Integrated MSc-PhD in Biotechnology Course Content and Details (Tentative)

Duration:

The duration of the integrated M.Sc.-Ph.D. program will be for a minimum of 5 years and a maximum of 7 years. However, a student can exit the program after 2 years and will receive M.Sc. degree certificate upon successful completion of the requirements therein.

Program and course structure:

The program will have three semesters of teaching and one semester of full-time research project dissertation. The students joining under this program will be provided extensive learning opportunities in the fundamentals of biotechnology though rigorous classroom teaching and hands-on laboratory experiments. Based on the performance during these two years, students will be permitted to continue in the program for pursuing Ph.D. thesis research in the same laboratory where he/she has completed the M.Sc. project dissertation. At this stage, the student can also opt his/her choice to exit the program with a Master's degree upon satisfactory completion of the course and dissertation requirements. For those students whose performance is below satisfactory or if they do not qualify in any of the national fellowship examinations, ILS will advise them to exit the program with a Master's degree, provided all academic and other requirements have been fulfilled.

Course No.	Credits	Course Title
Semester-I [seven courses; total 23 credits; all compulsory]		
ILS 301	3	Cell, Molecular and Developmental Biology
ILS 302	3	Microbiology
ILS 303	3	Genetics and Genomics
ILS 304	3	General Immunology
ILS 305	3	General Biochemistry
ILS 306	4	Biochemical and Analytical Techniques
ILS 307	4	Methods in Microbiology and Cell Biology
Semester-II [seven courses; total 23 credits; all compulsory]		
ILS 308	3	Plant Biotechnology
ILS 309	3	Cancer Biology
ILS 310	3	Structural Biology and Biophysics
ILS 311	2	Pharmacology, Drug discovery and Delivery

ILS 312	4	Methods in Genetic Engineering
ILS 313	4	Methods in Immunology and Genomics
ILS 314	4	Methods in Plant and Environmental Biotechnology

Semester-III: [five courses; total 25 credits; all compulsory]

ILS 401	3	Biostatistics and Bioinformatics
ILS 402	3	Research Methods
ILS 403	2	Advanced Topics in Life Science Research
ILS 404	2	Scientific Communication
ILS 405	15	Project Dissertation

Semester-IV: [M.Sc. project; 25 credits; compulsory]

ILS 405	25	Project Dissertation

Semester-V onwards: [Ph.D. Thesis project; 30 credits; compulsory]

ILS 406	30	Thesis Research

DETAILED SYLLABUS

ILS 301
CELL, MOLECULAR 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 as well as molecular mechanisms associated with replication, transcription and translation.

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.

Genome, DNA Replication, Repair and 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, long noncoding RNAs, microRNAs and circular RNAs

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

SUGGESTED READING

- *Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts R, Walter P. Molecular Biology of the Cell, 6th Edition, Garland Science.*
- *Gilbert SF, Barresi M. Developmental Biology, 11th Edition. Sinauer.*
- *Wolpert L, Tickle C, Arias AM. Principles of Development, 5th Edition. Oxford University Press.*
- *Lodish H, Berk A, Zipursky L, Matsudaira P, Baltimore D and Darnell J. Molecular Cell Biology, 4th Edition. W.H. Freeman and Company.*
- *Cooper GM. The Cell, A Molecular Approach, 2nd Edition. Sinauer Associates; 2000.*
- *Lewin B. Gene IX, 9th Edition, Jones and Barlett Publishers.*

- *Watson JD, Baker TA, Bell SP, Gann AAF. Molecular Biology of the Gene, 6th Edition, Benjamin Cummings Publishing Company Inc.*
- *Nelson D and Cox M. Lehninger Principles of Biochemistry, 5th Edition. Macmillan.*
- *Voet D and Voet J. Biochemistry, 4th Edition. John Wiley & Sons.*
- *Berg J, Tymoczko JL and Stryer L. Biochemistry, 6th Edition. W.H. Freeman and Company.*
- *Watson JD, Baker TA, Bell SP, Gann AAF. Molecular Biology of the Gene, 6th Edition, Benjamin Cummings Publishing Company Inc.*

ILS 302
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.

Microbial and Industrial Biotechnology: Microbes in biotechnology, microbes in brewery and biotechnological applications including recombinant DNA methodologies, production of industrial enzymes, enzyme immobilization, production of recombinant proteins having therapeutic applications.

Host-Microbe Interaction and Vaccine Development: Introduction to infectious diseases, Pharmacologic & non-pharmacologic infections, sexually transmitted diseases, vector-borne diseases, zoonotic diseases, emerging infectious diseases, Host-microbe interactions, immune evasion strategies, drug resistance, experimental and genome wide approaches to study microbial pathogenesis, manipulation of host, modulation of host immune response, pathobiology of infection, evolution of pathogens, introduction to vaccinology and current challenges in vaccine development for infectious diseases.

Tools and Techniques in Microbiology: High-throughput screening assays, drug screening, molecular barcoding methods, PCR and next-generation sequencing based techniques in microbiology.

SUGGESTED READING

- *Hogg S. Essential Microbiology, 1st Edition, John Wiley and Sons.*
- *Schlegel HG. General Microbiology, 7th Edition, Cambridge University Press.*
- *Prescott LM, Harley JP and Klein DA. Microbiology, 6th Edition, McGraw Hill.*
- *Hurst CJ, Crawford RL, Knudsen GR, McInerney MJ and Stetzenbach LD. Manual of Environmental Microbiology, 3rd Edition, ASM Press.*
- *David Schlossberg. Clinical Infectious Disease, 2nd Edition, Cambridge University Press.*
- *W. John Spice. Clinical Microbiology and Infectious Diseases, 2nd Edition, Churchill Livingstone.*
- *Gerald L Mandell, John Eugene Bennett, and Raphael Dolin. Principles and Practice of Infectious Diseases. 4th Edition, Churchill Livingstone.*
- *Emily P. Wen, Ronald Ellis, Narahari S. Pujar. Vaccine Development and Manufacturing*
- *Stefan H.E. Kaufmann: Concepts in Vaccine Development, 2012 Edition, De Gruyter Press.*
- *Steffen Rupp and Kai Sohn. Host-pathogen Interactions: Methods and Protocols, 2009 Edition, Humana Press.*
- *Michael San Francisco and Brian San Francisco. Host-Microbe Interactions, Volume 142, (Progress in Molecular Biology and Translational Science). 1st Edition, Academic Press.*

ILS 303
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

Introductory Genetics: DNA and chromosomes, mitosis, meiosis, gene inheritance, expression and regulation.

Principles: 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, Pedigree analysis, Multifactorial and complex traits and Linkage mapping.

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

Genetic Disorders and Autoimmune Diseases: Introduction to genetic disorders, mutational, deletional, and extra/missing chromosomal genetic disorders, X-liked syndromes, rare genetic diseases, immune regulation and tolerance, autoimmunity, disorders of immune response, development of autoimmune diseases, factors inducing autoimmune diseases, allergy and hypersensitivity and autoimmune diseases (diabetes mellitus, Crohn disease etc)**,** Genetic counseling and ethical issues in Reproductive genetics and Treatment of genetic diseases

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

- *Klug WS, Cummings MR, Spencer CA, Palladino MA. Concepts of Genetics, 11th Edition, Pearson Education Limited.*
- *Gardner EJ, Simmons MJ, Snustad DP. Principles of Genetics. 8th Edition, Wiley.*
- *Pierce BA. Genetics: A Conceptual Approach, 6th Edition, W. H. Freeman Publishers.*

- *Wolpert L, Tickle C, Arias AM. Principles of Development, 5th Edition, Oxford University Press.*
- *Gilbert SF. Developmental Biology, 10th Edition, Sinauer Associates.*
- *Pevsner J. Bioinformatics and Functional Genomics, 3rd Edition, Wiley-Blackwell.*
- *Lesk AM. Introduction to Genomics, 3rd Edition, Oxford University Press.*

ILS 304
GENERAL IMMUNOLOGY
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

- *Janeway CA, Travers P Jr, Walport M, Shlomchik MJ. Immunobiology, 5th Edition, Garland Science. Virella G. Medical Immunology, 6th Edition, CRC Press.*
- *Goldsby RA, Kindt TJ, Osborne BA. Kuby Immunology, 3rd Edition, W H Freeman & Co.*
- *Abbas A, Lichtman A, Pillai S. Cellular and Molecular Immunology, 8th Edition, Elsevier.*
- *Khan FA. Biotechnology in Medical Sciences, 1st Edition, CRC Press.*
- *Pongracz J, Keen M. Medical Biotechnology, 1st Edition, Churchill Livingstone.*

ILS 305
GENERAL 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

- *Nelson D and Cox M. Lehninger Principles of Biochemistry, 5th Edition. Macmillan.*
- *Voet D and Voet J. Biochemistry, 4th Edition. John Wiley & Sons.*
- *Berg J, Tymoczko JL and Stryer L. Biochemistry, 6th Edition. W.H. Freeman and Company.*
- *Watson JD, Baker TA, Bell SP, Gann AAF. Molecular Biology of the Gene, 6th Edition, Benjamin Cummings Publishing Company Inc.*
- *Walsh C. Posttranslational Modification of Proteins: Expanding Nature's Inventory, Robert and Company Publishers.*

ILS 306
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.
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.

ILS 307
METHODS IN MICROBIOLOGY AND 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.

ILS 308
PLANT BIOTECHNOLOGY
3 credit course

This course will introduce students to basic concepts in plant biology, metabolism, adaptation and stress response, methodologies in plant biotechnology, 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 Cell and Metabolism: Cellular organization and cell division, plant structure and development, structural organization and function of plant cell, programd cell death, aging and senescence, Photosynthesis, Respiration, lipid and nitrogen metabolism, Water and solute transport and Mineral nutrition.

Control of plant growth and development: Cell walls, Phytochrome and light control of plant development, Plant hormones and signaling

Adaptation and stress response: Environmental stress, acclimation and adaptation, Secondary metabolites and plant defense

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

- *Neal Stewart C Jr. Plant Biotechnology and Genetics: Principles, Techniques, and Applications, 2nd Edition, Wiley.*
- *Altman A, Hasegawa P. Plant Biotechnology and Agriculture: Prospects for the 21st century. 1st Edition. Elsevier.*
- *Grotewold E, Chappell J, Kellogg E. Plant Genes, Genomes and Genetics. 1st Edition, Wiley-Blackwell.*
- *Buchanan BB, Gruissem W, Jones RL. Biochemistry and Molecular Biology of Plants. 2nd Edition. Wiley-Blackwell.*
- *Loyola-Vargas VM, Ochoa-Alejo N, Plant Cell Culture Protocols, 3rd Edition, Springer.*
- *Smith RH, Plant Tissue Culture: Techniques and Experiments, 3rd Edition, Academic Press.*
- *Reinert J, Plant Cell and Tissue Culture, 1st Edition, Springer*
- *Barz WH, Oksman-Caldentey KM, Plant Biotechnology and Transgenic Plants, 1st Edition, CRC Press.*
- *Abdur Rashid , Developing Transgenic Plants, 1st Edition, Lambert Academic Publishing AG & Co KG.*

ILS 309
CANCER BIOLOGY
3 credit course

This course is designed to give a flavour of cancer biology and the basic concepts in molecular oncology, stem cell biology, cancer metastasis and therapeutics.

COURSE CONTENT

Introduction to Cancer: Basis of Cancer, How cancer develops, Major types of cancer worldwide, Manifestation of cancer, Markers and Cellular hallmarks.

Oncogenes and Tumor suppressors: Regulation of cell growth and proliferation, apoptosis, Genetic contribution to cancer, Effects of mutation and Genes involved.

Pathways associated with Cancer Biology: ErbB Family Pathway, p53-Mediated Apoptosis Pathway, TGF-Beta Pathway, growth hormone (GH)-insulin-like growth factor-1 (IGF1) pathway, Notch, Wnt, and Hedgehog developmental pathways

Metastasis: Different stages of cancer, various steps and molecular mechanisms involved in metastasis, Epithelial-Mesenchymal transition, tumor neoangiogenesis, spread of malignancy and cancer stem cells

Molecular Oncology: Cellular and molecular biology of cancer, cancer etiology and epidemiology (life style, viruses, environmental and occupational cancers), cancer pathology, cancer cell genetics, cancer signaling networks and invasion.

Stem Cells: Cell Cycle Regulation, Cell Cycle Dysfunction, Stem cells, stem cell development and differentiation, signaling pathways associated with stem cell development and induced pluripotent stem cells.

Cancer Therapeutics: Stage-wise diagnosis, cancer treatment modalities, chemotherapy and radiotherapy, therapeutic resistance, targeting signaling pathways, drug discovery, regenerative medicine and identification of new targets for cancer.

SUGGESTED READING

- *Selby PJ, Knowles MA, Introduction to Cellular and Molecular Biology of Cancer, 4th Edition, Oxford University Press.*
- *Robert A Weinberg, The Biology of Cancer, 2nd Edition, Garland Science.*
- *Kleinsmith LJ, Principles of Cancer Biology, 1st Edition, Pearson.*
- *Knoepfler P, Stem Cells: An Insiders Guide, 1st Edition, World Scientific Publishing Company.*
- *Al-Rubeai M, Naciri M, Stem Cells and Cell Therapy (Cell Engineering Book 8), 2014 Edition, Springer.*

- *Peterson S, Loring JF, Human Stem Cell Manual: A Laboratory Guide, 2nd Edition, Academic Press.*
- *Lanza R, Gearhart J, Hogan B, Melton D, Pederson R, Thomas ED, Thomson J, Wilmut I, Essentials of Stem Cell Biology, 2nd Edition, Academic Press.*
- *Mummery C, de Stolpe AV, Roelen B, Clevers H, Stem Cells: Scientific Facts and Fiction, 1st Edition, Academic Press.*
- *Bronchud MH, Foote MA, Giaccone G, Olopade OI, Workman P, Antman K, Principles of Molecular Oncology,3rd Edition, Humana Press.*
- *Gelmann EP, Sawyers CL, Rauscher FJ, Molecular Oncology: Causes of Cancer and Targets for Treatment, 1st Edition, Cambridge University Press.*
- *Farooqi AA, Ismail M, Molecular Oncology: Underlying Mechanisms and Translational Advancements, 1st Edition, Springer.*
- *Prendergast GC, Molecular Cancer Therapeutics: Strategies for Drug Discovery and Development, 1st Edition, Wiley-Liss.*
- *Jaffee EM, Prendergast GC, Cancer Immunotherapy, 2nd Edition, Academic Press.*

ILS 310
STRUCTURAL BIOLOGY AND BIOPHYSICS
3 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 and to characterize them by biophysical techniques will also be taught.

COURSE CONTENT

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.

Macromolecular Crystallography: Basic Concepts in Protein Crystallography, Protein Crystallization, Phase Diagram, Crystallization Methods, Principle of Salting Out, X-ray Data Collection in Practice, Synchrotrons, Phase Problem, Structure Solution, Electron Density, Model Building, Structure Refinement, Structure Validation, Ramachandran Plot, Protein Data Bank.

Nuclear Magnetic Resonance: NMR in Structural Biology, Solution *Vs* Solid State NMR, Basic Principle of NMR, NMR Experiment Setup, Types of NMR, Experimental Data collection in NMR, 3D Structure from NMR Data, Challenges in NMR field.

Cryo-Electron Microscopy: Principles of Cryo-EM, Workflow in single particle Cryo-EM, Advances in Cryo-EM and Challenges.

Integrative Structural Biology: Examples and Advantages of Integrative Approaches, Cryo-EM, NMR, X-ray Crystallography, Molecular Dynamics and Mass Spectrometry in Combination.

Biophysical Techniques for Molecular Sizing: Size Exclusion Chromatography, PAGE and Native-PAGE, Light Scattering, Circular dichroism, Analytical Ultra Centrifugation, Small Angle X-ray Scattering.

Biophysical Techniques for Molecular Interactions: Pull-down assays, Spectroscopy, Titration and Scanning Calorimetry, Surface Plasmon Resonance, Electrophoretic Mobility Shift Assays.

SUGGESTED READING

- *Schulz GE, Schirmer RH. Principles of Protein Structure, 1st Edition, Springer.*
- *Branden C, Tooze J. Introduction to Protein Structure, 2nd Edition, 2nd Edition, Garland Science.*
- *Liljas A, Liljas L, Piskur J, Lindblom G, Nissen P, Kjeldgaard M. Textbook of Structural Biology, 2nd Edition, World Scientific.*
- *Rhodes G. Crystallography Made Crystal Clear, 3rd Edition. Academic Press.*
- *McPherson A. Crystallization of Biological Macromolecules, 1st Edition, Cold Spring Harbor Laboratory Press.*
- *Stout GH, Jensen LH. X-Ray Structure Determination: A Practical Guide, 2nd Edition, John Wiley and Sons.*
- *Wilson K, Walker J, Principles and Techniques of Biochemistry and Molecular Biology, 7th Edition, Cambridge University Press.*
- *Robyt JF, White BJ, Biochemical Techniques Theory and Practice, 1st Edition, Waveland Press.*

ILS 311
PHARMACOLOGY, DRUG DISCOVERY AND DELIVERY
2 credit course

This course is designed to give an overview of pharmacology and the processes involved in drug development. The course also covers aspects of designing and formulation of drug delivery systems including latest developments and targeted systems.

COURSE CONTENT

Fundamentals of Pharmacology: Principles of Pharmacology, Principles of Chemotherapy, Principles of Toxicology, Immunopharmacology.

General pharmacology: Pharmacokinetics, Drug interactions, Drug toxicity, Drug allergy and Drug resistance, Drug-receptor interactions, Lipids & drugs, Pharmacogenetics and Immunopharmacology.

Biotechnology in Pharmaceutical Industry: Antibiotics, Vaccines, Biopharmaceuticals, Neutraceuticals.

Pharmacological analyses: Techniques in pharmaceutical analysis, physical and chemical methods in analysis of drugs, Pharmaceutical formulations, Biopharmaceutical evaluation and bioequivalence studies

Pharmacokinetics: Absorption and distribution kinetics, metabolism, clearance, dose adjustment, Therapeutic drug monitoring and Pharmacodynamics.

Pharmacognosy: Ethnomedicine, Aromatic plants, phytochemistry, screening procedures for phytochemicals, drugs derived from plant sources and their applications.

Drug Discovery: Contemporary Approaches to Drug Discovery, Traditional and Rational Drug Discovery and Development, Drug design, Stages in Drug Discovery, Clinical Trials, Structure Activity Relationships, Synthetic approaches to modern drugs.

Drug Delivery: Routes of drug administration, Advanced drug delivery systems, Nanoscience, Nanoparticles as drug delivery platforms.

SUGGESTED READING

- *Harvey RA, Clark MA, Finkel R, Rey JA, Whalen K, Pharmacology (Lippincott's Illustrated Reviews), 5th Edition, Lippincott Williams and Wilkins.*
- *Rang HP, Rang & Dale's Pharmacology, 8th Edition, Churchill Livingstone.*
- *Brunton L, Chabner BA, Knollman B, Goodman & Gilman's the Pharmacological Basis of Therapeutics. 12th Edition, McGraw-Hill Education.*

ILS 312
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.

ILS 313
METHODS IN IMMUNOLOGY AND GENOMICS
4 credit course

The course will involve practical sessions to provide experience in immunological and genomic 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. 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: Immunization of mice and methods of bleeding, serum separation, storage.
Practical 2: Antibody titre determination by ELISA method.
Practical 3: Cytokine analysis
Practical 4: Isolation and purification of IgG from serum.
Practical 5: Blood smear identification of leucocytes by Giemsa stain.
Practical 6: Separation of leucocytes by dextran method.
Practical 7: Separation of mononuclear cells by Ficoll-Hypaque.
Practical 8: Flow cytometry, identification of T cells and their subsets.
Practical 9: RT-PCR to quantitate gene expression.
Practical 10: Introductory tutorial to RNASeq analysis.
Practical 11: Gene Ontology (GO) enrichment and pathway analysis.

ILS 314
METHODS IN PLANT AND ENVIRONMENTAL 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.
Practical 9: Identification and characterization of bacteria from environmental samples
Practical 10: Bioremediation approaches

ILS 401
BIOSTATISTICS AND BIOINFORMATICS
3 credit course

The course will provide information regarding basic concepts and common practices for the analysis of biological data using statistical and bioinformatics 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.

Introduction and Bioinformatics Resources: Knowledge of various databases and bioinformatics tools available at these resources, the major content of the databases, Literature databases:

Sequence analysis: Various file formats for bio-molecular sequences: genbank, fasta, gcg, msf, nbrf-pir etc**.,** Basic concepts of sequence similarity, identity and homology, definitions of homologues, orthologues, paralogues, Scoring matrices: basic concept of a scoring matrix, PAM

and BLOSUM series, Sequence-based Database Searches: what are sequence-based database searches, BLAST and FASTA algorithms, various versions of basic BLAST and FASTA.

Pairwise and Multiple sequence alignments: Basic concepts of sequence alignment, Needleman & Wuncsh, Smith & Waterman algorithms for pairwise alignments, Progressive and hierarchical algorithms for MSA. Use of pairwise alignments and Multiple sequence alignment for analysis of Nucleic acid and protein sequences and interpretation of results.

Phylogeny: Phylogenetic analysis, Definition and description of phylogenetic trees and various types of trees, Method of construction of Phylogenetic trees

Current Advancements in Bioinformatics: Introduction to System Biology, Structural Biology, Structural bioinformatics, Chemoinformatics, Immunoinformatics, etc, 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.

SUGGESTED READING

- *Quinn GP, Keough MJ. Experimental Design and Data, 1st Edition, Cambridge University Press.*
- *Zar JH. Biostatistical Analysis, 5th Edition. Pearson Publishers.*
- *Indrayan A. Medical Biostatistics, 2nd Edition, Chapman and Hall.*
- *Altman DG. Practical Statistics for Medical Research, 1st Edition, Chapman and Hall.*
- *Aurther M lesk, Introduction to Bioinformatics, 3rd Edition, Oxford University Press.*
- *Gibas C, Jambeck P, Developing Bioinformatics Computer Skills: An Introduction to Software Tools for Biological Applications, 1st Edition, O'Reilly Media.*
- *Webster DM, Protein Structure Prediction: Methods and Protocols, Springer.*
- *Xiong J, Essential Bioinformatics, 1st Edition, Cambridge University Press.*
- *Rastogi SC, Mendiratta N, Rastogi P, Bioinformatics: Concepts, Skills and Applications, CBS Press.*
- *Rastogi SC, Mendiratta N, Rastogi P, Bioinformatics: Methods and Applications: (Genomics, Proteomics and Drug Discovery), PHI Learning Press.*

ILS 402
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, Spectroscopy, Flow Cytometry, Bioinformatics, Mass Spectrometry.

Nanobiotechniques: Nanoparticles, Quantum dots, Nanotubes and Nanowires, Different classes of biosensors, Molecular recognition elements and nanosensing, Transducing elements and nanosensing, Lab on a chip, Use of nanoparticles in diagnostics, Drug delivery and Cancer research.

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

- *Wilson K, Walker J. Principles and Techniques of Biochemistry & Molecular Biology, 7th Edition, Cambridge University Press.*
- *Allen T. Microscopy: A very short Introduction, 1st Edition, Oxford University Press.*
- *Katz MJ. From Research to Manuscript: A Guide to Scientific Writing, 2nd Edition, Springer.*
- *Xie Y, The Nanobiotechnology Handbook, 1st Edition, CRC Press.*
- *Hornyak GL, Tibbals HF, Dutta J, Moore JJ, Introduction to Nanoscience and Nanotechnology, 1st Edition, CRC Press.*

ILS 403
ADVANCED TOPICS IN LIFE SCIENCE RESEARCH
2 credit course

COURSE CONTENT

Chromatin and Epigenetics: Histone proteins, histone octamer, and DNA, nucleosome, chromatin, chromatin remodeling, epigenetic code

Genomic Studies: Genomic DNA preparation, DNA sequence analysis methods, DNA fingerprinting, Human genome project and the genetic map, Gene variation and Single Nucleotide Polymorphisms, Expressed sequenced tags, Gene-disease association

Stem cells and Cancer: Pluripotency, Totipotency, Embryonic stem cells, Adult stem cells, Stemness, Stem cells and cancer, Leukemia

Autophagy: Definition of autophagy, Molecular mechanism of autophagy, Autophagy in cell differentiation and embryonic development, Autophagy in defense and inflammation, Autophagy and disease conditions

Host-Microbe Interaction and Vaccine Development: Host-microbe interactions, immune evasion strategies, drug resistance, experimental and genome wide approaches to study microbial pathogenesis, manipulation of host, modulation of host immune response, pathobiology of infection, evolution of pathogens, introduction to vaccinology and current challenges in vaccine development for infectious diseases.

Genetic Disorders and Autoimmune Diseases: Chromosomal genetic disorders, X-liked syndromes, rare genetic diseases, immune regulation and tolerance, autoimmunity, disorders of immune response, development of autoimmune diseases, factors inducing autoimmune diseases, allergy and hypersensitivity and autoimmune diseases (diabetes mellitus, Crohn disease etc)**,** Genetic counseling and ethical issues in Reproductive genetics and Treatment of genetic diseases

Advanced Immunology and Immunogenomics: Immunotherapy, Application of genomics to understand immune system, Immuno-genomics and disease, Autoimmunity, Genomic diversity of immune cells, Primary immune deficiencies, Immune regeneration, Regulation of antigen receptor assembly, Experimental approaches to immunological studies and animal models, Application of genomics to understand immune system, Immunogenomics and disease, Autoimmunity, Genomic diversity of immune cells, Primary immune deficiencies, Immune regeneration.

Systems biology: Mathematics and computation to study complex biological systems, Modelling of metabolic networks, Cell signaling, Omics approach

SUGGESTED READING

- *Allis CD, Caparros ML, Jenuwein T, Reinberg D, Epigenetics, 2nd Edition, Cold Spring Harbor Laboratory Press.*
- *Lanza R, Essentials of Stem Cell Biology, 2nd Edition, Academic Press.*
- *Gottlieb RA, Autophagy in Health and Disease, 1st Edition, Associated Press.*
- *Falus A, Immunogenomics and Human Disease, 1st Edition, Wiley.*
- *Alon U, An Introduction to Systems Biology: Design Principles of Biological Circuits, 1st Edition, Chapman & Hall/CRC.*
- *Mackay IR, Rose NR, The Autoimmune Diseases, 5th Edition, Elsevier.*
- *Oksenberg JR, Brassat D, Immunogenetics of Autoimmune Disease, 1st Edition, Springer*
- *Male DK, Champion B, Cooke A, Advanced Immunology, 1st Edition, Mosby.*
- *Kulkarni S, Pfeifer J, Clinical Genomics, 1st Edition, Academic Press.*
- *Ginsburg GG, Willard HF, Essentials of Genomic and Personalized Medicine, 1st Edition, Academic Press.*
- *NCBI, Genes and Diseases, National Center for Biotechnology Information (US) Bethesda (MD).*

ILS 404
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 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 institute.

For developing the writing skills, the student will choose an area related to his research interest and write a short project proposal with background, objectives, research methodologies and expected outcomes. The area may be chosen in consultation with the guide who should help the student with the preparation of the report.

ILS 405
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.

ILS 406
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/her novel findings in the form of a PhD thesis.