

JIWAJI UNIVERSITY, GWALIOR-474011
MSc. BIOTECHNOLOGY

CURRICULUM- 2009-2011

Semester	Title of the Paper	Marks	
		EA	IA
First	101. Cell Biology	80	20
	102. Biomolecules and Biotechniques	80	20
	103. Microbiology	80	20
	104. Biostatistics & Computer Applications	80	20
	105. Lab Course I	80	20
	106. Lab Course II	80	20
Second	201. Molecular Biology	80	20
	202. Immunotechnology	80	20
	203. Part A: Microbial Biotechnology Part B: Animal Biotechnology	40 40	10 10
	204 Part A: Basic Enzymology Part B: Environmental Biotechnology	40 40	10 10
	205. Lab Course III	80	20
	206. Lab Course IV	80	20
Third	301. Genetic Engineering	80	20
	302. Plant Biotechnology	80	20
	303. Bioprocess Engineering and Technology	80	20
	304. Emerging Trends in Biotechnology	80	20
	305. Lab Course V	80	20
	306. Lab Course VI	80	20
Fourth	401. Optional 1: Bioinformatics Optional 2: Entrepreneurship in Biotechnology & IPR	80 80	20 20
	402. Optional 1: Molecular & Immunodiagnostics. Optional 2: Management & Marketing of Biotech. products	80 80	20 20
	403. Lab Course VII	80	20
	404. Project Work	300	

* Evaluated both by the Internal and External examiner at the time of presentation. There are weekly seminars and continuous internal assessment throughout the course. Of the Three internal assessment tests one will be based on seminar in every semester.

101: CELL BIOLOGY

Unit I

1. Cell membrane: physiochemical properties; Molecular Organization- asymmetric organization of lipids, proteins and carbohydrates: Biogenesis and Functions
2. Transport of small molecules across cell membranes: types and mechanisms.
3. Active transport by ATP powered pumps: types, properties and mechanisms.
4. Transport of proteins into Mitochondria and Chloroplast.

Unit II

1. Transport of proteins into and out of Nucleus.
2. Transport of proteins into Endoplasmic Reticulum.
3. Transport by Vesicle formation: Endocytosis and Exocytosis.
4. Molecular mechanisms of Vesicular transport.

Unit III

1. Intracellular digestion: Ultra structure and function of lysosomes.
2. Cell Motility and Shape I: Structure and function of microfilaments.
3. Cell Motility and Shape II: Structure and Function of Microtubules and Intermediate filaments.
4. Intra cellular communication through Cell Junctions: Occluding Junctions, Anchoring Junctions and Communicating Junctions.

Unit IV

1. Molecular Mechanisms of Cell-Cell Adhesions: Ca^{++} dependent cell-cell adhesions.
2. Molecular Mechanisms of Cell-Cell Adhesions: Ca^{++} independent cell-cell adhesions.
3. Extracellular Matrix of animals: Organization and Functions.
4. Extracellular Matrix Receptors on animal cells: Integrins.

Unit V

1. Cell Signaling: Signaling via G-Protein linked and enzyme linked cell surface receptors, MAP kinase pathways, Interaction and Regulation of signaling pathways.
2. Eukaryotic Cell Division Cycle: Different Phases and Molecular Events.
3. Control of Cell Division Cycle: In yeast and mammalian cells.
4. Apoptosis: Phases and significance, Morphological and Biochemical changes associated with apoptotic cells, Apoptotic Pathways and regulators

Practical Exercises

1. Sub Cellular fractionation
2. Chromosome preparation: Mitosis-Onion root tip, rat/mouse cornea, rat mouse bone marrow, human lymphocytes
3. Chromosome preparation: Meiosis- Rat/mouse testis, Grasshopper testis.
4. Polytene chromosome preparation from drosophila salivary gland
5. Identification of tissue typing: Histological preparation of tissue
6. Identification of different biomolecules in different tissues by histochemical techniques
7. Electron microscopy: demonstration and good photographs for interpretation

Reference Books

1. Molecular Biology of the cell (2002) Alberts, et al
2. Molecular Cell biology (2004) Lodish, et al
3. Working with Molecular Cell Biology: A study companion (2000), Stories et al
4. Cell and Molecular Biology: concepts and Experiments (3rd Ed.,2002), Gerald Karp
5. The cell: A Molecular Approach, G.M.Cooper
6. The world of Cell (1996), Becker et al
7. Cell proliferation and apoptosis (2003), Hughes and Mehnet
8. Essential Cell Biology (1998), Alberts et al
9. Biochemistry and Molecular Biology of Plants (2000) Buchanan et al
10. Harpers biochemistry Murray et al

102. BIOMOLECULES & BIOTECHNIQUES

UNIT I

1. Chemical foundations of Biology- pH, pK, acids, bases, buffers, weak bonds & Covalent bonds, Principles of thermodynamics
2. Carbohydrates: classification, structure, functions; homo and hetero polysaccharides, animal, plant and microbe specific polysaccharides
3. Lipids: Classification, structure, functions; Lipids with specific biological functions, Lipoproteins and biological membrane, micelles and liposomes
4. Proteins: Classification, Primary, Secondary, tertiary and quaternary structure., Separation, purification and criteria of homogeneity, End group analysis

UNIT II

1. Nucleic acids: Structure, Properties of purines and pyrimidine bases, DNA : Structure, conformation, prokaryotic and eukaryotic DNA, Chromosomal and extra chromosomal DNA
2. RNA: Structure, types and function of mRNA, tRNA, Ribozymes: structure and functions.
3. Nucleic acid metabolism: biosynthesis and breakdown of purine and pyrimidine nucleotides by de novo and salvage pathways
4. Vitamins and cofactors: Structure, distribution, interaction and biological properties

UNIT III

1. Outlines of Carbohydrate, Lipid, Protein metabolisms & their integration.
2. Electron transport and oxidative phosphorylation: Electron carriers complexes I - IV
3. Analytical techniques for biomolecule separation: Paper, TLC, Gel filtration, Ion exchange and affinity chromatography
4. HPLC & Gas- liquid chromatography

UNIT IV

1. Centrifugation: Principle, techniques, preparative, analytical and ultracentrifuges, applications of centrifugation.
2. Photometry: Basic principles and applications of colorimetry, UV-visible spectrophotometry and IR-Spectrophotometry
3. Atomic absorption spectroscopy: Instrumentation, Principle and applications
4. Electrophoresis: PAGE-types, 2D-E, Isotachopheresis, Isoelectric focusing

UNIT V

1. Microtomy: types, principle and applications.
2. Microscopy: Light, Phase contrast, fluorescence and electron microscopies
3. Radioactivity: GM Counter, Liquid Scintillation counter, Solid Scintillation counters
4. Auto radiography: Principle and applications

Practical Exercises

1. Verification of Beer's law
2. Determination of absorption maxima
3. Electrophoresis of proteins-native and under denaturing conditions
4. Amino acid and carbohydrate separations by paper & thin layer chromatography
5. Gas Chromatography
6. Ion Exchange and gel filtration chromatography
7. Separation of sub cellular organelles by differential centrifugation
8. Separation of blood cells by density gradient centrifugation
9. Titration of amino acids
10. Colorimetric determination of pK
11. Reactions of amino acids, sugars and lipids
12. Quantitation of proteins and sugars by different methods
13. Analysis of oils-iodine number, saponification value, acid number.

Reference Books

1. Principle of Biochemistry by Nelson, Cox and Lehninger
2. Biochemistry by G.Zubay
3. Biochemistry by Stryer
4. Biochemistry by Garrett and Grisham
5. Biochemical Calculations, Irwin H.Segel, Jhon Wiley and sons Inc
6. Biochemistry, D Voet and JG Voet, J Wiley and Sons.
7. Biochemistry, D Freifelder, W.H.Freeman & Company
8. Laboratory techniques in Biochemistry and Molecular Biology, Work and Work.
9. A Biologists guide to Principles and techniques of practical Biochemistry, L Wilson & KH Goodling, ELBS Edition, 1986
10. Physical Biochemistry: Applications to Biochemistry and Molecular Biology by Friefelder
11. Biochemical Techniques: Theory and Practice by Robot and White
12. Principles of Instrumental Analysis by Scoff and West
13. Analytical Biochemistry by Holme and Peck
14. Biological Spectroscopy by Campbell and Dwek
15. Organic Spectroscopy by Kemp
16. A Biologists guide to Principles and Techniques of Practical Biochemistry by Wilson and Goulding
17. Principles of Instrumental Anal

103. MICROBIOLOGY

Unit I

1. Classification of Microorganisms: Bacterial & Fungal Classification.
2. Morphology and fine structure of eubacteria, archebacterial cell wall and fungal cell wall.
3. Preparation of culture media, pure culture techniques and microbial staining.
4. Cyanobacteria : General account and their economic importance

Unit II

1. Sterilization: Physical and chemical methods.
2. Microbial growth: Bacterial growth curve, Mathematical expression, measurement of growth and factors affecting growth.
3. Microbial Nutrition: Nutritional classification of Microorganisms, Different carbon and nitrogen sources, mode of nutrition, transport of nutrition across the bacterial membrane.
4. Oxygen toxicity: Study of catalase, peroxidase, superoxide dismutase, mechanism of oxygen toxicity/ Taxonomic classification of microbes using molecular markers- 16 rRNA typing.

Unit III

1. Infection and disease, types of infection, Mechanism of pathogenesis of bacterial and viral disease.
2. Staphylococcal and Clostridial food Poisoning, Bacterial Diseases: Salmonellosis and Shigellosis.
3. Fungal Diseases: Histoplasmosis, Aspergillosis and Candidiasis.
4. Viral diseases: Chicken Pox, Hepatitis B and Poliomyelitis.

Unit IV

1. Virus organization, Types, Isolation, cultivation, identification and viral replication.
2. Structure and morphology of bacteriophages, lytic and lysogenic cycle.
3. Life cycle of DNA viruses: SV 40, RNA viruses: Retroviruses.
4. Plant viruses: TMV, Gemini, CMV, Human Viruses: Influenza (SARS), Herpes Simples virus, Rubella.

Unit V

1. Mycoplasma and diseases caused by them.
2. Bacterial Recombination: Transformation, conjugation, transduction, Plasmids and Transposons.
3. Chemotherapeutic agents: Classification of Antibiotics, Broad and narrow spectrum antibiotics; Antibiotics from prokaryotes.
4. Anti-fungal and antiviral antibiotics, mode of action of antibiotics and mechanism of drug resistance, origin of drug resistance.

Practical Exercises

1. Preparation of Liquid and Solid media for growth of microorganisms.
2. Isolation and maintenance of organisms by plating, streaking and serial dilution method, slant and stab cultures, storage of microorganisms.
3. Isolation of pure cultures from soil and water
4. Growth; Growth curve; Measurement of bacteria population by turbidometry and serial dilution methods. Effect of temperature, pH and carbon and nitrogen sources on growth.
5. Microscopic examination of bacteria, Yeast and mold and study of organism by Gram's stain, acid fast stain and staining for spores
6. Study of mutation by Ame's Test.
7. Assay of antibiotics and demonstration of antibiotic resistance
8. Analysis of water for potability and determination of MPN.
9. Bacterial transformation.
10. Biochemical Characterization of selected microbes.
11. One Step growth curve of coli phage.

Reference Books

1. General microbiology, R.Y. Ingraham, J.L. Wheelis, M.L. and Painter, P.R. The MacMillian Press Ltd.
2. Brock Biology of microorganism, M.T. Martinko, J.M. and Parker, J. Prentice-Hall.
3. Microbiology, Pelzar, M.J., Chan E.C.S. and Kreig, N.R., Tata McGraw Hill.
4. Microbial Genetics, Maloy, S.R., Cronan, J.E. Jr and Freifelder, D.Jones, Bartlett Publishers
5. Microbiology-A Laboratory Manual, cappuccino, J.G. Sherman, N. Addison Wesley.
6. Microbiological Applications (A Laboratory Manual in General microbiology) Benson, H.J. WCB: Wm C Brown Publishers

104 BIostatISTICS AND COMPUTER APPLICATIONS

Unit I

1. Introduction to Biostatistics, Common terms, notions and Applications
2. Statistical population and Sampling Methods
3. Classification and tabulation of Data
4. Diagrammatic and graphical presentation
5. Frequency Distribution, Measures of central value
6. Measures of variability; Standard deviation, standard Error, Range, Mean Deviation, Coefficient of variation, Analysis of variance

Unit II

1. Basic tests, Test of significance; t-test, chi-square test.
2. Regression; Basic of regression, regression analysis, Estimation, Testing, prediction, checking and residual analysis.
3. Multivariate Analysis.
4. Design of Experiments, randomization, replication, local control, complimentary Randomized, randomized block design

Unit III

1. Factor Analysis.
2. Path analysis
3. Introduction to data mining
4. Virtuous Cycle.

Unit IV

1. Classification and Discriminant Analysis Tools: CART, Random forests,
2. Fisher's discriminant functions.
3. Neural networks.
4. Multilayer perception, predictive ANN model building using back propagation algorithm, exploratory data analysis.

Unit V

1. Introduction to computer basics, concept of hardware windows XP and LINUX
2. Concept of file, folders, directories and their management by windows XP and LINUX
3. Office applications : MS- Office, MS- Word, MS- Excel and MS- PowerPoint
4. Open Office on Linux: Word Processor, spread sheets, Impress
5. Statistical Packages: Sigma plot etc.

Reference Books:

1. An Introduction to computational Biochemistry by C Stan T Sai
2. Statistics for Agricultural Sciences by Nageswara Rao
3. Fundamental of Statistics by Goon et al 1962
4. Methods in Biostatistics by B.K. Mahajan
5. Statistical Methods by S P Gupta
6. Statistical Methods by G W Snedecor and W G Cochran
7. Fundamental of Artificial Neural Networks, Prentice-Hall of India, N.Delhi

105 Lab Course: I

Consists of Practical Exercises listed out under 101 & 102

106 Lab Course: II

Consists of Practical Exercises listed out under 103 & 104

201: MOLECULAR BIOLOGY

Unit I

1. Nature of Gene Concept, Chemical Nature of Gene, Gene cistron relationship in Prokaryotes and Eukaryotes
2. DNA Replication : General features of Chromosomal Replication: DNA Replication machinery in Prokaryotes and its comparison with Eukaryotes
3. Enzymology of DNA replication: DNA Polymerase; Primases; Ligases; Helicases; Topoisomerases; Gyrase and Single Stranded Binding Proteins
4. Regulation of DNA replication

Unit II

1. Transcription in prokaryotes: Initiation, elongation and termination
2. Structure and Function of prokaryotic promoter
3. Control of transcriptional initiation in prokaryotes: Structure and function of RNA Polymerase: Sigma factors- Types and functions
4. Control of transcriptional termination: Attenuation and antitermination

Unit III

1. Regulation of gene expression in prokaryotes: Operon concept, induction and repression, Structure and regulation of lactose, arabinose and tryptophan operons
2. Initiation of transcription in Eukaryotes: RNA Polymerases Types and properties
3. Transcription factors- Types and properties; Enhancers- Structure and properties; Response Elements
4. Post-transcriptional Modification Eukaryotes- 5' and 3' modification of mRNA

Unit IV

1. Post- transcriptional Processing of pre mRNA, pre rRNA and pre tRNA transcripts
2. Genetic Code: Evidence and properties; Wobble hypothesis; Transcriptional adaptors and amino acyl tRNA synthases
3. Translation: Successive stages of protein synthesis in prokaryotes and its comparison with eukaryotes
4. Post-translational Modification: Types and Significance

Unit V

1. Regulation of Gene Expression in Eukaryotes: cis- acting DNA elements; Chromatin organization and regulation of gene expression; regulation at the level of processing of transcripts
2. Regulation of Gene Expression in Eukaryotes: RNA editing; Gene Alteration; DNA methylation and gene regulation; Regulation of gene expression by hormones: regulation of gene expression at translational level
3. Transposable elements in Prokaryotes and Eukaryotes: Types and Significance
4. Oncogenes and Tumor Suppressor Genes: Properties and Significance

Practical Exercises

1. Isolation of Genomic DNA and restriction Digestion
2. Size fractionation of restricted DNA fragments by Agarose Gel Electrophoresis
3. Quantitation of DNA
4. Determination of Amax of purified DNA fragments
5. Determination of Tm of nucleic acid
6. Isolation of RNA
7. Fractionation of poly (A) RNA
8. *In vitro* transcription
9. *In vitro* translation
10. Metabolic labeling of proteins and immunoprecipitation
11. Protein-DNA interaction

Reference Books

1. Genes IX Benjamin Lewin
2. Molecular Biology , turner et al
3. Cell and Molecular Biology: Concepts and Experiments, Gerald Karp
4. Translational regulation in eukaryotes (2000), Carey and Smale
5. Translational control of Gene Expression (2000), Sonenberg et al
6. Chromatin and Gene Regulation (2001), Turner
7. An Introduction to Genetic Analysis, Griffiths et al
8. Genome (1999), Brown
9. Concepts pf Genetics, klug and Cummings
10. Proteins, Creighton
11. Molecular Cell Biology, Lodish et al
12. Biochemistry and Molecular Biology of Plants (2000), Buchanan
13. Plant Biochemistry and Molecular Biology, Lea and Leegood
14. Plant Biochemistry (1997), Dey and Harborne

Note: All text books are of latest editions

202. IMMUNOTECHNOLOGY

UNIT I

1. Immune response: Innate immune mechanisms and characteristics of adaptive immune responses, Hematopoiesis.
2. Anatomical organization of Immune System: Primary Lymphoid Organs, Secondary Lymphoid Organs, Ontogeny and Phylogeny of lymphocytes, Lymphocyte traffic.
3. Cell of immune system: Mononuclear cells and granulocyte, Antigen presenting cells, lymphocytes and their subsets. Antigen, Haptens: Factor affecting immunogenicity, Super antigen.
4. Inflammation: its mediator and the process, cell-adhesion molecules and their role in inflammation, lymphocyte homing, tissue injury and immune response leading to an inflammatory reaction, role of anaphylatoxins, granulocyte in inflammatory process.

UNIT II

1. Major histocompatibility systems: Structure of MHC I and II molecules, polymorphism, distribution variation and function. Organization of MHC complex in mouse and humans. Association MHC with disease.
2. Recognition of antigens by T and B cells: Antigen processing, Role of MHC molecules in Antigen presentation and co stimulatory signals.
3. T-Cell receptor complex, T- Cell accessory membrane molecules, activation of T –cells, organization and arrangement of T-receptor genes.
4. B-cell receptor complex, activation of B-cells, Immunoglobulins: molecular structures, types and function. Antigenic determinants on immunoglobulins.

UNIT III

1. Molecular mechanism of antibody diversity: Organization of genes coding for constant and variable regions of heavy chain and light chain. Mechanism of antibody diversity, Class Switching.
2. Antigen-Antibody interaction avidity and affinity measurement.
3. Monoclonal antibodies: production, characterization and application in diagnosis, therapy and basic research.
4. Complement System, components, Activation pathway and regulation of activation pathway, complement deficiency, role of complement system in immune responses.

UNIT IV

1. Cytokines: Structure and functions, cytokine receptors, signal transductions mediated by cytokine receptors, cytokine regulation of immune responses, cytokine related diseases and therapeutic applications of cytokines.
2. Cytotoxic T-cell and their mechanism of action, NK cell and mechanism of target cell destruction. Antibody dependent cell mediated cytotoxicity, delayed type hypersensitivity. Techniques of Cell-mediated immunity.
3. Immunoregulation by Antigens, Antibodies, immune complexes, MHC and cytokines.
4. Hypersensitivity: definition, IgE mediated hypersensitivity, mechanism of mast cell degranulation, mediators of type I reactions and consequences. Type II reactions, immune complex mediated hypersensitivity and delayed type hypersensitivity.

UNIT V

1. Autoimmunity: Organ specific diseases, systemic disease, mechanism of autoimmunity.
2. Immunodeficiency Syndrome: Primary Immunodeficiencies and Secondary Immunodeficiencies and their diagnosis and therapeutic approaches.
3. Vaccines: Active and passive immunization, whole organism vaccines, macromolecules as vaccines, Recombinant vector Vaccines, DNA Vaccines, synthetic peptide Vaccines and sub-unit Vaccines.
4. Immunodiagnostics: development of Immunodiagnostic Kits for infectious and non-infectious disease with examples. Precipitation techniques, Agglutination, Fluorescence Techniques, ELISA, RIA, Western Blotting and immuno-histochemical techniques.

Practical Exercises

1. Blood Film Preparation and identification of cells.
2. Lymphoid organs and their microscopic organization.
3. Immunization and production of polyclonal antibodies.
4. Double diffusion and Immuno-electrophoresis.
5. Radial immunodiffusion.
6. Purification of IgG from serum.
7. Separation of mononuclear cell by Ficoll-paque.
8. Con-A induced proliferation of thymocytes (by MTT Method).
9. Western blotting.
10. ELISA
11. Preparation of antibody-enzyme conjugates.

Reference Books:

1. Immunology, Kubey, R.A. Goldsby, Thomas J. Kindt, Barbara, A. Osbarne (Freeman).
2. Immunology- A short Course, Eli Benamini, Richard Coico, Geoffrey Sunshine.
3. Immunology by Tizzard
4. Fundamentals of Immunology, William Paul.
5. Immunology by Roitt and others.
6. Immunology by Abbas.

203: MICROBIAL & ANIMAL BIOTECHNOLOGY

Part A: Microbial Biotechnology

UNIT I

1. Microbial of Industrial Importance
2. Microbial Production of antibiotics: Penicillin; and Streptomycin
3. Microbial Production of Vitamins & amino acids (Vit B12 & Glutamic acid)
4. Microbial production of enzymes: Amylase, Protease and applications

UNIT II

1. Microbial production of alcoholic beverages: Distilled alcoholic beverages-Beer, microbial production of Vinegar.
2. Microbial production of Organic acids: Citric acid & Acetic acid
3. Microbial production of solvents: Ethanol and acetone
4. Microbial production of food –SCP

UNIT III

1. Biotransformation: Steroids
2. Mushroom Cultivation
3. Biofertilizers and its applications
4. Immobilization of microbial cells and their applications

Practical Exercises in Part A

1. Isolation of Industrially important microorganisms for microbial processes
2. Microbial production of citric acid using *Aspergillus niger*
3. Production and estimation of Alkaline protease
4. Biomass SCP from Algae and Fungi
5. Organic Solvent production
6. Bio-transformation
7. bio-insecticide isolation, purification and assay
8. Bio-fertilizer production
9. Use of alginate for cell immobilization

Part B Animal Biotechnology

UNIT IV

1. Introduction and organization of animal cell and tissue culture laboratory
2. Primary and established cell line cultures
3. Serum and protein free defined media and their applications
4. Introduction to balanced salt solutions and simple growth medium: rationale of composition of medium, role of CO₂ and supplements

UNIT V

1. Measurement of parameters of growth
2. Scaling up of animal cell culture, Cell synchronization
3. 3-D animal cell culture
4. FISH and applications of animal cell culture

Practical Exercises in Part B

1. Preparation of tissue culture medium and membrane filtration
2. Preparation of single cell suspension from spleen and thymus
3. Cell counting and viability
4. Macrophage monolayer from PEC and measurement of phagocytic activity
5. Cell fusion with PEG

Reference Books

1. Culture of Animal Cells by RI Freshney
2. Animal Cell Culture: Practical Approach John R W Masters
3. Animal Cell Culture Techniques by Ed. Martin Clynes
4. Methods in Cell Biology Vol. 57, Animal cell culture methods

204: BASIC ENZYMOLOGY AND ENVIRONMENTAL BIOTECHNOLOGY

Part A. Basic Enzymology

UNIT I

1. Enzyme : Historical aspects, Classification and nomenclature
2. Mechanism of Enzyme catalysis and action
3. Methods of enzyme assay: Continuous & Sampling techniques, coupled kinetic assays, Significance of enzyme turn over number, Specific activity.
4. Enzyme purification techniques, Criteria of purity and tabulation of data characterization of purified enzymes

UNIT II

1. Enzyme Engineering: site directed mutagenesis
2. Enzyme kinetics: Determination of V_{max} and k_m ., factors effecting rate of reaction
3. Enzyme inhibition: Types and significance
4. Rapid reaction techniques

UNIT III

1. Enzyme immobilization: Experimental procedures and effect on kinetic parameters
2. Uses of enzymes in Industries, textiles, leather and food
3. Use of purified enzymes in Biosensors
4. Development of enzyme sensor for clinical diagnosis with specific examples

Practical Exercises:

1. Urease estimation in plant tissues
2. Assay of alkaline phosphatase in kidney and Liver
3. Determination of optimum pH, temperature & Time
4. Determination of K_m value of alkaline phosphatase
5. Enzyme purification: Ammonium sulphate precipitation, ion exchange chromatography, molecular sieve chromatography
6. Checking of purity of enzyme by PAGE
7. Molecular weight determination of enzyme by Gel filtration
8. Immobilization of HRP (Horse reddish peroxidase)
9. Kinetic properties of Immobilized HRP
10. Sub cellular fractionation of rat liver and marker enzyme assays

Reference Books

1. The nature of enzymology by R.L.Foster
2. Enzymes by Dixon and Webb
3. Fundamentals of Enzymology by Price and Stevens
4. Enzyme catalysis and regulation by Hammers
5. Enzyme reaction mechanisms by Walsch
6. The Enzymes Vol. I & II by Boyer
7. Enzyme Structure and Mechanism by Alan Fersht

8. Enzyme Assays: A Practical approach by Eisenthal and Danson
9. Enzyme Biotechnology by G.Tripathi
10. Practical Biochemistry by Plummer
11. Practical biochemistry by sawhney and R.Singh

Part B. Environmental Biotechnology

UNIT IV

1. Environment: basic concepts, Environment pollution: types, methods for measurement of pollution
2. Waste treatment & Utilization:
3. Biomedical waste and its management
4. Xenobiotics and its degradation

UNIT V

1. Integrated pest management- An ecological approach
2. Bioremediation: In -situ and ex -situ techniques, advantages of bioremediation, applications of genetically engineered microbes (GEM) in bioremediation.
3. Phytoremediation: Types and its applications
4. Environmental monitoring: Bioindicators

Practical Exercises

1. Determination of dissolved oxygen concentration of water sample
2. Determination of biological oxygen demand (BOD) of sewage sample
3. Determination of Chemical oxygen demand (COD) of sewage sample
4. Isolation of xenobiotic degrading bacteria by selective enrichment technique
5. Test for the degradation of aromatic hydrocarbons by bacteria
6. Survey of degradative plasmids in microbes growing in polluted environment
7. Study on biogenic methane production in different habitats

Reference Books

1. Comprehensive Biotechnology. Vol. 4, M. Moo-Young (Ed-in-chief), Pergamon Press Oxford
2. Environmental chemistry. A.K.De, Wiley Eastern Ltd., New Delhi
3. Introduction to Biodeterioration. D.Allsopp and Seal, ELBS/ Edward Arnold
4. Environmental Biotechnologies and Cleaner Bioprocess by Eugenia J Olguin et al
5. Environmental Science: Physical Principles and applications by Egbert Booker et al

Lab Course III

Consists of practical exercises listed out under 201 & 202

Lab Course IV

Consists of practical exercises listed out under 203 & 204

301 GENETIC ENGINEERING

Unit I

1. The recombinant DNA Technology : General concept and principle of cloning
2. Enzymes: Nucleases and restriction endonucleases- properties and types; phosphomonoesterases; polymerase; terminal deoxynucleotidyl transferase; poly A polymerase, Linkers, adaptors and homopolymer tailing.
3. prokaryotic host- vector system: Characteristics of *E.coli* as host; vectors for cloning in *E.coli* (plasmid, bacteriophage- EMBL, λ DASH, λ gt10/11, λ ZAP etc and plasmid-phage),
4. Other Prokaryotic host vector systems: BAC ,Characteristics of Gram positive and Gram negative organism as host and suitable vectors for cloning; Shuttle Vectors

Unit II

1. Design and characteristics of expression vectors for cloning in prokaryotes and factors that affect expression.
2. Cloning in Yeast: Properties of yeast as host for cloning and different types of vectors designed for cloning in yeast
3. Cloning in animal system: Animal system as a model host, Methods of introduction of foreign DNA in animal system; Vectors for cloning in animal system- SV-40, vaccinia virus, baculovirus and retrovirus vectors ,pMal, GST, pET based vectors, Pichia based vectors.
4. Plant transformation technology: Features of Ti and Ri plasmids, mechanism of DNA transfer.

Unit III

1. Methods for Constructing rDNA and cloning: Inserts; vector insert ligation; infection, transferring and cloning
2. Methods for screening and selection of recombinant clones
3. DNA Libraries: types, advantages and disadvantages of different types of libraries; Different methods for constructing genomic and full length cDNA libraries
4. Gross anatomy of cloned insert- size, restriction mapping and location

Unit IV

1. Fine anatomy of DNA segment- General principle of chemical and enzymatic methods of nucleotide sequence analysis and advantages of automatic gene sequencers.
2. Localization of cloned segments in genomes- molecular and chromosomal location
3. Methods for determination of copy number of a cloned gene in genome
4. Mutant construction: Introduction, deletion, insertion and point mutation

Unit V

1. Principles and applications of Blotting techniques- Southern, Northern, Western and Eastern blotting; Polymerase Chain reaction and types (multiplex, nested, RT, real time, touch down PCR, hot start PCR, colony PCR), Oligonucleotide
2. Principle and applications of gel mobility shift assay, DNA fingerprinting and DNA Foot printing, restriction fragment length polymorphism, Chromosome mapping and chromosome painting
3. Application of Recombinant DNA technology in Medicine & Industry
4. Si RNA and si RNA technology: Micro RNA Construction of si RNA vectors: Gene silencing and its applications in agro industry.

Practical Exercises

1. Bacterial Culture and antibiotic selection media. Preparation of competent cells
2. Isolation of plasmid DNA
3. Isolation of phage DNA
4. Quantitation of nucleic acids
5. Restriction mapping of plasmid DNA
6. Cloning in plasmid/phagemid vectors
7. Preparation of helper phage and its titration
8. Preparation of single stranded DNA template
9. Gene expression in *E. coli* and analysis of gene product
10. Polymerase Chain Reaction

Reference Books

1. Recombinant DNA – By Watson et al
2. Principles of Gene Manipulation, Old and Primrose
3. Gene Cloning: An introduction , Brown
4. Biotechnology: Theory and Techniques (Vol I & II, 1995), Chirikjian
5. Molecular Genetics of Bacteria , Dale
6. Molecular Cloning (Vol I, II & III, 2001), Sambrook & Russell
7. Applied Molecular Genetics (1999), Miesfeld
8. Genes and Genome (1991), Singer & Berg
9. Molecular Biotechnology , Glick & Pasternak
10. Plant Molecular Biology (Vol I & II, 2002), Gilmartin & Bowler

302. PLANT BIOTECHNOLOGY

Unit I

1. Objectives, roles and landmarks in plant breeding.
2. Special breeding techniques: Mutational breeding and distant hybridization.
3. Generation of genetically modified crops for resistance against biotic and abiotic stresses and nutritional quality.
4. Seed production techniques: release of new varieties.

UNIT II

1. Introduction to plant tissue culture: Tissue Culture Media preparation.
2. Initiation of callus culture and its maintenance.
3. Cell synchronization
4. Organogenesis: Somatic embryo hybridization.

UNIT III

1. Somaclonal variation and its application for plant improvement
2. Anther culture: haploid and Diploid plant cell production and their applications
3. Protoplast isolation and fusion, selection of hybrid cell and cybrids
4. Cryopreservation techniques and application

UNIT IV

1. Plant cloning vectors: ti Plasmid and viral vectors (CaMV based vectors, Gemini viruses, TMV based vectors, Antisense RNA and ribosome technology
2. Transgenics in crop improvement: Methods for gene transfer field, Chloroplast transformation, testing and commercialization.
3. Marker assisted selection: Morphological, Biochemical and Molecular markers, advantages and disadvantages, choice of mapping populations
4. Plant DNA fingerprinting: Hybridization and PCR based markers (RFLP, SSR's, RAPD, QTLs, SCARS, AFLP etc)

UNIT V

1. Plant Genome mapping: Physical and molecular maps , Gene tagging
2. insect resistance, Bt genes, Non-Bt like protease inhibitors, alpha amylase inhibitor, green House technology
3. Seed production techniques, release of new varieties and plant breeders' right: UPOV 369, 370, 372. germplasm maintenance
4. intellectual property right (IPR) and protection (IPP, Patenting of Biological material

Practical Exercises

1. Preparation of media
2. Surface sterilization
3. Organ Culture
4. Callus propagation, organogenesis, transfer of plants to soil
5. Protoplast isolation and culture
6. Anther culture, production of haploids
7. Agrobacterium culture, selection of transformant, reporter genes (GUS) assays
8. Genomic DNA isolation from seeds and plant tissues, electrophoretic analysis
9. restriction digestion of plant genomic DNA
10. Setting up of PCR reactions

Reference Books

1. Plant Biotechnology, Springer Verlag, 2000. Hammond. P, Mc Garvey and V. Yusibov (Eds)
2. Introduction to plant tissue culture by Kalayan Kumar
3. Plant tissue culture by Bhojwani
4. Practical applications of Plant Molecular Biology by Henery et al
5. Principles of Plant Biotechnology by Montell SH et al
6. Plant Genome Analysis by PM Gresshoff
7. Essentials of Plant Breeding by Phudan Singh
8. Biotechnology: Theory and Techniques Vol I & II by Jack Chirikjian
9. Genetic Engineering by Sandhya Mitra
10. Plant Molecular Biology Vol I & II by Phillip M Gimartin & Chris Bowler

303: BIOPROCESS ENGINEERING AND TECHNOLOGY

UNIT I

1. Introduction to bioprocess engineering
2. Isolation, preservation and Maintenance of Industrial microorganisms.
3. Kinetics of microbial growth and death,
4. Media for industrial fermentation.

UNIT II

1. Air and media sterilization,
2. Safety in fermentation laboratory
3. Strain improvement of industrially important microorganism.
4. Bioreactors: Principle, Kinetics, types, design, and application.

UNIT III

1. Aeration and Agitation systems for bioreactor.
2. Flow behaviour of fermentation fluids
3. Gas-Liquid mass transfer, significance of K_{La} , and Heat transfer.
4. Automation for monitoring and control.

UNIT IV

1. Downstream processing: Introduction, removal of microbial cells and solid matter, foam separation, precipitation, centrifugation, cell disruption, chromatography
2. Extraction: -solvent, two phase, liquid extraction
3. Product recovery processes
4. Crystallization, packaging and quality assurance.

UNIT V

1. Safety consideration in down stream processing
2. Bioprocess economics.
3. Classification of product formation
4. Product synthesis kinetics

Practical Exercises:

1. Isolation of industrially important microbes from the environment
2. Determination of TDP & TDT of microorganisms for a design of a sterilizer

3. Determination of growth curve of a industrial organism and compute substrate, degradation profile, specific growth rate & growth yield
4. Screening and enrichment for a primary / secondary metabolite from the environment
5. Strain improvement for higher yield of a product
6. Random and strategic screening for a metabolite
7. Media balancing experiments
8. Alcohol fermentation using different substrates and its down stream process.

Reference Books:

1. Biochemical Engineering, Aiba S. , Humphrey A E , Millis N F. Univ. Tokyo Press, Tokyo
2. Biochemical Reactors, Atkinson B., Pion Ltd London.
3. Biochemical Engineering Fundamentals, Bialy J E & Ollas D F. McGraw Hill Book Cooperation New York.
4. Bioprocess Technology: Fundamentals & Applications, KTH, Stockholm.
5. Biochemical Engineering, Alba,S., Humphrey, A.E. and Millis, N.F. Univ. Tokyo Press
6. Biochemical Reactors, Atkinson, B... Pion Ltd, London
7. Biochemical Engineering Fundamentals, Bialy, J.E. and Olli's, DF Mcgraw-Hill Book Co. New York
8. Bioprocess Technology: Fundamentals and Applications, KTH, Stockholm
9. Process Engineering in Biotechnology, Jackson, A.T., Prentice Hall, Englewood Cliff
10. Bioprocess Engineering : Basic concepts Shuler,M.L. and Kargi, F.Prentice Hall Englewood Cliff
11. Principles of fermentation Technology, Stanbury, P.F. and Whitaker, A.,pergmon Press, Oxford
12. Bioreactor Engineering Principles, Nielson,J and Villadsen, J.,Plenum Press
13. Chemical Engineering, Problems in Biotechnology, Shuler, M.L.(Ed.), AICHE
14. Bioprocess Engineering, Lee, J.M.Prentice Hall Inc.
15. Bioprocess Engineering Kinetics- , Mass Transport, Reactors and Gene Expression, Vieth, W.F., John Wiley & Sons, Inc.

304 EMERGING TRENDS IN BIOTECHNOLOGY

Unit I

1. Genome & Genomics: Concept and methods of genome analysis, genome projects.
2. Transcriptome & Transcriptomics: Concept and methods
3. Proteome & Proteomics: Concept and methods of Proteome analysis
4. Metabolome & Metabolomics

Unit II

1. Stem Cell technology: Types of stem cells
2. Manipulations of stem cells and applications in medicine
3. In vitro fertilization: Principle, methods, applications and ethics.
4. Cloning of animals: Methods and applications.

Unit III

1. Nano biotechnology: Introduction, Biomaterials and biological materials-examples and uses
2. DNA nanotechnology-structural DNA assembly-Nanopore and
3. Nanoparticles-biological arrays- nanoprobes for analytical applications
4. Nano biosensors-nanoscale organization-characterization-quantum size effects- sensors of the future.
5. Tools for measuring nanostructures. Microscopies-SEM-TEM-AFM modern advances-microanalysis-optical detection of single molecules

Unit IV

1. Microarray chips: Concept, design of biochip, types of DNA chips
2. Gene Therapy for Human Diseases.
3. Protein Crystallization; Theory and methods: API Electro spray and MALDI-TOF.
4. SNP's and GMS (Genome mismatch Signals)

Unit V

1. Biosensors: Concept, principle, Organization of biosensors & types
2. Biosensors: Health & Medicine
3. Biosensors: Food technology, Environment monitoring
4. Bacterial biosensors; Array Biosensors

Practical Exercises: Appropriate exercises based on theory

Reference Books

1. DNA Microarrays and gene expression by P. Baldi & GW Hatfield
2. Protein – Protein Interactions by Erica Golemis
3. A passion for DNA (Genes, genomes and Society) By JD Watson
4. Modern Genetic analysis by Anthony JF Griffiths et al.
5. Nan biotechnology- next big idea by Mark, Ratner Daniel Ratner
6. Gene cloning by TA Brown
7. Latest information on academic Web sites.

Note: All books are of latest editions

305. Lab Course V

Consists of practical exercises listed out under 301 & 302

306. Lab Course VI

Consists of practical exercises listed out under 303 & 304

401: BIOINFORMATICS (Optional 1)

Unit I

1. Over view of Bioinformatics: Merger of life sciences with computers.
2. Search engines: Google, Pub Med, NCBI, EMBL,
3. Protein and DNA databases: Swiss port, PIR, OMIM, Embank, ENTREZ, DDJB, MIPS, Hovered, ECDC, Cambridge small molecular crystal structure data bank.
4. Analysis packages: Commercial databases and packages, GPL software for bioinformatics, web based analysis protocol.

Unit II

- 1 Sequence Databases: Contents, Structure, and annotation for Human Genome Databases, Plant Genome Databases, Retrieving and installing a programme (Tree Tool), Multiple sequence alignment programme - Clustal W , X.
2. Genome analysis programs; BLAST, FASTA, CGC, Motif and profile Sequence search.
3. Phylogenetic analysis: Phylogenetic reconstruction, distance matrices, Parsimony, Philip.
4. Data models: Instances and schemes; E-R Model, E-R diagrams, reducing E-R diagrams to tables, network data model.

Unit III

1. Methods of prediction of Proteins, DNA, RNA, fold recognition , Ab initio methods for structure prediction
2. Computer aided drug designing: Basic principles, docking, ADME/TOX
3. Genome mapping applications: EST and Functional genomics, EST clustering gene discovery, ORF prediction.
4. Use of genome analysis programs, primer designing tools.

Unit IV

1. Cluster analysis; Phylogenetic clustering by simple matching coefficients
2. Sequence Comparison; Sequence pattern; Regular expression based pattern; Theory of profiles and their use in sequence analysis
3. Markov models; Concept of HMMS; Baum-Welch algorithm; Use of profile HMM for protein family classification; Pattern recognition methods
4. Structure determination: X-ray crystallography; NMR spectroscopy; PDB (protein data bank) and NDB (nucleic acid data bank); File formats for the storage and dissemination of molecular structure

Unit V

1. Modeling and conformational analysis: Homology modeling; Threading and protein structure prediction
2. Force fields; Molecular energy minimization
Monte Carlo and molecular dynamics simulation
3. Tagging of genes and molecular modeling
4. Modeling & Drug design

Practical Exercises: Appropriate exercises based on public data bases

References

1. Introduction to Bioinformatics: Theoretical and practical approach by Stephen A Krawetz and DD Womble.
2. Bioinformatics genes, proteins and computers by CA Orengo, DT Jopnes and JM Thornton
3. An Introduction to computational Biochemistry by C Stan T Sai
4. Instant Notes on Bioinformatics By DR Westhead, JM Perish and RM Toyman
5. Essential Bioinformatics by Jin Xiong
6. An Introduction to Bioinformatics Algorithms by by Neil C. Jones, Pavel Pevzner
7. Bioinformatics: Sequence and Genome Analysis by by David W. Mount
8. Statistical Methods in Bioinformatics: An Introduction by Stephen Misener, Stephen A. Krawetz
9. Bioinformatics: databases and algorithms by N. Gautham
10. Bioinformatics Technologies by Yi-Ping Phoebe Chen
11. Data Mining: Multimedia, Soft Computing, and Bioinformatics
by Sushmita Mitra, Tinku Acharya

401: ENTREPRENEURSHIP IN BIOTECHNOLOGY & IPR (Optional 2)

Unit 1

1. Creativity & Entrepreneurial personality and Entrepreneurship in Biotechnology
2. Organizational structure & Management
3. Capital Management
4. Product innovation and management
5. Government schemes for commercialization of technology (Eg. Biotech Consortium)

Unit 2

1. Basics of production management: Methods of manufacturing-Project/Jobbing, Batch Production, Flow/Continuous production, process production-Characteristics of each method. Plant location-Importance-Factors affecting location-factory Building-Plant layout-Installation of Facilities.
2. Operational Research: Linear Programming, PERT and CPM; Production Planning & Control-Scheduling-Gantt Charts-Documentation-Production Work Order.
3. Basics of material management
4. Personnel management Eg, Communication skills; Managerial and personal, training etc.

Unit 3

1. Kaizen (Continuous improvement in product & management)
2. Six Sigma
3. Biotech enterprises: Small, Medium & Large
4. Quality control in Biotech industries

Unit 4

1. Govt. regulations for biotech products
2. Public policy, regulatory and ethical challenges facing the biotechnology entrepreneurship
3. Business development for medical products
4. Business development for consumable products

Unit 5

1. Patenting System: WTO, Paris Convention, Indian Legislations
2. Intellectual Property: A. Copy Right & Industrial Properties, Trademarks, Designs, Geographical Indications
3. IPR & Technology transfer, Role of patentee & Licensor
4. Patent process & Patent laws & e-filing

Practical Exercises: Appropriate exercises based on theory

References

Innovation and entrepreneurship in biotechnology: Concepts, theories & cases by D. Hyne & John Kapeleris, 2006

The Business of Biotechnology: From the Bench to the Street: By Richard Dana Ono
Published by Butterworth-Heinemann, 1991

Entrepreneurship in Biotechnology: Managing for growth from start-up: By Martin Grossmann, 2003.

Best Practices in Biotechnology Education: By Yali Friedman
Published by Logos Press, 2008. 356 pages

Plant Development and Biotechnology: By Robert Nicholas Trigiano, Dennis John Gray;
Published by CRC Press, 2004, 358 pages

402: MOLECULAR AND IMMUNO DIAGNOSTICS (Optional 1)

Unit I

1. Introduction and Concept of Molecular Diagnostics
2. DNA diagnostics: PCR based diagnostics, RAPD etc
3. Southern blot & RFLP in diagnostics
4. Western blot diagnostics

Unit II

1. Genetic and chromosomal disorders: autosomal; sex chromosomal; karyotype analysis, single cell disorders and complex traits.
2. Single nucleotide polymorphisms and diagnostic significance.
3. Nanodiagnosics
4. Microarray Technology

Unit III

1. Array-based diagnostics
2. G-banding, *in situ* hybridization (FISH and on-FISH), and comparative genomic hybridization (CGH)
3. Phage display concept and applications of Phage display
4. Immunoarrays, FACs.

Unit IV

1. Immuno electrophoresis: rocket immunoelectrophoresis; CIE, Graber and William Technique, RIA, ELISA – Principle, Methodology and applications.
2. Agglutination: Direct and Indirect, Widal test, VDRL test
3. Immuno fluorescence: Direct, indirect and Sandwich
4. Immunodiagnosics: diagnosis of infectious diseases, respiratory diseases

Unit V

2. Monoclonal antibodies in diagnosis
3. Immunoblot analysis & immunocytochemical staining.
4. Development of rapid diagnostic tests and their applications
5. Biochemical diagnostics: Biochemical markers of disease diagnosis and their applications.

Practical Exercises: Appropriate exercises based on theory

References:

1. Molecular Diagnostics: Current Technology and Applications
by Juluri R. Rao, Colin Craig Fleming, John Edmund Moore – 2006
2. Molecular Diagnostics: A Training and Study Guide
by Gregory J. Tsongalis, William B. Coleman - 2002
3. Molecular Diagnostics: For the Clinical Laboratorian
by William B. Coleman, Gregory J. Tsongalis - 2006
4. Molecular Diagnostic PCR Handbook
by Gerrit J. Viljoen, L. H. Nel, J. R. Crowther – 2005
5. The Neuropathology of Dementia
by Margaret M. Esiri, Virginia M.-Y. Lee, John Q. Trojanowski
6. Diagnostic Bacteriology Protocols,
by Louise O'Connor - 2006
7. Immunodiagnosis of Cancer
by Ronald B. Herberman, Donald W. Mercer – 1990
8. Immunodiagnosics: A Practical Approach
by Ray Edwards - 1999

402: MANAGEMENT & MARKETING OF BIOTECH. PRODUCTS (Optional 2)

Unit I: Basics of Marketing

1. Marketing Concepts – Approaches to Marketing-Study Approaches and Functional Approaches-marketing Process-Functions of Marketing.
2. Marketing Planning-Nature and Process – Contents of Marketing Plan-Analyzing need and trends in Macro Environment, Economic Environment, Technical Environment, Political Environment and Socio-cultural Environment.
3. Consumer Behaviour-Factors influencing buyer behaviour-Buyer decision process-Consumer Psychology-Industrial Buyer behaviour vs. domestic buyer behaviour-Customer satisfaction Vs. customer delight.
4. Market Segmentation-Bases for market segmentation of consumer goods, industrial goods and services-targeting and positioning strategies.
5. Market Evaluation and Control-Types, process, obstacles to marketing control-marketing Ethics.

Unit II: Management Accounting

1. Double Entry Book Keeping-Data entry in the primary and secondary books of accounts-Preparation of Trial Balance-Rectification of Errors-Final Accounts of Non-Corporate organizations like Proprietary firms and Partnership Firms-Bank Reconciliation Statement.
2. Cost Accounting – Relationship with financial accounting-elements of Cost-Preparation of Cost Sheet.
3. Materials Cost-Materials purchasing, receiving, storing issuing including pricing of issues.
4. Labour Cost – Time Keeping and time Booking-Idle Time-Labour Turnover.
5. Overheads-Identifying the overheads with the cost center-Allocation, Apportionment and Absorption-Under Absorption and Over Absorption of Overheads.

Unit III: Materials & Logistics Management

1. Materials Management-Evolution, Scope and Objectives-Interface with other functions.
2. Forecasting-Methods of forecasting-moving Average Method, Regression Analysis, Exponential Smoothing Method.

3. Inventory-Types of Inventory-Need of Inventory-Costs associated with Inventory-Basic EOQ Model-EOQ with discounts- Classification of material-ABC Analysis-VED, FSN, GOLF,SOS- fixing of inventory levels.
4. Material requirement Planning-Master Production Schedule-Bill of Material-Material flow in MRP.
5. Purchasing Management-Responsibilities of Purchase Department-Purchase Cycle-Relevant Provisions of state/Central Sales tax Act, Central Excise Act and Import/Export Procedures.

Unit IV: Materials Specialization Logistics and Supply Chain Management

1. Logistics-concept and significance-Distribution Strategies-Customer Service policies and Integrated Logistics Management.
2. Distribution Network Planning system-Location-Number and size of facilities-Stocking Policies-Storage and handling capacities.
3. Packaging-Principles, functions and type-Containerization-Concepts-Infrastructure-Customs Issues-Service Utilization Modes-Rail, Sea and Road.
4. Role of Freight and Insurance in Logistics.
5. Concept of Supply Chain Management and its strategic role in the organization-Intra and Inter Organization Supply Chain.

Unit V

1. Market Research
2. Impact of Govt. policies on marketing
3. International marketing
5. Consumer laws

Practical Exercises: Appropriate exercises based on theory

References:

1. Pharma management: Smith
2. Establishment of pharmaceutical factory: Aganil
3. Dispensing of pharmaceutical students: Cooper and Gunn's.

4. The science and practice of pharmacy: Remington
5. The theory and practice of industrial pharmacy: Lachman, Lieberman & Kanig.
6. Sales management: Still, Candiff & Goroni.
7. Marketing channels: Stern & Adel
8. Theory on distribution channel structure: Louis Bucklin.
9. Marketing Management by Philip Kotler
10. Best practices in Biotechnology business development: Yali Friedman, Ph.D., Editor
First Edition, March 2008,
9. Building Biotechnology, Yali Friedman, Ph.D.
Third Edition, August 2008
10. Challenges of 21st Century by Peter Drucker

403: Lab course: Based on exercises in 401 & 402