, determinants, number Systems, series summations, etc., Geometry, Co-ordinate Geometry, e.g. straight lines, Circles, conic section, etc, Calculus, e.g. functions, limits, derivatives etc., Taylor and McLaurin series expansion.
- **Vectors:** Vector algebra and vector calculus; dot & cross products; concept of gradient, Divergence, curl and Laplacian operators.
- **Linear Algebra:** Vector space, linear independence, basis and dimension, linear Transformations, inner product, orthogonality, Fourier series and transform.
- **Application of Derivatives and Dynamical System:** Stability and derivatives, the Logistic dynamical system, optimization, approximating functions, Newton's method.
- **Differential Equations, Integrals & Applications:** Linear differential equations and Autonomous differential equations, methods of solutions and applications.
- **Introduction of Dynamical Systems**: Biology and Dynamics, basic examples, function Describing growth and finding solutions, expressing solutions of population growth, Power-law functions, modeling & graphical analysis of functions, linear & non-linear Systems.
- **Probability Theory & Descriptive Statistics:** Introduction to Probabilistic Models, Stochastic Models of Diffusion and other Biological Applications, Markov chains with Biological Applications.
- **Probability Models:** Applications of the Binomial and Poisson distribution, Applying The Normal Distribution to Biology, Monte-Carlo Methods.
- **Statistical Reasoning:** Estimating Parameters, Confidence Limits, Estimating the Mean, Hypothesis testing, Comparing Experiments.
- **Discrete Mathematics:** Fast Fourier Transformation & Applications, Graphs &

Networking with Biological Applications.

4. Concepts of Biochemistry

- **Introduction:** Composition of living matter, comparison of bacterial animal and plant Cells, concepts of acids, bases, pH and buffers, Water & its role in life.
- **Function of biological macromolecules:** Concept of proteins structure and function, Nucleic Acids as genetic information carriers, metabolic activities and functions of Carbohydrates and Lipids, Enzyme as bio-catalysts (classification, specificity, Activity units, isozymes), Enzyme Kinetics (Michaelis-Menten equation determination of Kinetic parameters), multistep reaction and rate limiting steps, enzyme inhibitions, Principles of allosterism.
- **Cell Metabolism:** Catabolic principles and break down of carbohydrates, lipids and Proteins (schematics). Biosynthesis of macromolecules (schematics), Hormonal Regulation of metabolism, vitamins and their role as co-enzymes.
- **Metabolic Pathways:** Glucose and glycogen metabolism, Citric acid cycle, Photosynthesis, lipid metabolic pathways, amino acid metabolism, nucleotide metabolism
- **Immune system:** Basic principles; Different types of immunoglobulins and antigens. Antigen-antibody interactions; complements, mechanism of generation of diverse Antibodies in the same host, synthesis of antibodies; major disorders of the immune System, auto-immune diseases.

5. Molecular Biology

- **The nature of Genetic material:** The structure of DNA and RNA; melting of DNA, Super-helicity, organization of microbial genomes, organization of eukaryotic genomes, Chromatin arrangement, nucleosome formation.
- **DNA replication:** Arrangement of replicons in a genome, various modes of replication, Continuous, discontinuous synthesis, various replication enzymes, replication fork and Priming, leading and lagging strand, elongation, termination, specific features of Replication in prokaryotes and eukaryotes, action of topoisomerases, telomere Maintenance and chromatin assembly, single stranded DNA replication, relationship Between DNA replication and cell cycle, and DNA copy number maintenance.
- **Recombination and Repair of DNA:** DNA repair and recombination, DNA mismatch

Repair, Double Strand Break repair, recombination as a molecular biology tool, CRISPRCas systems for editing, regulating and targeting genomes.

- **Transcription:** Transcription machinery of prokaryotes, various transcription enzymes And cofactors, initiation, elongation and termination, sigma factors, transcription Machinery of eukaryotes, various forms of RNA polymerase and cofactors, initiation, Elongation and termination, promoters, enhancers, silencers, activators, effect of Chromatin structure, regulation of transcription.
- **Post-transcriptional processes:** RNA processing, splicing, capping and polyadenylation, rRNA and tRNA processing, RNA Editing; RNAi and miRNAs, Antisense RNA, Posttranscriptional gene regulation.
- **Translation:** The genetic code and protein structure, Mechanisms of translation in Prokaryotes, Mechanisms of translation in eukaryotes, initiation complex, ribosomes and tRNA, factors, elongation and termination, in-vitro translation systems, polycistronic/ Monocistronic synthesis, Regulation of translation, RNA instability, inhibitors of Translation, stringent response in bacteria.
- **Post-translational processes:** Protein modification, folding, chaperones, transportation. The Signal Hypothesis, protein degradation.

6. Molecular Biophysics

- **Nature of Chemical bonds:** Forces responsible for molecular conformation, e.g. Hydrogen bonds, ionic/electrostatic interactions, van der waals interaction, hydrophobic. Interaction, stereo-chemical factors.
- **Macromolecular Structure**

  Protein Structure: Amino acids, peptide bond, primary, secondary, tertiary and Quaternary structure of proteins, motifs and folds, super-secondary structures.
  Nucleic acid Structure: nucleosides and nucleotides, RNA structure, DNA structure And conformation, polymorphism of DNA, protein-DNA and Drug-DNA interaction
  Other Biological Polymers: polysaccharides, associations formed among different Macromolecular types, protein lipid interactions, nucleoproteins, membrane proteins.
- **Macromolecular Conformation**

  Defining Conformation: Parameters defining conformation of a macromolecular Chain, strategies for calculating the probable conformational status of a macromolecule, Computer simulation of macromolecular conformation, membrane protein conformation.

Supercoiling of bio-macromolecules: Linking, twisting and writhing,

Topoisomerases, relevance of supercoiled DNA in biology.

- **Special Bio-Macromolecules:** Metalloproteins, nucleoproteins, ribozymes, chaperons & Prions.
- **Cooperativity in bio-macromolecular interactions:** the phenomenon of cooperativity, DNA and protein melting, allosteric enzymes, other examples of cooperativity in biology.
- **Non-equilibrium Thermodynamics in Biology:** Information and Entropy, Nonequilibrium Processes, Coupling of Fluxes, Coupling of Chemical Reactions, far-from Equilibrium Molecular processes.
- **Physical Methods in Biology**
- **Spectroscopy**

  UV & Visible absorption spectrophotometry: Lambert Beer's Law, molar extinction Coefficient and its determination, instrumentation & applications

  Fluorescence Spectroscopy: principles and applications, Polarization of light, Fluorescence studies of plane-polarized light.

  Other common spectroscopic techniques: Principles, use and interpretation of Optical Rotatory Dispersion (ORD), Circular Dichroism (CD).
- **Macromolecular Structure Determination**

  Introduction to X-ray Crystallography: basis of crystallography theory, symmetry, Instrumentation and biological applications, macromolecular diffraction and methods of Phase determination.

  Principles of magnetic resonance spectroscopy: Nuclear Magnetic Resonance (NMR) & Electron Spin Resonance (ESR) and biological applications, Relaxation Studies.
- **Hydrodynamic Methods:** Viscosity, Sedimentation equilibrium and Velocity Centrifugation, Density Gradient method, applications to bio-macromolecules and biomaterials.
- **Chromatography:** Partition and Adsorption Chromatography, paper and thin layer Chromatography, gel filtration, ion-exchange and affinity chromatography. GLC, HPLC And FPLC. Emerging trends in chromatography.
- **Electrophoresis:** Behaviour of bio-macromolecules in electric fields, Types of Electrophoresis, PAGE, Agarose Gel Electrophoresis, 2D Electrophoresis, Dialectrophoresis.

- **Radioactive methods:** Radioactive isotopes, nature of radioactive decay, sample Preparation and counting, G.M. and Scintillation counters, Precautions in radio isotope Handling, Autoradiography and its biological applications.
- **Microscopy:** Optical Microscope, Fluorescent Microscope, Confocal Microscope, Electron Microscope, Applications of each microscopic method.
- **Emerging topics in Biophysical methods**

7. Recombinant DNA Technology Methods of DNA, RNA and protein analysis:

- **Electrophoretic techniques** – agarose and polyacrylamide gel electrophoresis, native-, SDS-, and 2-D PAGE; Blotting techniques - Southern, northern, and western blots; Preparation of probes; RFLP analysis, DNA fingerprinting and its application
- **Gene cloning and identification**
- **Basics of cloning:** Restriction and DNA modifying enzymes; Isolation and purification of Nucleic acids; cloning methods; cloning vectors – plasmids, phages, lambda vectors, phagemids, Cosmides, fosmids, PAC, BAC and YAC; Selection and screening of clones
- **Construction of DNA libraries**

  Genomic and cDNA libraries; Screening of genomic and expression libraries

  Gene identification

  Subtractive hybridization, chromosome walking and jumping.

  Genome sequencing

  DNA sequencing by Maxam and Gilbert method, Sanger's method, whole genome Shotgun sequencing, next generation sequencing; Genome annotation: an overview
- **Expression Analysis**

  Analysis of gene expression- Northern blotting, RT-PCR, EST analysis, Promoter Analysis; Mapping transcriptional start sites, Transcriptome analysis – cDNA- and oligo Arrays; Serial Analysis of Gene Expression (SAGE); Polymerase Chain Reaction (PCR)- Concept of PCR, various kinds of PCR, Real Time PCR, Ligation Chain Reaction;
- **Applications of PCR**

  Protein expression, engineering and interactions

  Expression of recombinant proteins- Expression and tagging of recombinant proteins in E. coli, other expression systems; Protein engineering- Insertion and deletion Mutagenesis, site-directed mutagenesis; Proteome analysis - MALDI, protein arrays and

Their applications; Analysis of protein-DNA and Protein-protein interactions- Gel Retardation assay, DNA foot printing, Yeast one- two- and three-hybrids assay; ChIP on Chip assay; Split and reverse hybrids, Co-immuno precipitations; Phage display

- **Applications of recombinant DNA technology in biology and medicine**
- **Gene editing technologies.**

8. Photo-Biophysics, Radiation & Environmental Biophysics

- **Photochemistry:** Interaction of photons with chemical compounds, photosensit Chemicals, photo induced electronic transitions in organic molecules, quantum yield, Photo induced chemical reactions in air (troposphere, stratosphere, other spheres, Examples, reaction mechanisms and applications, Chemi-luminescence.
- **Photosynthesis:** The phenomenon and types, Chlorophyll molecules, Chloroplasts, Photochemical Systems, Electron Transport Processes, Vision, Molecular Mechanism of Photoreception, Bioluminescence, Bacteriorodopsin.
- **Radiation in Environment:**

  Ionizing & Non-Ionizing Radiations and their origins; Dose Measurement;
  Nuclear Radiation: Nuclear structure & stability, Radio-Isotopes, Radioactive decay Kinetics.
  Electromagnetic Radiations and classification.
- **Radiation Biophysics:**

  X-Ray: Effects on Bio-macromolecules.
- **Gamma Radiation:** Molecular Effects of Gamma Radiation, Radiation Chemistry of Water, Free Radicals, Effects on Biomolecules & Molecular Structures: Radiation Effects On Proteins, Radiation Effects on Nucleic Acids, Radiation Effects on Membranes. Effects on Cells and Organalles.
- **Ultraviolet Radiation:** Effects on Bio-macromolecules & Molecular Structures, UV Radiation Effects on Proteins, Nucleic Acids, Cells and Organelles.
  Alpha & Beta Radiations: Effects on Cells and Organalles, human body.
  Radiation Hazards & Protection: Radiation Effects and Genetics, Methods to Combat ionizing, non-ionizing and particle radiations, use of radiations in cancer & other Diseases.
- **Environmental Biophysics:** Introduction to Ecosystem: Physical Environment,

Geological Environment and Biosphere.

- **Ecosystem Analysis:** Population Dynamics, Prey-Predator Models
- **Environmental Stress:** Depletion of Oxygen Pressure with altitude, Pollutants and Ozone layer depletion, Toxicity and its effect on Bio-macromolecular Structure and Function, Physiological effects of environmental stress.

9. Programming and Data Analytics

- **Basics of Programming:** Introduction to Perl/C/Python, Flowcharting, Decision table, Algorithms, Structured programming concepts, Concept of data-structure, if-else loops And decision, Use and definition of sub-routines.
- **Introduction to R Language and Environment of Statistical Computing and**
- **Graphics:** Introduction to R, Getting Started - R Console, Data types and Structures, Exploring and Visualizing Data, Programming Structures, Functions, and Data Relationships.
- **Introduction to R-studio:** R-studio screen, Workspace tab, History tab, Defining and Setting Working directory, making script in R-studio, Installing and saving packages, Plotting different type of graphs.
- **Probability Distribution:** Random Variables and Probability Distributions, Inferential Statistics –Motivation and Single sample tests.
- **Machine Learning:** Introduction to Machine Learning, Supervised Learning, Unsupervised Learning, Ordinary Least Squares Regression, Model Assessment and Selection, Support Vector Machines, Artificial Neural Networks, Ensemble Methods and Random Forests, Deep Learning, Association Rule Mining, Clustering Analysis of Data And Big Data, Association Rule Mining, Big Data, Clustering Analysis.

10. Cellular Biophysics and Bioenergetics

- **The Dynamic Cell:** Architecture and Life Cycle of Cells; Cells into Tissues
- **Cell Organization:** Microscopy and Cell Architecture, Organelles of the Eukaryotic Cell.
- **Regulation of Eukaryotic Cell Cycle:** Overview of the Cell Cycle and its Control, Biophysical Principles of Molecular Mechanisms for Regulating Mitotic Events, CellCycle Control in Mammalian Cells, Checkpoints in Cell-Cycle Regulation.
- **Biophysics of Cell Signalling:** Strategies of chemical signalling, signalling mediated by

Intracellular receptors, Extracellular signalling, Cell-Surface Receptors, G Protein–Coupled Receptors and Their Effectors, Phosphoinositol cycle, Role of Kinases, e.g. MAP Kinase Pathways, Second Messengers, Ca oscillations, Interaction and Regulation Of Signalling Pathways, Molecular Mechanisms of Vesicular Traffic, From Plasma Membrane to Nucleus, bacterial and plant two-component signalling systems, Bacterial Chemotaxis & Modeling.

- **Biophysics of Excitable Cells:** Electrical Activities of Cardiac and Neuronal cells, Glial Cells.
- **Cell Differentiation and Developmental Biophysics:** Cellular differentiation; Localization of cytoplasmic determinants in egg; Molecular mechanism of cell Differentiation: Role of morphogens, protein kinase C, cytoskeleton, extracellular matrix, Etc.
- **Biophysics of Apoptosis:** Relevance of Programmed Cell Death, Necrosis & Apoptosis, Mechanisms of Apoptosis, Role of beta Amyloid, Caspases and Mitochondrial proteins.
- **Cancer:** Tumor Cells and the Onset of Cancer, Proto-Oncogenes and Tumor-Suppressor Genes, Oncogenic Mutations Affecting Cell Proliferation, Mutations Causing Loss of Cell-Cycle Control, Mutations Affecting Genome Stability.
- **Energy production in the cell:** oxidation-reduction reactions, coupled reactions and Group transfer.

11. Computer Applications in Biology

- **Biological Databases:** Introduction; Types of databases in terms of biological Information content; Protein and gene information resources; Specialized genomic Resources; Different formats of molecular biology data.
- **Sequence Alignment:** Global and local alignment; Methods and algorithms of pairwise And multiple sequence alignment; Alignment scoring matrices; Database similarity. Searching; Different approaches of motif detection; Concept and use of protein families.
- **Molecular Phylogenetics:** Concept of orthology, paralogy and homology in gene and Protein sequences. Methods and tools for phylogenetic analysis; Creation, evaluation and
- **Interpretation of evolutionary trees:** Advantages and disadvantages of phenetic and cladistic approaches.
- **Genomics and Gene Annotation:** Organization and structure of prokaryotic and

Eukaryotic genomes; Genome annotation and databases; Automated in-silico methods of Finding gene and relevant features.

- **Protein Structure Databases and Visualization:** Understanding structures from Protein Data Bank (PDB); Accessing and mining other protein structure classification databases Such as SCOP, CATH; Tools for viewing and interpreting macromolecular structures e.g. Deep View, PyMol.
- **Protein Structure Prediction and Comparison:** Ab-initio and homology based Methods, Algorithms, and programs for superimposition of protein structures; RMSD Calculations, multiple structure alignment; Flexible structural alignment; Concept and Methods of homology modeling, threading and fold recognition; Concept and available Methods for ab-initio protein structure prediction.
- **Inferring Function from Protein Structure:** Using evolutionary information; Gene Neighbourhood; Phylogenetic profiles; Gene fusion; Catalytic templates; Prediction and Analysis of binding cavities for function prediction. How new fold and functions evolve convergent and divergent evolution.
- **Bioenergetics:** Gibb's Free Energy, Gibb's Law of Chemical Reactions; Entropy and Enthalpy driven reactions, Biological Oxidation: Aerobic Oxidation and Photosynthesis, Oxidation of Glucose and Fatty Acids to CO2; Structure and Properties of Mitochondria, Cytochrome c, Chemiosmotic Coupling, Electron Transport and Oxidative Phosphorylation, Photosynthetic Stages and Light-Absorbing Pigments, Molecular Analysis of Photosystems.

12. Physiological Biophysics

- **Digestion and Nutrition:** Composition, function and regulation of salivary, gastric, Pancreatic, bile and intestinal juices.
- **Biophysics of the circulatory system:** Composition and function of blood and lymph. Blood pressure, capillary pressure, regulation of blood pressure, role of ionic balance. Blood groups and Rh factors, blood coagulation, structure and function of haemoglobin. Sickle-cell anaemia, thalassemia and other disorders; Biophysical perspective of the above.
- **Biophysics of Muscle Function:** Ultra-structural, chemical and physiological basis of Skeletal muscle contraction; Molecular mechanisms in muscle contraction.
- **Biophysics of Heart:** Structure, origin, conduction and regulation of heartbeat; Cardiac

Cycle; Electrocardiogram; Disorders of the heart; Atherosclerosis, arrhythmias.

- **Biophysics of Respiration:** Mechanisms and control of breathing; Transport of oxygen And carbon-di-oxide; Oxygen dissociation curves of haemoglobin and myoglobin, Bohr Effect; Chloride shift; Human respiratory disorders.
- **Structure and Function of the kidney:** Physiology of urine formation; Role of kidney in The regulation of water, salt and acid-base balance, renal disorders, remedies; Biophysical Perspective of the above.
- **Integration and Control:** The endocrine system, hormones and other signaling Molecules, hypothalamus, pituitary, parathyroid, adrenal, pancreas and gonads; other Endocrine elements (pancreatic islets etc.); Local chemical mediators, prostaglandins; Consequences of endocrine malfunction; Biophysical perspective of the above.

13. Methods in High-throughput Biology

- **Proteomics:** Application of mass spectroscopy for protein quantification and Identification; Finding post-translational events using proteomic tools, Structural and Functional implications of post-translation modifications, Current developments and Recent progress.
- **Structural Genomics:** Aims and need, High throughput methods of structure Determination: Inferring function from structure, Methods to detect positive selection in a Gene and implications of functional divergence, Current developments.
- **Macromolecular Interactions:** Prediction, analysis and comparison of different modes And types of macro-molecular interactions, Current developments.
- **High-throughput Drug Screening:** Different methods of drug discovery; Different Methods of target identification and validation; Quantitative structure-activity relationship And objectives and concept of QSAR; Ways of lead identification and optimization; insilico prediction of ADMET properties for drug molecules; Current developments.
- **High Throughput Genomic Sequencing:** Different methods of sequencing; Different File formats; Concepts of Metagenomics; Gene regulation and the ENCODE project. Need and use of personal genomics projects, Current developments.
- **Metabolomics:** Introduction of different tools for metabolic profiling; Different tools Used for metabolic data and database analysis e.g. KEGG, Bio Cyc, Met Explore and Cytoscape; Current developments.

- **Large Scale Gene Expression Analysis (Microarray, Transcriptomics):** Data Pre-processing and normalization, Significance testing and Gene filtering, Cluster Analysis and down-stream enrichment analysis, Identification of differential gene Expression, Gene annotation and gene ontology analysis, Current developments.
- **Genome-wide Association Studies (GWAS):** Introduction and need of GWAS; Study Design at marker, gender and subject levels; various technologies for data generation, Progress and promises of GWAS; Current developments.

14. Developmental Biology

- **History and basic concepts** of developmental processes, mechanisms of specifying. Cell fate, role of development in evolutionary change.
- **Early events** of fertilization, implantation, generation of multicellular embryo, Formation of germ layers, patterning of vertebrate body plan. Morphogenesis: Cell Adhesion, cleavage and formation of blastula, gastrulation, neural tube formation and cell Migration.
- **Molecular events of embryogenesis:** Nieuwkoop center, Spemann-Magold Organizer theory and mesodermal induction. Role of cell-cell communication in Development; Concepts of induction and competence; Epithelial-mesenchymal Interactions and developmental signals from extracellular matrix. Brief discussion on role Of various signalling pathways during development.
- **Model systems**

  A.C.elegans: Study of cell lineage, cell fate determination, regulation of blastomere identity, anterior-posterior axis formation and organogenesis (Vulva formation).

  B. Drosophila: Polarily determination of embryo by maternal genes, pattern Formation, formation of body segments, homeotic genes and their significance.

  C. Zebrafish: Developmental stages, somite formation, mechanisms of pigment Patterning in fish skin.

  D. Mouse: Vertebrate development, determining function of genes during development by generation of knockout and knock-in models.

  E. Arabidopsis: Development and morphogenesis of plants, role of

Phytohormones, embryogenesis, flowering, shoot and root development.

- **Role of stem cells in development:** Definition, types and properties of stem cells, Adult stem cells and embryonic stem cells, cancer stem cells, stem cell markers, Applications of stem cells, advancement in research and associated ethical issues.
- **Medical implications of developmental biology:** Developmental disorders, invitro fertilization, design of future medicines like gene therapy, therapeutic cloning and regeneration therapy.

15. Membrane Biophysics and Neuro-Biophysics

Electrical behaviour of the biological membrane: Model membranes; Biological Membranes and Dynamics; Membrane Capacitance; Transport across cell and organelle Membranes; Ion Channels; Experimental methods to study Ion Channels.

- **Nervous System:** Introduction to Nervous system; Neurons; Glial cells; Sensory Receptors and perception; Chemical and Electrical synapses.
- **Synaptic Transmission:** Physicochemical principles; Resting potential; Action Potential; Membrane theory of action potential; Hodgkin Huxley's (HH) model; Mathematical Solutions of H-H equations.
- **Models of Neurons & Action Potential:** Artificial neurons; FHN and other models; Physiological neuronal network versus artificial neural network.
- **Neural Basis of Cognition and Behaviour:** Principles of learning & memory; Cellular Mechanism of learning & memory and comparison with machine learning; Animal Behaviour.
- **Intrinsic or Non-Synaptic Plasticity:** The phenomenon and its importance; the role of Various Ion Channels.
- **Computability:** Origin of the concept of computability; Turing machines; Logic circuits; Principles of functioning of a computer. Discussion on the interface of artificial neural net and the brain.

16. Theoretical and Mathematical Biology

Non-Linear Systems Analysis: Definition of Non-linearity, Non-linear differential Equations, examples, critical points, Stability & Liyapunov's Theorem, Near Equilibrium Solutions, Behaviour in the Phase plane, feed Back Process and Oscillations, B-Z Equations, Lotka Volterra and other Models with examples.

- **Information Theory and its Application in Biology:** Basic concept of information and The related theorems, information theory and protein structure, coding of genetic Information, information and sensory perception.
- **Statistical Mechanics and its application in Biology:** Basic Foundation, Canonical & Grand Canonical Ensembles, Biomolecular System as an analogue of many body system. Quantitative analysis of a co-operative process.Ising Model and DNA melting, drug-DNA Interaction and other cooperative process, Lipid phase Transitions, Collective Process in Cell Membranes and application of statistical Mechanics.
- **Stochastic Processes in Biology:** Examples of Stochastic Behaviour, Stochastic Models, Markovian Processes in Biology, Stochastic Resonance.
- **Time Series Analysis:** The Background and Necessity, Correlation Coefficient, Fourier Analysis, Wavelet Analysis, Application in the analysis of Electrophysiological Recordings e.g. EEG, ECG, Fractals and Evolution of a System, Examples from Biological Systems, Difficulties and Limitation of Analysis.
- **Prebiotic Evolution:** Theories and Models, Eigen's Hypercycle, Kimura's idea, Non Linearity and Biological Evolution.
- **Networks:** Neural Network, Artificial Neural Networks, Metabolic Networks, Brain as a Complex network, Theories and Analytical Methods, Cellular Automata and its Application in microbial and lower Organismic Population.
- **Elements of Topology:** Elementary Concepts and Theorems, Topology of DNA, Supercoiling, Knots, Twists etc, Catastrophe Theory and Applications to Morphogenesis.