



United Nations  
Educational, Scientific and  
Cultural Organization



- क्षेत्रीय जैव प्रौद्योगिकी केन्द्र
- Regional Centre
- for Biotechnology

# **PhD (integrated) Program**

# **MSc-PhD**

# **Biotechnology**

## **COURSE CURRICULUM**

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All courses listed above are compulsory for the PhD (integrated) program.

**RCB 201**  
**INTRODUCTORY BIOLOGY**  
**Non-credit course**

*The course is designed for students from branches of science such as physics, chemistry, mathematics and engineering who have not studied biology after high school. The course will provide a primer in biology for these students.*

**COURSE CONTENT**

**Classification in Biology**

Distinction between living and non-living; Viruses, bacteria, protists, fungi; Taxonomy of Plants & Animals.

**Biological systems**

Tissue and organ systems in animals and plants; Ecology; Populations and communities; Biosphere; Conservation.

**Heredity & Evolution**

Reproduction and Heredity; Cell division: mitosis, meiosis, gamete formation, pollination; Mendelian genetics; Evolution; Variation; Darwin's theory of evolution.

**Biological Molecules**

Introduction to Bio-macromolecules; Carbon chemistry; Proteins: Structure, folding, catalysis; Nucleic acids: storage and transfer of genetic information; Lipids: membranes, energy storage; Carbohydrates: energy storage, building blocks.

**Molecular Genetics**

Genes; Basics of DNA replication, transcription, translation, Genome organization; Mutations; Gene technology.

**Cell biology**

Cell structure; Membranes; Function of cell organelles.

**Bioenergetics**

Energetics; ATP and glycolysis; Respiration; Photosynthesis.

**SUGGESTED READING**

1. Purves WK, Sadava DE, Orians GO, Heller HC. Life: The Science of Biology, 7th Edition, W. H. Freeman and Co.
2. Raven PH, Johnson GB. Biology, 6th Edition, McGraw Hill.
3. Campbell NA, Reece JB. Biology: Concepts and connections. Pearson Education Ltd.

**RCB 301**  
**BIOCHEMISTRY**  
**3 credit course**

*This course is designed to provide students a comprehensive understanding of basic building blocks of life. An overview on synthesis and metabolism of key biomolecules with special emphasis on associated energy transductions and maintenance of cellular homeostasis will be covered.*

**COURSE CONTENT**

**Basic Chemistry and Water**

Basic chemistry, Elements, Functional groups, pH, Mole concept, Bonding and chirality, Non-covalent interactions, Water, interactions in aqueous systems, Ionization state of biomolecules, Water as reactant, Laws of thermodynamics, Gibbs free energy, Statistical thermodynamics, and maintenance of equilibrium.

**Amino acids and Proteins**

Amino acids – structure and functional group properties; pH and properties of amino acids, Peptides and covalent structure of proteins; peptide bond, polypeptide, protein structure-secondary, tertiary and quaternary, protein structure & function, protein folding and chaperones, Protein-Ligand interactions and function, Post-translational modification of proteins.

**Enzymes**

Fundamentals of enzyme biochemistry including nomenclature, Mechanism of action, Enzyme kinetics and mode of inhibition, Enzyme catalysis – general principles of catalysis, Quantitation of enzyme activity and efficiency, Enzyme characterization and Michaelis-Menten kinetics, Relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification.

**Carbohydrates, Lipids and Nucleic Acids**

Carbohydrates: Monosaccharides and Disaccharides, Polysaccharides, Glycoconjugates, Sugar Code; Nucleic Acids: Nucleotides, Nucleic Acid composition, Nucleic Acid structure, Nucleic Acid chemistry, ATP, Nucleotides as regulators; Lipids: Storage lipids, Structural lipids in membranes, Lipoproteins, Lipids as signals, cofactors and pigments.

**Biological Membranes**

Composition and architecture, Membrane dynamics, Anchoring of proteins in membranes, Hydropathy index, Solute Transport across membranes, Rafts and nanocluster, Membrane vesicles.

**Bioenergetics and Metabolism**

Principles of bioenergetics, Glycolysis, Citric acid cycle, Oxidative phosphorylation, Photosynthesis, Biosynthesis of amino acids, lipids, nucleotides.

**SUGGESTED READING**

1. Nelson D and Cox M. Lehninger Principles of Biochemistry, 5th Edition. Macmillan.
2. Voet D and Voet J. Biochemistry, 4<sup>th</sup> Edition. John Wiley & Sons.

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3. Brändén C and Tooze J. Introduction to Protein Structure, Taylor & Francis.
  4. Bowden AC. Principles of Enzyme Kinetics, Butterworths & Co Ltd.
  5. Haynie D. Biological Thermodynamics, 2<sup>nd</sup> Edition, Cambridge University Press.

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**RCB 302**  
**CELL AND DEVELOPMENTAL BIOLOGY**  
**3 credit course**

*This course is designed to introduce the basic concepts of eukaryotic cell biology to students. The topics covered include the organization of a typical eukaryotic cell, its compartments and its cytoskeleton, cell division and specialized cell types, the communication between cells and the development of single cells into multicellular organisms.*

### COURSE CONTENT

#### **Introduction to Cell Biology**

Fundamental aspects of cell biology, Understanding the basic cell, visualizing cells, Evolution of the cell, Internal organization of the cell membrane structure, Intracellular traffic, Protein sorting, Compartmental diversity, Endocytosis, Exocytosis, Secretory pathway, Mechanisms that maintain compartmental identity and crosstalk.

#### **Cytoskeleton, molecular motors and dynamics**

Basic elements of the cytoskeleton of a cell, Mechanisms of assembly, Dynamic structure and regulation of actin and microtubules, Cytoskeleton-based molecular motors and their varieties, Intracellular transport of cargo and its regulation.

#### **Cell cycle and regulation**

The cell cycle and its control system, Interphase, Mitosis, Cytokinesis and molecular regulation, cell transformation, cell death and apoptosis.

#### **Intercellular communication**

Transport mechanisms across membrane, Cell signaling, Cell junctions, Cell adhesion and the extracellular matrix, Specialized cells, tissues, stem cells and tissue renewal.

#### **Development of multicellular organisms**

The basic principles of the development of multicellular organisms, Early development, Metamorphosis and hormonal regulation, Sexual reproduction including meiosis, Germ cells and fertilization, Classical examples of organogenesis, Concept of tissue homeostasis and aging.

### SUGGESTED READING

1. Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts R, Walter P. Molecular Biology of the Cell, 6<sup>th</sup> Edition, Garland Science.
2. Lodish H, Berk A, Kaiser C, Krieger M, Scott M, Bretscher A, Ploegh H. Molecular Cell Biology, 6<sup>th</sup> Edition. WH Freeman.
3. Gilbert SF, Barresi M. Developmental Biology, 11<sup>th</sup> Edition. Sinauer.

4. Wolpert L, Tickle C, Arias AM. Principles of Development, 5<sup>th</sup> Edition. Oxford University Press.
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**RCB 303**  
**MOLECULAR BIOLOGY & GENETIC ENGINEERING**  
**3 credit course**

*This course is designed to give students knowledge of molecular processes associated with DNA and RNA. The course will also discuss genetic engineering tools and their application in modern biology.*

### COURSE CONTENT

#### **Genome, DNA Replication, Repair & Recombination**

Genome: Composition and Structure of DNA, Gene, Introns & Exons, Supercoiling, Epigenetic modification; Genome Replication: Initiation, elongation and termination in prokaryotes and eukaryotes, Enzymes and accessory proteins, Replication of single stranded circular DNA; Recombination: Homologous and non-homologous recombination, Site-specific recombination; Genetic Alterations and Mutation: Types and causes, Transposition in prokaryotes and eukaryotes; DNA repair: Direct reversal, DNA mismatch repair, Base excision repair, Nucleotide excision repair, Recombination repair, DNA damage tolerance.

#### **Transcription and Post-transcriptional processing**

Prokaryotic Transcription: Transcription unit, Promoters - Constitutive and Inducible, Operators, Regulatory elements, Initiation, Attenuation, Termination, Anti-termination; Transcriptional regulation: Positive and negative, Operon concept; Eukaryotic transcription: RNA polymerase structure and assembly, RNA polymerases, Eukaryotic promoters and enhancers, Transcription factors, Role of Nucleosomes, Epigenetic regulation; Processing of RNA: Transcript processing, Processing of tRNA and rRNA, Splicing and role of introns and exons, RNA editing, mRNA stability, Transcriptional and post-transcriptional gene silencing.

#### **Translation**

Translation: Mechanism of initiation, Elongation and termination, Regulatory factors, Genetic Code, Differences and similarities in eukaryotic and prokaryotic translational process and machinery, Translational regulation of gene expression.

#### **Genetic Engineering**

Isolation and quantification of nucleic acids, Gel electrophoresis, Restriction digestion, Hybridization; Polymerase chain reaction: discovery, primer design, different kinds of PCR, cDNA synthesis; Chemical Synthesis of DNA: oligonucleotide synthesis, phosphoramidites, whole gene synthesis; Molecular Cloning: Different steps in cloning of genes from prokaryotes and eukaryotes; Different types of vectors for gene cloning and expression, Expression of foreign proteins in various expression systems; Genetic Transformation: Gene knock outs, knock ins, Agrobacterium, TALEN and CRISPR technology.

## SUGGESTED READING

1. Watson JD, Baker TA, Bell SP, Gann AAF. Molecular Biology of the Gene, 6th Edition, Benjamin Cummings Publishing Company Inc.
  2. Lewin B. Gene IX, 9th Edition, Jones and Barlett Publishers.
  3. Alberts B, Bray D, Watson J, Lewis J, Raff M. Molecular Biology of the Cell, Garland Science.
  4. Primrose SB, Tyman RM, Old RW. Principles of Gene Manipulation, 6th Edition, Blackwell Publishing.
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**RCB 304**  
**MICROBIOLOGY**  
**3 credit course**

*This course is designed to cover fundamental aspects of the microbial world with special emphasis on how microbes live, divide and cause diseases. The course will also cover the vast diversity of microbes and how they maintain their genomes. Theoretical teachings on tools and assays of microbiology will also be a part of the course. Pathogenic microbes and their mode of disease pathogenesis will be taught. The emerging area of the human commensal microbiota will be discussed with special emphasis on their role in health and disease.*

## COURSE CONTENT

### **Microbes and their taxonomy**

Introduction to microbes and the microbial cell, General organization of a cell, Prokaryotes, Eukaryotes and Archaea. Gram staining and microbial typing, Cell wall organization of various microbes, Microbial cell surface appendages, locomotion by flagella, chemotactic movement, peptidoglycan synthesis-inhibitors in different steps, Changing concepts in microbial classification, molecular taxonomy, Growth and nutrition, Growth kinetics, Batch and continuous cultures, Microbes in extreme environment, extremophiles, thermophiles and their applications, Viruses, bacteriophages and their applications.

### **Microbial Metabolism**

Metabolic pathways of microbes, metabolic versatility, aerobic and anaerobic carbon metabolism, fermentation, glycolysis, ED pathway, Pentose phosphate pathway, TCA cycle and ETC; Photophosphorylation; nitrogen metabolism, symbiotic microbes, assimilatory nitrate reduction, ammonia assimilation and synthesis of amino acids, nitrogen fixation and its regulation; sulphate-metabolism; putrefaction, methane oxidizing and methanogenic bacteria.

### **Microbial Genetics**

Pasteur experiment and Griffith's experiment, Modes of genetic exchange in microbes, transformation, transduction, conjugation and evolutionary significance.

### **Microbes and Health**

Pathogenic bacteria and viruses, Bacterial and viral infections, Molecular biology of pathogen-host crosstalk, Human microbiota and their role in human health, Chronic microbial

infections and their long-term consequences, Drug-resistant bacteria, biofilms, antibiotics and antimicrobial agents, Protozoan parasites and human diseases.

### **Tools and Techniques in Microbiology**

High-throughput screening assays, drug screening, molecular barcoding methods, PCR and next-generation sequencing based techniques in microbiology, Microbes in biotechnology, microbes in brewery and biotechnological applications including recombinant DNA methodologies.

### **SUGGESTED READING**

1. Hogg S. Essential Microbiology, John Wiley and Sons.
  2. Schlegel HG. General Microbiology, Cambridge University Press.
  3. Prescott LM, Harley JP, Klein DA. Microbiology, McGraw Hill.
  4. Hurst CJ, Crawford RL, Knudsen GR, McInerney MJ, Stetzenbach LD. Manual of Environmental Microbiology, ASM Press.
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## **RCB 305**

### **BIOCHEMICAL AND ANALYTICAL TECHNIQUES**

**4 credit course**

*The course will involve practical sessions to provide experience in basic biochemical and analytical techniques and help the students to develop rigor and discipline required to do experiments on the bench, and the ability to think analytically.*

### **COURSE CONTENT**

- Practical 1: Preparation of buffers of different pH and assessment of quality of the buffers.
- Practical 2: Estimation of protein concentration by plotting a standard graph of BSA using UV spectrophotometer.
- Practical 3: Estimation of total carbohydrates and free amino acids in cereals.
- Practical 4: Estimation of protein molecular weight using standard markers and SDS-Polyacrylamide Gel Electrophoresis.
- Practical 5: Gel Filtration Chromatography.
- Practical 6: Affinity purification of a recombinant protein and assessment of purity.
- Practical 7: Identification of proteins using immunoblotting.
- Practical 8: Determination of the catalytic efficiency of a standard enzyme.
- Practical 9: Binding assay to quantitate interaction between biological macromolecules.

**RCB 306**  
**METHODS IN GENETIC ENGINEERING**  
**4 credit course**

*The course will involve practical sessions to provide experience in recombinant DNA technology methods and inculcate skills in students to work with genetic material and carry out molecular cloning.*

**COURSE CONTENT**

- Practical 1: Agarose gel electrophoresis of DNA.
  - Practical 2: Isolation of genomic DNA, quantitation, and characterization.
  - Practical 3: Isolation of RNA and assessment of quality.
  - Practical 4: Isolation of Plasmid DNA, assessment of quality, and characterization.
  - Practical 5: Preparation of competent E. coli cells and genetic transformation.
  - Practical 6: Polymerase chain reaction and assessment.
  - Practical 7: Restriction digestion of plasmid DNA and assessment of quality.
  - Practical 8: DNA ligation and transformation.
  - Practical 9: Confirmation of DNA cloning through PCR and restriction digestion.
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**RCB 307**  
**METHODS IN MICROBIOLOGY & CELL BIOLOGY**  
**4 credit course**

*This course provides hands-on experience in various contemporary techniques in microbiology and cell biology including bacterial and mammalian cell culturing, preservation, sterilization techniques, and some basic virology.*

**COURSE CONTENT**

- Practical 1: Media preparation, microbial culture (bacterial and fungal).
- Practical 2: Growth curves, preservation of the bacteria, plating, dilution plating.
- Practical 3: Effect of temperature, pH, salts and other stress factors on bacterial growth.
- Practical 4: Isolation of bacteria from various surroundings.
- Practical 5: Identification of bacteria by biochemical assays and Gram staining.
- Practical 6: Antibiotic or drug inhibition assays.
- Practical 7: Mammalian cell culture, counting, and cryopreservation.
- Practical 8: Staining of various cellular compartments.
- Practical 9: Expression of foreign protein in mammalian cells.
- Practical 10: Mammalian virus culture and titration.

**RCB 308**  
**IMMUNOLOGY & IMMUNOTECHNOLOGY**  
**3 credit course**

*This course will provide information regarding the cells, molecules and processes associated with the immune system. The topics covered include innate immunity, molecules and cells of the adaptive immune system, the adaptive immune response and the role of the immune system in health & diseases. In addition, information regarding methods in immunology and development of vaccines will be provided.*

### **COURSE CONTENT**

#### **Introduction to the immune system & Innate Immunity**

Primary and secondary lymphoid organs; Cells of the immune system; Innate Immunity as first line of host defense, distinction between self and non-self, complement system- classical and alternative, Types of innate immune cells and their functions in immune responses, Molecules of innate cells, Response of the innate immune systems to pathogens.

#### **Molecules & Cells of the Adaptive Immune System**

Antigens: chemical and molecular nature, adjuvants and their functions; Recognition of antigen by B-cell and T-cell Receptors; Generation of lymphocyte antigen receptors (antibodies and TCR), Antigen presentation by Major histocompatibility complex molecules. Antigen receptor structure and signaling pathways; Generation of lymphocytes in bone marrow and thymus, Survival and maturation of lymphocytes in peripheral lymphoid tissues.

#### **Adaptive Immune Response**

T Cell-Mediated Immunity, the production of armed effector T cells, General properties of armed effector T cells, T cell-mediated cytotoxicity; Humoral immune response, B-cell activation by armed helper T cells, Adaptive immunity to infection, Infectious agents and how they cause disease, The course of the adaptive response to infection, The mucosal immune system, Immunological memory.

#### **Immune System in Health and Disease**

Pathogen response to immune system, Immunodeficiency diseases, Allergy and hypersensitivity; Autoimmunity and transplantation; Disorders of immune response: IBD and MS: a case study; Cancer immunology.

#### **Immunotechnology**

Principles of immunization, techniques for analysis of immune response, antibody related techniques; Hybridoma, epitope mapping; Immuno assays: RIA, ELISA, Immunoblotting, ELISPOT, Immunofluorescence and live cell imaging; Flow cytometry, live cell tracking techniques; Vaccine development principles and rationale of vaccine design, different types of vaccines; Immunotherapy: rational, technology development; Development of monoclonal antibodies, applications in diseases including cancer therapy; Gene editing technology in designing antibody and applications; Designing antibody library for immunotherapy.

## SUGGESTED READING

1. Janeway CA, Travers P Jr, Walport M, Shlomchik MJ. Immunobiology, 5th Edition, Garland Science.
  2. Virella G. Medical Immunology, 6th Edition, CRC Press.
  3. Goldsby RA, Kindt TJ, Osborne BA. Kuby Immunology, 3rd Edition, W H Freeman & Co.
  4. Abbas A, Lichtman A, Pillai S. Cellular and Molecular Immunology, 8<sup>th</sup> Edition, Elsevier.
  5. Khan A. Biotechnology in Medical Sciences, CRC Press.
  6. Pongracz J, Keen M. Medical Biotechnology, Churchill Livingstone.
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## RCB 309 GENETICS AND GENOMICS 3 credit course

*This course is designed to familiarize students with the basic principles of genetics and genomics and their applications in the life sciences. The topics covered include fundamentals of genetics and inheritance, cytogenetics, genetic tools, developmental genetics, genetic disorders, organization of genomes, next generation sequencing strategies, metagenomics, comparative genomics and transcriptomics.*

### COURSE CONTENT

#### **Principles of Genetics**

Principles of genetics and inheritance, cytogenetics, developmental and human molecular genetics and associated genetic disorders, Mendelian and non-Mendelian modes of inheritance, linkage and crossing over, complementation.

#### **Chromosomes and inheritance**

Chromosomes and their role in inheritance, chromosomal aberrations, sex determination and transposable elements, Genetics in animal development.

#### **Human Genetics**

Recent advances in human molecular genetics, introduction to the human genome, pedigree analysis, gene mapping and linkage analysis, prenatal diagnosis and cancer genetics. Diagnosis and genetic counseling in genetic and metabolic disorders.

#### **Genomics**

Basic concepts of genome organization in prokaryotes and eukaryotes, dynamic components of genomes, and C-value paradox, Computational platforms and pipelines for genome analysis.

#### **DNA Sequencing and Applications**

Strategies for the systematic sequencing, analysis of sequenced model genomes, Human Genome Project, the 1000 genome project, the ENCODE Project, Basic principles and methodologies of various next generation sequencing, Molecular phylogenetics, synteny and SNP analysis, Basic concept of transcriptomics and its application in human health and

agricultural biotechnology.

## SUGGESTED READING

1. Klug WS, Cummings MR, Spencer CA, Palladino MA. Concepts of Genetics, 11<sup>th</sup> Edition, Pearson Education Limited.
  2. Gardner EJ, Simmons MJ, Snustad DP. Principles of Genetics. 8<sup>th</sup> Edition, Wiley.
  3. Pierce BA. Genetics: A Conceptual Approach, 6<sup>th</sup> Edition, W. H. Freeman Publishers.
  4. Wolpert L, Tickle C, Arias AM. Principles of Development, 5<sup>th</sup> Edition, Oxford University Press.
  5. Gilbert SF. Developmental Biology, 10<sup>th</sup> Edition, Sinauer Associates.
  6. Pevsner J. Bioinformatics and Functional Genomics, 3<sup>rd</sup> Edition, Wiley-Blackwell.
  7. Lesk AM. Introduction to Genomics, 3<sup>rd</sup> Edition, Oxford University Press.
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**RCB 310**  
**PLANT BIOTECHNOLOGY**  
**2 credit course**

*This course will introduce students to basic concepts, methodologies, and applications of plant tissue culture, genetic engineering, and molecular breeding in the context of crop improvement. Emphasis will be laid on the practical applications of plant biotechnology such as sustainable food and bioenergy production, quality enhancement, and supply of high-value products.*

### COURSE CONTENT

#### **Introduction to Plant Biotechnology**

Organization of plant genomes, history of plant biotechnology, adoption of plant biotechnology and its impact on the environment.

#### **Plant Breeding and tissue culture**

Concepts and methodologies in plant breeding, hybridization, clonal propagation, double haploidy, marker-assisted selection, Manipulation of plant development, plant growth regulators for regeneration, Commercial applications of plant tissue culture in agriculture, medicine and industry.

#### **Plant Genetic Engineering**

Genes and traits of interest for genetic manipulation of plants, Integrating genomics, transcriptomics and proteomics for transgenic development, Strategies of DNA modification, evaluation of transformation methodologies, phenotypic analysis, choice of selectable markers, reporter genes and promoters, marker-free strategies, RNAi-based silencing.

#### **Plant Immunity**

Molecular basis of plant immunity, Key defensive players and their operation at multiple levels during a pathogen attack, Conceptualized model on gene-for-gene hypothesis, guard hypothesis, decoy models etc., Potential defense targets and their mode of signaling that forms the basis of engineering disease-resistant plants.

## **Regulations, Biosafety and the Future of Plant Biotechnology**

Benefits and risks of genetic modifications, environmental risk assessment strategies, challenges in plant biotechnology; Case studies: Success, failures and misleading interpretations; Use of genome-editing for crop improvement.

## **SUGGESTED READING**

1. Neal Stewart C Jr. Plant Biotechnology and Genetics: Principles, Techniques, and Applications, 2<sup>nd</sup> Edition, Wiley.
  2. Altman A, Hasegawa P. Plant Biotechnology and Agriculture: Prospects for the 21st century. 1<sup>st</sup> Edition. Elsevier.
  3. Grotewold E, Chappell J, Kellogg E. Plant Genes, Genomes and Genetics. Wiley.
  4. Buchanan BB, Gruissem W, Jones RL. Biochemistry and Molecular Biology of Plants. 2nd Edition. Wiley-Blackwell.
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## **RCB 311** **STRUCTURAL BIOLOGY AND BIOINFORMATICS** **2 credit course**

*The course is designed to prepare students to understand basic concepts regarding structure, function and interaction of macromolecules. The different methods utilized to determine structure of macromolecules will also be taught. In addition, the students will learn how to use biological data (literature, sequence, and structure-function) to obtain mechanistic insights of biological processes.*

## **COURSE CONTENT**

### **The structure and function of Macromolecules and complexes**

Principles of protein structure and function, Structure and function of enzymes, Structure and function of Nucleic Acids, Structure and function of Lipids and Carbohydrates, Structure of Complexes and Macromolecular Assemblies, Virus Structures and Assembly, Protein Folding.

### **Methods of macromolecular structure determination**

Basic concepts and methods in Macromolecular Crystallography, Nuclear Magnetic Resonance, Cryo-Electron Microscopy, Circular dichroism, Förster Energy Resonance Transfer, Small Angle X-ray Scattering.

### **Bioinformatics**

Retrieval of information from structural and sequence databases; structure visualization and analysis, sequence, structure alignment and phylogenetic trees, Protein secondary structure prediction methods, homology modeling, ab initio structure prediction, critical assessment of methods of protein structure prediction (CASP), molecular docking to model complexes, force fields and energy calculations, energy minimization, molecular dynamic simulations, molecular docking, structure-based drug design; Introduction to Systems Biology.

## SUGGESTED READING

1. Schulz GE, Schirmer RH. Principles of Protein Structure, Springer.
  2. Branden C, Tooze J. Introduction to Protein Structure, 2nd Edition, Garland Science.
  3. Liljas A, Liljas L, Piskur J, Lindblom G, Nissen P, Kjeldgaard M. Textbook of Structural Biology, 2nd Edition, World Scientific.
  4. Rhodes G. Crystallography Made Crystal Clear, 3<sup>rd</sup> Edition. Academic Press.
  5. McPherson A. Crystallization of Biological Macromolecules, Cold Spring Harbor Laboratory Press.
  6. Stout GH, Jensen LH. X-Ray Structure Determination: A Practical Guide, 2nd Edition, John Wiley and Sons.
  7. Lesk A. Introduction to Bioinformatics, 4<sup>th</sup> Edition, Oxford University Press.
  8. Tramontano A, Lesk AM. Protein Structure Prediction: Concepts and Applications, Wiley.
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## RCB 312 INDUSTRIAL BIOTECHNOLOGY 2 credit course

*The goal of this course is to teach student the fundamentals of biochemical engineering and impart knowledge about the biochemical production processes, specifically of biomolecules that are used for therapeutics.*

### COURSE CONTENT

#### **Fermentation technology and downstream processing**

Types of bioreactors used in industrial microbial processes; biochemistry of fermentation: Aerobic and Anaerobic metabolism; Process Optimization using Plackett Burman and Box Behnken design; Media and air sterilization; Downstream processing for product recovery; Production of different Bio-products and process involved such as ethanol, lactic acid, glutathione, insulin etc.

#### **Development, production, recovery and analysis of Viral & Bacterial vaccines**

Case studies of the vaccine manufacturing processes focusing on generation of antigen/virus/bacteria/recombinant product, purification of the same, testing the product, evaluation of the efficacy of the product, stability of the product, formulation of the product and its stability etc.

#### **Process development for production of enzyme and other Bioproducts**

Production of industrial enzymes, enzyme immobilization, biopesticides, biofertilizers, biopreservatives, biopolymers biodiesel; Production of recombinant proteins having therapeutic applications.

#### **Metabolic Engineering**

Basic biochemistry of central carbon metabolic network: TCA cycle, Glycolysis, Pentose phosphate pathway etc.; Anaerobic and aerobic carbon metabolism; Metabolic reconstruction and flux analysis; Redesigning metabolic pathways for improved product formation using different synthetic biology approach.

## **Biosafety and Biosecurity**

Understanding of Clean rooms and Biosafety levels: Clean Room classifications, clean room gowning, proper sanitation techniques, the regulations and recommendations for biosafety, ascending levels of containment, defining microbiological practices, safety equipment, and facility safeguards: Introduction to safe Laboratory Practices: Guidelines for safe laboratory practices, role of institution's safety committee and local rules and regulations pertaining to laboratory, GLP & GMP concepts.

## **SUGGESTED READING**

1. Stanbury PF, Whitaker A, Hall SJ. Principles of Fermentation Technology, 3<sup>rd</sup> Edition, Elsevier.
  2. Jones L, McKnight AJ, Biotherapeutics: Recent Developments using Chemical and Molecular Biology, The Royal Society of Chemistry.
  3. Chakraborty C. Production Technology of Recombinant Therapeutic Proteins, Biotech Books.
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## **RCB 313** **METHODS IN IMMUNOLOGY** **4 credit course**

*The course will involve practical sessions to provide experience in immunological methods. Students will learn the basics of experimental animal handling, injection, and bleeding. They will also carry out hands-on experiments on cells involved in immune responses.*

## **COURSE CONTENT**

- Practical 1: Immunization of mice and methods of bleeding, serum separation, storage.
- Practical 2: Antibody titre determination by ELISA method.
- Practical 3: Double diffusion, Immuno-electrophoresis and Radial Immunodiffusion.
- Practical 4: Complement fixation test.
- Practical 5: Isolation and purification of IgG from serum.
- Practical 6: Blood smear identification of leucocytes by Giemsa stain.
- Practical 7: Separation of leucocytes by dextran method.
- Practical 8: Separation of mononuclear cells by Ficoll-Hypaque.
- Practical 9: Flowcytometry, identification of T cells and their subsets.
- Practical 10: Lymphoproliferation by mitogen / antigen induction.

**RCB 314**  
**METHODS IN GENETICS & GENOMICS**  
**4 credit course**

*Lab sessions will include a general introduction to laboratory experimental genetics using animal model. Topics include Drosophila life cycle, identification of phenotypes, basics of setting up genetic crosses and genotyping assays. Genomics lab component will include hands-on tutorials on the use of databases and online tools to analyze large sequence data for various applications.*

**COURSE CONTENT**

- Practical 1: Learning fly culture to study life cycle.
  - Practical 2: Studies on external morphology of Drosophila.
  - Practical 3: Studying dominant and recessive mutations using Drosophila.
  - Practical 4: Genetic crosses and recombination.
  - Practical 5: Chromosome segregation and gene function.
  - Practical 6: Genotyping assays to study inheritance.
  - Practical 7: RT-PCR to quantitate gene expression.
  - Practical 8: Introductory tutorial to RNASeq analysis.
  - Practical 9: Gene Ontology (GO) enrichment and pathway analysis.
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**RCB 315**  
**METHODS IN PLANT BIOTECHNOLOGY**  
**4 credit course**

*The course will involve practical sessions to provide experience in Plant biotechnology methods where students will learn plant molecular biology, tissue culture methods, and plant transformation.*

**COURSE CONTENT**

- Practical 1: Seed sterilization, germination.
- Practical 2: Selection on antibiotic plates.
- Practical 3: Genomic DNA isolation from plant tissues.
- Practical 4: PCR-based genotyping to trace segregation of marker/mutation.
- Practical 5: Transient Agrobacterium-mediated expression in planta.
- Practical 6: Tissue culture of explants for callus formation.
- Practical 7: Regeneration of calli.
- Practical 8: Agrobacterium-mediated floral-dip transformation of plants.

**RCB 316**  
**BIOSTATISTICS**  
**2 credit course**

*The course will provide information regarding basic concepts and common practices for the analysis of biological data using statistical tools and provide opportunity to students to apply these methods on available data sets.*

**COURSE CONTENT**

**Scope of Statistics in Biological Research**

Applications of statistics in biology, definitions (populations, samples), Basic Concepts, type of data, various data collection methods, Diagrams and graphs; Measures of averages and location; Measures of dispersion; Probability and probability theory, Use of statistical packages on biological data.

**Statistical Methods**

Descriptive: Graphical representation on various type of data, Use of each measure of location; Measures of spread: Variance and Standard Deviation, Standard Error; Skewness, Kurtosis; Quantiles, Outliers; Inferential: Framing hypothesis, Hypothetico-deductive method, Definition & Concept of types of hypothesis, types of errors, Power, Level of Significance, Rejection Region, p-value; Procedures of hypothesis testing based on objective: z- and t-test, Two-way contingency tables, Chi-square and Fisher's exact test.

**Correlation & Regression**

Karl-Pearson Correlation, Spearman Rank- Correlation, Regression, fitting data to a linear model; Variances and co-variances; least-square parametric estimates; Hypothesis test with regression; Assumptions, Analyses of variance, ANOVA and Partitioning of Sum of Squares, Assumptions; Hypothesis tests with ANOVA; Constructing F-Ratios; ANOVA tables, Analyses of categorical data, and G-Test.

**SUGGESTED READING**

1. Quinn GP, Keough MJ. Experimental Design and Data. Cambridge University Press.
2. Zar JH. Biostatistical Analysis, 5th Edition. Pearson Publishers.
3. Indrayan A. Medical Biostatistics, 2nd Edition, Chapman and Hall.
4. Altman DG. Practical Statistics for Medical Research, Chapman and Hall.

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**RCB 411**  
**RESEARCH METHODS**  
**3 credit course**

*This course is designed to enable the student to understand the basic principles and practices of common methods used for research in Life Science & Biotechnology. The course deals with contemporary research methodologies, experimental design, data analysis and presentation.*

## **COURSE CONTENT**

### **Research Design, Conduct, Recording & Presentation**

Formulation of a research problem, Ethics and code of conduct in research, Data falsification, Plagiarism, Data security, Laboratory behavior, Biosafety and IT usage policy, maintenance of laboratory notebooks, Grant/Fellowship/Report writing, Manuscript Writing, and Seminar Presentation; Regulatory issues in Biotechnology.

### **Advanced Research Techniques**

Principles of methods associated with Genomics and Proteomics, Molecular Interactions, Microscopy- Optical, Electron & Atomic Force, Macromolecular Crystallography, NMR, Spectroscopy, Flow Cytometry, Bioinformatics, Mass Spectrometry.

### **Mathematics for Life Sciences**

Basic concepts in algebra, trigonometry, numbers, probability and their applications in biology, basics of building mathematical models.

### **Basics of Information Technology & Computer Programming**

Introduction to different software available for documentation and analysis of scientific data, Basics of maintenance of computers, basics of networking, Introduction to programming and programming languages.

### **Bio-entrepreneurship and IP management in Biotechnology**

These classes will discuss basic of bio-entrepreneurship, and practices involved in patenting, process of patent filing and patent securing.

## **SUGGESTED READING**

1. Wilson K, Walker J. Principles and Techniques of Biochemistry & Molecular Biology, 7th Edition, Cambridge University Press.
2. Allen T. Microscopy: A very short Introduction, Oxford University Press.
3. Katz MJ. From Research to Manuscript, Springer.
4. Kumar A. Mathematics for Biologists, Alpha Science.

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### **RCB 412**

### **ADVANCED CHEMICAL BIOLOGY**

#### **2 credit course**

*This course teaches the advances in chemical biology with major focus on recent developments in the areas of sugar, nucleic acid, lipid, and protein chemistry and its significance in biology. The course will also provide the overview of different discoveries suggesting the role of these biomolecules and their biological processes in disease biology and therapy.*

## COURSE CONTENT

### Glycobiology

Glycobiology of cell migration - extravasation (selectin–sialyl Lewis X interactions) and carbohydrate mediated cell homing, glycosylation of antibodies in immune modulation, carbohydrate based blood group antigens, and chemical methods for manipulation of glycans.

### Chemical Biology of Nucleic Acids

chemical synthesis of modified RNA, expansion of the genetic alphabet in nucleic acids by creating new base pairs, nucleic-acid-templated chemistry, chemical biology of peptide nucleic acids (PNA), the interactions of small molecules with DNA and RNA, the architectural modules of folded RNAs, genesis and biological applications of locked nucleic acid (LNA), nucleic acids based therapies, light-responsive nucleic acids for the spatiotemporal control of biological processes, DNA methylation, frameworks for programming RNA devices, RNA as a catalyst: The Diels-Alderase-Ribozyme, evolving an understanding of RNA function by in vitro approaches, the chemical biology of aptamers: synthesis and applications, nucleic acids as detection tools, bacterial riboswitch discovery and analysis.

### Chemical Biology of Proteins

Introduction to Post-translational modifications, Phosphorylation, Acetylation, Methylation, Chemical ligation (shortage mediated and Intein mediated), Expanded genetic code, amber stop codon suppression methodology and its application, Bioorthogonal chemistry and its application, Activity based chemical profiling.

### Chemical Biology of Lipids

Introduction to Classes of Lipids (Structural and Signaling); Lipid Functions, Lipid Synthesis and Lipid traffic, Sphingolipids, Sphingolipid-mediated signaling and their role in Disease Progression like Cancer, Inflammation, Diabetes, Atherosclerosis.

## SUGGESTED READING

1. Mayer G. *The Chemical Biology of Nucleic Acids*, John Wiley & Sons.
2. Hannun YA, Luberto C, Mao C, Obeid LM. *Bioactive Sphingolipids in Cancer Biology and Therapy*, Springer.
3. Walsh C. *Posttranslational Modification of Proteins: Expanding Nature's Inventory*, Robert and Company Publishers.
4. Koehrer C, RajBhandary UL. *Protein Engineering*, Springer.
5. D'Andrea LD, Romanelli A. *Chemical Ligation: Tools for Biomolecule Synthesis and Modification* John Wiley & Sons.
6. Sieber SA. *Activity-based Protein Profiling*, Springer.
7. Pavão MSG. *Glycans in Diseases and Therapeutics*, Springer.

**RCB 413**  
**SCIENTIFIC COMMUNICATION**  
**2 credit course**

*For a successful scientist, it is very important to effectively convey his work to both the technical and non-technical audience. This may be in the form of verbal and visual communication in the form of seminars and presentations, and written communication in the form of reports, manuscripts, and grant proposals. This course aims to encourage the students to inculcate these attributes by making presentations and writing reports.*

*Each student will be required to choose a recent high quality primary research publication and make a power point presentation to the class. The presentation should cover all the background literature of the chosen research area. Stress should be given to the objectives of the paper, logic of each experiment and the data analyses. In addition, they will be expected to highlight shortcomings and alternate approaches as appropriate. This endeavor would give them the exposure of what it takes to defend a scientific concept in an open audience. Additionally, students of this course will mandatorily attend all seminars conducted at the Centre.*

*For developing the writing skills, the student will choose an area related to his research interest and write a 10-page review of the field providing a critique of the research opportunities. The area may be chosen in consultation with the guide who should help the student with the preparation of the report.*

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**RCB 414**  
**PROJECT DISSERTATION**  
**40 credit course**

*As a primer to building a career in biotechnology research, the student will choose a small lab project in consultation with the supervisor, learn and master the relevant research techniques, conduct experiments and collect data that may be collated in the form of a dissertation.*

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**RCB 415**  
**THESIS RESEARCH**  
**180 credit course**

*In consultation with the supervisor, the student will identify a novel area for research in a given field of biological sciences, develop a hypothesis and set objectives for his PhD thesis to be approved by the Student Advisory Committee. Over the next 3-5 years, the student will conduct experiments, collect data towards the set objectives, and present his novel findings in the form of a PhD thesis.*