Regional Centre for Biotechnology

Course Details

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, 4th Edition. John Wiley & Sons.

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, 2nd Edition, Cambridge University Press.

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, 6th Edition, Garland Science.
2. Lodish H, Berk A, Kaiser C, Krieger M, Scott M, Bretscher A, Ploegh H. Molecular Cell Biology, 6th Edition. WH Freeman.
3. Gilbert SF, Barresi M. Developmental Biology, 11th Edition. Sinauer.

4. Wolpert L, Tickle C, Arias AM. Principles of Development, 5th Edition. Oxford University Press.

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.

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.

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.

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, 8th Edition, Elsevier.
5. Khan A. Biotechnology in Medical Sciences, CRC Press.
6. Pongracz J, Keen M. Medical Biotechnology, Churchill Livingstone.

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, 11th Edition, Pearson Education Limited.
2. Gardner EJ, Simmons MJ, Snustad DP. Principles of Genetics. 8th Edition, Wiley.
3. Pierce BA. Genetics: A Conceptual Approach, 6th Edition, W. H. Freeman Publishers.
4. Wolpert L, Tickle C, Arias AM. Principles of Development, 5th Edition, Oxford University Press.
5. Gilbert SF. Developmental Biology, 10th Edition, Sinauer Associates.
6. Pevsner J. Bioinformatics and Functional Genomics, 3rd Edition, Wiley-Blackwell.
7. Lesk AM. Introduction to Genomics, 3rd Edition, Oxford University Press.

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, 2nd Edition, Wiley.
2. Altman A, Hasegawa P. Plant Biotechnology and Agriculture: Prospects for the 21st century. 1st 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.

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, Forster 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, 3rd 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, 4th Edition, Oxford University Press.
8. Tramontano A, Lesk AM. Protein Structure Prediction: Concepts and Applications, Wiley.

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, 3rd 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.

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.

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.

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.

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.

RCB 414
PROJECT DISSERTATION

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.

RCB 415
THESIS RESEARCH

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.

RCB 433
DATA DRIVEN STATISTICAL METHODS
3 credit course

This course is designed to provide a comprehensive understanding of applications of statistical theory to real data. Each topic will be taught by hands-on analyses or descriptions of analyses of relevant biological datasets with emphasis on methodologies, rather than on proofs and derivations. Outline of statistical theories, whenever required, will be provided to aid better understanding of practical applications and for gauging validity of the underlying assumptions.

COURSE CONTENT

Study Design & Data Analysis
Common Study Designs and Biases, Parameters and Statistics, Parameter Estimates and Standard Errors (e.g., Relative Risk, Odds Ratio, Mean), Tests of Hypotheses commonly used in Biology (e.g. standard normal tests, chi-square and t-tests, sign and rank based tests), Multiple Testing, Power and Sample Size.

Linear Regression
Linear Models (Fixed and Random Effects), Least-squares, Regression Diagnostics, Analysis of Variance, Kruskal-Wallis, Mixed-Effects Models.

Logistic regression
Odds ratio: Estimation, Confidence Interval and Testing, Interaction effects, Polytomous data.

Multivariate data
Principal components analysis, Factor analysis, Multivariate Normal Distribution, Hotelling's T^2 statistic, Multivariate Analysis of Variance.

Frequentist Inference
Maximum Likelihood, Likelihood Ratio and Wald Tests, Permutation and Bootstrap.

Bayesian Inference
Bayesian Estimation and Hypothesis testing (Bayes Factors), Bayesian Credible Intervals and Conjugate Priors.

SUGGESTED READING

1. Julian J. Faraway: Linear Models with R, Chapman & Hall/CRC Texts in Statistical Science.
2. Norman R. Draper, Harry Smith: Applied Regression Analysis, 3rd Edition, Wiley Series in Probability and Statistics.
3. Alan Agresti: An Introduction to Categorical Data Analysis, Wiley Series in Probability and Statistics.
4. Richard A. Johnson and Dean W. Wichern: Applied Multivariate Statistical Analysis, Pearson International Edition.
5. Kneib, Thomas. "Applied Statistical Inference: Likelihood and Bayes. L. Held and D. SabanésBové (2014). Heidelberg: Springer.

RCB 434
PROGRAMMING IN R
3 credit course

This course is designed to develop proficiency in statistical data analysis and programming using R and biological data analysis using R/Bioconductor. Each topic will be taught using biological datasets, hands-on sessions, and short projects.

COURSE CONTENT

R Basics
Various Data Types, Variables and Assignment, Arithmetic and Logical Operators, Vectors and Vectorized Operations, Factors, Data-type Conversions.

Matrices, Arrays and Data Frames
Creating matrices and arrays, Indexing and subsetting of matrices and arrays, Concatenating matrices, Matrix operations and linear algebra, Mixed array-vector operations: Recycling, Data-frames, File input/ output, R objects and workspace.

Lists and Functions
Creating and handling lists, Data-frames as lists, Summarizing data, Built-in and user-defined functions, Loops and control flow, 'Apply' functions, Vectorized functions.

R Packages
Built-in R Packages: 'base', 'stat', 'graphics'etc., Using contributed packages, Creating packages, Documentation and vignettes, Dynamic report generation, Parallel computing in R.

Bioconductor
S4 classes and methods, Bioconductor infrastructure and annotation packages, Hands-on Workflows using Genomic and other high-throughput assays.

SUGGESTED READING

1. Crawley, Michael J. The R book. John Wiley & Sons, 2012.
2. Dalgaard, Peter. Introductory statistics with R. Springer, 2008.
3. Peng, Roger D. R programming for data science. Lulu.com, 2015.
4. Gentleman, Robert, et al., eds. Bioinformatics and computational biology solutions using R and Bioconductor. Springer Science & Business Media, 2006.
5. Hahne, Florian, et al. Bioconductor case studies. Springer Science & Business Media, 2010.

RCB 435
COMPUTATIONAL STATISTICS
3 credit course

This course is designed to provide an understanding of computationally intensive statistical techniques for large or complex biological datasets. Topics covered include optimization of likelihoods, Bayesian inference using Markov Chain Monte Carlo and Machine Learning methods. Each topic will be taught using example datasets, appropriate R packages and brief outlines of the underlying statistical theories.

COURSE CONTENT

Likelihood Theory & Computations
Calculating score, Information and Hessian matrices, Newton's Method and basics of other optimizers, Generalized Linear Models, Fisher's Scoring and Iteratively Reweighted Least-squares (IRWLS) algorithm, EM algorithm.

Non-linear and Penalized Regression
Non-linear regression (Local-regression, Splines, Generalized Additive Models); High Dimensional Regression (e.g. PCR, Ridge, LASSO).

Bayesian Inference & Computations
Approximating Integrals, Review of Monte Carlo Simulation of Random Variables, Rejection sampling, Importance sampling, Markov Chain Monte Carlo (Metropolis Hastings and Gibbs Samplers), Convergence diagnostics.

Machine Learning
Classification and Prediction: Hierarchical and K-means clustering, Supervised Learning (e.g., Linear Discriminant Analysis, Classification and Regression Trees, Support Vector Machines), Cross-validation, Prediction Error, Receiver Operating Characteristic (ROC) curve, Feature Selection.

SUGGESTED READING

1. Kundu Debasis and Basu Ayanendranath. Statistical Computing: Existing Methods and Recent Developments. Alpha Science International 2004
2. Gentle, James E., Wolfgang Karl Härdle, and Yuichi Mori, eds. Handbook of computational statistics: concepts and methods. Springer Science & Business Media, 2012.
3. P. McCullagh and John A. Nelder: Generalized Linear Models, Chapman & Hall/CRC Monographs on Statistics & Applied Probability.
4. Tibshirani, Robert, and Jerome Friedman. The elements of statistical learning: Data mining, Inference, and Prediction. Second Edition. Springer, 2009.

RCB 436
SURVIVAL ANALYSIS & CLINICAL TRIALS
3 credit course

This course is designed to provide a comprehensive understanding of application of statistical theory to analysis of survival and clinical trial data. Each topic will be taught using real datasets and without detailed derivations of the underlying statistical theories. Outlines of the theories will be given to enhance clarity of understanding the practical applications and for gauging validity of the underlying assumptions.

COURSE CONTENT

Part I. Survival Analysis

Introduction
Types of data (uncensored, censored, grouped, truncated), Kaplan-Meier curve, Dependence on covariates, Survival and hazard functions.

Failure time models
Exponential, Weibull and Gamma, Discrete hazard.

Likelihood based inference for censored data
Construction of likelihood for different types of censoring, Maximum-likelihood estimation, Testing of hypotheses in parametric models.

Nonparametric inference
Kaplan-Meier estimate, Two-sample problem.

Regression models
Exponential and Weibull regression, Proportional Hazards and Accelerated Life Time models, Discrete regression models, Two-sample problem using regression models.

Part II. Clinical Trials

Introduction
Ethical issues, protocols, Comparative and controlled trials, Different phases, Randomization, Different types of biases, Sample size determination.

Phase I trial
Dose-response studies, 3+3 design, Continual Reassessment Method (CRM).

Phase II & III trials
Sequential allocation, Treatment adaptive allocation, Interim Analyses and Stopping Rules, Missing data and Intention-to-Treat, Delayed responses, Longitudinal responses, Crossover designs, Covariates and surrogate responses. Analysis of data using generalized linear models, quasi-likelihood and generalized estimating equations, real clinical trial examples and illustrations.

SUGGESTED READING

Part I.

1. Kalbfleisch, John D., and Ross L. Prentice. The statistical analysis of failure time data. Vol. 360. John Wiley & Sons, 2011.
2. Cox, David Roxbee, and David Oakes. Analysis of survival data. Vol. 21. CRC Press, 1984.
3. Lawless, Jerald F. Statistical models and methods for lifetime data. Vol. 362. John Wiley & Sons, 2011.
4. Klein, John P., and Melvin L. Moeschberger. Survival analysis: techniques for censored and truncated data. Springer Science & Business Media, 2005.

Part II.

1. Matthews, John NS. Introduction to randomized controlled clinical trials. CRC Press, 2006.
2. Atkinson, Anthony C., and Atanu Biswas. Randomised response-adaptive designs in clinical trials. CRC Press, 2013.
3. Whitehead, John. The design and analysis of sequential clinical trials. John Wiley & Sons, 1997.
4. Pocock, Stuart J. Clinical trials: a practical approach. John Wiley & Sons, 2013.

RCB 437
HUMAN GENETICS & GENOMICS
3 credit course

This course is designed to give an overview of human genetics. The topics covered include basic principles of genetics and human population genetics, methods for mapping of disease genes including Genome-wide Association Studies and Next Generation Sequencing based strategies.

COURSE CONTENT

Principles of Genetics
Mendel's Laws, Gene, Locus, Allele, Allele Frequency, Random mating, Mating table, Hardy-Weinberg equilibrium (HWE), Test of HWE, Estimation of allele frequencies based on different modes of inheritance: co-dominance, dominance, recessivity, inbreeding.

Population Genetics
Mutation; Probabilities of survival of mutants over generations, under different mutation models, Natural Selection; Probabilities of survival of alleles over generations, under different selection regimes, including heterozygote advantage, Consequences when both mutation and selection pressures operate, Measuring genomic differentiation between populations, Genetic distance and phylogenetic analysis.

Gene Mapping
Concepts of Linkage, Recombination and Linkage Disequilibrium, Differences between Mendelian and Complex traits, Linkage mapping using family data, Case-control studies: Design considerations, Genome-wide association studies, Population stratification, GWAS: Precautions to be taken, Family-Based Association Methods, Genetic analysis of a Quantitative Phenotype: Principles and methods, Gene-expression microarrays and Enrichment Analysis.

Next-Generation Sequencing
Introduction to Analyses of Massively Parallel sequencing, NGS applications, Alignment, Variant Calling, RNASeq Normalization and Analysis.

SUGGESTED READING

1. Hartl, Daniel L., and Andrew G. Clark. "Principles of population genetics." (1998).
2. Nei, Masatoshi Molecular Evolutionary Genetics. Columbia University Press, New York, 1987
3. Cavalli-Sforza, Luigi Luca, Paolo Menozzi, and Alberto Piazza. The history and geography of human genes. Princeton university press, 1994.

4. Ziegler Andreas, Konig Inke . A Statistical Approach to Genetic Epidemiology; Concepts and Applications . Wiley VCH 2014.
5. Thomas, Duncan C. Statistical methods in genetic epidemiology. Oxford University Press, 2004.

THS 409
Introduction to Drug Discovery & Development
Credits: 2

This course is designed to enable the students to understand the basic concept of drug discovery. This course work is intended to teach students about different aspects of pre-clinical drug discovery and development. This course will start with a general introduction and historical prospective of the drug discovery followed by understanding different stages of pre-clinical drug discovery and development. The course will also cover the uses and applications of mass spectrometry for drug target identification and biomarker discovery. There will be teaching on theme revolving around structural biology and in-vitro screening followed by lectures on computational biology and bioinformatics. The course will be concluded with understanding of general aspects of medicinal chemistry and details of pre-clinical pharmacology and toxicology.

COURSE CONTENT

A general introduction with historical perspective on drug discovery and development

General introduction to drug discovery research and development, history of drug discovery research and development, different approaches to drug target and drug lead discovery, different domains and steps in drug discovery and development.

Mass spectrometry and proteomics for drug target discovery

Separation sciences in proteomics – basic concepts, Basics of mass spectrometry proteomics, Peptide mass fingerprinting (PMF) and PMF database searching, Tandem mass spectrometry (MS/MS) for peptide sequencing, Statistical evaluation and protein inference problem, Quantitative proteomics – II (Labelled and label free quantitation), Analysis of Post translational modifications (PTM).

Structural biology, *in-vitro* screening

Basic understanding of Protein, Protein expression and purification, Introduction to X ray Crystallography and crystallization, understanding protein-protein, protein-small interaction study, Role of Structural Biology in Drug Discovery, Introduction to High Content Screening, exploiting cell biology to design assay platforms, Designing and development of disease model, Application of High content screening.

Molecular Modelling and Structural Bioinformatics

Basics of structural bioinformatics, Biological databases/webservers, sequence analysis, secondary structure prediction and analysis, phylogeny and clustering, Role of Bioinformatics in drug design, Target understanding at molecular level, lead optimization and *in-silico* validation, Structure- and ligand-based drug design, Molecular docking and docking algorithms, de-novo ligand design and molecular dynamics simulation.

Medicinal Chemistry, Pharmacology and Drug Development

Basic understanding of the medicinal chemistry & Structure Activity Relationship, hit identification to lead development process, Chemistry Manufacturing and Control (CMC), Concept of Pharmacology and Toxicology, Drug absorption and distribution Drug action/pharmacodynamics, Pharmacokinetics, Drug metabolism Phase-I, Drug metabolism Phase-II, Drug toxicity and poisoning.

SUGGESTED READING

1. *Basic Concepts in Medicinal Chemistry by Marc W. Harrold.*
2. *Goodman and Gilman's The Pharmacological Basis of Therapeutics, 13th Edition*