RAJIV GANDHI CENTRE FOR BIOTECHNOLOGY,
THIRUVANANTHAPURAM 695014, KERALA STATE, INDIA

An Autonomous National Institute for Discovery, Innovation & Translation
In Biotechnology and Disease Biology,
Government of India,
Ministry of Science & Technology, Department of Biotechnology.

MSc BIOTECHNOLOGY PROGRAM

AFFILIATED TO REGIONAL CENTRE FOR BIOTECHNOLOGY

MSc IN BIOTECHNOLOGY

Stream 1: Disease Biology
Stream 2: Genetic Engineering

MSc BIOTECHNOLOGY PROGRAM WITH TWO STREAMS AFFILIATED TO UNESCO-RCB

Stream 1: Disease Biology
Stream 2: Genetic engineering

CONTENTS

Duration of the Course: Two years (four semesters)

Objectives of the program

Biotechnology is a much wanted field of study that evolved from many revolutions in biology, chemistry, computational sciences and engineering, which allows students to keep up with the pace of new discoveries and remain competitive in the realm of applied sciences. Biotechnology makes use of biological systems, living organisms and its components to create products and other technological systems and may come in the form of increased food production, medical breakthroughs or health improvement as result of new knowledge and products. Biotechnology is a big concept and encompasses many industries, but with a common emphasis on the use of living organisms to reach whatever goal its branch may have. It aims to develop technologies and procedures to modify living organisms to improve human living.

The MSc program at RGCB will be unique, as it will cover the fundamental fields of theories in Biotechnology, while focusing on laboratory exercises and industrial as well as research applications. The students will be introduced to the concepts of “Enterprise and Entrepreneurship”. This allows students who wish for a career beyond the laboratory in an existing biotechnology industry or for those who dream of starting a new biotechnology enterprise. Students get trained in a real business & technology development bio-incubator where startup companies function. Every student will have a personal tutor who will constantly provide mentorship for course work as well as pastoral advice on living through the entire course.

We aim at developing and retaining a sustainable pipeline of biotechnology professionals across a range of related disciplines including fundamental science, technology development, translation, policy and outreach through efforts in education, training, and career development.

Number of seats per year: 15 per stream; Total 45 students.

Eligibility criteria

Students with 60% aggregate marks (or an equivalent grade point average) in Bachelor's degree in any branch of Science, Engineering, or Medicine are eligible to be apply for admission. Students from the SC, ST, OBC (non-creamy layer), and PWD categories shall be given a relaxation of 5% aggregate marks. Students in the final year of their qualifying degree program are also eligible to apply provided that they produce a proof of having secured the required marks in their undergraduate degree program at the time of admission.

Reservation

There shall be reservation of seats for students from the SC, ST, OBC, PWD and Economically backward categories as per the rules and regulations of the Government of India.

COURSE DETAILS AND SYLLABUS FOR TWO MSc BIOTECHNOLOGY COURSES AT RGCB

Stream 1: Disease Biology
Stream 2: Genetic Engineering

CORE COURSES (for all two streams)

ONE CREDIT = 12 TEACHING HOURS

SEMESTER I

CODE	COURSE	CREDIT (S)
RGC 301	**Biochemistry and Biophysics** *This course is designed to provide students a broad understanding of basic macromolecules of life. This course will also cover a wide range of topics applying physical principles and techniques to different problems in biology.* Unit I: Basic principles and role of 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. Unit II: 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. Unit III: Enzymes General principles of enzyme catalysis, Activation energy and stereospecificity, Quantitation of enzyme activity and efficiency, Enzyme characterization and Michaelis-Menten kinetics, Regulation and Inhibition of enzymes, Enzymes and Metabolic pathways, Study of model enzymes such as proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase. Production of industrial enzymes, enzyme immobilization Unit IV: Carbohydrates, Lipids and Nucleic Acids Carbohydrates: Monosaccharides and Disaccharides, Polysaccharides, Nucleic Acids: Nucleotides, Nucleic Acid composition,a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material. Lipids: Storage lipids, Structural lipids in membranes, Lipoproteins. Lipids as signals, cofactors and pigments Unit V: Biological Membranes Composition and architecture, Membrane dynamics, Anchoring of proteins in membranes, Organization of proteins on membranes, Solute Transport across membranes, Membrane vesicles. Unit VI: Bioenergetics & Metabolism Principles of bioenergetics, Glycolysis, Citric acid cycle, Oxidative phosphorylation, Photosynthesis, Biosynthesis of amino acids, lipids, nucleotides.	**3**
RGC 302	**Microbiology** *This course is designed to cover fundamental aspects of the microbial world (pathogenic and non- pathogenic) with special emphasis on how microbes live, divide and cause diseases, understanding the contribution of their genomes.*	**3**

	Unit I: Microbial characteristics and diversity Introduction to microbiology and microbes. General organization of a microbial cell morphology, structure, growth and nutrition of bacteria, bacterial growth curve, bacterial culture methods; Gram staining and microbial typing, Cell wall and cell organelle structure and organization of various microbes. Microbial taxonomy: classification of microorganisms, criteria for classification. Prokaryotes, Eukaryotes and Archaea. Microbial evolution of diversity. Unit II: Microbial Metabolism and genetics Metabolic pathways of microbes, Photophosphorylation; nitrogen metabolism, symbiotic microbes, nitrogen fixation and its regulation; sulphate-metabolism; putrefaction, methane oxidizing and methanogenic bacteria. Bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation; antimicrobial resistance. Pasteur experiment and Griffith's experiment, Modes of genetic exchange in microbes. Unit III: Microbes and Health Pathogenic bacteria and viruses, Human microbiota and their role in human health, Drug-resistant bacteria, biofilms, antibiotics and antimicrobial agents, Protozoan parasites and human diseases. Antibiotics, antiviral and antifungal drugs, biological control of microorganisms. Virus and bacteriophages Unit IV: Host-Microbe interaction Host-pathogen interaction, ecological impact of microbes; microbial communication system; bacterial quorum sensing; microbial fuel cells; prebiotics and probiotics. Unit V: 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 Unit VI: Virology Viruses and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles –viroids and prions. Viruses, bacteriophages and their applications. Unit VII: Fermentation technology Bioreactors, biochemistry of fermentation, Downstream processing for product recovery, Production of different Bio-products involving microbes.	
RGC 303	**Immunology** *This course will provide information regarding the immune system involving different molecules, cells and processes.* Unit I: Introduction to Immunology and innate immunity Fundamental concepts and overview of the immune system Components of innate and acquired immunity; Innate immune cells and functions; phagocytosis; complementand inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); Major Histocompatibility Complex Organs of immune system, primary and secondary lymphoid organs. Unit II: Adaptive immune system Immunoglobulins, B-cell receptor, B cell and T cell maturation, activation and differentiation; cell-mediated immune responses, antigen processing and presentation,	**2**

	Adaptive immune system and response, antigen-antibody interactions, immunological techniques Unit III:Immunotechnology Principles of immunization, Vaccine development, Immunotherapy, Development of monoclonal antibodies, Gene editing technology in designing antibody, Designing antibody library for immunotherapy. Unit IV: Immunogenetics Major histocompatibility complex genes, HLA typing, Complement genes, implication for linkage disequilibrium and disease associations, genetic studies of rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis, genetics of human immunoglobulin, immunogenetics of spontaneous control of HIV complex.	
RGC 304	**Cell and Molecular Biology** *The objectives of this course are to introduce students to fundamental concepts of cell biology. The course will also cover various biological and molecular processes associated with DNA, RNA and proteins.* Unit I: 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, Proteins sorting, Compartmental diversity, Endocytosis, Exocytosis, Secretory pathway, Mechanisms that maintain compartmental identity and crosstalk. Unit II: 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. Unit III: Cell cycle and regulation The cell cycle and its control system, Interphase, Mitosis, Cytokinesis and molecular regulation, cell transformation, cell death and apoptosis. Unit IV: Intercellular communication Transport mechanisms across membrane, Cell signaling, Cell junctions, Cell adhesion and the extracellular matrix, Specialized cells, tissues, stem cells and tissue renewal. Unit V: Genome, DNA Replication, Repair & Recombination Genome: Composition and Structure of DNA, Supercoiling, Epigenetic modification, Replication of single stranded circular DNA. 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. Unit VI: Chromatin structure and dynamics Chromatin and chromatin control, Transcriptional control, post-transcriptional control, miRNAs and siRNAs, protein translation machinery, ribosomes, universal genetic codes, degeneracy of codons, Wobble hypothesis, co- and post-translational modifications Unit VII: Transcription and Translation Prokaryotic Transcription: Transcription unit, Promoters - Constitutive and Inducible, Operators, Regulatory elements, Initiation, Attenuation, Termination, Anti-termination; Transcriptional regulation: Positive and negative, Operon concept; Eukaryotic	**3**

	transcription: RNA polymerase structure and assembly, 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: 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.	
RGC 305	**Methods in Biochemical Techniques** Practical 1: Preparation and assessment of quality of 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.	**4**
RGC306	**Methods in Microbiology and Cell Biology** 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, Identification of bacteria by biochemical assays and Gram staining. Practical 5: Antibiotic or drug inhibition assays. Practical 6: Mammalian cell culture, counting, and cryopreservation. Practical 7: Staining of various cellular compartments. Practical 8: Expression of foreign protein in mammalian cells. Practical 9: Mammalian virus culture and titration.	**4**
RGC 307	**Methods in Immunology** 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: Flow cytometry, identification of T cells and their subsets. Practical10: Lympho-proliferation by mitogen antigen induction.	**4**
RGC 308	**Scientific Engagement-I** 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.	**1**
	Total Credit	**24**

PRESCRIBED READING

RGC 301	**Biochemistry and Biophysics** 1. Nelson, D. L., Lehninger, A. L., & Cox, M. M. (2008). *Lehninger principles of biochemistry*. Macmillan. 2. Tymoczko, J. L., Berg, J. M., &Stryer, L. (2011). *Biochemistry: a short course*. Macmillan. 3. Cornish-Bowden, A. (2014). *Principles of enzyme kinetics*. Elsevier. 4. Haynie, D. T. (2001). *Biological thermodynamics*. Cambridge University Press. 5. Voet, D., &Voet, J. G. (2016). *Fundamentals of Biochemistry*. *5th edn*.Wiley & Sons.
RGC 302	**Microbiology** 1. Pelczar, M. J., Chan, E. C. S., & Krieg, N. R. (2001). Text book of microbiology. *MC Graw-Hill publications, 5th edn, New York*, *1193*, 504-508. 2. Sherwood, L., Willey, J. M., &Woolverton, C. (2011). *Prescott's microbiology*. McGraw-Hill. 3. Black, J. G. (2005). *Microbiology: principles and explorations*(Vol. 1). John Wiley & Sons Incorporated. 4. Hogg, S. (2013). *Essential microbiology*. John Wiley & Sons. 5. Stanbury, P. F., Whitaker, A., & Hall, S. J. (2013). *Principles of fermentation technology*. Elsevier.
RGC 303	**Immunology** 1. JanewayJr, C. A., Travers, P., Walport, M., &Shlomchik, M. J. (2001). The complement system and innate immunity. In *Immunobiology: The Immune System in Health and Disease. 5th edition*. Garland Science. 2. Virella, G. (2001). *Medical immunology*. CRC Press. 3. Abbas, A. K., Lichtman, A. H., &Pillai, S. (2014). *Cellular and molecular immunology E-book*. Elsevier Health Sciences. 4. Khan, F. A. (2014). *Biotechnology in medical sciences*. CRC Press. 5. Pongracz, J., & Keen, M. (Eds.). (2009). *Medical biotechnology*. Elsevier Health Sciences. 6. Goldsby, R. A., Kindt, T. J., Osborne, B. A., &Kuby, J. (2003). Immunology New York.
RGC 304	**Cell and Molecular Biology** 1. Alberts, B., Johnson, A., Walter, P., Lewis, J., Raff, M., & Roberts, K. (2008). Molecular cell biology. *New York: Garland Science*. 2. Lodish, H., Berk, A., Darnell, J. E., Kaiser, C. A., Krieger, M., Scott, M. P. &Matsudaira, P. (2008). *Molecular cell biology*. Macmillan. 3. Lewin, B., Krebs, J. E., Goldstein, E. S., & Kilpatrick, S. T. (2014). *Lewin's Genes XI*. Jones & Bartlett Publishers. 4. Cooper, G. M., Hausman, R. E., &Hausman, R. E. (2000). *The cell: a molecular approach* (Vol. 2). Washington, DC: ASM press.. 5. Hardin, J., Bertoni, G. P., &Kleinsmith, L. J. (2017). *Becker's World of the Cell*. Pearson Higher Ed. 6. Baker, T. A., Watson, J. D., & Bell, S. P. (2003). *Molecular biology of the gene*. Benjamin-Cummings Publishing Company.

SEMESTER 2

CODE	COURSE	CREDIT (S)
RGC 309	**Genetics and Genetic Engineering** *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 and genetic disorders.* Unit I: 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, epistasis, quantitative genetics, population and evolutionary genetics Unit II: Chromosomes and inheritance Chromosomes and their role in inheritance, chromosomal aberrations, sex determination and transposable elements, Genetics in animal development. Unit III: Human Genetics Recent advances in human molecular genetics, introduction to the human genome, pedigree analysis, gene mapping and linkage analysis, Diagnosis and genetic counselling in genetic and metabolic disorders. Unit IV: Methods and Tools for genetic engineering Isolation and quantification of nucleic acids, Gel electrophoresis, Enzymes such as restriction endonucleases, ligases etc., Different types of vectors for gene cloning and protein expression, cohesive and blunt end ligation, linkers, adaptors, homopolymeric tailing, Hybridization techniques, gene synthesis, Unit V: PCR techniques Principles of PCR, Primer design, Types of PCR, T-vectors, proof reading enzymes; Site specific mutagenesis; PCR in molecular diagnostics, sequencing methods; mutation detection: SSCP, DGGE, RFLP Unit VI: Gene manipulation and protein-DNA interaction Insertion of foreign DNA into host cells; construction of libraries; isolation of RNA, reverse transcriptase and cDNA synthesis; cDNA and genomic libraries, study of protein-DNA interactions, Gene silencing technologies, genome editing by CRISPR-Cas.	**3**
RGC 310	**Proteomics and Genomics** *The objective of this course is to provide introductory knowledge concerning genomics, proteomics and their applications.* Unit I: Introduction to Genomics Organization of genome in Prokaryotes and Eukaryotes; C-value paradox, Organelle DNA; DNA sequencing-principles and translation to large scale projects; Recognition of coding and non-coding sequences and gene annotation; Tools for genome analysis-RFLP, DNA fingerprinting, RAPD, PCR, Linkage and Pedigree analysis-physical and genetic mapping Unit II: Genome sequencing projects Microbes, plants and animals; Accessing and retrieving genome project information from web; Comparative genomics, Identification and classification using molecular	**2**

	markers-16S rRNA typing/sequencing, ESTs and SNPs, ENCODE project, exome sequencing and Databases Unit III: Proteomics Protein analysis (includes measurement of concentration, amino-acid composition, N-terminal sequencing);2-D electrophoresis of proteins; Micro-scale solution iso-electric focusing; Peptide fingerprinting; LC/MS-MS for identification of proteins and modified proteins; MALDI-TOF; Differential display proteomics, Yeast/Bacterial two hybrid system Unit IV: Functional genomics and proteomics Analysis of microarray data; Protein and peptide microarray-based technology; SAGE, RNA-Seq & Transcriptomics, Chip-Seq; PCR- directed protein *in situ* arrays; RNAi screens, Protein-protein interactions & Interactome studies.	
RGC 311	**Bioinformatics and Structural Biology** *The course will provide an overview on the databases and methods available to exploit genomics data. Also, the function of the majority of biological macromolecules is governed by their three dimensional structure. This course will introduce basic concepts regarding macromolecule structure and the computational/experimental methods utilized to obtain structural information.* Unit I: Tools for Bioinformatics Introduction to UNIX environment, Unix file system; Installing & executing programs in LINUX environment; Web-Based & Command-Line Software culture, Basic command line operations; Fundamentals of computer programming & Biostatistics – Python and R package. Introduction to common text editors. Unit II: Biological data resources Biological data resources, access & management–Genomes across the tree of life, Major sequencing projects, Major centralized bioinformatics databases to store DNA, RNA, protein sequences & 3-D structures. Navigating through major resources and services at NCBI, Web based and command- line access to information. Overview of major web resources for the study of genomes. Unit III: Biological sequence analysis Scoring matrices; Evaluation of significance of results using E-value and Bit score; Sequence alignment programs, Molecular Phylogenetics, Web resources available for Plants. Unit IV: 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. Unit V: Structure determination of Macromolecules Basic concepts and methods in Macromolecular Crystallography, Nuclear Magnetic Resonance, Cryo-Electron Microscopy, Circular dichroism, Forster Energy, Resonance Transfer, Small Angle X-ray Scattering, Mass Spectrometry, Dynamic Light Scattering, Analytical Ultracentrifugation, Computational Methods for determination of structure, Molecular Dynamics Simulations.	**2**
RGC 312	**Biostatistics and Data Analysis** *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*.	**2**

	Unit 1: 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;Measuresof averages and location; Measures of dispersion; Probability and probability theory, Use of statistical packages on biologicaldata. Unit II: 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; Storing Data in public repositories; Applications ofNGS. Unit III: Transcriptomics and Proteomics Data Analysis Next generation sequence analysis – RNA Introduction to Microarrays and RNA-Seq: Data acquisition & Analysis. Microarray data analysis using TopHat and Cuffflinks, Functional annotation of microarray/Rna-seq data. Proteomics: Protein analysis & prediction using different Protein Data Bank (PDB); Basics of Protein Structure Prediction (Homology Modeling, Fold Recognition, Ab-Initio Prediction); Proteomic resources; Fundamentals of molecular docking, Chip-Seq data analysis.	
RGC 313	**Research Methodology** *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*. Unit I: Research Design, Conduct, Regulation, 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, Regulatory issues in Biotechnology, Maintenance of laboratory notebooks, Grant/Fellowship/Report writing, Manuscript Writing, Seminar Presentation. Unit II: Literature Search, Use of Databases and Experimental Design Databases for literature search, Bibliometrics, Citation, Impact factor, Hypothesis as a framework for scientific projects, Experimental design, taking measurements, Data Analysis, sampling, statistical tests with excel, handling data, hypothesis testing Unit II: Good Laboratory Practices Responsibilities of a researcher, handling and storage of biological material, laboratory waste disposal, management of personnel, facilities, buildings and equipment. Unit III: Bio-entrepreneurship and IP management in Biotechnology Bio-entrepreneurship, Funding options, Introduction to Intellectual Property Rights, Types of IP, Patent search, IP management, Technology transfer.	**2**
RGC 314	**Methods in Genetic Engineering** 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.	**4**

	Practical 9: Confirmation of DNA cloning through PCR and restriction digestion.	
RGC 315	**Methods in Bioinformatics** Practical 1: Basic UNIX commands for routine tasks Practical 2: Running NCBI-BLAST for protein, DNA and RNA sequences. Practical3: Installation of NCBI SRA toolkit and to download raw sequencing data (DNA-seq, RNA-seq, ChIP-seqetc). Practical 4: Simple applications of UCSC Genome Browser like Quality Check of raw sequencing data and estimation of number of SNPs per exon in human chromosome 22. Practical 5: Processing of raw sequencing data like adapter trimming, removal of bad quality reads and trimming bad quality tails of reads etc. Practical 6: Alignment of reads against reference genome using bowtie or bwa or/and tophat, STAR aligner etc including analysis of output files. Practical 7: Visualization of protein structures using Pymol, Rasmol& UCSF Chimera etc. Practical 8: Homology modelling using Swiss Model and/or Modeller. Practical 9: Calculation of binding affinity (K_d) for protein-ligand interactions using Autodock and/or DOCK.	**4**
RGC 316	**Methods in Proteomics** Practical 1: Protein isolation from cells and protein estimation for proteomics analyses. Practical 2: Gel based proteomics (all steps in two-dimensional gel electrophoresis). Practical 3: Demonstration of biological mass spectrometry & soft ionizations (MALDI-TOF & ESI-Q-TOF). Practical 4: In-gel and in-solution trypsin digestion of protein. Practical 5: Sample preparations for MALDI & Electro Spraylonization. Practical 6: Protein identification by peptide mass fingerprinting & database search. Practical 7: Protein identification by MS/MS sequencing & database search. Practical 8: High throughput proteomic protein profiling, data pre-processing,quality control and post-MS data analyses. Practical 9: Analyses of protein post-translational modifications. Practical 10: Label-free protein relative quantification or protein expression	**4**
RGC 317	**Scientific Communication** 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.	**1**
	Total Credits	**24**

PRESCRIBED READING

RGC 309	**Genetics and Genetic Engineering** 1. Klug, W. S., Cummings, M. R., Spencer, C. A., &Palladino, M. A. (2015). *Concepts of Genetics*. 11th Edition. Pearson Higher Ed. 2. Snustad, D. P. & Simmons, M. J., (2015). *Principles of genetics*. 7th Edition. John Wiley & Sons. 3. Pierce, B. A. (2017). *Genetics: A conceptual approach*. 6th Edition Macmillan. 4. Green, M. R., &Sambrook, J. (2012). Molecular cloning. *A Laboratory Manual,* 4th Edition, CSHL Press. 5. Watson, J. D, Baker, T. A., Bell, S. P., Gann, A., Levine, M. &Losick, R.M. (2013). *Molecular*

	biology of the gene. 7th Edition. Pearson. 6. Krebs, J. E., Goldstein, E. S., & Kilpatrick, S. T. (2017). *Lewin's Genes XII*. 12th Edition Jones & Bartlett Learning.
RGC 310	**Proteomics and Genomics** 1. Voet, D., Voet, J. G., & Pratt, C. W. (2016). *Fundamentals of biochemistry: life at the molecular level*. 5th Edition. John Wiley & Sons. 2. Campbell, A. M., &Heyer, L. J. (2006). *Discovering genomics, proteomics, and bioinformatics*. 2nd Edition. Pearson. 3. Primrose, S. B., &Twyman, R. (2013). *Principles of gene manipulation and genomics*. John Wiley & Sons. 4. Glick, B. R., Pasternak, J. J., & Patten, C. L. (2010). *Molecular biotechnology: principles and applications of recombinant DNA*. Washington, DC: ASM Press.
RGC 311	**Bioinformatics and Structural Biology** 1. Schulz, G. E., &Schirmer, R. H. (2013). *Principles of protein structure*. Springer Science & Business Media. 2. Liljas, A., Liljas, L., Piskur, J., Nissen, P., &Kjeldgaard, M. (2009). *Textbook of structural biology*. World Scientific Publishing Company. 3. Lesk, A. (2014). *Introduction to bioinformatics*. Oxford University Press. 4. Tramontano, A. (2006). Protein structure prediction: concepts and applications. In *Protein Structure Prediction: concepts and applications.*
RGC 312	**Biostatistics and Data Analysis** 1. Mann, P. S. (2007). *Introductory statistics*. John Wiley & Sons. 2. Rice, J. A. (2006). *Mathematical statistics and data analysis*. Cengage Learning. 3. Campbell, A. M., &Heyer, L. J. (2003). *Discovering genomics, proteomics, and bioinformatics* (No. QH447 C35 2007). San Francisco: Benjamin Cummings.
RGC 313	**Research Methodology** 1. Katz, M. J. (2009). *From research to manuscript: a guide to scientific writing*. Springer Science & Business Media. 2. Holmes, D. , Moody, P., Dine, D. and Trueman, L.(2016). Research Methods for the Biosciences. Oxford University Press. 3. Glass, D.J. (2014). Experimental Design for Biologists, Cold Spring Harbor Laboratory. 4. Ruxton, G.D. and Colegrave, N.(2016). Experimental design for the Life Sciences 4th Edition Oxford University Press. 5. https://www.who.int/tdr/publications/documents/glp-trainer.pdf 6. http://www.w3.org/IPR/http://www.wipo.int/portal/index.html 7. http://www.ipr.co.uk/IP_conventions/patent_cooperation_treaty.html 8. http://www.cbd.int/biosafety/background.shtml 9. http://web.princeton.edu/sites/ehs/biosafety/biosafetypage/section3.html

STREAM SPECIFIC COURSES

SEMESTER III

STREAM 1: DISEASE BIOLOGY

ONE CREDIT = 12 TEACHING HOURS

Code	Course	Credit(s)
RGC 401	**Human Anatomy and Physiology** *This course covers all major organs and systems of human body, including basic anatomy, cellular structure and function, integration, organization and control of the body systems.* Unit I: Cellular and tissue level of organization Chemical and Cellular levels of organization, cell division, cellular diversity and cell ageing. Tissue level of organization, epithelial and connective tissues, muscular tissue, nervous tissue and tissue repair. Unit II: Bone, skeletal and muscular systems Overview of the skeletal and muscular systems, skeletal muscle tissue, contraction and relaxation of skeletal muscle fibers, muscle metabolism, cardiac muscle tissue, smooth muscle tissue regeneration of muscle tissue, ageing and muscle tissue, structure and functions of the bone, bone formation, fracture and repair of the bone, role of bone in calcium homeostasis; ageing and bone tissue. Unit III: Nervous tissue Overview of the nervous system, histology of nervous tissue, electrical signals in neurons, signal transmission at synapses, neurotransmitters, neural circuits, central nervous system, brain organization, blood supply to brain and spinal cord, cerebrospinal fluid, somatic and autonomic nervous systems Unit IV: Endocrine system Overview of the endocrine system, endocrine glands, hormones and their function, mechanisms of hormone action, hormone-producing glands (hypothalamus, pituitary, pineal gland, thyroid, parathyroid, adrenals, pancreas, ovaries and testis). Unit V: Blood, Cardiovascular and Lymphatic systems Overview of blood, cardiovascular and lymphatic systems, anatomy of the heart, blood circulation to heart, heart valves, cardiac muscle tissue and contraction, cardiac cycle, anatomy and function of blood vessels, capillary exchange, hemodynamics, regulation of blood pressure, circulatory routes, shock and homoeostasis, anatomy and function of lymphatic system, development of lymphatic tissues. Unit VI: Respiratory system Overview of the respiratory system, anatomy of the respiratory system, pulmonary ventilation, exchange of oxygen and carbon dioxide, transport of oxygen and carbon dioxide, control of respiration. Unit VII: Digestive and Gastro-intestinal systems Overview of the digestive system: peritoneum, mouth, pharynx, esophagus, stomach, pancreas, liver, gall bladder, small intestine and large intestine; and phases of digestion. Fluid	**3**

	compartments, electrolytes and acid-base homeostasis. Unit VIII: Urinary system Overview of urinary system, structure and function of kidney, glomerular filtration, tubular reabsorption and secretion. Unit IX: Reproductive system Overview of male and female reproductive systems, hormones, female reproductive cycle.	
RGC 402	**Human Diseases and Health Care Policy** *Over the last decade, there has been increasing recognition of the value of epidemiological analysis in aiding the design and interpretation of diseases from a population perspective. This course will provide a study based understanding of epidemiology, pathophysiology and treatment of common human diseases as well as the healthcare policy of India.* Unit I: Epidemiology. Overview of epidemiology, epidemiology tools, definition and natural history of diseases, quantifying disease in population, comparing disease rate, outbreaks of disease, epidemiological aspects of infections and chronic diseases of national importance. Unit II: Basics of Pathophysiology. Introduction to the basics of pathophysiology, altered cellular and tissue biology, cellular adaptation, atrophy, hypertrophy, hyperplasia, dysplasia, metaplasia, cell injury, immunological & inflammatory injury, manifestations of cellular injury, cell death: apoptosis, necrosis and autophagy. Unit III: Pathophysiology of Organ Dysfunction and Disorders. Diseases of nervous system: definition of pain, neuro anantomy of pain, sleep disorders, alteration of cognitive systems, seizure disorders, alterations in cerebral hemodynamics, alterations in neuromotor functions, disorders of the central and peripheral nervous systems and neuromuscular junctions. Diseases of the endocrine system: alterations of the hypothalamic and pituitary systems and diseases, thyroid dysfunction and diseases, endocrine pancreas dysfunction and diseases, adrenal dysfunction and diseases. Disorders of perfusion, alterations of hemostasis, vascular disorders, coronary circulation disorders, cardiac disorders and heart failure. Reproductive dysfunctions, female and male reproductive disorders, sexually transmitted diseases. Unit IV: Public Heath Policy. Overview of public health policy, overview of WHO and global health policies, overview of Indian public health policies, Indian public health policies for infections and chronic diseases, concept of one health, design and implementation of public health policy, impact of socioeconomic and political factors on public health care policy. Unit V: Health Care Management Overview of public health care management in India and other countries. Strategic health care management to major health care challenges in India. Health care management for major diseases in India. Organizational performance of hospitals, physician practices and community health care centers for treating above diseases.	**2**
RGC 403	**Introduction to Drug Discovery and Development** *In this course, students will gain a comprehensive understanding of the principles of Drug Discovery and Development.* Unit I: Drug Discovery and Development. An Overview of Modern Methods and Principles; Different domains and steps in drug discovery and development; Challenges in modern drug discovery	**2**

	Unit II: Classical Targets in Drug Discovery Protein Structure, Enzymes, Inhibition of Enzymes, G-Protein-Coupled Receptors (GPCRs), Ion Channels, Membrane Transport Proteins (Transporters), Emerging Targets Unit III: In vitro Screening Systems. The Language of Screening: IC50, EC50, GI50 values. Biochemical versus Cellular Assays; Assay Systems and Methods of Detection; Radio ligand Assay Systems; Enzyme-Linked Immunosorbent Assay (ELISA); Fluorescence-Based Assay Systems; Reporter Gene Assays; Kinetic Fluorescent Measurement Systems; Label-Free Assay Systems; Electrophysiological Patch Clamp Assays; Application of Streptavidin and Biotin affinity assays. Unit IV: Medicinal Chemistry, Safety and Toxicology Basic understanding of the medicinal chemistry & Structure Activity Relationship, hit identification to lead development process; Basic principal of Pharmacokinetics and Pharmacodynamics; Ligand and Target based Toxicity; Acute versus Chronic Toxicity; Carcinogenicity, Genotoxicity, and Mutagenicity; Drug–Drug Interactions; Cardiovascular Safety and Toxicology Studies; Central Nervous System Safety and Toxicology Studies Unit V: Basics of Clinical Trials and Biomarkers Phases of Clinical Trails (I-IV), Translational Medicine and Biomarkers; Definition of a Biomarker and Their Classification; Characteristics and Impact of Biomarkers; the Practical Application of Biomarkers.	
RGC 404	**Human Disease Biology** *This course will provide detailed understanding of cancer,diabetes and cardiovascular disorders, and also infectious diseases and stem cell disorders.* **Cancer** Unit I: Fundamentals of cancer Overview of cancer biology, nature of cancer, classification of cancers and tumors, cancer epidemiology. Unit II: Etiology of cancer Tobacco and cancer development, cancer susceptibility syndromes, viruses and cancer (RNA and DNA viruses), inflammation and cancer, chemical & physical carcinogens, carcinogenesis, types of carcinogenesis, diet and cancer. Unit III: Molecular Biology of Cancer Cellular Oncogenes, tumor suppressor genes, signaling, cell cycle regulation, programmed cell death, telomeres. Unit IV: Invasion and Metastasis Angiogenesis and its implication in tumor progression, evolution and pathogenesis of metastasis, models for metastasis, cancer stem cells. Unit V: Tumor Immunology and Immunotherapy Anti-tumor immune response of regulatory T cells, NK cells, immune surveillance theory, tumor associated antigens, evasion of immune surveillance by cancer cells, principles of immunotherapy, CART cells. Unit VII: Cancer treatment and management Cancer treatment – radiation, chemotherapy and surgery, use of cell kinetics to optimize cancer treatment, principles of drug trials for new cancer treatment, monoclonal antibodies as anti cancer agents, new modalities in cancer treatment.	**4**

Diabetes and Cardiovascular Diseases

Unit I: Diabetes
Overview of diabetes, types of diabetes (Type I, II diabetes mellitus and MODY), pathophysiology of diabetes, clinical symptoms of diabetes, hyperglycemia, insulin resistance, alteration in blood lipid signatures,vascular clot formation, atherosclerotic clot formation,activation of vascular endothelium, vascular complications, treatment and management.

Unit II: Cardiovascular Diseases
Overview of cardiovascular diseases, pathophysiology and changes in circulation of heart, cardiac electrophysiology, diagnosis of altered coronary arteries and veins, risk factors, coronary artery disease, congenital heart defects; heart failure, venous diseases, pulmonary vascular disease, rheumatic heart disease, pericardial diseases and endocarditis; diagnostic/prognostic methods of cardiovascular diseases. Recent advances in cardiovascular disease therapeutics, experimental models of cardiovascular diseases.

Infectious Diseases

Unit I: Viral Infections

Overview of viral infection, structure and classification of viruses, viral diseases, epidemiology, pathogenesis and clinical symptoms, vaccines and antiviral strategies, treatment and management.

Unit II: Bacterial Infections.
Overview of bacterial infections, structure and classification of bacteria, molecular biology of pathogen-host interaction, human microbiota and their role in human health, gut microbiom, chronic microbial infections and their long-term consequences, drug-resistant bacteria, biofilms, antibiotics and antimicrobial agents, treatment and management.

Unit III. Protozoan infections.
Overview of protozoan infections, classification, diseases, epidemiology, pathogenesis, treatment and management.

Stem Cell and Developmental Disorders

Unit I: Stem Cells
Overview of stem cell biology, culture, derivation, differentiation of embryonic/adult/fetal stem cells, differentiation to different lineages, clinical applications, stem cell niches, organoids; and cancer stem cells.

Unit II: Stem Cell Disorders
Overview of stem cell dysfunctions and disorders, stem cell aplasia (aplastic anemia), monoclonal hematopoietic stem cell proliferative syndrome (leukemia and myelodysplastic syndrome), and polyclonal hematopoietic stem cell proliferative syndrome (systemic and organ-specific autoimmune diseases), mesenchymal stem cell disorders (Alzheimer's disease, osteoporosis, and lung fibrosis) and organ-specific stem cell disorders (carcinosarcoma in the lung and adeno-endocrine cell carcinoma in the stomach), pathogenesis and treatment.

Unit III: Therapeutic applications of stem cells
Clinical and experimental applications of stem cells, tissue engineering approaches for stem cells, ethical issues of using these cells, clinical facilities required for human stem cell transplantation. Current therapeutic use of stem cells in disease: neural disorders,

	hematopoietic disorders and cardio vascular diseases, use of embryonic stem cells, derivation of induced pluripotent stem cells (iPSCs), recent advances in use of iPSCs, different kind of stem cell banking. Unit IV: Developmental Disorders Overview of developmental disorders, childhood anxiety disorders, attention-deficit hyperactivity disorder (ADHD), conduct disorder, autism, and intellectual disability (intellectual developmental disorder), prevalence and pathogenesis, treatment.	
RGC 405	**Methods in Cell & Molecular Biology applied toCancer and Cardiovascular Disease Biology** Practical 1: Immunocytochemistry and immunohistochemistry for the detection of tumor specific markers in different types of cancers Practical 2: Genotyping of HPV viruses Practical 3: Apoptosis assay Practical 4: Flow cytometry based analysis of cancer cell cycle. Practical 5: Cancer cell invasion assay by matrigel invasion and scratch assay Practical 6: In vivo Tumorigenic assay in NOD-SCID mice Practical 7: Metastatic assay- Tail vein Injection of cells in NOD-SCID mice followed by IHC of metastatic lesions. Practical 8: Telomere repeat assay Practical 9: Staining of animal heart tissues including masson trichome and Oil Red O staining.	**3**
RGC 406	**Methods in Cell & Molecular Biology applied to Infectious Disease Biology** Practical 1: Culture and Isolation of animal viruses Practical 2: Haemagglutination and Hemaglutination inhibition assays Practical 3: ELISA method for virus Ag/Ab detection Practical 4: Detection of viral proteins by Western Blot Practical 5: PCR based detection of viral nucleic acid Practical 6: Viral genome sequencing by Sanger's method Practical 7: Basic computational approaches in viral phylogenetics- Sequence alignment by Clustal W, construction of Neighbour Joining trees Practical 8: Bacteriological examination of water Practical 9: Isolation of Metagenome from microbial populations in environmental samples and gut microbiome Practical 10: Detection of protozoa in contaminated water samples.	**4**
RGC 407	**Methods in Stem Cell Biology** Practical 1: Observation and understanding the cell morphology of mouse/human embryonic stem cell in culture condition Practical 2: Culture and passaging of Embryonic stem cells Practical 3: Differentiation of embryonic stem cell to embryoid bodies and analysis of gene expression pattern in cells Practical 4: Differentiation of embryonic stem cells to different lineages followed by the sorting of these cells by FACS Practical 5: Isolation of adult stem cells from patient samples. Practical 6: Observation and understanding the generation of induced pluripotent stem cells from fibroblasts.	**4**
	Total Credits	**22**

PRESCRIBED READING

RGC 401	**Human Anatomy and Physiology** 1. Tortora, G. J., &Derrickson, B. H. (2008). *Principles of anatomy and physiology*. John Wiley & Sons. 2. Kurpad, A., Vaz, M., & Raj, T. D. (2013). *Guyton & Hall: Textbook of Medical Physiology-A South Asian Edition*. Elsevier India
RGC 402	**Human Disease and Health Care Policy** 1. DeVita, V. T., Lawrence, T. S., & Rosenberg, S. A. (2012). *Cancer: principles & practice of oncology: primer of the molecular biology of cancer*. Lippincott Williams & Wilkins. Wolters Kluwer. 2. Libby, P., Bonow, R. O., Mann, D. L., &Zipes, D. P. (2007). *Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine, 2-Volume Set*. Elsevier Health Sciences. *3.* Sorenson, M., Quinn, L., Klein, D. (2018). *Pathophysiology: A Case-based Approach.* 4. Harris, R.E., (2007). Epidemiology of chronic diseases. Jones & Bartlett learning. 5. Banerjee B. (2018). DK Taneja's Health Policies &Programmes in India. Ed. 16. Jaypee Brothers Medical Publisher 6. https://www.nhp.gov.in/health-policies_pg 7. http://shodhganga.inflibnet.ac.in/bitstream/10603/38985/9/09_chapter-i.pdf
RGC 403	**Introduction to Drug Discovery and Development** 1. Blass, B. (2015). *Basic principles of drug discovery and development*. Elsevier. 2. Brunt LL, Hilal-Dandan R, Knollmann BC. (2017). *Goodman and Gilman's The Pharmacological Basis of Therapeutics. 13th edn.* Publisher: McGraw Hill Education 3. Tozer, T.N., Rowland, M. (2006). *Introduction to Pharmacokinetics and Pharmacodynamics*. *4th edn*.Lippincott Williams & Wilkins.
RGC 404	**Human Disease Biology** **<u>Cancer</u>** 1. DeVita, V. T., Lawrence, T. S., & Rosenberg, S. A. (2012). *Cancer: principles & practice of oncology: primer of the molecular biology of cancer*. Lippincott Williams & Wilkins. Wolters Kluwer. 2. Weinberg, R. (2013). *The biology of cancer*. Garland science, Taylor & Francis Group. **<u>Diabetes& Cardiovascular Diseases</u>** 1. Libby, P., Bonow, R. O., Mann, D. L., &Zipes, D. P. (2007). *Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine, 2-Volume Set*. Elsevier Health Sciences. 2. Poretsky, L. (Ed.). (2010). *Principles of diabetes mellitus* (pp. 347-351). New York: Springer. 3. Skyler, J. (Ed.). (2012). *Atlas of diabetes*. Springer Science & Business Media. 4. Alsahli, M., &Gerich, J. E. (2012). *Pathogenesis of type 2 diabetes. In Atlas of* 1. Evans, A. S. (2013). *Viral infections of humans: epidemiology and control*. Springer Science & Business Media. 2. Flint, S. J., Enquist, L. W., Krug, R. M., Racaniello, V. R., &Skalka, A. M. (2000). *Principles of virology: molecular biology, pathogenesis and control*. ASM press. 3. Murray, P. R. (2017). *Basic Medical Microbiology*. Elsevier Health Sciences. 4. Russell, D. G., & Gordon, S. (Eds.). (2009). *Phagocyte-pathogen interactions*. 1. Knoepfler, P. (2013). *Stem cells: an insider's guide*. World Scientific. 2. Meyers, R. A. (Ed.). (2013). *Stem cells: from biology to therapy*. John Wiley & Sons. 3. Lanza, R., Langer, R., &Vacanti, J. P. (Eds.). (2011). *Principles of tissue engineering*. Academic press.

STREAM 2: GENETIC ENGINEERING

SEMESTER III

ONE CREDIT = 12 TEACHING HOURS

CODE	COURSE	CREDIT (S)
RGC 408	**Genetic Engineering: Techniques, Models and Applications** *Genetic engineering is a technology that has been developed based on our fundamental understanding of the principles of molecular biology and this is reflected in the contents of this course. This technology has revolutionized the way modern biological research is done and has impacted mankind with a number of biological products and processes. Here in this course, we would understand the different techniques used to manipulate genes, means to transfer these genes, express those genes in microbes, their application in biology and the generation of genetically modified organisms/plants.* Unit I: Gene manipulation techniques Cloning, Transgenesis and site-specific recombination: Cre-Lox, Phi31 integrase, Genome editing: ZFNs, TALENs, CRISPR/Cas9, Multi-gene assemblies and high-throughput DNA assembly techniques. Molecular imaging: Fluorescent tagging of fixed and live cells, CRISPR-based DNA tagging, rainbow imaging, Quantitative and high-throughput single-cell image analysis. Unit II: Gene transfer techniques Biological methods, chemical methods, physical or mechanical methods, Agrobacterium- mediated gene transfer in plants, Chloroplast transformation. Bacteria as model systems in genetic analysis: Mutation, recombination, test of allelism, gene mapping. Methods of gene transfer in bacteria. Unit III: Microbial biotechnology Genetic manipulation, Engineering microbes for the production of antibiotics, enzymes, insulin, growth hormones, monoclonal antibodies, microbes for clearing oil spills Unit IV: Application of genome engineering Application in synthetic and developmental biology - Application in human genetics, disease phenotyping, Gene targeting and silencing, Gene therapy in the treatment of diseases, Challenges and future of gene therapy. Biopharming-plants and animals as bioreactors. Unit V: Genetically Modified Organisms/plants Importance in Basic & Applied Research, Cloning by nuclear transfer, transgenic technology: Transgenic mice, Transgenic Drosophila, Transgenic C elegans, Transgenic Zebra Fish, Transgenic Arabidopsis, Transgenic Cattle, Transgenic Chicken, Transgenic Goat, Gene-targeted Mouse models, Transgenic Plants.	**3**

RGC 409	**Plant Genetic Engineering** *The course is designed to provide students with specialized knowledge of the theory and practical skills of plant tissue culture, somatic cell genetics and genetic engineering relevant to crop improvement. It deals with the various cell and tissue culture systems and their applications, plant transformation vectors and methods, and potential applications of transgenic technology in agriculture and healthcare.* Unit I: Plant tissue culture Scope, Importance and limitations of plant tissue culture; Tissue culture media - composition and preparation. Unit II: Micro propagation of plants Initiation and maintenance of callus and suspension cultures; in vitro genetic conservation; in vitro clonal multiplication; Plant growth regulators for organogenesis, somaclonal variation and cell line selection, production of haploids and homozygous cell lines. Selection and maintenance of cell lines, cryopreservation, germplasm collection and conservation. Unit III: Genetics in evolution Origins of Agriculture, Evolution and distribution of species and forms - wild relatives and germplasm; Genetics – cytogenetics and genome relationship, Centers of origin and biodiversity hot spots; Crop domestication: domestication syndrome, monophyletic and polyphyletic domestication with examples. Twenty-first Century Plant Domestication. Gene bank management: Gene conversion, Gene duplication and divergent evolution, collecting, maintenance, evaluation, storage and documentation Genetic diversity within crops, Tools for drawing phylogenetic inferences and its importance. Unit IV: Genetics in Crop improvement methods Breeding, Hybridization, backcross breeding, recombinant inbred lines, Molecular breeding- marker assisted selection (MAS), foreground and background selection, QTLs- cisQTLs, eQTLs, trait introgression, Genome wide association studies. Cytoplasmic male sterility and principles of hybrid seed production, TGMS and PGMS, applications of male sterility in hybrid seed production. Transgenic male sterility, clonal propagation, grafting and their uses, Plant tissue culture, Hormones and their uses, Double haploids development mechanisms and its application in crop improvement. Whole genome sequencing and transcriptomics uses in crop improvement. Unit V: Biotechnological advances in crop improvement Plant transformation vectors - T-DNA and viral vectors, direct gene transfer vectors; Selectable marker and reporter genes, Plant transformation by Agrobacterium sp., non-Agrobacterium sp., and in planta transformation, Molecular mechanism of T-DNA transfer; Direct gene transfer methods in plants - Gene gun and other methods; Chloroplast transformation; Transgene analysis, silencing and targeting; Marker-free and novel selection strategies; Multigene engineering; Genetic engineering methods to improve stress tolerance. Binary vectors, overexpression, gene silencing, gene editing, plant transformation, transgenic plants few examples (Bt-cotton, Bt-brinjal). Socio-economic benefits of transgenic plants, Biosafety - ethical issues associated with GM crops. Gene knock-down by ribozymes, antisense RNA and RNA interference. Applications of plant transgenic technology:	**3**

	Transgenic crops for resistance against biotic and abiotic stresses; Engineering crops for male sterility and modification of flower colour, flowering, fruit ripening and senescence; GM crops for nutritional quality and quantity; RNAi-mediated crop improvement; Molecular pharming; Metabolic engineering and hairy root culture for secondary plant products; Other applications; Global status and biosafety of transgenic plants.	
RGC 410	**RNAi- Biology and applications** *This course covers the basic aspects of RNAi biology, use of siRNA and microRNAs for gene silencing, RNAi vectors and generation of transgenic animals and plants expressing dsRNA. The current and potential applications of RNAi in healthcare and agriculture are also covered.* Unit I: Types of RNAi Discovery of RNA interference (RNAi)- a historical perspective across multiple species, RNAi in plants and fungi, RNAi in Ceanorhabdites elegans and Drosophila, RNAi in mammalian systems: PTGS, RNAi and related phenomena. Categories of small non-coding RNAs: dsRNAs, siRNAs, shRNAs, piRNAs and miRNAs, Detection of small RNAs. Unit II: Mechanism of RNAi Different components of RNAi pathway and their evolutionary conservation and role in gene silencing, RNAi-like pathway in bacteria, Molecular basis of RNAi /siRNA /miRNA mediated gene silencing, Enzymes involved in RNAi including Dicer, RISC, RNA helicase, RNA dependent RNA polymerase. RNAi in defense and the regulation of chromatin structure and gene expression; RNAi suppressors. Unit III: Large-scale analysis by RNAi Large-scale genetic analysis using RNAi: Genome-wide RNAi screens in mouse and human geneomes to identify new transcriptional module, gene discovery related disease like cancer, building mammalian signaling pathways, High-throughput small RNA profiling, RNAi microarrays. Unit IV: miRNAs and siRNAs Pathways, expression and functions of microRNAs, High-throughput analysis of miRNA gene expression including analysis using sensitive probes; siRNA vectors-their composition, selectable markers, use of RNA PolIII promoter; siRNA delivery in vitro and in vivo like plasmid injection, tail vein injection and liposome formulation, the techniques in creating knockout mice using transgenic siRNA, Advantages of transgenic siRNA over conventional knockout technology; RNA informatics - Computational tools for miRNA discovery, Regulatory RNAs, RNA processing, RNA sequence and structure, RNA complexes, Translational control and RNA biology and disease, siRNA and miRNA design Unit V. Double stranded RNA and its applications Expression of dsRNA in animals and plants, and its applications: RNAi vectors and generation of transgenic animals and plants, Analysis of expression of dsRNA and gene silencing; The use of RNAi in the prevention of diseases in animal models and crop improvement; RNAi therapy; Future prospects of RNAi in biology, medicine and agriculture.	**2**
RGC 411	**Genetic engineering in animals** *The course is designed to provide students with specialized knowledge of the theory and practical skills of genetic engineering involved in the generation of transgenic animals and the ethics associated with it.*	**2**

	Unit I: Genetic engineering in creation of transgenic animals Functional genomics and animal models in human disease: cDNA/gene cloning; site-directed mutagenesis; mammalian tissue culture; cell line transfections; functional assays; Use of model organisms, methods for generation of transgenic animals/ knock-in, knock- out models (microinjection, ES cell transformation); ENumutagenesis; RNAi approach, In vitro gamete maturation. In vitro fertilization (IVF) and embryo transfer (ET), Sex determination or sex specific makers, sexing of sperm and embryos, Assisted reproductive technology (ART). Somatic cloning of animals.Improvements of animal production and quality using transgenic approach with specific examples. Unit II: Gene Transfer methods in Animals Gene cloning vectors, Techniques for genetic engineering, Gene cloning, Gene transfer and expression of induced genes, Microinjection, Embryonic-stem cells Transfer, Retro-virus and Gene transfer, Xenografting Unit III. Biosafety in genetic engineering Value of Transgenic Animals, Biosafety measures in Transgenic Animal Research, Compliance with NIH Guidelines, Policies & Protocols, Disposal of Transgenic Animals, Transfer of Recombinant DNA and Transgenic Materials. Unit IV. Bioethics in genetic engineering Patenting Genetically Engineered Animals -Trends in Biotechnology Patenting, Biotech Patent Processing, Pharmaceutical Biotech Patents, Genetic Engineering Patents, PTO Analysis, Patent protection of living organisms, Gene technology laws in other countries Unit V. Pharmaceutical products of DNA technology Human protein replacements, Human therapies, Vaccines	
RGC 412	**Methods in genetic manipulation of plants** Practical 1: Media preparation, Basic techniques of plant tissue culture and somatic embryogenesis. Practical 2: Restriction analysis of recombinant vector, Agrobacterium mediated transformation: preparation of explants, co-cultivation of explants with *Agrobacterium tumefaciens.* Practical 3: Selection of transformed tissues and regeneration of transformed tissues. Practical 4: Isolation of genomic DNA from transgenic plants, PCR, Southern hybridization analysis. Practical 5: Over expression by floral dip transformation, Chloroplast transformation, Transgene analysis, Gene silencing and targeting. Practical 6: Molecular breeding- marker assisted selection	**4**
RGC 413	**Methods in RNAi biology** Practical 1: Designing of shRNA and siRNA Practical 2: siRNA and shRNA mediated knockdown of genes in plant/animals cells mediated cells by retroviral or lentiviral delivery Practical 3: Preparation of RNAi libraries and screening Practical 4: Functional assays of microRNA mediated gene regulation Practical 5: Designing and use of TALEN/ZFN/Cre-Lox mediated gene editing tool Practical 6: Use of CRISPR/Cas9 mechanism as a gene-editing tool.	**4**

RGC 414	**Methods in genetic engineering in animals** Practical 1: Gene cloning Practical 2: Transfection in ES cells for generating knockdown of genes Practical 3: Genotyping Analysis in Human Practical 4: Expression of induced genes Practical 5: Microinjection techniques Practical 6: Embryo transfer	**4**
	Total Credits	**22**

PRESCRIBED READING

RGC 408	**Genetic Engineering: Techniques, Models and Applications** 1. Nicholl. (2006), Introduction to Genetic Engineering - Cambridge Low Price Edition. 2. Primrose S.B. and Twyman R.M., (2008) Principles of gene manipulation and Genomics, Blackwell Scientific Publications. 3. Benjamin Lewis (2008) Genes IX - Oxford University & Cell Press. 4. Curell BR et al., (2004) Techniques for Engineering Genes. 5. Tagu D &Moussard C, (2006) Techniques for Molecular Biolog, INRA 6. Brown TA , (2006) Gene Cloning and DNA Analysis ; 5th Ed 7. Reece RJ, (2004) Analysis of Genes and Genomes ; Wiley 8. Kreuzer H and Massey A, (2006) Recombinant DNA and Biotechnology, ASM; 2nd Ed 9. Korf BR, (2007) Human Genetics and Genomics; 3rd Ed ; Blackwell
RGC 409	**Plant Genetic Engineering** 1. Kung, S. D., & Wu, R. (2012). Transgenic plants: engineering and utilization. Academic Press. 2. Stewart Jr, C. N. (2016). Plant biotechnology and genetics: principles, techniques, and applications. John Wiley & Sons. 3. Smith, R. H. (2012). Plant tissue culture: techniques and experiments. Academic Press. 4. Chrispeels, M. J., &Sadava, D. E. (2003). Plants, genes, and crop biotechnology. Jones & Bartlett Learning.
RGC 410	**RNAi- Biology and applications** 1.TGesteland et al., (2006) The RNA World TEds. CSHL Press 2. Fire et. Al., (2005)RNA Interference Technology: From Basic Science to Drug Development. Cambridge University Press. 3. Gregory J. Hannon (2003) RNAi: A Guide to Gene Silencing. CSHL Press. 4. Gordon G. Carmichael (2005) RNA Silencing: Methods and Protocols CSHL Press. 5. Ute Schepers, (2006) RNA Interference in Practice, Wiley-VCH GmbH & Co. KGaA.
RGC 411	**Genetic engineering in animals** 1. Strickberger MW (2004) Genetics, - Garland 2. Riddle DL, Blumenthal T, Meyer BJ, Priess JR (1997) C. elegans II,– Cold Spring Harbor Press 3. Jackson IJ and Abott CM (1999) Mouse Genetics and Transgenics: A Practical

	Approach,– Oxford 4. Freshney IR (2010) Culture of Animal Cells: A manual of basic techniques and specialized applications, Wiley-Blackwell 5. Stephenson F. H. (2016) Calculations for Molecular Biology and Biotechnology: Academic Press

SEMESTER IV

RGC 422	**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.*	**22**