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S.P. Mandali's

RAMNARAIN RUIA AUTONOMOUS COLLEGE

Syllabus for Masters of Science

Program: M.Sc. Life Science

Program Code: RPSLSc

(Semester based credit and grading system with effect from academic year 2019-2020)

M.Sc. Part - I Life Sciences Syllabus
Choice based Credit and Grading System
Academic year 2019-20

SEMESTER I

COURSE CODE	UNIT	TOPIC HEADINGS	CREDITS	L / WEEK
Paper I	**Environmental Biology, Evolution, Genetics**			
RPSLSc101	I	Environmental biology	4	4
	II	Biodiversity		4
	III	Evolution		4
	IV	Genetics		4
Paper II	**Cell and Molecular Biology**			
RPSLSc102	I	Cell Biology	4	4
	II	Cell cycle and cell death		4
	III	DNA Replication, Repair and Recombination		4
	IV	Transcription and Translation		4
Paper III	**Biochemistry**			
RPSLSc103	I	Proteins and Lipids	4	4
	II	Carbohydrates, vitamins and minerals		4
	III	Enzymology		4
	IV	Thermodynamics and Electron Transport Chain		4
Paper IV	**Biostatistics and Instrumentation**			
RPSLSc104	I	Biostatistics I	4	4
	II	Biostatistics II		4
	III	Basic Instrumentation		4
	IV	Advanced Instrumentation		4

SEMESTER I

PAPER – RPSLSc101

Paper Title: Environmental Biology, Evolution, Genetics

Unit I: Environmental biology (15L)

Ecosystems: Types of ecosystems [terrestrial (Tropical evergreen forests, Tropical deciduous forests, Deserts, Chaparral, Temperate grasslands, Savannahs and thorn forests, Temperate deciduous forests, Boreal forests/ Taiga, Tundra) and aquatic (Lentic, Lotic, Oceans, Estuaries, Coral reefs)], Habitat fragmentation and niche overlap, Competitive exclusion principle, resource partitioning, character displacement, ecosystem modelling and resource management and conservation.
Community ecology: Nature of communities; fundamental properties of biological communities (Productivity, Diversity, Complexity, Resilience, Stability, Structure); levels of species diversity and its measurement – Simpson's diversity index, Shannon index; edges and ecotones, Succession, disturbances and invasion.
Population ecology: Characteristics of a population; population growth curves; population regulation; life history strategies (*r* and *K* selection); concept of metapopulation, demes and dispersal.
Renewable energy: Types and advantages over non-renewable sources.
Environmental health: Environmental stress and adaptation, effects of pollution on living systems, environmental pollutants related human disorders, biomonitoring indicators, Climate change
Toxicology: Basic principles of toxicology including LD_{50} and ED_{50}, management of acute intoxication, Biochemical and Genetic mechanism of natural detoxification.

Unit II: Biodiversity Management and GMOs (15L)

Biodiversity: Concept, characterization, generation, maintenance and loss, Magnitude and distribution of biodiversity, economic value, bioprospecting, ecotourism and biodiversity management approaches.
Species interactions: Types of interactions, interspecific competition, herbivory, carnivory, pollination, symbiosis.
Conservation biology: Principles of conservation, major approaches to management, conservation strategies and cryopreservation.
Genetically modified organisms (GMOs): Definition of GMOs, applications in food and agriculture, Release of GMO in environment – risk analysis, risk assessment and risk management, Identification of GMO in environment and their impact, emergence of drugs/ pesticide/ herbicide resistance and disease burden.
GMO and GMO product detection and analysis: Detection and analysis of GMOs and GMO products: modified gene copy number determination, detection of chromosomal changes, toxicological studies, residual DNA analysis, product analysis – microbial, biochemical and molecular, toxicological evaluation

Unit III: Evolution (15L)

Emergence of evolutionary thoughts: Lamarck; Darwin–concepts of variation, adaptation, struggle, fitness and natural selection; Types of selection; Speciation – Punctuated equilibrium and phyletic gradualism; Modern evolutionary synthesis.
Origin of cells and unicellular evolution (For Assignment)
Paleontology and evolutionary history: Introduction to time scales, origins of unicellular and multicellular organisms; major groups of plants and animals; Mass

extinction events; Adaptive radiation, convergent evolution and coevolution; stages in primate evolution, Carbon dating, fossils.

Molecular Evolution: Concepts of neutral evolution, molecular divergence and molecular clocks; origin of new genes and proteins; gene duplication and divergence, molecular taxonomy.

Astrobiology: Concepts, planetary habitability, extremophiles, abiogenesis, research on surviving extreme habitats, evolution of advanced life, astrobiology of Mars.

Unit IV: Genetics (15L)

Extensions of Mendelian principles: Codominance, incomplete dominance, Multiple alleles, Lethal and Essential Genes.

Non Mendelian Inheritance: Cytoplasmic inheritance, organelle genetics, maternal inheritance.

Microbial genetics: transformation, conjugation, transduction and sex-duction, mapping genes by interrupted mating.

Quantitative genetics: Pleiotropy and epitasis, polygenic inheritance, heritability and its measurements, QTL mapping, linkage and crossing over.

Population Genetics: gene pool, gene frequency, Hardy Weinberg Law and its role in evolution and speciation, Pedigree analysis.

Gene mapping methods: Linkage maps and lod score for linkage testing, tetrad analysis, mapping with molecular markers, mapping by using somatic cell hybrids, development of mapping population in plants.

Human Genome Project and Genome wide associated studies. SNPs

PRACTICALS: RPSLScP101

1. Study of animal interaction (For identification):
2. Determination of population density (Daphnia or any suitable organism) by sub sampling method.
3. Comparison of two population of a species collected from two areas.
4. Effect of toxicity on *Daphnia / C. elegans / Yeast /Pollen grains.* Apply biostatistical analysis
5. Production/ Extraction of biofuel from plant source and characterization.
6. Problems in Genetics
   a. Problem solving: Multiple alleles, Lethal genes
   b. Problem solving: Hardy Weinberg equation, Pedigree analysis.
7. Practical on fossil specimen (ID)
8. Bioinformatics problem on evolutionary/ phylogenetic time scale, using Mega 7
9. Residual DNA analysis
10. Determination of phosphorous by Fiske-Subbarao method.
11. Honey analysis.

References:

- The Cambridge Encyclopedia of Human Evolution (Cambridge Reference Book) by Steve Jones
- Evolution by Monroe W. Strickberger, CBS publishers and distributors
- Astrobiology: An Introduction by Alan Longstaff, CRC Press.
- Astrobiology: A brief introduction by Kevin W. Plaxco and Michael Gross, The Johns Hopkins University Press.
- Biodiversity, Wilson E.O. (Ed.), National Academy Press, Washigton, D. C.

- Understanding Biodiversity by David Zeigler (May 30, 2007): Amazon Press
- Fundamentals of Ecology by E.P. Odum, Cengage publishers
- Ecology and environment by P.D. Sharma, Rastogi publications
- Elements of Ecology by Smith and Smith, Pearson publishers
- Environmental Biology edited by Mike Calver*et al*: Cambridge University Press
- Molecular Environmental Biology by Seymour J. Garte, Lewis Publishers (1994)
- Basic Environmental Toxicology, Lorris G. Cockerham& Barbara S. Shane, CRC Press.
- David Wright and Pamela Welbourn, Environmental Toxicology, Cambridge university press
- Principles of Genetics- Tamarin
- Microbial Genetics- Freifelder
- iGenetics- Russell
- Genetics- Benjamin Pierce
- Introduction to Genetics- T.A. Brown

PAPER – RPSLSc102
Paper Title: Cell and Molecular Biology

Unit I: Cell Biology (15L)

Plasma membrane: Different model membrane and their structures, lipid bilayer.
Endoplasmic reticulum: RER and SER, synthesis and transport of protein into the lumen of the ER and its control. Oil bodies and protein bodies in plants.
Golgi complex: Cisternal progression, secretory pathway – transport to the plasma membrane and the extracellular space.
Nucleus: including nuclear pore, lamins, chromatin.
Other organelles: Lysosomes, peroxisomes, mitochondria, chloroplasts and vacuoles.
Cytoskeleton: Filaments and concept of cellular architecture and motility.

Unit II: Cell cycle and Cell Death: (15L)

Introduction: Stages of the cell cycle – G0, G1, S, G2 and M. Molecular events in the various cell cycle stages.
Concept of cyclin and CDKs; activation of the cyclin-CDK complexes.
G1 cyclins: Cln1, Cln2 and Cln3 and its relevance in commitment to cell division.
S phase and G2 phase: S phase cyclin, its inhibitors and pre-replication complex and its significance in DNA replication in the cell cycle.
M phase: Prophase, Metaphase, Anaphase and Telophase, condensins, securin, separase and the end of mitosis.
Checkpoints (unreplicated DNA, spindle attachment, segregation of chromosomes) Meiosis (special division; Ime2, Rec8 and monopolin) Cell-cell fusion in normal and abnormal cells.
Apoptosis: Concept of programmed cell death, Comparison with necrosis, Function of apoptosis in development and maintenance (formation of digits, removal of old cells etc.); Extrinsic and intrinsic pathways of Apoptosis, effects of aberrant apoptosis. Practical- Visit .

Unit III: DNA Replication, Repair and Recombination (15L)

DNA replication: Unit of replication and enzymes, replication origin and replication fork, fidelity and processivity of replication, extrachromosomal replicons (plasmid).
DNA repair: Direct repair, Excision of base pair, Post replicative, SOS.
Recombination: Homologous and Non Homologous.

Unit IV: Transcription and Translation (15L)

Transcription: Classes of RNA molecules - structure and function.
Basic features of RNA synthesis: Transcription factors and machinery.
Transcription in prokaryotes: *E. coli* RNA polymerase, transcription activators and repressors, initiation, elongation and termination, processing of tRNA and rRNA in *E. coli*.
Transcription in Eukaryotes - formation of initiation complex, capping, elongation & termination, RNA processing, RNA editing, major and minor splicing systems, polyadenylation, Eukaryotic rRNA genes, formation of eukaryotic tRNA molecules, RNA Polymerases of eukaryotes, RNA polymerase II Promoters, Eukaryotic Promoters for RNA polymerase III, Hypersensitive sites, Upstream activation sites and enhancers.
Translation: Outline of Translation.
The Genetic Code: The Decoding System, Codon -Anticodon interaction.

Ribosomes: the special properties of the prokaryotic and eukaryotic ribosomes, ribosome biogenesis.
Translation process: initiation, elongation and termination factors of prokaryotes and eukaryotes mechanisms to overcome premature translation termination, role of suppressor tRNAs.
Inhibitors of protein synthesis: Prokaryotic and eukaryotic protein synthesis inhibitors and their significance.

PRACTICALS: RPSLScP102

1. Electron Micrographs of cell organelles and cytoskeletal elements.
2. Localization of cytoskeleton elements using Fluorescence staining.-
3. Isolation of chloroplasts and chlorophyll estimation from spinach or any other suitable system.
4. Cell stages of mitosis – Onion root tip/meiosis.
5. Inhibition of cell division by colchicine.
6. Isolation and estimation of RNA from Yeast or a suitable system.
7. PCR amplification of 16s rRNA for genus/strain identification.
8. Effect of UV exposure on bacterial colonies to understand DNA repair mechanism.

Reference:

- Principles of Biochemistry- Lehninger, Nelson and Cox
- Gene VIII- Lewin
- Principles of Genetics- Tamarin
- Microbial Genetics- Freifelder
- iGenetics- Russell
- Genetics- Benjamin Pierce
- Introduction to Genetics- T.A. Brown
- Molecular Cell biology: 5th Edition and above. Harvey Lodish, Arnold Berk, S Lawrence Zipursky, Paul Matsudaira, David Baltimore, and James Darnell

PAPER – RPSLSc103
Paper Title: Biochemistry

Unit I: Protein and Lipids (15L)

Protein: Primary structure elucidation, secondary structure structures eg. Keratin, Collagen, tertiary structure and the underlying interactions/ forces, quaternary structure (example: haemoglobin), protein folding, domains and motifs, cytoskeletal and extracellular proteins.

Lipids: structure, classification and properties of lipids, lipid assembly, model membranes, formation of liposomes and drug targeting.

Unit II: Carbohydrates, Vitamins, Minerals (15L)

Carbohydrate: Classification and stereochemistry, structure, properties and biological roles of storage and structural polysaccharides such as, starch, glycogen cellulose, pectin, hemicelluloses, chitin, mucopolysaccharides. Biosynthesis and role of N and O-linked glycoprotiens and proteoglycans.

Vitamins: Structure and biological roles of water soluble and lipid soluble vitamins. Hypervitaminosis and deficiency.

Minerals: Structure and biological roles of bulk and trace elements

Unit III: Enzymology (15L)

Enzyme: enzyme and enzyme substrate interactions, enzyme kinetics, chemical modification, and identification of active site amino acids, mechanism of enzyme catalysis with reference to chymotrypsin, lysozymes, metalloenzymes and the role of metals in catalysis with reference to carboxypeptidase.

Regulation of enzyme activity: theory of allostery with reference to AT case, Isozymes with reference to LDH: Co-enzymes and their roles, types of enzyme inhibitors and activators and their kinetics, ribozymes and abzymes.

Unit IV: Thermodynamics and Electron Transport Chain (15L)

Thermodynamics: The laws of thermodynamics, enthalpy, entropy and free energy concepts and their relevance to biological systems.

ET: electron transport chain (ETC) and oxidative/photophosphorylation: structure and function of mitochondrial and chloroplast ETC proteins and light harvesting complex, mechanism of oxidative and photophosphorylation, F_0 F_1 ATPase, theories of ATP synthesis.

PRACTICALS: RPSLScP103

1. Estimation of sugar by DNSA method from a biological source.
2. Enzyme kinetics, effects of pH, temperature, time and substrate concentration, determination of Km and Vmax using phosphatase/Amylase.

3. Estimation of protein by Folin Lowry and Biuret methods. Compare sensitivity by using Folin Lowry method, Biuret method and UV absorbance at 280nm.
4. Lipid extraction and estimation by Bligh and Dyer method.
5. Estimation of ascorbic acid from vegetable source by colorimetric method.
6. Estimation of Ca, Fe, Mg etc from samples using Atomic Absorption Spectroscopy.
7. Extraction of isoenzymes of LDH from different tissues in chicken and separation by SDS PAGE.

References

Name :Principle of Biochemistry
Author :Lehninger, Albert L. (III Ed. 2000 worth pub)
Publisher :CBs publishers and distributors

Name :Biochemistry
Author :Stryer, Lubert
Publisher :W. H. Freeman

Name :Student's companion for Stryer's biochemistry
Author :Gumport, Richard I, Jonas, Ana, Mintel, Richard, Rhodes,Carl
Publisher :W. H. Freeman

Name :Biochemistry and Molecular biology
Author :Elliott, Willam H, Elliott, Daphne C
Publisher :Oxford University Press

Name :Oxford dictionary of biochemistry and molecular biology
Publisher :Oxford University Press

Name :Proteins- Structures and molecular properties
Author :Creighton, T. E
Publisher :Freeman and Co

Name :Biochemistry of cell membranes: a compendium of selected topics
Author :Papa S., ed. Tager, J. M., ed
Publisher :Birkhauser Verlag

Name :Membrane protein models
Author :Findlay, J. B. C., ed
Publisher :IOS scientific publishers

PAPER – RPSLSc104
Paper Title: Biostatistics and Instrumentation

Unit I: Biostatistics I (15L)

Introduction: Introduction, scope, application and uses of statistics, collection and classification of data, census and sampling, graphs and diagrams, arithmetic mean, median, standard deviation.

Correlation and regression: for ungrouped data, scatter diagram, calculation and interagtion of correlation coefficient, linear regression coefficient and equation of the lines of regression, non-linear relationship transformable to linear form ($Y=ab^X$, $Y=a^xb$).

Probability: definition, addition and multiplicative laws (without proof). Random variable and its distribution, binomial probability distribution, examples and conditions, means and variance, poisson probability distribution, examples and conditions, means and variance, continuous variable, normal distribution, use of normal probability table for finding probabilities.

Population Statistics: Population parameters and sample statistics, sampling techniques, simple random sampling, stratified random sampling, systematic sampling, standard error of mean.

Estimation, point and interval, confidence interval for population, mean and proportion.

Unit II: Biostatistics II (15L)

Hypothesis testing: type-1 and typr-2 errors, levels of significance, one tailed and 2 tailed tests, application to single mean and single proportion, equality of two population means and two population proportions.

Chi-test: for independent attributes in rxc table, special case 2x2 table.

Students test for significance for correlation, coefficient r for P=0 (small sample tests). Fishers Z transformation coefficient for getting rp=0 in large samples, test of significance for r (p=0).

Design of experiment: principles and concepts of completely randomised design, randomized block design and Latin square design.

Variance ratio F tests: analysis of variance in one way classification.

Non-parametric tests: distribution free methods, sign test for method pairs, Willcoxon test for unpaired data, run test.

Unit III: Basic Instrumentation (15L)

Spectroscopy: Basic principles, nature of electromagnetic radiation, principles of spectroscopy, types of spectra- absorbance, emission, fluorescence and action spectra, single and double beam spectrophotometers, densitometers, circular dichroism and their applications.

Microscopy: Basic principles, instrumentation, sample preparation for optical, phase-contrast, interference, polarisation, inverted, fluorescence, confocal and electron microscopes and their applications.

Centrifugation: Principles and types, simple and differential, ultracentrifugation – preparative and analytical.

Visits to Research Institutes.

Unit IV: Advanced Instrumentation (15L)

Chromatography: Principle, methodology and applications of chromatography using (paper, thin layer, column(gel filtration, ion exchange, affinity, gas, HPLC,FPLC etc).

Electrophoresis: Principles and types of electrophoresis and their applications for proteins, nucleic acids, including gradient gel and pulse-field gel electrophoresis, gel matrices-polyacrylamide, agarose etc, critical parameters for optimum separation and resolution , two dimensional electrophoresis(IEF).

X-ray crystallography, Nuclear Magnetic Resonance (NMR) spectra, Magnetic Resonance Imaging (MRI – fMRI) lasers in biology and medicines.

Radioisotope methods and tracer techniques in biology: Basic principles of radioactivity, properties and handling of radioisotopes in biology and medicine, radiation units, Geiger- Muller and scintillation counters, autoradiography, radionucleide imaging, CT Scan and PET scan

Techniques: Histology, ELISA, RIA, Immunoprecipitation - single and double, Primers, PCR and its types, RFLP, RAPD, AFLP, Blotting techniques: Southern, Western and Northern, In- situ Hybridization: FISH, GISH SKY, Chromosome Painting.

PRACTICALS: RPSLScP104

1. Preparation of Phosphate, Tris, citrate buffers of various molarity.
2. Determination of lambda max of $KMnO_4$, $CoCl_2$, methylene blue by spectrophotometer.
3. Verification of Beer-lamberts law by UV Visible spectrophotometer
4. Separation of amino acids by paper chromatography.
5. Separation of lipids by TLC.
6. Separation of plant pigments by column chromatography.
7. Analyzing the data using Students t-Test, ANOVA and Regression analysis.

References:

- Practical biochemistry – Principles and Techniques- Wilson K and Walker J
- Essentials of Biophysics- Narayanan P.
- Analytical Techniques in Biochemistry and Molecular Biology by Rajan Katoch,
- Modern Analytical Biochemistry; Rodney Boyer (3rd Edition)
- Principles of Instrumental Analysis: Skoog
- Methods in Biostatistics- Mahajan P.K

M.Sc. Part - I Life Sciences Syllabus

Choice based Credit and Grading System

Academic year 2019-20

SEMESTER II

COURSE CODE	UNIT	TOPIC HEADINGS	CREDITS	L / WEEK
Paper I	**Microbiology, Immunology and Plant Physiology**			
RPSLSc201	I	Microbiology	4	4
	II	Immunology		4
	III	Plant physiology I		4
	IV	Plant physiology II		4
Paper II	**Molecular Biology and Cell signalling**			
RPSLSc202	I	Gene and Epigenetics	4	4
	II	Gene Expression Regulation		4
	III	Gene cloning		4
	IV	Cell communication and signaling in normal cells and cancer cells		4
Paper III	**Animal Science**			
RPSLSc203	I	Animal Physiology	4	4
	II	Developmental Biology		4
	III	Neurobiology		4
	IV	Model Organisms		4
Paper IV	**Bioinformatics, IPR and Bioethics**			
RPSLSc204	I	Bioinformatics	4	4
	II	Alignment problem and solutions		4
	III	Genomics and Proteomics		4
	IV	IPR and Bioethics		4

SEMESTER - II

PAPER – RPSLSc201

Paper Title: Microbiology, Immunology and Plant Physiology

Unit I: Microbiology (15L)

Microbial diversity: Bacteria, Archaea and their Outline of classification; Eukaryotic microbes: Yeasts, molds and protozoa; Viruses and their classification; Molecular approaches to microbial taxonomy. Bacteria: Purple and green bacteria, budding bacteria rods, Spirochaetes, Sheathed bacteria, Endospore forming rods and cocci. Archaea: Archaea as earliest life forms; halophiles, Methanogens

Eukarya: Algae, Fungi, Slime molds- General characteristic and types.

Prokaryotic Cell Structure- Differences between eukaryotic and prokaryotic cells. Cell wall, cell membrane synthesis and nucleoid; Flagella and motility; cell inclusions like endospores, gas vesicles.

Microbial Growth: Growth curve; Mathematical expression of exponential growth phase; Measurement of growth and growth yields; Synchronous growth; Continuous culture; Effect of environmental factors on growth; diauxic growth.

Antibiotics: General characteristics of antimicrobial drugs; Antibiotics: Classification, mode of action and resistance; Antifungal and antiviral drugs.

Host Parasite Interaction: Recognition, mechanism of microbial pathogenicity and establishment of disease by different pathogens like viruses, bacteria and parasites into animal hosts (one example each). Nosocomial infection; Emerging infectious diseases; alteration of host cell behavior by pathogens.

Unit II: Immunology: (15L)

Lymphatic system, structure and function of spleen and lymph node.

Major Histocompatibility Complex I and II and their importance.

B cells: Development, generation of antibody diversity, activation somatic hypermutation and class switch. Primary and secondary immune modulation

T cells: Development, TCR diversity, selection and types of T cells and activation.

The Complement and its regulation.

Immune response to infectious diseases: Viral, Bacterial, Parasitic, AIDS.

Congenital immunodeficiencies: SCID.

Autoimmune diseases - Myasthenia gravis, Rheumatoid arthritis.

Disease and application: Monoclonal antibodies, SCFV, Chimeric antibodies, bispecific antibodies, phage display, Recombinant and polyvalent vaccines.

Unit III: Plant Physiology I: (15L)

Photosynthesis – Light and dark reaction, CO2 fixation by C3, C4 and CAM pathways.

Material transportation: through xylem, phloem and plasmodesmata.

Nitrogen metabolism: Symbiotic nitrogen fixation, Ammonia and nitrate uptake and metabolism, amino acid biosynthesis.

Plant Hormones: Biosynthesis and biological activity of auxins, cytokinins, gibberellins, Ethylene, Abscissic acid, Salicylates, Jasmonates and Brassinosteroids.

Sensory Photobiology: Cryptochromes, phytochromes, phototropins; photoperiodism and biological clocks.

Stress response: Plant response to abiotic stress- Water, salt and temperature.

Response and resistance to biotic stress (viral, fungal and insects): Host recognition and establishment of disease, overview of plant defense methods (anatomical, secondary metabolites, hypersensitive reactions, hormonal signals and the *R - avr* system).

Unit IV: Plant physiology II: (15L)

Plant Development: Phytochromes and its role in plant development including flowering, germination of pollen and self-incompatibility, Double fertilization and seed formation (one typical example of each).

Seed germination: The hormonal and nutritional aspect of seed germination.

Root and Shoot: Development, organization of root and shoot apical meristems.

Leaf: Development and phyllotaxy, stomatal movement.

Flower development: Floral organogenesis and the genes involved: Examples *Arabidopsis* and *Antirrhinum*.

Programmed Cell Death and Senescence in plants: Concept, effect on pigments in plants, environmental factors and hormonal factors.

Plant model systems: *Arabidopsis thaliana, Zea mays, Physcomitrella patens, Medicago truncatula, Populus trichocarpa, Oryza sativa.*

PRACTICALS: RPSLScP201

1. Diauxic growth curve.
2. Antimicrobial activity by agar cup/ disc method.
3. Sandwich ELISA. (Demonstration), HepElisa/ HCG Kit
4. Semi-quantitative Mancini test.
5. Proline content in normal and saline stressed plants.
6. Effect of Salinity on seed viability.
7. Use of DNA Fluorochromes for studies on pollen grain and pollen tube nuclei.
8. Estimation of Indole Acetic Acid.

References:

- Text book of microbiology: Ananthanarayan and Paniker; Orient blackswan
- Microbiology: Prescot and Dunn
- Biochemistry and Molecular Biology of Plants: Bob Buchanan (Editor), Wilhelm Gruissem (Editor) and Russel Jones.
- Plant Physiology 3rd Edition: Taiz and Zeiger.
- Plant Physiology and Development, 6th Edition: Taiz and Zeiger.
- Immunology 5th Edition, Janis Kuby; OR Kuby Immunology 7th Edition: Judy Owen (*Haverford College*) , Jenni Punt (*Haverford College*) , Sharon Stranford(*Mount Holyoke College*)
- Pollen biology - A laboratory manual, K.R. Shivanna and N.S. Rangaswamy

PAPER – RPSLSc202

Paper Title: Molecular Biology and Cell signalling

Unit 1: Gene and Epigenetics: (15L)

Structure of Gene: Monocistronic and Polycistronic, Promoter, Operator, ORF, Terminator, Gene families, Pseudogenes, Split Gene.

Other elements of Eukaryotic Genome: Satellite DNA, Tandem repeat array, Transposons: LINE and SINE.

Genomic Mutations: Introduction, Deletions, Addition, Insertion, Inversions and Translocations.

Chromatin Structure: Histones, Non-Histones, Scaffolding proteins.

Epigenetics: Hypothesis, Imprinting, Mechanism (Methylation and Acetylation), Cancer epigenetics, Anticipation, Penetrance and Expressivity.

Unit 2: Gene Expression Regulation: (15L)

Regulation of Gene expression in Prokaryotes: General aspects of Regulation, transcriptional regulation - inducible and repressible system, positive regulation and negative regulation; Operon concept – lac, trp, Ara operons, the galactose operon, relative positions of Promoters and Operators, Regulons, Master switches, Regulation of Translation, Regulation of the synthesis of Ribosomes, Unregulated changes in gene expression, Feedback Inhibition, RNA interference, mRNA half-life, riboswitches, ribozymes.

Regulation of Gene expression in Eukaryotes: Regulatory strategies in Eukaryotes, Transcriptional Control by hormones, signalling factors and environmental factors, Role of transcription factors, enhancers, silencers, chromatin remodelling in regulation of gene expression, role of post-translational modifications of transcription factors, Regulation of processing, Regulation through RNA splicing, RNA degradation and RNA interference, Translational control, Regulation of gene expression in plant cells by light. Diseases associated with defects in regulation.

Unit 3: Gene cloning (15L)

Clone: Importance of DNA Cloning, Principles of Cell-based DNA Cloning and cell independent DNA cloning, Cutting and Joining DNA methods,

Vectors: Essential components of vectors and their significance, Plasmid vectors, Vectors based on the lambda Bacteriophage, Cosmids, M13 vectors, expression vectors, YACs and BACs. Use of plant viruses as episomal expression vectors. Production of transgenic mice, Embryonic Stem cells for genetically modified mice. Genomic and cDNA libraries.

Transfection/Transformation/Transduction (microinjection, electroporation, biolistics): liposome, adenovirus, lentivirus, retrovirus. Protoplasts for gene transfer in eukaryotic and prokaryotic cells.

Unit 4: Cell communication and signaling in normal cells and cancer cells (15L)

Concept of cell surface receptors, second messengers and regulation of the signalling pathway.

Signalling pathways: (a). Receptor tyrosine kinases (RTK): EGFR pathway (b). JAK-STAT pathway. (c). G protein coupled receptors. (d). Bacteriorhodopsin signaling. (e). Toll-like receptors (in immunology). (f) Wnt and SHH, Notch

Two component signalling: (a). Bacterial – chemotaxis, quorum sensing. (b). Plant two component signalling.

Extracellular matrix: Fibres, cell adhesion molecules and their functions, gap junctions.

Cancer: As an aberration of the cell cycle; oncogenes, tumor suppressor genes, virus induced cell transformation, metastasis and treatment.

PRACTICALS: RPSLScP202

1. Isolation of plasmid from *E. coli.*
2. Induction of the Lac operon and assessment of enzyme activity using a suitable system (e.g. *E. coli*).
3. Isolation of histone from yeast cells.
4. FISH (Demonstration). Visit NIRRH/ others
5. Assessment of signaling pathways in the regulation of nitrate assimilation in plants/ bacteria.

References:

- Principles of Biochemistry- Lehninger, Nelson and Cox
- Gene VIII- Lewin
- Principles of Genetics- Tamarin
- Microbial Genetics- Freifelder
- iGenetics- Russell
- Genetics- Benjamin Pierce
- Introduction to Genetics- T.A. Brown
- Molecular Cell biology: 5th Edition and above. Harvey Lodish, Arnold Berk, S Lawrence Zipursky, Paul Matsudaira, David Baltimore, and James Darnell.

PAPER – RPSLSc203

Paper Title: Animal Science

Unit I: Animal Physiology (15L)

Vascular system: Blood corpuscles, hematopoiesis and formed elements, plasma function, blood volume, blood volume regulation, blood groups, haemoglobin, immunity, haemostasis.
Cardiovascular System: Comparative anatomy of heart structure, cardiac tissue, cardiac cycle, blood pressure, neural and chemical regulation.
Respiratory system: Comparative anatomy, transport and exchange of gases, neural and chemical regulation.
Digestive system: Comparative anatomy, human digestive system, Diet and BMR.
Excretory system: Comparative physiology, human excretory system, osmoregulation.
Endocrine system: Structure and functions of Endocrine glands (Pituitary, Thyroid, Parathyroid, Adrenal, Pancreas – islets of Langerhans, Sex glands, Pineal, Thymus), Biological roles and mechanism of actions of hormones (protein, glycoprotein and steroid hormones), hormonal disorders.
Thermoregulation: Comfort zone, body temperature – physical, chemical, neural regulation, acclimatization.
Stress and adaptation

Unit II: Developmental biology (15L)

Concepts of development: Brief history of developmental biology, Potency, commitment, specification, induction, competence, determination and differentiation; morphogenetic gradients; cell fate and cell lineages; stem cells; genomic equivalence and the cytoplasmic determinants; imprinting; mutants and transgenics in analysis of development.
Gametogenesis, fertilization and early development: Production of gametes, cell surface molecules in sperm-egg recognition in animals; zygote formation, cleavage, blastula formation, embryonic fields, gastrulation and formation of germ layers in animals
Morphogenesis and organogenesis: *Dictyostelium* - Cell aggregation, differentiation and culmination, *Drosophila* - axes and pattern formation, Vertebrates - eye lens induction and limb development; Differentiation of neurons; metamorphosis; environmental regulation of normal development; sex determination.

Unit III: Neurobiology (15L)

Overview: central nervous system (CNS) and peripheral nervous system (PNS)-structure, organization and function
Cellular perspective: types of cells and function
Impulse generation and conduction of nerve impulse
Synaptic transmission: Electrical and Chemical with examples of two neurotransmitters and their receptors; cAMP as messenger, Neuromuscular junctions – structure and function.
Sensory systems: Visual, Auditory, Chemosensory, Somatosensory
Motor systems – Overview of motor circuits and neural control.
Behavior– Reflexive behavior and homeostasis, Associative and non-associative memory.

Unit IV: Model Systems (15L)

Fruit fly *(Drosophila melanogaster)* - History and description of the invertebrate model. Culturing and maintenance. Research tools: Flybase, Mutant collection (Gene disruption project), Genome-wide application of genetic tools.

Nematode worm *(Caenorhabditis elegans)* - History and description of the model. Culturing and maintenance. Research tools – Wormbase, Wormatlas, Validation of target molecules in *C. elegans* (genome-wide RNAi, knockouts, compound libraries, HTPS and the MOA strategy)

Western clawed frog *(Xenopus tropicalis)* - Trans-NIH Xenopus Initiative, Xenbase

Mouse *(Mus musculus)* - Model organism for mammalian physiology, Types used for research, The Mouse Knockout & Mutation database.

Zebrafish *(Danio rerio)* - Model organism to study vertebrate physiology and development. Culturing and maintenance. Research tools- Genetic screens with morpholino's. Zebra fish assays. ZFIN database

Computational models

PRACTICALS: RPSLScP203

1. Mounting of cornea and statocyst of prawn.
2. Chick embryology- Fresh Mounting.
3. Neutral red staining for apoptosis in developing chick embryo.
4. Permanent slides of different stages of chick embryo.
5. Microtomy- sections of chick liver and histopathological study.
6. Permanent slides of tissues.
7. Study of ECG in humans.
8. Study of EEG in humans.
9. H&E staining
10. Culturing and imaging *C. elegans.*

References:

- Principles of Development: L. Wolpert, R. Beddington, J. Brockes, T. Jesell and P. Lawrence. Oxford University Press
- Developmental Biology: W.A. Miller, Springer – Verlag.
- Developmental Biology: S.F. Gilbert. Sinauer Associates Inc. Publishers (4th edition) .
- An Introduction to Embryology: B. I. Ballinsky' Saunders, College Publishing Co. 4th Ed.
- Molecular Biology of the Cell: Bruce Alberts. Pub: Garland Science
- Neuroscience: D. Purves, G. Augustine, D Fitzpatrick, W. Hall, A. LaMantia, L. White.Sinauer Associate Inc (2012) 5th edition
- Principles of Neural Science: E. R. Kandel, J.H.Schwartz and T.M. Jessel.Prentice Hall Internation. (2012)
- Neuroscience: Exploting the brain M. F. Baer, B.W.Connors & M. A. Paradiso, William & Wilkins, Baltimore
- Text Book of Medical Physiology: A. C. Guyton and J.E.Hall, Saunders College Publishers.
- Principles of Anatomy and Physiology: G. Tortora and S.Grabowski John Wiley & Sons, Inc. 10th edition .
- Fundamentals of Neurobiology: Shepherd G M 3rd Edition, Oxford University Press.
- Elements of Molecular Neurobiology: C.U.M. Smith, Wiley and sons Publication.
- Text Book of Biochemistry and Human Biology: Talwar and Srivastava (3rd Edison)
- Developmental Biology: Mohan and Arora.

- Model organisms in Drug Discovery (edited by Pamela M. Carroll and Kevin Fitzgerald). ISBN 0-470-84893-6, John Wiley & Sons Ltd
- A Guinea Pig's History of Biology, Jim Endersby, Harvard University Press.

PAPER – RPSLSc204

Paper Title: Bioinformatics, IPR and Bioethics

Unit I: Bioinformatics (15L)

Introduction to Bioinformatics: Definition and History of Bioinformatics, Different Omics and its application and Current status.
Computers: Operating systems, Internet and its components, Internet sources for Bioinformatics, Flat file.
Introduction to Data Mining: Types of Data (Text formats, sequence data, protein structures, links), Data mining and warehousing, Process of knowledge discovery through data mining.
Biological databases: Classification, Primary DNA Databases, Primary and Secondary Protein Databases, Composite Structure Databases, UniProt, Protein Databank (PDB), Metabolism Database (KEGG).

Unit II: Alignment problem and solutions (15L)

Multiple Sequence Alignment (MSA): Definition, Objective, Consensus, Methods for MSA: Heuristic approach, Dynamic programming approach and their combinations.
Pairwise Alignment: Introduction, PAM Matrix, BLOSUM Matrix, The Dot Plot, Global alignment, Local alignment, FASTA and BLAST. Statistics: P and E value.
Phylogenetic Analysis: Molecular-Phylogenetics, Phylogenetic-trees, Terminology of tree-reconstruction, rooted and un-rooted trees, gene vs species trees and their properties, Methods: UPGMA, Neighbor-Joining Method, Maximum Parsimony.

Unit III: Genomics and Proteomics (15L)

Genomics: Basic concepts on identification of disease genes, role of bioinformatics-OMIM database, reference genome sequence, integrated genomic maps, gene expression profiling; identification of SNPs, SNP database (DbSNP). Role of SNP in Pharmacogenomics, SNP arrays.
Proteomics: Introduction and current status, Prediction of secondary structure: PHD and PSI-PRED method. Tertiary (3-D) Structure prediction: Fundamentals of the methods for 3D structure prediction (sequence similarity/identity of target proteins of known structure, fundamental principles of protein folding etc.) Homology Modelling (Ramchandran plot), fold recognition, threading approaches, and ab-initio structure prediction methods. Application in drug designing: Drug targets, Lead Identification and Modification, Computer-Aided Drug Design.

Unit IV: IPR and Bioethics (15L)

IPR: Introduction to IPR; Types of Intellectual property – Patents, Trademarks, 12 Copyrights and related rights; Traditional vs. Novelty; Importance of intellectual property rights in the modern global economic environment, Importance of intellectual property rights in India; IPR and its relevance in biology and environmental sciences; Case studies and agreements - Evolution of GATT and WTO and IPR provisions under TRIPS; Madrid agreement; Hague agreement; WIPO treaties; Budapest treaty; Indian Patent Act (1970).
Patents: Definition, patentable and non-patentable inventions; types of patent application – Ordinary, Conventional, PCT, Divisional, and Patent of addition;

Concept of Prior Art; Precautions while patenting - disclosure / non- disclosure; Time frame and cost; Patent databases, Searching International databases; Patent licensing and agreement; Patent infringement – meaning, scope, litigation, case studies.

Bioethics: Definition – moral, values, ethics and ethics in biology; Role and importance of ethics in biology; Basic Approaches to Ethics, Bioethics: legal and regulatory issues; Bioethics in healthcare, agriculture, modern biology, biotechnology, animal welfare & right / animals in research, wildlife conservation and management, commercialism in scientific research, Past and Present 'Bioethical Conflicts' in Biotechnology- Interference with Nature , Fear of Unknown, Regulatory Concerns, Human Misuse Future 'Bioethical Conflicts' in Biotechnology - Changing perception of Nature, Human Genetic Engineering, GMOs.

PRACTICALS: RPSLScP204

1. Multiple sequence alignment
2. Phylogenetic tree analysis
3. BLAST- BLASTn, BLASTp, primer BLAST.
4. Motif Finding- MEME and TomTom
5. Secondary Structure Prediction: Porter 5.0
6. Pathway Browsing using Reactome and Plant Reactome
7. Tertiary Structure: ExPasy in SWISS
8. Computer-aided Drug Design – Click2Drug, Autodock4
9. Case study for IPR issues

References:

- Introduction to Bioinformatics- Attwood, Parry-Smith and Phukan
- Bioinformatics: Sequence and Genome Analysis- David W. Mount
- Bioinformatics and Functional Genomics- Jonathan Pevsner
- Fundamentals of Bioinforamtics: Harisha S.
- Bioinformatics and Molecular Evolution: Higgs & Attwood
- Bioinformatics: Harshwardhan Pal
- Law of Intellectual Property Rights-Shiv Sahai Singh
- WTO And Intellectual Property Rights-Talwar Sabanna
- IPR: Unleashing the Knowledge Economy- Prabuddha Ganguli

EVALUATION PATTERN

	PAPER	EXAM	TOTAL MARKS
Semester I	I	Theory	60
		Internals	40
		Practicals	50
	II	Theory	60
		Internals	40
		Practicals	50
	III	Theory	60
		Internals	40
		Practicals	50
	IV	Theory	60
		Internals	40
		Practicals	50
Semester II	I	Theory	60
		Internals	40
		Practicals	50
	II	Theory	60
		Internals	40
		Practicals	50
	III	Theory	60
		Internals	40
		Practicals	50
	IV	Theory	60
		Internals	40
		Practicals	50

INTERNALS FOR SEMESTER I AND II

Paper	20 mks	10 mks	5 mks	5 mks
I	Written Test	Presentation on topic from syllabus	Presentation on any journal article/ newsletter/ book review/ conference/ guest lecture	Attendance
II	Written Test	Presentation on topic from syllabus	Presentation on any journal article/ newsletter/ book review/ conference/ guest lecture	Attendance
III	Written Test	Presentation on topic from syllabus	Presentation on any journal article/ newsletter/ book review/ conference/ guest lecture	Attendance
IV	Written Test	Visit / Project	Presentation on any journal article/ newsletter/ book review/ conference/ guest lecture	Attendance

M.Sc. Part - II Life Sciences - Biotechnology Syllabus

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SEMESTER III

COURSE CODE	UNIT	TOPIC HEADINGS	CREDITS	L / WEEK
Paper I	**Genetic Engineering**			
RPSLSc301	I	Recombinant Techniques	4	4
	II	Microbial Cell Factories		4
	III	Engineering Lower eukaryotes I		4
	IV	Engineering Lower eukaryotes II		4
Paper II	**Fermentation Technology**			
RPSLSc302	I	Upstream Processes	4	4
	II	Fermentation process I		4
	III	Fermentation process II		4
	IV	Downstream Processes		4
Paper III	**Industrial Enzymes, Tissue Culture and its applications**			
RPSLSc303	I	Enzymes in Industry	4	4
	II	Plant Tissue Culture		4
	III	Animal Tissue culture		4
	IV	Assisted Therapies		4
Paper IV	**Research Methodology and Quality Control**			
RPSLSc304	I	Research Methodology	4	4
	II	Scientific writing		4
	III	ISO, GMP, GLP		4
	IV	Using Computers in Research		4

SEMESTER III

PAPER - RPSLSc301

Paper Title: Genetic Engineering

Unit I: Recombinant Techniques (15L)
Introduction to recombinant proteins.
Modifying genes/regulating sequences/proteins: Site-directed Mutagenesis Methods: Error prone PCR, Cassette mutagenesis, Site Saturation mutagenesis, Overlap PCR, DNA/Domain/Exon shuffling, ICTHY, SCRATCHY, RACHITT.
Expression: phage, cell, DNA, RNA, ribosome and IVC display,
Analysis and detection, applications - modifying activity, substrate specificity, cofactor requirement, increasing stability, pH and temperature optima,
Construction of deregulated mutants resistant to feedback inhibition and repression: Examples of modified proteins.
Genome editing: Homologus recombination, zinc finger nuclease, TALENS, CRISPR/Cas9, Modified nucleases – meganuclease.
Application of RNAi in strain improvement: use of siRNA, shRNA, miRNA, ribozymes and riboswitches to regulate and optimize gene expression.
Metabolic Engineering: Metabolic pathway analysis and modelling – approaches, Methods for metabolic engineering, Model organisms – *E. coli*, *B. subtilis*, *Saccharomyces*, plants and animals, Industrial applications.
Systems Biology and Synthetic Biology for strain improvement: Omics analysis, *in silico* modelling, development of improved strains.

Unit II: Microbial Expression Systems (15L)

Prokaryotic: *E. coli*: Expression systems – pET, pBAD, λPL, prhaBAD systems, Expression of Foreign Genes in Bacteria – Problems, optimization of expression: host, transcriptional, translational, post translational compatibility, solubility and purification, transport and localization (use of Promoters, Ribosome Binding Site, Fusion Proteins, signal sequences, Tags and cleavage sites), Modification of gene – codon optimization, host strain modification Expression of Native Proteins, Detecting Expression of Foreign Genes.

Gram Positive Bacteria: *Bacillus subtilis*, *Lactobacilli*, *Streptomyces* – Expression systems, optimization of expression and applications.

Unit III: Engineering Lower eukaryotes I (15L)

Algae: Types, Culture systems, Genetic modification - transformation strategies, selection markers, promoters, terminators, translational regulation of protein production, strategies for efficient protein production, applications – increasing photosynthetic efficiency, yield of commercial and therapeutic products, Risks of GM algae.
Filamentous fungi – Host strains, transformation strategies, selection markers, promoters, terminators, translational regulation of protein production, strategies for efficient production, signal sequences, gene fusion approach, overproduction of foldases and chaperones, role of glycosylation, heterologous and homologous gene expression, humanization of filamentous fungi (*Aspergillus*, etc.), applications - pharmaceutically important secondary metabolites, medicinal mushrooms (*Ganoderma*, etc.), polysaccharides from basidiomycetes for immunostimulating and anticancerous activity.

Unit IV: Engineering Lower eukaryotes II (15L)

Yeasts: Yeast Selectable Markers and Vector Systems, commercially used yeast strains (*S. cerevisiae* and *Pichia*) and their expression systems

Heterologous Protein Production - Design parameters: Source of DNA, Heterologous mRNA and protein levels and downstream applications, humanization of yeast for post translational compatibility.

Uses: Analysis of Genes, Genomes and Protein-Protein Interactions - YAC Technology, Constructing Gene Knockouts and Novel Reporter Systems, synthesis of commercially compounds.

Protozoa: Advantages of protozoan expression systems from *Dictyostelium discoideum, Leishmania tarentolae*, *Perkinsus marinus and Tetrahymena thermophila*, cultivation and applications of protozoan biotechnology.

PRACTICALS – RPSLScP301:

1. Isolation of plasmid DNA from *E. coli*.
2. Transformation of *E .coli* and blue-white colony screening.
3. Isolation of Protease degraders from soil and estimation of the protease activity.
4. Preparation and regeneration of fungal protoplast.
5. Detection and estimation of gene copy number by real time PCR (demonstration).
6. Transformation of Yeast
7. Slide culture of filamentous fungi with nuclei tracking using DAPI stain.
8. Replica Plating.
9. Restriction Fragment Length Polymorphism (RFLP).

References:

1. Molecular Biology and Biotechnology, 5th and 4th edition by J. M. Walker and R. Rapley
2. Biotechnology, Concepts and Applications by R. R. Vittal and R. Bhat
3. Biotechnology, Principles and Applications by S. C. Rastogi More
4. Gene Manipulations in Fungi by J. W. Bennette and Linda L. Lasure
5. Microbial Metabolism and biotechnology, ebook by Horst Doelle
6. The Metabolic Pathway Engineering Handbook- Fundamenals Christina D Somlke
7. Systems Biotechnology for strain improvement. Trends in Biotechnology. Volume 3 (7), 2006.
8. Molecular Biology: A laboratory Manual, 2ndedition, 1989: Maniatis, Fritsch and Sambrook
9. Molecular Biology: A laboratory Manual, 4th edition, 2012: M. Green and J. Sambrook

PAPER – RPSLSc302

Paper Title: Fermentation Technology

Unit I: Upstream Processes (15L)

Fermenter design: Components of the fermenter, sterilization, aeration and agitation.
Types of Fermenters: batch, continuous, air lift, fluidized bed, stirred tank.
Isolation and Screening of microorganisms: Isolation of microorganisms from various sources, Preservation, Primary and Secondary Screening of microorganisms.
Fermentation Media: Definition, Criteria, Various components, Types: crude and synthetic, sterilization, rheology of various components of media.
Microbial growth: General parameters, growth kinetics for various fermentation and types of stock culture, scaling up of culture for fermentation.
Process improvement in Fermentation: Improve strains, media, pH, temperature, aeration and agitation.

Unit II: Fermentation process I (15L)

Single Cell Protein, Biomass and Immobilization: Need of single cell production, production of bacteria, yeast, algae, fungi. Immobilization: cells and enzymes, methods of immobilization, applications.
Commercial Fermentations: Cheese: Culture, Fermentation process, Applications.
Alcohol: Wine, Commercial Ethanol (by-product fusel oils): Culture, Process and Applications.
Acids: Lactic acid industrial production and applications.
Carbohydrate: High fructose corn syrup.
Flavour/fragrance production with example.

Unit III: Fermentation Process II (15L)

Biotransformations: Classification and charactristics of enzymes – OTHLIL, applications of enzymes: (chiral synthesis of enantiomerically pure compounds, resolution of isomers). Examples of biotransformations: Oxidoreductases- Oxidation of 1- amino - D - sorbitol in the production of miglitol using *Gluconobacter oxydans* ; Hydrolases: any one example. Catalytic antibodies.
Secondary metabolites production from plants: Secondary metabolite types (alkaloids, terpenes [include IPP synthesis: Classic pathway and Alternate pathway for IPP synthesis in plastids], tannins, lignans pigments, lipids); Selection of callus cultures.
Examples of secondary metabolite production (industrial scale**)**: [shikonin, taxol (biosynthesis and bioreactor production) capsasin/ berbrine].
From microbes: Polymers [dextrans, xanthan gums, alginate], antibiotics [peptide, lantibiotics, aminoglycosides, beta lactam], cyclosporins, biosurfactants.

Unit IV: Downstream Processes (15L)

Product recovery: Product: internal, external, cell disruption methods: physical, chemical and biological, precipitation, filtration, centrifugation, extraction and purification, drying.
Product Economics: Microbial culture, Fermentation: Upstream and Downstream processes, recovery process, product processing.

Effluent Treatment: Need, Traditional methods disposal and disadvantage, physical, chemical and biological methods.

PRACTICALS: RPSLScP302

1. Immobilization of cells.
2. Demonstration of fermenter/ chemostat.
3. Estimation of alcohol production: Sucrose/ fruit (s)/ sugarcane juice.
4. Isolation of cellulase producing microorganisms from natural source(s).
5. Determination of cellulose activity using Filter paper assay/ carboxy-methyl cellulose assay.
6. Secondary metabolite production using plant tissue culture (dye/ drug Alkaloids etc.)
7. Effect of elicitor(s) on the production of the plant secondary metabolite.
8. Estimation of tannins using the Vanillin Hydrochloride method.

Reference:

1. Principles of Fermentation Technology by Stanbury and Whitaker
2. Industrial Microbiology by Casida
3. Industrial Microbiology by Prescott and Dunn
4. Industrial Biotrasformations by A. Liese, K. Seelbach and C. Wandrey; Wiley – VCH
5. Role of Biotechnology in Medicinal and Aromatics Plants by Khan and Khanum Vol.1
6. Plant Tissue Culture by M. K. Razdan

PAPER – RPSLSc303

Paper Title: Industrial Enzymes, Tissue Culture and its applications

Unit I: Enzymes in Industry (15L)

Industries: Textile Processing, Leather Processing, Paper & Pulp Processing, Detergents and laundry.
Food biotechnology: Fruit and vegetable processing: juices, nectars, purees; syrup and glucose isomerases, enzymatic synthesis of aspartame.
Other industrial uses: Vinegar, Baking, Cocoa fermentation, Olive oil production, fish processing industries.
Nutraceuticals: Probiotics: lycopene, isoflavonoids, glucosamine, phytosterol.
Feed Biotechnology: lignocelluloses into feed using cellulases, silage.
Bio preservation: chemical preservatives and their safety concerns, LAB Bacteriocins. Types of bacteriocins, mode of action, applications and regulations.

Unit II: Plant Tissue Culture (15L)

Basics of plant tissue culture: totipotency, macro and micro nutrients, media.
Culture: Micropropagation, Callus culture, Somaclonal variation, Suspension cell culture, Protoplast culture, Somatic hybridization, Cybrids, Somatic embryogenesis and synthetic seed production.
Conservation: Improvement, exploitation and conservation of genetic resources, Cryopreservation of genetic resources.
Recombinant technology: Plant transformation by *Agrobacterium tumfaciens* [including mechanism of T DNA transfer in wild type Agrobacterium], *A. rhizogenes* its plasmid, Biolistic: factors that influence transformation success, chloroplast transformation: vectors, advantages and disadvantages of the technique.
Applications of transgenic: Overview, Recombinant proteins of pharmaceutical importance in plants including vaccine subunits, edible vaccines, from hairy root cultures.
Transgenic plants: Strategies for virus resistance, Herbicide resistance, Insect resistance, nematode infections and resistance, stress resistance [salt, water and temperature], Improved nutrition [carbohydrate, protein], improved shelf life; Novel applications: change in lipid profile for industrial purpose, biodegradable plastics, novel horticultural traits [flower colour, variegation].

Unit III: Animal Tissue culture (15L)

Basics of animal tissue culture: Methods of cell dissociation/separation and preparation of primary cell culture, characteristics of cells *in vitro*, cell culture growth parameters, detection, prevention and determination of contamination in tissue culture.
Culture: Primary cell culture, immortalized cell culture, stem cell culture and transformed cell culture. Specialized cells: bone marrow, myogenesis, skin cell culture, erythrogenesis-, chondriogenesis- *in vitro*, **Preservation:** Cryopreservation of tissues and cell lines.
Analysis and Production: cell synchronization, cell transformation *in vitro*, Mass cultivation-cytodex and biofermentors.
Applications: Stem cells & therapeutic cloning, Tissue engineering and 3D printing.

Unit IV: Assisted Therapies (15L)

In Vitro Fertilization (IVF): History, Causes of infertility, Stimulation protocols for IVF, Baseline assessment, sperm and egg culture, Preimplantation Genetic Screening/Diagnosis (PGS/D), Mitochondria replacement therapy (MRT), fertilization using ICSI, embryonic culture at various stages of development, Grading embryos, transfer of embryos- Direct embryo transfer, Zygote intrafallopian transfer (ZIFT), Assisted Zona Hatching (AZH); Risks of IVF.

Antisense therapy: Introduction, strategies. oligodeoxyribonucleotide, catalytic antisense RNA, triple - helix forming oligonucleotides (TFOs), production, and limitations, first generation antisense drugs, second generation antisense drugs.

Applications: cancer therapy, viral diseases, gene function analysis and in agriculture.

Gene therapy: Overview, viral and non-viral Vectors for somatic cell gene therapy, Gene therapy for inherited immunodeficiency syndromes, Cystic fibrosis gene therapy, HIV-1 gene therapy.

PRACTICALS: RPSLScP303

1. Isolation and partial purification of Acid/ Alkaline phosphatase from potato
2. Analysis of purification fold of the extracted enzyme
3. Determination of molecular weight of enzyme by SDS-PAGE
4. Isolation and estimation of Nutraceuticals (lycopene/ isoflavanoids) by TLC
5. Micropropagation of selected ex-plants.
6. Production of artificial seeds.
7. Preparation of plant protoplasts.
8. Transformation using *Agrobacterium* spp**.**
9. RAPD analysis (plants/ bacteria).
10. Establishment of Primary Culture (ATC) using a suitable source.

References:

1. Principles of Biochemistry by Lehninger, Nelson and Cox
2. Industrial Biotransformations by A. Liese, K. Seelbach and C. Wandrey; Wiley
3. Introduction to plant tissue culture by M. K. Razdan
4. Animal Cell Culture by Ian Freshney
5. Basic Cell Culture by J. M. Davis
6. A Textbook of In Vitro Fertilization and Assisted Reproduction by Peter R. Brinsden (2005)
7. In-Vitro Fertilization, Third Edition by Kay Elder, Brian Dale - (2011, Cambridge University Press)

RPSLSc304

Paper Title: Research Methodology and Quality Control

Unit I: Research Methodology (15L)

Introduction: Meaning, Objectives and Motivation in research;
Types of research – Descriptive, Analytical, Applied, Fundamental, Quantitative, Qualitative, Conceptual, Empirical and Other Types of Research;
Research Approaches; Research Methods vs. Methodology; Research and Scientific Method;
Research Process: Steps of research process; Criteria of Good Research; Sampling, Sample size determination, Plan for data collection, Methods of data collection, Plan for data processing and analysis;
Scientific misconduct: Plagiarism, Fabrication, Authorship conflicts, Salami and imalas publication.

Unit II Scientific writing (15L)

Introduction: Meaning of Scientific and non-scientific writing; Scientific Vocabulary and grammar. Synopsis, Dissertations, Thesis, Posters.
Correspondence: Formal letters, cover letters, drafting emails, replying to reviewers.
Writing a Research paper: Title, Abstract, Introduction, Review of literature, Methodology, Observations, Results, Discussions, Summary, Conclusion, and Bibliography (Referencing and citation styles). Supplementary data.
Writing a Research Grant Proposal: Funding agencies, guidelines, structure of research proposals – Setting a budget (Manpower, Consumables, Equipment, Travel, Contingencies, Overheads) with justifications, Expected outcomes, Cost benefit analysis, Work plan, and Time schedule of activities.
Presentations: Presenting numerical data - Graphical, Tabular, Animations, Slides etc.

Unit III: ISO, GMP, GLP (15L)

Introduction: Over View of standards in ISO9000 Family
Key principles: Key principles of ISO 9000- Quality Management System
ISO 9001: Detailed study on ISO 9001:2015 standard, based on a seven principles of quality management, including a strong customer focus, the motivation and implication of top management, the process approach and continual improvement
Application: Sector specific Application of ISO 9001- Quality Management System adapted by various industries
Introduction to GMP (Good Manufacturing Practices) and GLP (good Laboratory Practices) in Pharmaceutical Industries.
Overview: of GMPs are enforcement by the U.S. Food Drug Administration (US FDA) under Title 21 CFR. Documentation requirement related to GMP and GLP.
Case studies for SOP preparation and CAPA (Corrective action Preventive Action).

Unit IV: Use of Software in Research (15L)

Literature Search: Query formulation, PubMed, NCBI, Google Scholar, Unpaywal, Shodganga.
Word Processing systems, LATEX.
Image Editors: Adobe Photoshop, Pagemaker.
Referencing: Mendeley, EndNote, Zotero.
Graphing and Statistics: Microsoft Excel, Google Sheets, GraphPad Prism, Max Stat, SPSS.
Antiplagiarism: Plagiarism checker X, TurnItIn, Online plagiarism checkers.

Presentation and Design: Microsoft PowerPoint, Google Slides, Microsoft Publisher.
Using Cloud tools, Microsoft One Note.

PRACTICALS: RPSLScP304:

Literature review

References:

1. Research Methodology in the Medical and Biological Sciences by Petter Laake, Haakon Breien Benestad, Bjorn Reino Olsen (2007, Elsevier_AP)
2. Research Methodology - Methods and Techniques by C.R. Kothari (1985, New Age Publications)
3. The Oxford Book of Modern Science Writing (Oxford Landmark Science) 2009 by Richard Dawkins (Author, Editor)
4. Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded (2012) by Joshua Schimel (Author)
5. The Best of the Best of American Science Writing (The Best American Science Writing) 2010 by Jesse Cohen (Author)
6. From Research to Manuscript A Guide to Scientific Writing (Second Edition) By Katz**,** Michael J. (Springer Publication)
7. Science Research Writing for Non-Native Speakers of English by Hilary Glasman-Deal (Author), Imperial College Press, London, UK
8. Scientific Writing and Communication by Angellka Hofmann, Oxford University Press (2014)
9. ISO 9000 quality systems handbook fourth edition by David Hoyle
10. International standard ISO 9001: quality management systems requirements 5th edition 2015-09-15.
11. Jürg P. Seiler - Good Laboratory Practice - the Why and the How (2005, Springer)
12. Good Manufacturing Practices and Inspection volume 2 (2007, World Health Organization)
13. GLP Essentials - A Concise Guide to Good Laboratory Practice by Milton A. Anderson - (2002, CRC Press)

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SEMESTER IV

COURSE CODE	UNIT	TOPIC HEADINGS	CREDITS	L / WEEK
Paper I	**Medical Biotechnology and Biomathematics**			
RPSLSc401	I	Therapeutics I	4	4
	II	Therapeutics II		4
	III	Biomathematics		4
	IV	Diagnostics and Drug design		4
Paper II	**Applied Biotechnology**			
RPSLSc402	I	Aquaculture	4	4
	II	Nanotechnology		4
	III	New Emergent Technologies		4
	IV	Economics of Biotechnology and industrial considerations		4
Paper III	**Environmental Biotechnology**			
RPSLSc403	I	Biological Controls and Biopesticides	4	4
	II	Nitrogen Fixation and Biofertilizers		4
	III	Bioremediation		4
	IV	Phytoremediation and phytomining		4
Paper IV	**Protein Trafficking, Folding and Engineering and Drug Development**			
RPSLSc404	I	Protein Trafficking and Targeting	4	4
	II	Protein folding and Biomolecular interactions		4
	III	Natural products		4
	IV	Activity Guided Drug Development		4

SEMESTER - IV

PAPER - RPSLSc401
Paper Title: Medical Biotechnology and Biomathematics

Unit I: Therapeutics I (15L)

Introduction, Disease Models, Genomic Protein Targets and Recombinant Therapeutics; Structural Biology - Rational Drug Design, Repurposing of drugs. Traditional medicine versus emerging areas of research,

Therapeutic Proteins: Group I, II, III and IV and their applications in humans and animals, mode of action, stability, processing and formulation. Examples of each class - Monoclonal Antibodies, vitamins, blood proteins, human hormones – Growth hormones, insulin, somatostatin, steroid hormones, immune modulators – factors VIII, IX, interferons and interleukins, erythropoietin, relaxin, epinephrine, TNF, tissue plasminogen activator protein and vaccines, glucagon, secretin and antigens.

Unit II: Therapeutics II (15L)

Genetic Engineering of Vaccines: Identification and Cloning of Antigens with Vaccine Potential - DNA/Oligonucleotide Hybridization, Hybrid Selection and Cell-free Translation, Expression cloning and Genomic Sequencing, Analysis of Vaccine Antigens - B-cell Epitopes and T-cell Epitopes. Generation of Subunit Vaccines, Improvement and Generation of New Live Attenuated Vaccines - *Pseudorabies* Virus, *Vibrio* and *Poliovirus*, Recombinant Live Vectors - *Vaccinia* Virus, Recombinant BCG Vaccines, Attenuated *Salmonella* Strains, Poliovirus Chimaeras, Cross-species Vaccination, 'Live- dead' Vaccines, Other Virus Vectors and Recombinant *E. coli* Strains, DNA, RNA and peptide Vaccines, Anti-idiotypes, Enhancing Immunogenicity and modifying Immune Responses - Adjuvants, Carriers and Vehicles, Carriers, Mucosal Immunity, Modulation of Cytokine Profile, Modulation by Antigen Targeting and Modulation of Signaling.

Peptibodies: Definition, peptide-Fc fusion, advantages over monoclonal antibodies, production in *E. coli* using recombinant DNA technology, production, and mechanism of action, applications – pain, ovarian cancer and immune thrombocytopenic purpura, limitations. Peptidomimetics and biosimilars: (Definition, design, features, analysis and application)

Unit III: Biomathematics (15L)

Binomial Theorem (without infinite series), Determinants, Matrices, Rank of Matrices by Diagonalisation method Limit and derivatives, Differentiation (including differentiability), Successive Differentiation, Integration – Definite and Indefinite (ordinary, method of substitution, special trigonometric function, partial fraction) Application of integration to find area, Differential equations, homogeneous and Linear ODE's and its simple applications to biological problems. Applications of maths in biology.

Unit IV: Diagnostics and Drug design (15L)

Diagnostics and Forensics: Inherited and non-inherited diseases, Direct Detection of Gene Mutations - Allele-specific Oligonucleotides and Restriction Enzyme Site Analysis, ARMS, Oligonucleotide Ligation, and Fluorescently Labelled DNA Sequencing; Indirect Diagnosis with Linked Genetic Markers, Cancer screening; **Forensics:** SNPs, Markers MLP, SLP, mitochondrial DNA, Y chromosome analysis, X chromosome analysis, Applications.

Drug designing and Pharmacogenomics: types of pharmacogenetic knowledge and obstacles, variations of drug metabolizers, transporters, drug targets and biological milieu of drug action, pharmacogenomics of cancer syndromes, neuropsychotic disorders, alzheimer's disease, mental retardation, cardiovascular diseases and smoking and alcoholism, Eugenetics and epigentics of above disorders, genetic influences on drug targets involved in pharmacodynamics, long QT syndromes, emerging technologies.

PRACTICALS: RPSLScP401

1. Residual DNA analysis of recombinant therapeutic protein.
2. *In silico* drug designing using Click2Drug and Autodock4.
3. Hair microscopy for forensic analysis.
4. PAGE of DNA samples and silver staining.
5. Multiplex PCR
6. Pedigree analysis (disease/disorder/trait)

References:

1. Molecular Biology and Biotechnology, 4th edition (2002) by J. M. Walker and R. Rapley
2. Biotechnology for Beginners (2006) by Reinhard Renneberg
3. Biotechnology Vol5 by Rehm& Reed
4. Biotechnology, An Introduction (2008) by S. Ignacimuthu, S. J.
5. Biotechnology, Concepts and Applications (2009) by R. R. Vittal and R. Bhat
6. Biotechnology, Principles and Applications (2007) by S. C. Rastogi
7. Microbial Metabolism and biotechnology, e-book by Horst Doelle
8. Medical Biotechnology, Himalaya Publishing House, Mumbai, (2008) by Jogdand S. N.,
9. Medical Biotechnology, Churchill Livingstone, Elsevier (2009) by Judit Pongracz, Mary Keen
10. Medical Biotechnology, Oxford University Press, India (2010) by Pratibha Nallari& V. Venugopal Rao,
11. Therapeutic peptides and proteins by A. K. Banga

PAPER – RPSLSc402
Paper Title: Applied Biotechnology

Unit 1: Aquaculture (15L)

Aqua culture technology: definition, history and scope, constraints and recent development, criteria for selection of species, aquafarm engineering.

Pisiculture: cultivable fish species, seed production technology of Carps, Carp culture, mono and poly culture.

Prawn culture: cultivable prawn species, spawning techniques, culture methods in India.

Pearl oyster culture: pearl producing species, pearl culture technology, composition of pearl quality and prospects.

Seaweed culture: economically important species culture and post-harvest technology.

Unit II: Nanotechnology (15L)

Bionanotechnology: Concept. Types of bionanostructures (Carbon nanostructures, nanoshells, dendrimers, quantum dots, nanowires, liposomes).

Synthesis of bionanoparticles: Physical, chemical and biological methods.

Applications of nanotechnology: medicine and diagnostics (antimicrobial properties, therapies, drug delivery including rate programmed drug delivery, Microencapsulation of cells. imaging) agriculture, environment.

Potential risks of Bionanotechnology.

Unit III: New emergent Technology (15L)

Biosensors: Concepts. Types of biosensors: ampereometric, potentiometric, conductometric, calorometric, peizoelectric, evanascent wave sensors, Surface Plasmon resonance, whole cell biosensors.

Biomimetics: Concept and possible applications: Adhesion (lizard's foot) Water repulsion (lotus leaf), nanostructures in colour display (butterfly wings/ peacock feather).

Microfluidics: Fundamental characteristics of fluidics at microscales applications of microfluidics (cell separation, dip sticks).

Biomechanics: Introduction and Biotechnology in biomechanics.

Unit IV: Economics of Biotechnology law and industrial considerations (15L)

Emerging trends in biotechnology industry, organizational structure, funding and investment, Demand, markets, viability, licensing, collaboration and technology transfer.
Bioenterpreneurship laws in Rural and Urban India, Business ethics and CSR, Government policies for biotechnology industries, Indian Bioentreprenuers

PRACTICALS: RPSLScP402

1. Identification of cultivable fish species.
2. Identification of cultivable prawn species.
3. Identification of cultivable pearl bivalves and oyster species.
4. Identification of cultivable seaweed species.
5. Isolation and determination of colony characteristics of marine organisms.
6. Synthesis of silver nanoparticles - biological method.
7. Preparation of gold nanoparticles, ferromagnetic fluid, corn flour non Newtonian fluid
8. Antimicrobial activity of SNP by the tetrazolium microplate assay.
9. Antioxidant activity of SNP.
10. Demonstration of Laminar Flow in Microfluidic system

References:

1. Aquaculture by Ujwala Jadhav
2. Bio - Nanotechology by Madhuri Sharon.
3. Molecular Biology and Biotechnology, 4th edition (2002) by J. M. Walker and R. Rapley
4. Microfluidics for Biotechnology 2nd Edition by Jean Berthier and Pascal Silberzan
5. Introduction to microfluidics by Patrick Tabeling
6. Economics of Biotechnology by T.V.S Rama Mohan Rao
7. Entrepreneurship and Business of Biotechnology by S. N. Jogdand
8. Economic dynamics of Modern Biotechnology by Maureen D. McKelvey, Annika Rickne, Jens Laage-Hellman

PAPER – RPSLSc403
Paper Title: Environmental Biotechnology

Unit I: Biological Controls and Biopesticides (15L)

Chemical Pesticides: Spectrum of chemical pesticides for control of biotic stress: uses, advantages and disadvantages.
Spectrum of biological pesticides: types, advantage on chemical pesticides, mode of action, stability and formulation in natural and genetically modified organism, Selective targeting, Molecular mechanism of resistance development and strategies including integrated pest management.
Biopesticides from Plants: Neem and pyrethrins, mode of action on insect pests, Bio-control against fungal diseases of plants.
Biological Controls: Viral/ fungal/ bacterial parasites for control of insect pests, life cycle, symptoms and mode of action.

Unit II: Nitrogen Fixation and Biofertilizers (15L)

Nitrogen fixation: Molecular genetics: *nif* genes and regulation of *nif* gene expression, *fix* genes.
Biofertilizer: definition, methods of manufacture, application to soil and seed.
Aquaponics: fish culture and plant culture using this water.
Composting: physical and chemical factors, microbiology, health risk from pathogens, odour sources.
Mycorrhiza: Types, importance to plant health (nutrient uptake, resistance to stress, microbial symbiosis), importance of network analysis, role in ecosystem (Plant to plant interaction).
Biofuels: Liquid and gaseous. Bioenergy: Biofuels - Introduction, in the form of gas– hydrogen and methane (biogas), biofuel in form of liquid– ethanol and diesel, biofuel from phytoplankton.

Unit III: Bioremediation (15L)

Solid management: Types, need, unit processes, laws and regulations.
Adaptation: Effect of metals and salts on the growth of microbes and higher organisms, Different adaptation mechanism to tolerate higher concentration of metals by organisms.
Bioremediation: using natural, genetically engineered bacterial systems with examples and Coal, crude oil.
Biomineralization: Heaps and Dumps.

Unit IV: Phytoremediation and phytomining (15L)

Phytoremediation: Contaminants treated, Contaminant removal mechanisms of plants, Site conditions, Procedure, Types of phytoremediation**,** Criteria for good phytoextractors. Improvement of phytoremediation using genetic engineering. Advantages and disadvantages of phytoremediation. Aquatic plants used for wastewater treatment. Indicator plants, Restoration of soil, water and air quality citing suitable examples**.**

Phytomining: Factors influencing metal uptake by plants in soil, Implementing phytomining, extraction of valuable minerals/ metals from low grade ore/soils.

Biotechnology in gold mining/ extraction.

PRACTICALS: RPSLScP403

1. Soil analysis - chloride, organic matter, & calcium carbonate content.
2. Waste water analysis - pH, Total solids, BOD, Hardness, acidity, alkalinity and chlorides.
3. Effect of Neem pesticides on plant pathogens.
4. Staining of mycorrhiza from root tips.
5. Analysis of metals accumulation in plants.
6. Identification of indicator plants for environmental conditions
7. Biofuels production from algae.

References:

1. Environmental Biotechnology by M. H. Fulekar
2. Environmental Sciences: Odum
3. Environmental Biotechnology: Alan Scragg
4. Environmental Biotechnology: Bimal Bhattachraya and Ritu Banerjee
5. Environmental pollution control engineering. C. S. Rao. New Age International Publishers.

PAPER – RPSLSc 404

Paper Title: Protein Trafficking, Engineering and Drug Development

Unit I: Protein Trafficking and Targeting (15L)

N-glycosylation in the ER and Golgi (quality control, UPR, ERAD and proteosomal degradation

Intracellular and membrane protein trafficking and targeting; Secretory pathways in prokaryotes and eukaryotes; Endocytic pathways; Signal sequences; Co-translational transport (protease protection assay); Targeting of mitochondrial, chloroplast, peroxisomal and nuclear proteins; Vesicle biogenesis and ER to Golgi transport; ER translocation of polypeptides (soluble and transmembrane); ER chaperons; SNAPs and SNAREs; Methods of studying Protein Transport; Disorders of protein transport.

Unit II: Protein folding and Biomolecular Interactions: **(15L)**

Protein Folding: Folding pathways; Intermediates of protein folding; Compact Intermediates; Hierarchical and non-hierarchical folding mechanisms; Molten globule structure; Role of chaperons (trigger factor, prefoldin), heat shock proteins (Hsp70, Hsp90), chaperonins (Group I & II) and enzymes in protein folding (PDI, PPI). Protein folding disorders.

Biomolecular Interactions and diseases:

Structural and functional aspects of proteins and DNA: Relationships between structure and function and their role in human diseases; Protein-DNA interactions; Protein-RNA interactions; Protein-Protein interactions; Protein aggregation; Non-Enzymatic glycosylation (Protein- sugar interactions); Methods to study these interactions.

Unit III: Natural products: (15L)

History of natural drugs, Sources of natural drug ie Plants, Animals, Microorganisms**;** Primary metabolites: carbohydrates, proteins, nucleic acids and lipids and their importance to plants**;** Secondary metabolites: Types, mechanism of synthesis, Importance in plants and for mankind as fragrance, pigments, flavours and medicines.

Unit IV: Activity Guided Drug Development: (15L)

Plant collection and Extract preparations: Methods of Plant collection, solvent extraction (cold, hot, critical fluid extraction etc), screening of medicinal properties; Natural products: methods of identification (Qualitative and Quantitative), isolation and purification (Chromatography), Characterization (LC-MS**,** GC-MS, NMR, XRD, Elemental analysis etc); Bio efficacy studies: *In vitro* testing- Antimicrobial, Antidiabetic, Antioxidant, Anti-inflammatory, anti-larvicidal etc. Pre-clinical and clinical trials.

PRACTICALS: RPSLScP404:

Research Project

References:

1. Chemistry of Natural Products by Sujata V. Bhat, B.A. Nagasampagi, Meenakshi Sivakumar(Springer Publication)
2. Indian Uses of Native Plants by Edith Van Allen Murphey
3. Plant Taxonomy (2nd Edition) by Sharma
4. Plant Drug analysis by H. Wagner
5. Biochemistry and Molecular Biology of *Plants* by Bob B. *Buchanan*
6. Plant Secondary Metabolites
   Volume 1: Biological and Therapeutic Significance
   Volume 2: Stimulation, Extraction, and Utilization by Kamlesh Prasad,
7. Vasudha Bansal Herbal Cosmetics &Ayurvedic Medicines by P. K. Chattopadhyay
8. *Textbook of Clinical Trials* by David Machin, Simon Day, Sylvan Green
9. Plant Bioactives and Drug Discovery: Principles, Practice, and Perspectives 1st Edition Valdir Cechinel-Filho(Author), Wiley Publication.
10. Drug Discovery from Plants By Angela A. Salim, Young-Won Chin, A. Douglas Kinghorn (Springer publication)
11. Bioassay Methods in Natural Product Research and Drug Development By Lars Bohlin, Jan G. Bruhn (Springer Publication)
12. Principles of Biochemistry by Lehninger, Nelson and Cox
13. Biochemistry by Stryer
14. Biochemistry by Harper

EVALUATION PATTERN

	PAPER	EXAM	TOTAL MARKS
Semester IV	I	Theory	60
		Internals	40
		Practicals	50
	II	Theory	60
		Internals	40
		Practicals	50
	III	Theory	60
		Internals	40
		Practicals	50
	IV	Theory	60
		Internals	40
		Practicals	50

INTERNALS FOR SEMESTER IV			
Paper	**20 mks**	**10 mks**	**10 mks**
I	Written Test / online test	Presentation on topic from syllabus	Presentation on any journal article/ newsletter/ book review/ conference/ guest lecture
II	Written Test / online test	Presentation on topic from syllabus	Presentation on any journal article/ newsletter/ book review/ conference/ guest lecture
III	Written Test / online test	Presentation on topic from syllabus	Presentation on any journal article/ newsletter/ book review/ conference/ guest lecture
IV	Written Test / online test	Visit / Project	Presentation on any journal article/ newsletter/ book review/ conference/ guest lecture

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