Maulana Abul Kalam Azad University of Technology, West Bengal
(formerly West Bengal University of Technology)

Department of Biotechnology

M.Sc. (Biotechnology)
Master of Science in Biotechnology

Syllabus 2019
(Two-Year Course)

(Syllabus of Biotechnology is adapted & modified from the syllabus prescribed by the Department of Biotechnology, Govt. of India)

M.Sc Biotechnology (2-Year, 4-Semester Course)

S. No.	Paper Code	Course Title	Contact Hours/ wk L-T-P	Credits
SEMESTER ONE				
1	MSUBT-101	Biochemistry	3-0-0	3
2	MSUBT-102	Laboratory Techniques & Safety	3-0-0	3
3	MSUBT-103	Cell and Molecular Biology	3-0-0	3
4	MSUBT-104	Biostatistics	3-0-0	3
5	MSUBT-105	Microbiology	3-0-0	3
6	MSUBT-191	Laboratory I: Biochemistry and Analytical Techniques	0-0-6	3
7	MSUBT-192	Laboratory II: Microbiology	0-0-6	3
9	MSUBT-181	Seminar / Journal Presentation		1
		TOTAL		**22**
SEMESTER TWO				
1	MSUBT-201	Genetics and Molecular Diagnostics	3-0-0	3
2	MSUBT-202	Genomics and Proteomics	3-0-0	3
3	MSUBT-203	Immunology	3-0-0	3
4	MSUBT-204	Genetic Engineering	3-0-0	3
5	MSUBT-205	Applied Bioinformatics	3-0-0	3
6	MSUBT-206	Elective I (From MOOCs Basket)		2
7	MSUBT-291	Laboratory III: Molecular Biology & Genetic Engineering	0-0-6	3
8	MSUBT-292	Laboratory IV: Immunology	0-0-6	3
9	MSUBT-281	Seminar / Journal Presentation		1
		TOTAL		**24**
SEMESTER THREE				
1	MSUBT-301	Bioprocess Engineering and Technology	3-0-0	3
2	MSUBT-302	Emerging Technologies	3-0-0	3
3	MSUBT-303	Critical Analysis of Classical Papers	3-0-0	3
4	MSUBT-304	Intellectual Property Rights, Biosafety and Bioethics	3-0-0	3
5	MSUBT-305	Research Methodology and Scientific Communication Skills	2-0-0	1
6	MSUBT-306	Elective II	3-0-0	2
7	MSUBT-391	Laboratory V: Bioprocess Engineering and Technology	0-0-6	3
8	MSUBT-392	Laboratory VI: Applied Bioinformatics	0-0-6	2
9	MSUBT-381	Project Proposal Preparation and Presentation		2
		TOTAL		**22**
SEMESTER FOUR				
1	MSUBT-481	Dissertation		22
2	MSUBT-482	Industry/ Lab visit		1
3	MSUBT-483	Seminar / Journal Presentation		1
		TOTAL		**24**
		TOTAL CREDITS		**92**

Recommended Electives:

1. **Biological Imaging**
2. **Computational Biology**
3. **Drug Discovery and Development**
4. **Environmental Biotechnology**
5. **Microbial Technology**
6. **Nanobiotechnology**
7. **Protein Engineering**
8. **Vaccines**
9. **Bioentrepreneurship**
10. **From MOOCs BASKET**

Semester One

1.Biochemistry	**MSUBT 101**	**Credits 3**
Unit I	Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies.	
Chemical Basis of Life		
Unit II	Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.	
Protein structure		
Unit III	Enzyme catalysis – general principles of catalysis; quantitation of enzyme	

Enzyme kinetics	activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.
Unit IV **Glycobiology**	Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.
Unit V **Structure and functions of DNA & RNA and lipids**	Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, 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.
Unit VI **Bioenergetics**	Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways;
Unit VII **Role of vitamins & cofactors in metabolism**	Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/ exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; target of rapamycin (TOR) & Autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.
Recommended Text books and References	1. Stryer, L. (2015). Biochemistry. (8th ed.) New York: Freeman. 2. Lehninger, A. L. (2012). Principles of Biochemistry (6th ed.). New York, NY: Worth. 3. Voet, D., & Voet, J. G. (2016). 4. Biochemistry (5th ed.). Hoboken, NJ: J. Wiley & Sons. 5. Dobson, C. M. (2003). Protein Folding and Misfolding. Nature, 426(6968), 884-890. doi:10.1038/nature02261. 6. Richards, F. M. (1991). The Protein Folding Problem. Scientific American, 264(1), 54-63. doi:10.1038/scientificamerican 0191-54.

2. Laboratory Techniques & Safety	MSUBT 102	Credits 3
Unit I **Chromatography Techniques**	Paper Chromatography, Thin-layer chromatography, Displacement chromatography, Gas chromatography, High performance / pressure liquid chromatography, Ion exchange chromatography, Size-exclusion chromatography, Affinity chromatography.	
Unit II **Electrophoretic techniques and blotting techniques**	Theory and application of Polyacrylamide and Agarose gel electrophoresis; Capillary electrophoresis; 2D Electrophoresis; Immunoelectrophoresis, Isoelectric focussing, Disc gel electrophoresis; Gradient electrophoresis; Pulsed field gel electrophoresis, Western blot, Eastern blot, Southern blot, Northern blot.	
Unit III **Radioactivity**	Radioactive & stable isotopes; Pattern and rate of radioactive decay; Units of radioactivity; Measurement of radioactivity; Geiger-Muller counter; Solid & Liquid scintillation counters (Basic principle, instrumentation & technique); Applications of isotopes in biochemistry; Autoradiography.	
Unit IV **Centrifugation**	Basic principles; Mathematics & theory (RCF, Sedimentation coefficient etc); Types of centrifuge, Micro centrifuge, High speed & Ultracentrifuges; Preparative centrifugation; Differential & density gradient centrifugation; Applications (Isolation of cell components); Analytical centrifugation; Determination of molecular weight by sedimentation velocity & sedimentation equilibrium methods.	
Unit V **Microscopy**	Optical microscopy, Electron microscopy, Confocal microscopy	
Unit VI **Advanced techniques**	DNA and Amino acid Sequencing, DNA CHIP, Microarray, Substractive Hybridization, RNase protection assay, ELISA, Mass spectroscopy, Infra-red spectroscopy, NMR, Circular Dichroism	
Recommended Text books and References	1. Cantor & Schimmel : Biophysical Chemistry (Part I, II & III) 2. A. Lehninger : Principles of Biochemistry 3. Freifelder D., Physical Biochemistry, Application to Biochemistry and Molecular Biology, 2nd Edition, W.H. Freeman & Company, San Fransisco, 1982. 4. Keith Wilson and John Walker, Principles and Techniques of Practical Biochemistry, 5th Edition, Cambridge University Press, 2000. 5. D. Holme & H. Peck, Analytical Biochemistry, 3rd Edition, Longman, 1998. 6. R. Scopes, Protein Purification - Principles & Practices, 3rd Edition, Springer, Verlag, 1994. 7. Selected readings from Methods in Enzymology, Academic Press.	

3. Cell and Molecular Biology	MSUBT 102	Credits 3
Unit I **Dynamic organization of cell**	Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes.	
Unit II **Chromatin structure and dynamics**	Chromatin organization - histone and DNA interactome: structure and assembly of eukaryotic and prokaryotic DNA polymerases, DNA-replication, repair and recombination; chromatin control: gene transcription and silencing by chromatin- Writers,-Readers and –Erasers; Transcriptional control: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors, trancriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code translation product cleavage, modification and activation.	
Unit III **Cellular signalling, transport and trafficking**	Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.	
Unit IV **Cellular processes**	Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and trans- membrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.	
Unit V **Manipulating and studying cells**	Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.	
Unit VI **Genome instability and cell transformation**	Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.	
Recommended Text books and References	1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2008). Molecular Biology of the Cell (5th Ed.). New York: Garland	

	Science. 2. Lodish, H. F. (2016). Molecular Cell Biology (8th Ed.). New York: W.H. Freeman. 3. Krebs, J. E., Lewin, B., Kilpatrick, S. T., & Goldstein, E. S. (2014). Lewin's Genes XI. Burlington, MA: Jones & Bartlett Learning. 4. Cooper, G. M., & Hausman, R. E. (2013). The Cell: a Molecular Approach (6th Ed.). Washington: ASM ; Sunderland. 5. Hardin, J., Bertoni, G., Kleinsmith, L. J., & Becker, W. M. (2012). Becker's World of the Cell. Boston (8th Ed.). Benjamin Cummings. 6. Watson, J. D. (2008). Molecular Biology of the Gene (5thed.). Menlo Park, CA: Benjamin/Cummings

4. Biostatistics	**MSUBT 104**	**Credits 3**
Unit I **Introduction to Biostatistics**	Basic definitions and applications. Sampling: Representative sample, sample size, sampling bias and sampling techniques. Data collection and presentation: Types of data, methods of collection of primary and secondary data, methods of data presentation, graphical representation by histogram, polygon, o give curves and pie diagram.	
Unit II **Measures of central tendency: Mean, Median, Mode**	Measures of variability: Standard deviation, standard error, range, mean deviation and coefficient of variation. Correlation and regression: Positive and negative correlation and calculation of Karl- Pearsons co-efficient of correlation. Linear regression and regression equation and multiple linear regression, ANOVA, one and two way classification. Calculation of an unknown variable using regression equation	
Unit III **Tests of significance**	Tests of significance: Small sample test (Chi-square t test, F test), large sample test (Z test) and standard error. Introduction to probability theory and distributions, (concept without deviation) binomial, poison and normal (only definitions and problems) Computer oriented statistical techniques. Frequency table of single discrete variable, bubble spot, computation of mean, variance and standard Deviations, t test, correlation coefficient. Randomized block design, complete block design, Usage of Statistical software.	
Unit IV	Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.	
Recommended Text books and References	1. Aitken, M., Broadhursts, B., & Haldky, S. (2009) Mathematics for Biological Scientists. Garland Science. 2. Billingsley, P. (1986). Probability and Measure. New York: Wiley. 3. Rosner, B. (2000). Fundamentals of Biostatistics. Boston, MA: Duxbury Press. 4. Daniel, W. W. (1987). Biostatistics, a Foundation for Analysis in the Health Sciences. New York: Wiley., 264(1), 54-63. doi:10.1038/scientificamerican 0191-54.	

5. Microbiology	MSUBT 105	Credits 3
Unit I **Microbial characteristics**	Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes.	
Unit II **Microbial diversity**	Chromatin organization - histone and DNA interactome: structure and assembly of eukaryotic and prokaryotic DNA polymerases, DNA-replication, repair and recombination; chromatin control: gene transcription and silencing by chromatin- Writers,-Readers and –Erasers; Transcriptional control: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors, trancriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code translation product cleavage, modification and activation.	
Unit III **Control of microorganisms**	Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, biological control of microorganisms.	
Unit IV **Virology**	Virus and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles – viroids and prions.	
Unit V **Interaction of microbes with its environment**	Host-pathogen interaction, ecological impacts of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbes and nutrient cycles; microbial communication system; biofilms, bacterial quorum sensing; microbial fuel cells.	
Recommended Text books and References	1. Joanne M. Willey, Linda Sherwood, Christopher J. Woolverton; (2011) Prescott's Microbiology, McGraw Hill. 2. Michael Joseph Pelczar, Eddie Chin Sun Chan, Noel R. Krieg; (1993) Microbiology by Pelczar. McGraw Hill. 3. Gerard J. Tortora, Berdell R. Funke, Christine L. Case; (2015); Microbiology by Tortora. Pearson Education.	

6. Laboratory I Biochemistry & Analytical Techniques	MSUBT 191	Credits 3
Syllabus	1. Preparing various stock solutions and working solutions that will be needed for the course. 2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation. 3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer- Lambert's Law. 4. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography. 5. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution's choice). a) Preparation of cell-free lysates b) Ammonium Sulfate precipitation c) Ion-exchange Chromatography d) Gel Filtration e) Affinity Chromatography f) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method g) Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification) h) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis i) Enzyme Kinetic Parameters: Km, Vmax and Kcat. 6. Experimental verification that absorption at OD260 is more for denatured DNA as compared to native double stranded DNA. reversal of the same following DNA renaturation. Kinetics of DNA renaturation as a function of DNA size. 7. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools. (Optional Experiments) 8. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy). 9. Determination of mass of small molecules and fragmentation patterns by Mass Spectrometry.	
Recommended Text books and References	1. Joanne M. Willey, Linda Sherwood, Christopher J. Woolverton; (2011) Prescott's Microbiology, McGraw Hill. 2. Michael Joseph Pelczar, Eddie Chin Sun Chan, Noel R. Krieg; (1993) Microbiology by Pelczar. McGraw Hill. 3. Gerard J. Tortora, Berdell R. Funke, Christine L. Case; (2015); Microbiology by Tortora. Pearson Education.	

7. Laboratory II Microbiology	MSUBT 192	Credits 3
Syllabus	1. Sterilization, disinfection and safety in microbiological laboratory. 2. Preparation of media for cultivation of bacteria. 3. Isolation of bacteria in pure culture by streak plate method. 4. Study of colony and growth characteristics of some common bacteria: Bacillus, E. coli, Staphylococcus, Streptococcus, etc. 5. Preparation of bacterial smear and Gram's staining. 6. Enumeration of bacteria: standard plate count. 7. Antimicrobial sensitivity test and demonstration of drug resistance. 8. Maintenance of stock cultures: slants, stabs and glycerol stock cultures. 9. Determination of phenol co-efficient of antimicrobial agents. 10. Determination of Minimum Inhibitory Concentration (MIC) 11. Isolation and identification of bacteria from soil/water samples.	
Recommended Text books and References	1. Cappuccino, J. G., & Welsh, C. (2016). Microbiology: a Laboratory Manual. Benjamin-Cummings Publishing Company. 2. Collins, C. H., Lyne, P. M., Grange, J. M., & Falkinham III, J. (2004). Collins and Lyne's Microbiological Methods (8th ed.). Arnolds. 3. Tille, P. M., & Forbes, B. A. Bailey & Scott's Diagnostic Microbiology.	

Semester Two

Genetics & Molecular Diagnostics	MSUBT 201	Credits 3
Unit I **Genetics of bacteria, bacteriophages and Yeast**	Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; genetic complementation and other genetic crosses using phenotypic markers; Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios	
Unit II **Drosophila genetics as a model of higher eukaryotes**	Monohybrid & dihybrid crosses, back-crosses, test-crosses, analyses of autosomal and sex linkages, screening of mutations based on phenotypes and mapping the same, hypomorphy, genetic mosaics, genetic epistasis in context of developmental mechanism.	
Unit III **Population genetics and genetics of evolution**	Introduction to the elements of population genetics: genetic variation, genetic drift, neutral evolution; mutation selection, balancing selection, Fishers theorem, Hardy- Weinberg equilibrium, linkage disequilibrium; in-breeding depression & mating systems; population bottlenecks, migrations, Bayesian statistics; adaptive landscape, spatial variation & genetic fitness.	

Unit IV **Genome Biology in Health, Disease Detection and Analysis; Molecular Oncology**	An overview of chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs. ARMS PCR; ISH; FISH; ISA; RFLP; DHPLC; DGGE; CSCE; SSCP; EST; SAGE; Diagnostic proteomics: SELDI-TOF-MS; Bioinformatics data acquisition & analysis. Detection of predictive biomarkers for personalized onco-therapy of human diseases such as chronic myeloid leukemia, as well as matching targeted therapies with patients and preventing toxicity of standard systemic therapies.
Unit V **Detection and Identity of Microbial Diseases, Inherited Diseases and Diagnostic Metabolomics**	Direct detection and identification of pathogenic-organisms through microscopy, ELISA, PCR and immunoprecipitation that are slow growing or currently lacking a system of in vitro cultivation as well as genotypic markers of microbial resistance to specific antibiotics. Exemplified by inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: e.g., Fragile X Syndrome: Metabolite profile for biomarker detection the body fluids/tissues in various metabolic disorders by making using LCMS & NMR technological platforms.
Unit VI **Quality assurance and control**	Quality oversight; regulations and approved testing (according to ICMR guideline)
Recommended Text books and References	1. Campbell, A. M., & Heyer, L. J. (2006). Discovering Genomics, Proteomics, and Bioinformatics. San Francisco: Benjamin Cummings. 2. Brooker, R. J. (2009). Genetics: Analysis & Principles. New York, NY: McGraw-Hill. 3. Glick, B. R., Pasternak, J. J., & Patten, C. L. (2010). Molecular Biotechnology: Principles and Applications of Recombinant DNA. Washington, DC: ASM Press. 4. Coleman, W. B., & Tsongalis, G. J. (2010). 4. Molecular Diagnostics: for the Clinical Laboratorian. Totowa, NJ: Humana Press. 5. Hartl, D. L., & Jones, E. W. (1998). Genetics: Principles and Analysis. Sudbury, MA: Jones and Bartlett. 6. Pierce, B. A. (2005). Genetics: a Conceptual Approach. New York: W.H. Freeman. 7. Tamarin, R. H., & Leavitt, R. W. (1991). Principles of Genetics. Dubuque, IA: Wm. C. Brown. 8. Smith, J. M. (1998). Evolutionary Genetics. Oxford: Oxford University Press.

Genomics and Proteomics	MSUBT 202	Credits 3
Unit I **Basics of genomics and proteomics**	Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.	
Unit II **Genome mapping**	Genetic and physical maps; markers for genetic mapping; methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, in situ hybridization, comparative gene mapping.	
Unit III **Genome sequencing projects**	Human Genome Project, genome sequencing projects for microbes, plants and animals, accessing and retrieving genome project information from the web.	
Unit IV **Comparative genomics**	Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence.	
Unit V **Proteomics**	Aims, strategies and challenges in proteomics; proteomics technologies: 2D-PAGE, isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, proteome databases.	
Unit VI **Functional genomics and proteomics**	Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in genome, gene function- forward and reverse genetics, gene ethics; protein- protein and protein-DNA interactions; protein chips and functional proteomics; clinical and biomedical applications of proteomics; introduction to metabolomics, lipidomics, metagenomics and systems biology.	
Recommended Text books and References	1. Primrose, S. B., Twyman, R. M., Primrose, S. B., & Primrose, S. B. (2006). Principles of Gene Manipulation and Genomics. Malden, MA: Blackwell Pub. 2. Liebler, D. C. (2002). Introduction to Proteomics: Tools for the New Biology. Totowa, NJ: Humana Press. 3. Campbell, A. M., & Heyer, L. J. (2003). Discovering Genomics, Proteomics, and Bioinformatics. San Francisco: Benjamin Cummings.	

Immunology	MSUBT 203	Credits 3
Unit I **Immunology: fundamental concepts and overview of the immune system**	Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens: immunogens, haptens; Major Histocompatibility Complex: MHC genes, MHC and immune responsiveness and disease susceptibility, Organs of immune system, primary and secondary lymphoid organs.	
Unit II	Immunoglobulins - basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of	

Immune responses generated by B and T lymphocytes	immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self & non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines: properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation, Hapten-carrier system.
Unit III **Antigen-antibody interactions**	Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques: RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence microscopy, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosensor assays for assessing ligand –receptor interaction; CMI techniques: lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs.
Unit IV **Vaccinology**	Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology: role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; antibody genes and antibody engineering:chimeric, generation of monoclonal antibodies, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine.
Unit V **Clinical immunology**	Immunity to infection : bacteria, viral, fungal and parasitic infections (with examples from each group); hypersensitivity: Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; treatment of autoimmune diseases; transplantation: immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology: tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency: primary immunodeficiencies, acquired or secondary immunodeficiencies, autoimmune disorder, anaphylactic shock, immunosenescence, immune exhaustion in chronic viral infection, immune tolerance, NK cells in chronic viral infection and malignancy.
Unit VI **Immunogenetics**	Major histocompatibility complex genes and their role in autoimmune and infectious diseases, HLA typing, human major histocompatibility complex (MHC), Complement genes of the human major histocompatibility complex: 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, KIR complex.
Recommended Text books and References	1. Kindt, T. J., Goldsby, R. A., Osborne, B. A., & Kuby, J. (2006). Kuby Immunology. New York: W.H. Freeman. 2. Brostoff, J., Seaddin, J. K., Male, D., & Roitt, I. M. (2002). Clinical Immunology. London: Gower Medical Pub. 3. Murphy, K., Travers, P., Walport, M., & Janeway, C. (2012). Janeway's Immunobiology. New York: Garland Science. 4. Paul, W. E. (2012). Fundamental Immunology. New York: Raven Press. 5. Goding, J. W. (1996). Monoclonal Antibodies: Principles and Practice: Production and Application of Monoclonal Antibodies in Cell Biology,

	Biochemistry, and Immunology. London: Academic Press. 6. Parham, P. (2005). The Immune System. New York: Garland Science.

Genetic Engineering	**MSUBT 204**	**Credits 3**
Unit I **Introduction and tools for genetic engineering**	Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes, hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence in situ hybridization	
Unit II **Different types of vectors**	Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression expression vectors; pMal; GST; pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and Pichia vectors system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.	
Unit III **Different types of PCR techniques**	Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.	
Unit IV **Gene manipulation and protein-DNA interaction**	Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.	
Unit V **Gene silencing and genome editing technologies**	Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by	
Recommended Text books and References	1. Old, R. W., Primrose, S. B., & Twyman, R. M. (2001). Principles of Gene Manipulation: an Introduction to Genetic Engineering. Oxford: Blackwell Scientific Publications. 2. Green, M. R., & Sambrook, J. (2012). Molecular Cloning: a Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. 3. Brown, T. A. (2006). Genomes (3rd ed.). New York: Garland Science Pub.	

	4. Selected papers from scientific journals, particularly Nature & Science. 5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

Applied Bioinformatics	**MSUBT 205**	**Credits 3**
Unit I **Bioinformatics basics**	Bioinformatics basics: Computers in biology and medicine; Introduction to Unix and Linux systems and basic commands; Database concepts; Protein and nucleic acid databases; Structural databases; Biological XML DTD's; pattern matching algorithm basics; databases and search tools: biological background for sequence analysis; Identification of protein sequence from DNA sequence; searching of databases similar sequence; NCBI; publicly available tools; resources at EBI; resources on web; database mining tools.	
Unit II **DNA sequence analysis**	DNA sequence analysis: gene bank sequence database; submitting DNA sequences to databases and database searching; sequence alignment; pairwise alignment techniques; motif discovery and gene prediction; local structural variants of DNA, their relevance in molecular level processes, and their identification; assembly of data from genome sequencing.	
Unit III **Multiple sequence analysis**	Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTALW and CLUSTALX for multiple sequence alignment; submitting DNA protein sequence to databases: where and how to submit, SEQUIN, genome centres; submitting aligned sets of sequences, updating submitted sequences, methods of phylogenetic analysis.	
Unit IV **Protein modelling**	Protein modelling: introduction; force field methods; energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; fitting monomers; RMS fit of conformers; assigning secondary structures; sequence alignment- methods, evaluation, scoring; protein completion: backbone construction and side chain addition; small peptide methodology; software accessibility; building peptides; protein displays; substructure manipulations, annealing.	
Unit V **Protein structure prediction and virtual library**	Protein structure prediction: protein folding and model generation; secondary structure prediction; analyzing secondary structures; protein loop searching; loop generating methods; homology modelling: potential applications, description, methodology, homologous sequence identification; align structures, align model sequence; construction of variable and conserved regions; threading techniques; topology fingerprint approach for prediction; evaluation of alternate models; structure prediction on a mystery sequence; structure aided sequence techniques of structure prediction; structural profiles, alignment algorithms, mutation tables, prediction, validation, sequence based methods of structure prediction, prediction using inverse folding, fold prediction; significance analysis, scoring techniques, sequence-sequence scoring; protein function prediction; elements of in silico drug design;Virtual library: Searching PubMed, current content, science citation index and current awareness services, electronic journals, grants and funding information.	
Recommended Text books and References	1. Lesk, A. M. (2002). Introduction to Bioinformatics. Oxford: Oxford University Press. 2. Mount, D. W. (2001). Bioinformatics: Sequence and Genome Analysis. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. 3. Baxevanis, A. D., & Ouellette, B. F. (2001). Bioinformatics: a Practical	

	Guide to the Analysis of Genes and Proteins. New York: Wiley-Interscience. 4. Pevsner, J. (2015). Bioinformatics and Functional Genomics. Hoboken, NJ.: Wiley-Blackwell. 5. Bourne, P. E., & Gu, J. (2009). Structural Bioinformatics. Hoboken, NJ: Wiley-Liss. 6. Lesk, A. M. (2004). Introduction to Protein Science: Architecture, Function, and Genomics. Oxford: Oxford University Press.

Laboratory III Molecular Biology and Genetic Engineering	**MSUBT 291**	**Credits 3**
Syllabus	1. Concept of lac-operon: a) Lactose induction of B-galactosidase. b) Glucose Repression. c) Diauxic growth curve of E.coli 2. UV mutagenesis to isolate amino acid auxotroph 3. Phage titre with epsilon phage/M13 4. Genetic Transfer-Conjugation, gene mapping 5. Plasmid DNA isolation and DNA quantitation 6. Restriction Enzyme digestion of plasmid DNA 7. Agarose gel electrophoresis 8. Polymerase Chain Reaction and analysis by agarose gel electrophoresis 9. Vector and Insert Ligation 10. Preparation of competent cells 11. Transformation of E.coli with standard plasmids, Calculation of transformation efficiency 12. Confirmation of the insert by Colony PCR and Restriction mapping 13. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in E.coli, SDS-PAGE analysis 14. Purification of His-Tagged protein on Ni-NTA columns a) Random Primer labeling b) Southern hybridization	
Recommended Text books and References	1. Green, M. R., & Sambrook, J. (2012). Molecular Cloning: a Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.	

Laboratory IV Immunology	**MSUBT 292**	**Credits 3**
Syllabus	1. Selection of animals, preparation of antigens, immunization and methods of blood collection, serum separation and storage.	

	2. Antibody titre by ELISA method. 3. Double diffusion, Immuno-electrophoresis and Radial Immuno diffusion. 4. Complement fixation test. 5. Isolation and purification of IgG from serum or IgY from chicken egg. 6. SDS-PAGE, Immunoblotting, Dot blot assays. 7. Blood smear identification of leucocytes by Giemsa stain. 8. Separation of leucocytes by dextran method. 9. Demonstration of Phagocytosis of latex beads and their cryopreservation. 10. Separation of mononuclear cells by Ficoll-Hypaque and their cryopreservation. 11. Demonstration of ELISPOT. 12. Demonstration of FACS

Semester Three

Bioprocess Engineering & Technology	**MSUBT 301**	**Credits 3**
Unit I **Basic principles of biochemical engineering**	Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.	
Unit II **Stoichiometry and models of microbial growth**	Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.	
Unit III **Bioreactor design and analysis**	Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformation; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.	
Unit IV **Downstream processing and product recovery**	Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.	
Unit V **Fermentation economics**	Isolation of micro-organisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling;	

	effluent treatment and disposal.
Unit VI	Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. and their downstream processing; baking by amylases, deoxygenation and desugaring by glucoses oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing.
Applications of enzyme technology in food processing	
Unit VII	Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria – production and applications in food preservation; biofuels and biorefinery
Applications of microbial technology in food process operations and production, biofuels and biorefinery	
Recommended Text books and References	1. Shuler, M. L., & Kargi, F. (2002). Bioprocess Engineering: Basic Concepts. Upper Saddle River, NJ: Prentice Hall. 2. Stanbury, P. F., & Whitaker, A. (2010). Principles of Fermentation Technology. Oxford: Pergamon Press. 3. Blanch, H. W., & Clark, D. S. (1997). Biochemical Engineering. New York: M. Dekker. 4. Bailey, J. E., & Ollis, D. F. (1986). Biochemical Engineering Fundamentals. New York: McGraw-Hill. 5. El-Mansi, M., & Bryce, C. F. (2007). Fermentation Microbiology and Biotechnology. Boca Raton: CRC/Taylor & Francis.

Emerging Technologies	**MSUBT 302**	**Credits 3**
Unit I	Basic Microscopy: Light Microscopy: lenses and microscopes, resolution: Rayleigh's Approach, Darkfield; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy: what is fluorescence, what makes a molecule fluorescent, fluorescence microscope; optical arrangement, light source; filter sets: excitation filter, dichroic mirror, and barrier, optical layout for image capture; CCD cameras; back illumination, binning; recording color; three CCD elements with dichroic beamsplitters, boosting the signal. Advanced Microscopy: Confocal microscope: scanning optical microscope, confocal principle, resolution and point spread function, light source: gas lasers & solid-state, primary beamsplitter; beam scanning, pinhole and signal channel configurations, detectors; pixels and voxels; contrast, spatial sampling: temporal sampling: signal-to-noise ratio, multichannel images. nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence, advantages of two-photon excitation, tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, three-dimensional reconstruction; advanced fluorescence techniques: FLIM, FRET, and FCS, Fluorescence Lifetime, Fluorescence Resonant Energy Transfer (FRET), Fluorescence Correlation
Optical microscopy methods	

	Spectroscopy (FCS), Evanescent Wave Microscopy; Near-Field and Evanescent Waves, Total Internal Reflection Microscopy; Near-Field Microscopy; Beyond the Diffraction Limit: Stimulated Emission Depletion (STED), Super-Resolution Summary, Super-Resolution Imaging with Stochastic Optical Reconstruction Microscopy (STORM) and Photoactivated Localization Microscopy (PALM).
Unit II **Mass spectroscopy**	Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.
Unit III **Systems biology**	High throughput screens in cellular systems, target identification, validation of experimental methods to generate the omics data, bioinformatics analyses, mathematical modeling and designing testable predictions.
Unit IV **Structural biology**	X-ray diffraction methods, solution & solid-state NMR, cryo-electron microscopy, small-angle X-ray scattering, Atomic force microscopy.
Unit V **CRISPR-CAS**	History of its discovery, elucidation of the mechanism including introduction to all the molecular players, development of applications for in vivo genome engineering for genetic studies, promise of the technology as a next generation therapeutic method.
Unit VI **Nanobodies**	Introduction to nanobodies, combining nanobody with phage-display method for development of antibody against native proteins, nanobody as a tool for protein structure-function studies, use of nanobodies for molecular imaging, catabolic antibodies using nanobodies.
Recommended Text books and References	1. Campbell, I. D. (2012). Biophysical Techniques. Oxford: Oxford University Press. 2. Serdyuk, I. N., Zaccai, N. R., & Zaccai, G. (2007). Methods in Molecular Biophysics: Structure, Dynamics, Function. Cambridge: Cambridge University Press. 3. Phillips, R., Kondev, J., & Theriot, J. (2009). Physical Biology of the Cell. New York: Garland Science. 4. Nelson, P. C., Radosavljević, M., & Bromberg, S. (2004). Biological Physics: Energy, Information, Life. New York: W.H. Freeman. 5. Huang, B., Bates, M., & Zhuang, X. (2009). Super-Resolution Fluorescence Microscopy. Annual Review of Biochemistry, 78(1), 993-1016. doi:10.1146/annurev. biochem.77.061906.092014. 6. Mohanraju, P., Makarova, K. S., Zetsche, B., Zhang, F., Koonin, E. V., & Oost, J. V. (2016). Diverse Evolutionary Roots and Mechanistic Variations of the CRISPR-Cas Systems. Science, 353(6299). doi:10.1126/science.aad5147. 7. Lander, E. (2016). The Heroes of CRISPR. Cell, 164(1-2), 18-28. doi:10.1016/j. cell.2015.12.041. 8. Ledford, H. (2016). The Unsung Heroes of CRISPR. Nature, 535(7612), 342-344. doi:10.1038/535342a. 9. Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J. A., & Charpentier, E. (2012). A Programmable Dual-RNA-Guided DNA Endonuclease in Adaptive Bacterial Immunity. Science, 337(6096), 816-821. doi:10.1126/science.1225829. 10. Hamers-Casterman, C., Atarhouch, T., Muyldermans, S., Robinson, G., Hammers, C., Songa, E. B., Hammers, R. (1993). Naturally Occurring Antibodies Devoid of Light Chains. Nature, 363(6428), 446-448. doi:10.1038/363446a0. 11. Sidhu, S. S., & Koide, S. (2007). Phage Display for Engineering and

	Analyzing Protein Interaction Interfaces. Current Opinion in Structural Biology, 17(4), 481-487. doi:10.1016/j.sbi.2007.08.007. 12. Steyaert, J., & Kobilka, B. K. (2011). Nanobody Stabilization of G Protein-Coupled Receptor Conformational States. Current Opinion in Structural Biology, 21(4), 567-572. doi:10.1016/j.sbi.2011.06.011. 13. Vincke, C., & Muyldermans, S. (2012). Introduction to Heavy Chain Antibodies and Derived Nanobodies. Single Domain Antibodies, 15-26. doi:10.1007/978-1-61779- 968-6_2. 14. Verheesen, P., & Laeremans, T. (2012). Selection by Phage Display of Single Domain Antibodies Specific to Antigens in their Native Conformation. Single Domain Antibodies, 81-104. doi:10.1007/978-1-61779-968-6_6. 15. Li, J., Xia, L., Su, Y., Liu, H., Xia, X., Lu, Q. Reheman, K. (2012). Molecular Imprint of Enzyme Active Site by Camel Nanobodies. Journal of Biological Chemistry J. Biol. Chem., 287(17), 13713-13721. doi:10.1074/jbc.m111.336370. 16. Sohier, J., Laurent, C., Chevigné, A., Pardon, E., Srinivasan, V., Wernery, U. Galleni, M. (2013). Allosteric Inhibition of VIM Metallo-β-Lactamases by a Camelid Nanobody. Biochemical Journal, 450(3), 477-486. doi:10.1042/bj20121305. 17. Chakravarty, R., Goel, S., & Cai, W. (2014). Nanobody: The "Magic Bullet" for Molecular Imaging? Theranostics, 4(4), 386-398. doi:10.7150/thno.8006.

Critical Analysis of Classical Papers	**MSUBT 303**	**Credits 2**

How does the Course Module work? Students may be divided in groups and each group may be responsible for one classical paper. Each week there may be a 1.5 hour presentation cum discussion for each of the papers. At the end of the semester each student will be asked to write a mini-review (2-3 pages long) on any one classical paper, other than the one he/she presented/discussed.
A list of sixteen classic papers and some suggested reference materials:

Syllabus	
Molecular Biology	1. Studies on the chemical nature of the substance inducing transformation of Pneumococcal types: Induction of transformation by a deoxyribonucleic acid fraction isolated from Pneumococcus type III. Avery OT, Macleod CM, McCarty M.; J Exp Med. 1944 Feb 1;79(2):137-58. Note: This paper demonstrates that DNA is the transforming Principle originally described by Fredrick Griffith. 2. Independent functions of viral protein and nucleic acid in growth of bacteriophage, Hershey AD and Chase M.; J Gen Physiol. 1952 May;36(1):39-56. Note:This paper demonstrates that DNA, and not protein, component of phages enter bacterial cells. 3. Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid, Watson JD and Crick FH; Nature. 1953 Apr 25;171(4356):737-8 Note: In this one page paper Watson and Crick first described the structure of DNA double helix, Study help - Watson_Crick_Nature_1953_annotated 4. Transposable mating type genes in Saccharomyces cerevisiae James Hicks, Jeffrey N. Strathern & Amar J.S. Klar; Nature 282, 478-

	483,1979 Note: This paper provided evidence for 'cassette hypothesis' of yeast mating type switches i.e. interconversion of mating types in yeast (S. cerevisiae) occurs by DNA rearrangement. 5. Messelson & Stahl experiment demonstrating semi-conservative replication of DNA. Meselson M and Stahl FW.; Proc Natl Acad Sci U S A. 1958 Jul 15;44(7):671-82 Note: The experiment demonstrating semi-conservative mode of DNA replication is referred to as "the most beautiful experiment in biology" 6. In vivo alteration of telomere sequences and senescence caused by mutated Tetrahymena telomerase RNAs. Guo-Liang Yu, John D. Bradley, Laura D. Attardi & Elizabeth H. Blackburn; Nature 344, 126-132, 1990 Note: This paper demonstrates that the telomerase contains the template for telomere synthesis
Syllabus	1. A protein-conducting channel in the endoplasmic reticulum Simon SM AND Blobel G.; Cell. 1991 May 3;65(3):371-80 Note: This paper demonstrates the existence of a protein conducting channel Study help - A brief history of Signal Hypothesis 2. Identification of 23 complementation groups required for post-translational events in the yeast secretory pathway, Novick P, Field C, Schekman R.; Cell. 1980 Aug;21(1):205-15 Note: In this groundbreaking paper Randy Schekman's group used a mutagenesis screen for fast sedimenting yeast mutants to identify genes involved in cell secretion 3. A yeast mutant defective at an early stage in import of secretory protein precursors into the endoplasmic reticulum, Deshaies RJ and Schekman R.; J Cell Biol. 1987 Aug;105(2):633-45 Note: Using another yeast mutation screen Schekman lab identifies Sec61, a component of ER protein Conducting Channel (PCC) Suggested reference paper - A biochemical assay for identification of PCC. 4. Reconstitution of the Transport of Protein between Successive Compartments of the Golgi, Balch WE, Dunphy WG, Braell WA, Rothman JE.; Cell. 1984 Dec;39 (2 Pt 1):405-16 Note: This paper describes setting up of an in vitro reconstituted system for transport between golgi stacks which eventually paved the way for identification of most of the molecular players involved in these steps including NSF, SNAP etc. 5. A complete immunoglobulin gene is created by somatic recombination Brack C, Hirama M, Lenhard-Schuller R, Tonegawa S.; Cell. 1978 Sep;15(1):1-14 Note: This study demonstrates DNA level molecular details of somatic rearrangement of immunoglobulin gene sequences leading to the generation of functionally competent antibody generating gene following recombination. 6. A novel multigene family may encode odorant receptors: a molecular basis for odor recognition, Buck L and Axel R; Cell. 1991 Apr 5;65(1):175-87 Note: This paper suggests that different chemical odorants associate with different cell-specific expression of a transmembrane receptor in Drosophila olfactory epithelium where a large family of odorat receptors is expressed. 7. Kinesin walks hand-over-hand, Yildiz A, Tomishige M, Vale RD, Selvin PR.; Science. 2004 Jan 30;303(5658):676-8 Note: This paper shows that kinesin motor works as a two-headed dimeric
Cell Biology	

	motor walking hand-over-hand rather than like an inchworm on microtubule tract using the energy of ATP hydrolysis.
Syllabus	1. Mutations affecting segment number and polarity in Drosophila Christiane Nusslein-Volhard and Eric Weischaus; Nature 287, 795-801, 1980 Note: This single mutagenesis screen identified majority of the developmentally important genes not only in flies but in other metazoans as well. 2. Information for the dorsal--ventral pattern of the Drosophila embryo is stored as maternal mRNA, Anderson KV and Nüsslein-Volhard C; Nature. 1984 Sep 20-26;311(5983):223-7 Note: This landmark paper demonstrated that early dorsal-ventral pattern information is stored as maternal mRNA in flies and devised the method of identifying genes encoding such genes 3. Hedgehog signalling in the mouse requires intraflagellar transport proteins, Huangfu D, Liu A, Rakeman AS, Murcia NS, Niswander L, Anderson KV.; Nature. 2003 Nov 6;426(6962):83-7 Note: One of the architects of original fly mutagenesis screens conducted a mouse mutagenes screen which identified a gene Kif3a as a major component of hedgehog signaling pathway. Eventually this discovery revolutionizes our understanding of mechanisms of action of signaling pathways by demonstrating central role of cillia in it. Suggested Reference paper - Design and execution of a embryonic lethal mutation screen in mouse.
Developmental Biology/ Genetics	

Intellectual Property Rights, Biosafety and Bioethics	**MSUBT 304**	**Credits 2**
Unit I **Introduction to IPR**	Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of 'prior art': invention in context of "prior art"; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.	
Unit II **Patenting**	Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale,	

	licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.
Unit III **Biosafety**	Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.
Unit IV **National and international regulations**	International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).
Unit V **Bioethics**	Introduction, ethical conflicts in biological sciences - interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research – cloning and stem cell research, Human and animal experimentation, animal rights/welfare, Agricultural biotechnology - Genetically engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – biopiracy.
Recommended Text books and References	1. Ganguli, P. (2001). Intellectual Property Rights: Unleashing the Knowledge Economy. New Delhi: Tata McGraw-Hill Pub. 2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI 3. Complete Reference to Intellectual Property Rights Laws. (2007). Snow White Publication Oct. 4. Kuhse, H. (2010). Bioethics: an Anthology. Malden, MA: Blackwell. 5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/ 6. Karen F. Greif and Jon F. Merz, Current Controversies in the Biological Sciences-Case **Studies** of Policy Challenges from New Technologies, MIT Press 7. World Trade Organisation. http://www.wto.org 8. World Intellectual Property Organisation. http://www.wipo.int 9. International Union for the Protection of New Varieties of Plants. http://www.upov.int 10. National Portal of India. http://www.archive.india.gov.in 11. National Biodiversity Authority. http://www.nbaindia.org 12. Recombinant DNA Safety Guidelines, 1990 Department of

Biotechnology, Ministry of Science and Technology, Govt. of India. Retrieved from http://www.envfor.nic.in/divisions/csurv/geac/annex-5.pdf
13. Wolt, J. D., Keese, P., Raybould, A., Fitzpatrick, J. W., Burachik, M., Gray, A., Wu, F. (2009). Problem Formulation in the Environmental Risk Assessment for Genetically Modified Plants. Transgenic Research, 19(3), 425-436. doi:10.1007/s11248-009-9321-9
14. Craig, W., Tepfer, M., Degrassi, G., & Ripandelli, D. (2008). An Overview of General Features of Risk Assessments of Genetically Modified Crops. Euphytica, 164(3), 853-880. doi:10.1007/s10681-007-9643-8
15. Guidelines for Safety Assessment of Foods Derived from Genetically Engineered Plants. 2008.
16. Guidelines and Standard Operating Procedures for Confined Field Trials of Regulated Genetically Engineered Plants. 2008. Retrieved from http://www.igmoris.nic.in/guidelines1.asp
17. Alonso, G. M. (2013). Safety Assessment of Food and Feed Derived from GM Crops: Using Problem Formulation to Ensure "Fit for Purpose" Risk Assessments.
Retrieved from http://biosafety.icgeb.org/inhousepublicationscollectionbiosafetyreviews.

Research Methodology and Scientific Communication Skills	**MSUBT 305**	**Credits 1**
Unit I **History of science and science methodologies**	Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.	
Unit II **Preparation for research**	Choosing a mentor, lab and research question; maintaining a lab notebook.	
Unit III **Process of communication**	Concept of effective communication- setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using over-head projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.	
Unit IV **Scientific**	Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review	

communication	process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.
Recommended Text books and References	1. Valiela, I. (2001). Doing Science: Design, Analysis, and Communication of Scientific Research. Oxford: Oxford University Press. 2. On Being a Scientist: a Guide to Responsible Conduct in Research. (2009). Washington, D.C.: National Academies Press. 3. Gopen, G. D., & Smith, J. A. The Science of Scientific Writing. American Scientist, 78 (Nov-Dec 1990), 550-558. 4. Mohan, K., & Singh, N. P. (2010). Speaking English Effectively. Delhi: Macmillan India. 5. Movie: Naturally Obsessed, The Making of a Scientist.

Project Proposal Preparation & Presentation	**MSUBT 381**	**Credits 2**
Unit I **Project Proposal Preparation**	Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven. Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources. Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.	
Unit II **Poster Presentation**	Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.	
Unit III **Oral Presentation**	At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.	

Laboratory V Bioprocess Engineering & Technology	MSUBT 391	Credits 3
Syllabus	Basic Microbiology techniques a) Scale up from frozen vial to agar plate to shake flask culture. b) Instrumentation: Microplate reader, spectrophotometer, microscopy. c) Isolation of microorganisms from soil samples. 2. Experimental set-up a) Assembly of bioreactor and sterilization. b) Growth kinetics. c) Substrate and product inhibitions. d) Measurement of residual substrates. 3. Data Analysis a) Introduction to Metabolic Flux Analysis (MFA). 4. Fermentation a) Batch. b) Fed-batch. c) Continuous. 5. Unit operations a) Microfiltrations: Separation of cells from broth. b) Bioseparations: Various chromatographic techniques and extractions. 6. Bioanalytics a) Analytical techniques like HPLC, FPLC, GC, GC-MS etc. for measurement of amounts of products/substrates.	
Recommended Text books and References	1. Shuler, M. L., & Kargi, F. (2002). Bioprocess Engineering: Basic Concepts. Upper Saddle River, NJ: Prentice Hall. 2. Stanbury, P. F., & Whitaker, A. (2010). Principles of Fermentation Technology. Oxford: Pergamon Press. 3. Blanch, H. W., & Clark, D. S. (1997). Biochemical Engineering. New York: M. Dekker. 4. Bailey, J. E., & Ollis, D. F. (1986). Biochemical Engineering Fundamentals. New York: McGraw-Hill. 5. El-Mansi, M., & Bryce, C. F. (2007). Fermentation Microbiology and Biotechnology. Boca Raton: CRC/Taylor & Francis.	

Laboratory VI Applied Bioinformatics	MSUBT 392	Credits 2

Syllabus	1. Using NCBI and Uniprot web resources. 2. Introduction and use of various genome databases. 3. Sequence information resource: Using NCBI, EMBL, Genbank, Entrez, Swissprot/TrEMBL, UniProt. 4. Similarity searches using tools like BLAST and interpretation of results. 5. Multiple sequence alignment using ClustalW. 6. Phylogenetic analysis of protein and nucleotide sequences. 7. Use of gene prediction methods (GRAIL, Genscan, Glimmer). 8. Using RNA structure prediction tools. 9. Use of various primer designing and restriction site prediction tools. 10. Use of different protein structure prediction databases (PDB, SCOP, CATH). 11. Construction and study of protein structures using Deepview/PyMol. 12. Homology modelling of proteins. 13. Use of tools for mutation and analysis of the energy minimization of protein structures. 14. Use of miRNA prediction, designing and target prediction tools.

Semester Four

Dissertation	MSUBT 481	Credits 22

Syllabus	Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment. At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.
Planning & performing experiments	
Thesis writing	

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