DEPARTMENT OF BOTANY
UNIVERSITY OF NORTH BENGAL

"समानो मन्त्र समिति समानी"

REVISED CHOICE BASED CREDIT SYSTEM (CBCS) SYLLABUS FOR M.Sc. in BOTANY

2022-23 ONWARDS

Duration: Two years (Four Semesters); Total marks 1600 [64 CREDITS]

OUTLINE OF THE PROPOSED SYLLABUS

SEMESTER-I								
Course Type	**Course Name**	**Course Code**	**Groups**	**Credit Distribution**			**Total Credits**	**Total Marks**
				Theory	**Practical**	**Continuing Evaluation[$]**		
Core Course-I	**Microbiology**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
Core Course-II	**Mycology and Plant Pathology**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
Core Course-III	**Taxonomy and Biosystematics**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
DSE-I (*Any one to be selected out of the two choices)*	**i) Natural History and Evolution or ii) Techniques in Botany**			**1.68**		**0.32**	**2**	**50**
AEC-I	***Any one to be chosen from Basket 1***						**2**	**50**
							16	**400**

[$] Continuing Evaluation based on Class Tests / Assignments / Seminars / Field Studies / Scientific Outreach / Attendance etc.

SEMESTER-II								
Course Type	**Course Name**	**Course Code**	**Groups**	**Credit Distribution**			**Total Credits**	**Total Marks**
				Theory	**Practical**	**Continuing Evaluation[$]**		
Core Course-IV	**Plant Physiology & Biochemistry**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
Core Course-V	**Plant Breeding and Genomics & Cytology and Genetics**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
Core Course-VI	**Cryptogamic Botany & Gymnology**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
DSE-II (*Any one to be selected out of the two choices)*	**i) Pharmacognosy or ii) Plant Anatomy**		**Group-A**	**0.84**		**0.32**	**2**	**50**
			Group-B		**0.84**			
SEC-I	***Any one to be chosen from Basket 2***						**2**	**50**
							16	**400**

[$] Continuing Evaluation based on Class Tests / Assignments / Seminars / Field Studies / Scientific Outreach / Attendance etc.

SEMESTER-III								
Course Type	**Course Name**	**Course Code**	**Groups**	**Credit Distribution**			**Total Credits**	**Total Marks**
				Theory	**Practical**	**Continuing Evaluation[$]**		
Core Course-VII	**Plant Development & Metabolism**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
DSE-III * (*Any one to be selected out of the eight choices)*	**Special Paper-I**		**Group-A**	**0.84**		**0.32**	**2**	**50**
			Group-B	**0.84**				
DSE-IV * (*Any one to be selected out of the eight choices)*	**Special Paper-II**		**Group-A**	**0.84**		**0.32**	**2**	**50**
			Group-B	**0.84**				
DSE-V * (*Any one to be selected out of the eight choices)*	**Special Paper-III**				**1.68**	**0.32[#]**	**2**	**50**
AEC-II	***Any one to be chosen from Basket 3***						**2**	**50**
GE-I (*Any one to be selected out of the two choices)*	**i) Rice Breeding, Organic Farming & Tissue Culture or ii) Nanobiology, Bioseparation Techniques & Drug Designing and Bioinformatics**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C	**1**				
							16	**400**

*** Only one Special Paper title to be selected for DSE-III, DSE-IV, and DSE-V among the following titles: (A) Genetics and Bioinformatics, (B) Microbiology, (C) Molecular Plant Pathology and Fungal Biotechnology, (D) Plant Biochemistry, (E) Plant Genetics and Molecular Breeding, (F) Plant Physiology and Pharmacognosy, (G) Advanced Pteridology and Palaeobotany, (H) Taxonomy of Angiosperms and Biosystematics.**

[$] Continuing Evaluation based on Class Tests / Assignments / Seminars / Field Studies / Scientific Outreach / Attendance etc.

[#] Continuing Evaluation based on Review of Scientific Literature.

SEMESTER-IV								
Course Type	**Course Name**	**Course Code**	**Groups**	**Credit Distribution**			**Total Credits**	**Total Marks**
				Theory	**Practical**	**Continuing Evaluation[$]**		
Core Course-VIII	**Ecology & Biostatistics**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
Core Course-IX	**Genetic Engineering and GM Crops & Genome Biology and Evolution**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C		**1**			
DSE-VI * (*Title to be opted based up on the Special paper selected in Semester-III)*	**Dissertation**				**1.68**	**0.32[#]**	**2**	**50**
SEC-II	***Any one to be chosen from Basket 4***						**2**	**50**
GE-II (*Any one to be selected out of the two choices)*	**i) Climate Change, Stress Physiology & Sustainable Development or ii) Biodiversity, Plant Treaty & IPR**		**Group-A**	**1**		**1**	**4**	**100**
			Group-B	**1**				
			Group-C	**1**				
							16	**400**

*** The student should opt for dissertation work under the same Special Paper title selected in the 3rd Semester. There are eight Special Paper titles under which the title of the dissertation will be finalized: (A) Genetics and Bioinformatics, (B) Microbiology, (C) Molecular Plant Pathology and Fungal Biotechnology, (D) Plant Biochemistry, (E) Plant Genetics and Molecular Breeding, (F) Plant Physiology and Pharmacognosy, (G) Advanced Pteridology and Palaeobotany, (H) Taxonomy of Angiosperms and Biosystematics.**

[$] Continuing Evaluation based on Class Tests / Assignments / Seminars / Field Studies / Scientific Outreach / Attendance etc.

[#] Continuing Evaluation based on Seminar presentation of the Dissertation work.

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REVISED CHOISE BASED CREDIT SYSTEM (CBCS) SYLLABUS FOR M.Sc. in BOTANY

PREAMBLE

The Department of Botany of the University of North Bengal was initiated in the summer of 1984. Since then the Department flourished tremendously with the tireless efforts of faculties, staff and students. The Department has marked its golden presence by its remarkable achievements in shaping the scientific and academic pursuit of Sub-Himalayan West Bengal, Sikkim and neighbouring countries like Nepal, Bhutan and Bangladesh. Though, being a University situated in a remote location with limited resources and infrastructure, our University as well as the Department is second to none when it comes to producing quality students, researchers and scientists.

The voyage started in the year 1982 with the decision of the University authority to have two new departments namely Botany and Zoology under the Centre for Life Sciences, the then a unit exclusively for R&D. The Department has received a Special assistance program (SAP-DRS) for three phases (2002-2007, 2007-2012 and 2013-2018) as well as DST-FIST assistance in 2003. The Department has once again received support under the DST-FIST programme in 2022 for the up-gradation of research and networking facilities in the Department. With the support from the Department of Environment and Forests, Govt. of India, a Botanical garden has been set up while with the financial support from the Department of Biotechnology, Ministry of Science and Technology, Govt. of India, Infrastructural facilities including Immuno-Phytopathology Laboratory, Tea Germplasm Bank, Rice Germplasm Bank, Antisera Reserves for Plant pathogens, Mushroom Production Unit have been established. With the financial support of DST, West Bengal and the National Medicinal Plants Board a beautiful garden of Medicinal Plants has been developed on this campus that has been uplifted as a Centre for Conservation and Utilization of Medicinal and Aromatic Plants.

PROGRAMME OBJECTIVES:

The Master of Science (M.Sc.) in Botany Programme is framed to inculcate students with basic and advanced knowledge in plant sciences. Students would be taught different aspects of the subject comprising of a well-thought combination of core and elective papers which includes the developments in modern biology and interdisciplinary sciences. Students would be engaged in field trips to enhance their practical experiences with the diversity of plant forms and also the impact of ecological variations on the same. Students would be exposed to hands-on experiences of performing different experiments and usage of different instruments to develop their overall expertise and prepare them for the future.

PROGRAMME SPECIFIC OUTCOMES:

- Students after completing this programme will have complete knowledge about the different branches of the subject including the background and history of the development of the subject, basics and advances of the subject.
- Students would be able to distinguish the different life forms of plants and will have a detailed understanding of the recent systems of classification and techniques for identifying the plants.
- Students would be able to build upon the foundations of the topics including physiology, biochemistry, microbiology, genetics, molecular biology, genetic engineering, plant development, pharmacognosy and so on and would be able to explore the further advances in the topics on their own.
- Students would be able to utilize their experience of executing dissertation work and using different tools and techniques in their future research and development assignments.

SEMESTER-I

CORE COURSE - I		
COURSE CODE: - -		
COURSE NAME: MICROBIOLOGY		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

COURSE OBJECTIVES:

This course aims to teach the students with the basics and advances of Microbiology. The course is divided into two groups of equal weightage. At first, the diversity, growth and nutrition and metabolism of microorganisms will be dealt with. After that, the different aspects of viruses and plant-microbe interaction will be undertaken.

COURSE LEARNING OUTCOMES:

- ❖ Students will understand the diversity of microbial life forms and the recent system of their classification.
- ❖ Students will gain complete knowledge regarding the morphological and anatomical features of bacteria and viruses, different metabolic pathways associated with bacteria, concepts of the nutritional requirements and growth patterns and also learn about the basics and advances in bacterial genetics.
- ❖ Students will be able to understand the concept of plant-microbe interaction, its importance and its mechanism of it.
- ❖ Students will also learn about the importance of microorganisms in human welfare rights.

GROUP A: MICROBIOLOGY-I		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. **Diversity:** Classification and survey of microorganisms; Classification of bacteria - Bergey's manual of systematic bacteriology –outline only.
2. **Morphology and anatomy of cells:** Morphology; Cell surfaces (glycocalyx, cell wall, flagella, and pili) and their role; Plasma membrane; Prokaryotic chromosome: Ribosome; Endospores.
3. **Metabolism:** Photosynthesis (anoxygenic and oxygenic); Chemosynthesis; Fermentation (alcoholic, Entner-Doudoroff pathway; lactic acid – homo and hetero, Respiration (anaerobic and aerobic).
4. **Growth and nutrition:** Measurements of growth; Generation time; Continuous culture; Synchronized growth; Diauxy; Environmental factors influencing growth, Organic growth factors; Inorganic requirements; Physical and ionic requirements.
5. **Bacterial Genetics and Recombination:** Organisation and structure of bacterial genome, Replication of prokaryotic chromosomes; Modes of recombination (transformation, transduction, and conjugation).

GROUP B: MICROBIOLOGY-II		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. **Virology:** Morphological classes of viruses; Structure of Adenovirus, Tobacco mosaic virus, and coliphage T_4.
2. **Plant–microbe interactions:** Mycorrhizae, Nitrogen-fixing associations between rhizobia and legumes, cyanobacteria - plant symbiosis. Plant growth promoting rhizobacteria.
3. **Biological nitrogen fixation:** Biology and biochemistry; Rhizobial association with plant roots and root nodulation; Commercial production of rhizobia.
4. **Commercial application of Microbes:** Use of microbes in food industry, Use of microbes in agriculture, Use of microbes in the pharmaceutical industry, Use of microbes in biotechnology.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Study of microscope.
2. Basic principles of sterilization, disinfection, safety in microbiological laboratory.
3. Preparation of media, identification and culturing of various microorganisms (streak-plate, pour-plate, and spread-plate techniques).
4. Isolation and enumeration of viable microorganisms from soil by serial dilution-agar plate method.
5. Differential Staining (Gram- staining and endospore) and study of morphology of prokaryotic cells.
6. Study of bacterial growth using turbidimetric method.
7. Isolation and study of rhizobia from root nodules.
8. Antibiotics sensitivity test using paper disc method.

CORE COURSE - II		
COURSE CODE: - -		
COURSE NAME: MYCOLOGY AND PLANT PATHOLOGY		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

COURSE OBJECTIVES:

This course aims to teach basic, economic and molecular aspects of fungi, host-pathogen interactions and control measures will also be taught. Diseases of crop plants and their diagnosis will be taught with recent advancements. Information about immunological and molecular diagnostics will also be given to the students.

COURSE LEARNING OUTCOMES:

- Students will understand the role of fungi in different sectors of life with special reference to agriculture.
- Students will learn about different plant-pathogen interactions, their diagnosis and control.
- Students will learn about sustainable agriculture.

- Students will also learn about recent molecular developments of plant-microbe interaction.

GROUP A: MYCOLOGY AND PLANT PATHOLOGY-I		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. Cell cycle control points in yeast.
2. Fungi in industry & medicine: Antibiotics- Penicillin; Organic acids – Citric acid; Plant growth regulator- Gibberellin, alcohol and Fungal enzymes (general account)
3. Fungal toxins: Host non-selective toxins- cercosporin (Mode of action); Host-specific toxins- structure, mode of action and concept of V_b gene. Mycotoxin, Aflatoxin biosynthetic pathway, Mycotoxins in human and animal health.
4. Penetration, infection, invasion of host tissue, the relationship between pathogen and host factor(s), structural and biochemical defense mechanism in plants. Role of enzymes and toxins in plant disease.

GROUP B: MYCOLOGY AND PLANT PATHOLOGY-II		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. Fungal diseases of plants: symptoms, disease cycle and control measures with reference to Damping off, powdery mildew, downy mildew, smut, bunt, rust, wilt, root rot, leaf spots, leaf blight and gall of economically important crops.
2. Bacterial diseases: bacterial leaf blight of rice, bacterial wilt of potato, bacterial canker of tomato, crown gall of rose. Plant-bacterial interactions with emphasis on *Ralstonia* and Solanaceous plants.
3. Nematode disease: General features; Mechanism of nematode injury to plants; Factors affecting survival and parasitism of nematodes; Nematode - plant interaction; Molecular approach in the management of virulence genes in potato cyst nematodes.
4. Virus disease: Symptoms, carrier, transmission, Plant-virus interaction; Role of nucleic acid in virus infection; Establishment and development of virus infection; control strategies.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Identification of fungal cultures: *Colletotrichum, Curvularia, Alternaria, Pestalotiopsis, Trichoderma, Fusarium, Dreschlera* and others available.
2. Preparation of media, Isolation of pathogen (Fungi and Bacteria) from diseased plant material.
3. Study of mycoflora of air/soil.
4. Study of Koch's postulates; Pathogenecity test of a pathogen; and Disease assessment in whole plants/cut shoots/ leaves.
5. Identification of fungi by molecular technique (by ITS region amplification and BLAST analysis) - Demonstration from an Identified organism.
6. Bioassay of antifungal compounds/fungicides/Antibiotics by agar well/disc method.

7. Determination of ED_{50} value of fungicides by spore germination method.
8. Thin layer chromatography and bioassay of antifungal compounds.
9. Histopathological studies of fungal diseases of economically important crops from diseased samples.
10. Comparison of soluble protein content between healthy and artificially inoculated plants.
11. Comparison of total and orthodihydroxy phenol content between healthy and artificially inoculated plants.
12. Extraction and assay of Phenylalanine ammonia lyase/Peroxidase activity in plants following infection.

CORE COURSE - III		
COURSE CODE: - -		
COURSE NAME: TAXONOMY AND BIOSYSTEMATICS		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

COURSE OBJECTIVES:

This course aims to enhance the understanding of the students about the diversity and conservation of Flowering plants, their Description, Identification, Nomenclature and their classifications including recent advances in the field. The course also enhances the knowledge about IUCN threats parameters, Ethnobotany, Biodiversity conservation, Botanical gardens and Medicinal plants.

COURSE LEARNING OUTCOMES:

- Students will understand differences between Plant taxonomy and systematic; components, importance and data sources in systematics.
- Students will understand the principle of nomenclature, history and recent development in classifications. Students also learn the methods of naming plants.
- Students will understand the concept of phenetics and cladistics.
- Students will be able to use molecular tools with other morphological tools in understanding of phylogeny and evolution.
- Students will acquire knowledge of different methods of collecting and preserving plants, biodiversity conservation and ethnobotany.

GROUP A: TAXONOMY AND BIOSYSTEMATICS-I		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. International Code of Nomenclature (ICN/ICBN) - Basic Principles, Latest amendments, Type concept; Principle of priority and their limitations, Valid & effective publication, Starting points of Nomenclature. Names of new taxa (species); new combinations; names at new rank; replacement and rejection of names. Proposed BioCode and PhyloCode.
2. Character Concept and artificial keys.
3. Source of data for Systematics: (a) Anatomy, (b) Cytology, (c) Embryology, (d) Palynology, (e) Phytochemistry, (f) Molecular taxonomy–DNA barcoding, (g). Micro-morphology
4. The Origin of Species.

5. Types and importance of Taxonomic literatures and Index, Type and concept of herbarium techniques, index herbariorum, Concept of Botanic Gardens.

GROUP B: TAXONOMY AND BIOSYSTEMATICS-II		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. Major classification - its need, philosophy and brief history.
2. Phenetic versus cladistics; basis of APG Classification, brief idea about APG IV (2016). Concepts of palaeoherbs and eudicots (tricolpates). Cladistics: A brief account: definition and application.

3. Phylogeny of Basal Angiosperms and Magnoliids, monocots, Probable sister of eudicots, eudicots, Core eudicots, Superrosids, Superasterids
4. Biodiversity - Concept, levels, importance and conservation; Biodiversity conservation Hotspots, megadiversity centers, IUCN guide lines, CITES and TRAFFIC; invasions & introductions, endemism.
5. Ethnobotany and Traditional Knowledge: concept, need, methods of survey; sacred groves.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Workout of plant specimens, description, and identification of some representative plants from locally available families.
2. Training in identification of taxa and using relevant literatures and herbarium specimens.
3. Temporary preparation of pollen slides and study of exine morphology and aperture structure in a few simple palynomorphs.
4. Preparation of artificial keys.
5. Morphological peculiarities of some select flowering plants.
6. Embryo structure and micro-morphological study on some common angiospermic plants.
7. Field trip within and near-by areas; compilation of field notes and preparation of herbarium sheets of commonly available plants.
8. Herbarium preparation.

DISCIPLINE SPECIFIC ELECTIVE - I		
COURSE CODE: - -		
COURSE NAME: DSE-I *		
Credit: 2	**Full Marks: 42 (T) + 8 (CE)**	**Total lecture hours: 54**

*** Any One (01) paper to be selected out of Two (02) papers.**

(A) Natural History and Evolution (or)

(B) Techniques in Botany

(A) NATURAL HISTORY AND EVOLUTION		
Credit: 1.68	**Full Marks: 42 (T)**	**Total lecture hours: 54**

COURSE OBJECTIVES:

The course will focus on the enigma of origin of life and the evolution of life from the prehistoric times. The students will be taught about the contribution of various naturalists in biological sciences and the importance of natural history societies and museums.

COURSE LEARNING OUTCOMES:

- Students will get detailed study of concept of origin of life and the recent advances in the understanding of life.
- Students will get information about the Natural History Societies and museums across the world.
- Students will understand the recent understanding of the evolution of life forms.

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1. **Origin of life:** Spontaneous generation versus biogenesis; fermentation; germ theory of disease.
2. **Lamarck & Darwin:** The Lamarckian heritage; Charles Darwin; Theories of Darwin; Darwinian Evolution and religious attack; Support for Darwin.
3. **Noted Naturalists:** George Charles Wallich, Theodosius Dobzhansky, Birbal Sahni, Alfred Russel Wallace, David Attenborough, E. O. Wilson, Edward Forbes, J.C. Bose, R.L. Brahmachari and others.
4. **Natural History Societies and museums:** Bombay Natural History Society; Bengal Natural History Museum, Darjeeling; Indian Museum, Kolkata; Asiatic Society of Bengal, Kolkata; British Natural History Society and Museum, London; Musée des Confluences (Lyon); Muséum national d'histoire naturelle (Paris); American Museum of Natural History, New York City etc.
5. **Evolution:** History of Life; Evolution theory; Darwin and natural selection, coevolution; Adaptation; Phylogenetics; Mapping evolution; Sexual selection and life history; Species concept and macroevolution; Behavioral evolution.

(B) TECHNIQUES IN BOTANY		
Credit: 1.68	**Full Marks: 42 (T)**	**Total lecture hours: 54**

COURSE OBJECTIVES:

This course aims to familiarize the students with theoretical aspects of imaging, biochemical and molecular techniques that are being used extensively in plant sciences. This course attempts to acquaint the students with the working principle of major instruments and also inculcate the ability to choose the necessary instruments to perform research work.

COURSE LEARNING OUTCOMES:

- Students will learn about the advanced instrumentation techniques.
- Students will be able to know about the basic working principle of major instruments.
- Students will understand the concepts, techniques and applications of various instruments used in biology.

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1. **Imaging Techniques:** Principles of microscopy. Principles and applications of light microscopy, fluorescence microscopy, phase contrast, confocal microscopy and electron microscopy (Transmission and scanning electron microscopy).
2. **Bioseparation Techniques**: Principles and application of chromatography, HPLC and GLC, Electrophoresis: AGE, PAGE, SDS-PAGE, Isoelectric focusing and 2-D.
3. **Spectroscopic Techniques:** Principles of Colorimetry and Spectrophotometry. Biological Applications of UV-Visible Spectrophotometry, Mass spectroscopy and Infrared Spectroscopy.
4. **Immunochemical and Radioisotope Techniques:** General Principles. Antigen and Antibody Interaction. Antibody Production. Immuno-diffusion. Radioimmunoassay (RIA). Enzyme Linked Immuno-Sorbent Assay (ELISA). Fluorescent Immunoassay (FIA); Use of radioisoptes in biology.
5. **Basic principles and applications of molecular techniques**: RAPD, AFLP, RFLP, ISSR, SSR, PCR and its variants; functional genomics and proteomics.
6. **Histochemical techniques:** Staining - Principle and applications; Fluorescence in situ hybridization (FISH), CASFISH, CRISPRainbow; Chromosome painting (GISH/ multicolor FISH), Localization of plant secondary metabolites and oxidative markers.

SEMESTER-II

CORE COURSE - IV		
COURSE CODE: - -		
COURSE NAME: PLANT PHYSIOLOGY AND BIOCHEMISTRY		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

COURSE OBJECTIVES:

This course aims to teach the students with the basics and advances of Plant Physiology and Biochemistry. The course is divided in to two groups of equal weightage. This course aims to enhance the understanding of the students about importance of water in plant life, assimilate distribution and partitioning, perception of light and their signalling mechanisms along with physiology of plant growth regulators in the first group. In the second group, the students will learn about the basic and modern concepts of biomolecules including proteins, carbohydrates, lipids and enzymes. Also, thermodynamic principles and physical forces governing cellular life will be taught about.

COURSE LEARNING OUTCOMES:

- ❖ Students will learn about properties of water, their role in plant life, water potential and measuring system, transport of water through vascular tissues, possible challenges during adverse condition and their mitigation measures.
- ❖ Students will be taught about the concept photosensory biology, mechanism of light mediated physiological control of stomatal regulation, response in dark and their mechanism and their overall coordinated cascades.
- ❖ During this course students will learn about transport of assimilates from leaf to root, possible theories involved, crisis during pathogenic injury and the process of partitioning in different tissues.
- ❖ Students will also gain the knowledge about plant growth regulators, structure function relationship, physiology and homeostasis and control of signalling by degradation of repressors through ubiquitin ligation.
- ❖ Students will gain knowledge on the structural and biochemical properties of different macromolecules and also on cellular energetics.

GROUP A: PLANT PHYSIOLOGY		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. **Water balance in plants:** Structure and chemical nature of water; adhesive and cohesive properties; Diffusion, Osmosis and Bulk flow; Water Potential: physiological role; Measuring water potential; Aquaporin channels; Tracheid and Vessel anatomy; Transport through Xylem: Cohesion-tension theory; Cavitation and Embolism.
2. **Translocation in the phloem:** Pathways of translocation; Phloem anatomy; Pattern of translocation: source to sink; Phloem sap composition; Pressure-Flow model of Phloem transport; Apoplastic and symplastic phloem loading; Polymer Trapping Model; Phloem unloading.
3. **Photosensory biology of plants:** Photochemical and biochemical properties of phytochrome; Phytochrome induced physiological responses; Classification and properties of light responses; Structure and function of phytochrome protein; Phytochrome signalling pathways

4. **Plant growth regulators:** Concept of hormones and plant growth regulators; Structure, biosynthesis and metabolism of auxin and gibberellins; Physiological role of plant growth regulators; Signalling and molecular mode of action of auxin and gibberellins.
5. **Senescence in Plants:** Programmed cell death and autolysis; leaf and flower senescence; Altered metabolism during senescence; Oxidative stress and ROS signal in leaf senescence; Regulatory network and reprogramming of gene expression during leaf senescence; Hormonal modulation during senescence

GROUP B: PLANT BIOCHEMISTRY		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. **Aqueous solutions and Bioenergetics:** Properties of water; acids, bases and buffers; pH, indicator; thermodynamic principles; concept of free energy and chemical equillibrium; role of ATP and ATP cycle.
2. **Carbohydrates:** Structure, classification, properties and function; plant storage carbohydrates; cell wall- structure & function; glycoproteins and proteoglycans.
3. **Lipids and membranes:** Structure, classification, properties and function; types and function of membrane lipids; membrane transport proteins: types and mechanism; primary and secondary active transport.
4. **Proteins:** Amino acid components and structural features; primary and higher order structures; Ramachandran plot; motif, fold and domain; polypeptide sequencing and purification strategies.
5. **Enzymology:** Enzyme kinetics- Michaelis-Menten and Lineweaver Burke plot; enzyme inhibitions and their kinetics; collision & transition state theories; random and ordered Bi-Bi mechanisms, Ping Pong reaction; role of coenzymes and cofactors.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Determination of amylase activity of monocot seeds in different stages of germination.
2. Assay of Catalase activity of fresh and preserved potato tubers.
3. Study of mobilization of starch during seed germination by embryo.
4. Effect of different solutes and temperature on membrane permeability.
5. Determination of water potential of plant tissue.
6. Quantitative estimation of Indole-3-Acetic Acid by Salkowski Reagent.
7. Study of changes in free-radical scavenging properties during senescence
8. Preparation of buffers, solutions and dilutions.
9. Extraction of carbohydrates from plant materials and estimation of total and reducing sugars.
10. Determination of acid value and/or iodine number of fat.
11. Extraction of proteins from plant materials and estimation by Lowry/ Bradford method.
12. Extraction of chloroplast pigments and quantitative estimation of chlorophylls, carotenoids and anthocyanins.
13. Enzyme kinetics - effect of substrate concentration and temperature on enzyme activity.

CORE COURSE - IV		
COURSE CODE:		
COURSE NAME: PLANT BREEDING AND GENOMICS & CYTOLOGY AND GENETICS		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

COURSE OBJECTIVES:

This course aims to teach the students with the basics and advances of Plant breeding and Genomics & Cytology and Genetics which is divided in to two groups of equal weightage. Genomics is the subject directly linked to the genome study which may be structural genomics and functional genomics including comparative genomics. The course aims to provide basic information about the study of genome analysis and associated genome diversity for crop plant evolution. The course also aims to provide basic information about the cell which is a basic unit of life, cell theory, evolution of cell, Mendelian Genetics. The course provides insights in to modern day genetics.

COURSE LEARNING OUTCOMES:

- Students will gain overview knowledge about plant breeding.
- Students will learn the concepts of Mendelian Genetics and the recent views on the genomics.
- Students will gain knowledge on basics of plant breeding, hybridisation techniques and marker-assisted selection.
- Students will be able to understand the concepts of crop domestication and genome evolution.
- Students will gain knowledge about cell theory and evolution.

GROUP A: PLANT BREEDING AND GENOMICS		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. Plant breeding: An overview, objectives, and biotechnology in plant breeding.
2. Methods in plant breeding: Breeding for self and cross pollinated crops including clonally propagated crops; breeding for Hybrid cultivars; sexual hybridization and wide crosses and pre-breeding for germplasm enhancement.
3. Tools and techniques of plant breeding: Cytogenetic basis of plant breeding- variation in chromosome number, mutation, fertility regulation mechanism; gene recombination in plant breeding.
4. Genetic analysis of complex traits, prediction-broad sense and narrow sense heritability, QTL mapping and analysis; Marker assisted selection in Rice breeding.
5. Genomics- Brief overview; tools and techniques of plant genome study
6. RNA interference, PTGS for plant gene regulation. SAGE, RNase protection assay, nuclear run-on assay; yeast two-hybrid assay, FRET; EMSA, DNase I footprinting, ChiP.

GROUP B: CYTOLOGY AND GENETICS		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. Structure of DNA and chromosome, DNA polymerases-DNA synthesis, unique aspects of eukaryotic chromosome replication; gene expression and chromosome organization; Dosage compensation and genetic imprinting.
2. Mutation at morphological, biochemical and molecular level; nucleic acid and their structure; synthesis, modification and repair of DNA; DNA fingerprinting- RFLP, AFLP, RAPD etc.
3. DNA sequencing and its types; Maxam–Gilbert DNA sequencing; Sanger sequencing; 3rd generation DNA sequencing methods.
4. Gene amplification and PCR: Basic principles and methodologies of PCR, design of PCR primers, RT-PCR and Real-Time PCR and their utility.
5. Introduction to the elements of population genetics: genetic variation, genetic drift, neutral evolution; mutation selection, balancing selection, Fishers theorem, Hardy-Weinberg equilibrium, linkage disequilibrium; in-breeding depression & mating systems; population bottlenecks, migrations.
6. Genetic Code and its evolution; protein synthesis and its evolution.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Induction of polyploidy using colchicine in Onion root system (*Allium cepa*).
2. Probability and chi-square test for genetic analyses for goodness of fit.
3. Demonstration of plant hybridization example in Rice.
4. Flower biology and dissection during hybridization process
5. Chromosome specific CodonW analysis of Rice genome.
6. Demonstration of WGS through NGS technique.
7. Orcein and Feulgen staining of metaphase plates; preparation of karyotype and Idiogram.
8. Linear differentiation of chromosomes through G-banding, C-banding and Q-banding.
9. Study of Meiotic chromosome complements.
10. Analysis of bacterial genomes; comparative genomics.
11. Isolation of genomic and plasmid DNA.
12. Restriction digestion and electrophoresis.
13. PCR and RAPD analysis.
14. Human genetics study of simple human traits.
15. Tissue culture - basic techniques and regeneration of plantlets.

CORE COURSE - VI		
COURSE CODE:		
COURSE NAME: CRYPTOGAMIC BOTANY & GYMNOLOGY		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

COURSE OBJECTIVES:

This course aims to give a detailed knowledge about the ancestral plants and their origin, evolutionary trends and comparative analysis. This course also deals with anatomical and morphological details which can be studied to understand the basic interrelationship among different groups. The course is divided in

to two groups of equal weightages. The first group includes the discussions on morpho anatomical diversity of Bryophytes and Pteridophytes and their traditional and modern uses along with ecological importance. The second group includes the knowledge about extinct, extant Gymnosperms, their geological distribution evolutionary role and modern uses.

COURSE LEARNING OUTCOMES:

- Students will understand the structural diversity of Bryophytes, Pteridophytes, Gymnosperms; classification systems, morphological and anatomical features, phytochemical constituents of different plant parts, reproductive biology and evolution.
- Students will learn the structural details of different fossil plants, distribution in different ages and their significance.
- Students will also gain knowledge regarding the applications traditional and modern uses of the lower group of plants.

GROUP A: BRYOLOGY AND PTERIDOLOGY		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

Bryology

1. Recent trend for classification of Bryophytes and outline on a recent classification system of (liverworts, hornworts and mosses).
2. Comparative morphology and anatomy of Liverwort, Hornwort and Mosses and their evolutionary significance.
3. Role of Bryophytes in ecology, Desiccation tolerant, succession bio-indicator and as phytoremediator.

Pteridology

1. Introduction: A general account and outline of recent system of classification of Pteridophytes.
2. Origin and Evolution of pteridophytes, Gametophytes of pteridophytes, ecology of pteridophytes. Stomatal structures in pteridophytes, Spores of pteridophytes. Apogamy, Apospory and parthenogenesis. Sex organs and embryogeny in Pteridphytes.
3. Comparative morphology, anatomy, reproductive biology and evolutionary studies of the following groups: Early land plant and their evolutionary significance, Psilopsida, Lycopsida, Sphenopsida, Filicopsida. Coenopteridales, Ophioglosales, Marattiales, Osmundales and Filicales; Monographic study of *Isoetes, Psilotum, Ophioglossum, Osmunda, Lygodium, Cyathea, Gleichenia, Adiantum, Pteris, Christella* and aquatic ferns.

GROUP B: GYMNOLOGY AND PALAEOBOTANY		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

Gymnology

1. General characters and different systematic treatments of Gymnosprems as proposed by Sporne (1974) and Bhatnagar and Alok Moitra (1996);
2. Origin and Evolution of gymnosperms with special reference to Progymnosperms, Devonien pre ovules and origin of seed.

3. Comparative morphology, anatomy, reproductive biology and phylogenetic studies of the following groups: Pteridospermopsida-Lyginopteridales, Medullosales, Glossopteridales, Cycadopsida, Pentoxylopsida, Ginkgopsida, Coniferopsida and Gnetopsida.
4. Global distribution of gymnosperms with special reference to Indian plants. Endangered gymnosperms, their conservation and present status. Cytogenetics of Gymnosperms; Economic importance and biotechnology of gymnosperms.

Palaeobotany

1. Aims and objectives of Palaeobotany; Geological time scale and different types of fossil flora in India; Dating techniques of fossils.
2. Applied Palaeobotany Life as fuel maker, sources of natural fossil fuels, Peat, coal and its varieties, constitution of coal, Coal Palynology, coal maceral, Petroleum – its origin, Palynology in oil exploration. Fundamentals of Paleofloristics, Palaeogeography and Palaeoclimatology.
3. Applicaion of Palaeopalynology. Plant and animal interactions correlation Archaeobotany with special reference to phytoliths and palynological studies.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Study of reproductive members of different groups of Bryophytes: Hepaticopsia, Anthocerotopsida, Bryopsida.
2. Comparative studies of external and internal morphology of vegetative and reproductive structure (spore types and soral anatomy etc.) of: *Drynaria, Nephrolepis, Asplenium, Blechnum, Pyrossia* and *Salvinia*.
3. Study of the external morphology, reproductive structures and wood anatomy of the following taxa: *Cycas, Pinus, Ginkgo, Araucaria, Thuja, Cryptomeria, Gnetum* and *Ephedra*.
4. Study of different types of fossils.
5. Study of morphology of fern spores followed by Acetolysis method (demonstration).

DISCIPLINE SPECIFIC ELECTIVE - II		
COURSE CODE: - -		
COURSE NAME: DSE-II *		
Credit: 2	**Full Marks: 21 (T) + 21 (P) + 8 (CE)**	**Total lecture hours: 54**

*** Any One (01) paper to be selected out of Two (02) papers.**

(A) Pharmacognosy (or)

(B) Plant Anatomy

(A) PHARMACOGNOSY		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 27**

COURSE OBJECTIVES:

For several years, different plant parts and their extracted compounds were utilized by mankind for therapeutic purposes. The therapeutic potential of plants is determined by the presence of secondary metabolites in specific plant species. This course is designed to provide information about ethnomedicine, adulteration and quality control of herbal drugs and exploring tools about enormous diversity of secondary metabolites present in plant system.

COURSE LEARNING OUTCOMES:

- Students will learn the applications of ecological concept for benefit to different life forms.
- Students will acquire knowledge about historical perspectives of conceptual development of ethnomedicine.
- Students will learn about threats of possible drug adulteration and their scientific methods of measurement.
- Students will be acquainted with vast array of secondary metabolites in plants, their biosynthetic origin, chemical nature and bioactivity.
- Students will have appropriate understanding about the hallucinogenic drugs extracted from psychoactive plants and their bioactive components responsible for drug addiction.

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1. **Pharmacognosy:** Ethnic and modern concepts; Interdisciplinary spectrum of Pharmacognosy; History of Pharmacognosy: Egyptian, Babylonian, Ayurveda, Unani and Siddha Medication; Herbalism and Phytotherapy; Drugs and technical products; Pharmacopoeias; Preparation of herbal drugs for commercial market.
2. **Adulteration of herbal drugs:** Concept; Methods of Adulteration; Types of Adulteration; Disadvantages of Adulteration; Measures of Adulterants: Morphological, Microscopic, Chemical, Physical, Biological and Analytical methods.
3. **Methods of plant analysis**: Extraction and purification of natural products; Chromatographic study of drugs; Spectroscopic techniques; Methods of identification and analysis of results; Applications of phytochemical analysis.
4. **Secondary metabolites:** Characteristic features of secondary metabolites of plant origin; Basic metabolic pathways and origin of secondary metabolites; Structure and biological significance of terpenes, phenolic and nitrogen-containing compounds.
5. **Drugs and consciousness:** Psychoactive Drugs and physiology of brain; Drug dependence and addiction; Effect of Drugs; Depressants and Opioids; Stimulants; Hallucinogens- Marijuana; Psychoactive plants, bioactive constituents and therapeutic properties.

(A) PHARMACOGNOSY - PRACTICAL		
Credit: 0.84	**Full Marks: 21 (P)**	**Total lecture hours: 27**

1. Quantitative microscopy of leaf drug:
   i) Stomatal Frequency
   ii) Stomatal Index
   iii) Palisade Ratio
   iv) Vein Islets

v) Vein Termination Number

2. Qualitative detection of alkaloids and steroids in drug plants.
3. Quantitative estimation of total flavonoids content of drugs.
4. Study of powdered drugs – physical, chemical and microscopic examinations.
5. Anatomy of tea leaves and detection of sclereids for adulterant determination.
6. Choice of solvents for extraction of plant metabolites.
7. Study of unorganized drug: starch.

(B) PLANT ANATOMY		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 27**

COURSE OBJECTIVES:

This course aims to familiarize the students with the anatomical details of plant body. This course will also introduce the recent advances in the understanding of the development of plant tissues. Moreover, the course will introduce the subject of ecological significance of plant anatomy and diverse applications of the subject including forensics, dendroclimatology, etc.

COURSE LEARNING OUTCOMES:

- ❖ Students will learn about the advances in plant anatomy.
- ❖ Students will learn about the role of anatomical adaptations to environmental fluctuations.
- ❖ Students will understand the applications of plant anatomy as a subject.
- ❖ Students will also get a hands on training in visualizing different plant tissues.

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1. **Primary plant body:** Shoot and Root apex – Structure and function; Recent views on the development of shoot apical meristem and root apical meristem; Differentiation of primary tissues; Leaf initiation and development; Tissue – classification, organization in stem, leaf and roots; Differentiation of vascular tissues.
2. **Secondary plant body:** Vascular cambium formation, structure and function; Anomalous secondary growth; Structure and function of cork cambium and periderm; Secondary growth in monocots, periderm formation in monocots.
3. **Mechanical tissue:** Mechanical tissue system - Structure, function and types; Principles governing the construction of mechanical tissue.
4. **Ecological anatomy:** Habitat and plant structure; Ecological leaf, wood and root anatomy; Frost hardiness; Anatomy and plant resistance, responses to wounding and invasion by microorganisms, structural basis of resistance; Effect of pollution on wood.
5. **Applied plant anatomy:** Gene expression and anatomical traits, Anatomy and plant breeding; Fibers and fiber products; Food adulterants and contaminants; Herbal drugs; Plant anatomy as forensic evidence; Wood anatomy and environment, Dendroclimatology, tree rings and climate effect.

(B) PLANT ANATOMY - PRACTICAL		
Credit: 0.84	**Full Marks: 21 (P)**	**Total lecture hours: 27**

1. Introduction to staining.
2. Microscopy of multiple epidermis and pitting in cell walls.
3. Comparison of dicot and monocot stem.
4. Comparison of dicot root and monocot root.
5. Dissection and characterization of shoot apical meristem and root apical meristem.
6. Identification and characterization of collenchyma and sclerenchyma.
7. Anomalous secondary growth – *Boerhavia*, *Chenopodium*, *Tecoma*, *Tinospora*, *Dracaena*, etc.
8. Identification of secretory tissues – Hydathodes, Glandular trichomes, Salt glands, Resin ducts, Laticifers, etc.

SEMESTER-III

CORE COURSE - VII		
COURSE CODE: - -		
COURSE NAME: PLANT DEVELOPMENT & METABOLISM		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

COURSE OBJECTIVES:

Plants are adapted with complex system of development characterized with precisely programmed polar growth. In order to conceptualize this, one should inspect carefully the various stages of organ development from embryogenesis. This course is designed for making the students acquainted with gene expression at different stages and their interaction along with fundamental histological perspectives. In the second group, the course aims to teach the students with in depth knowledge of the major metabolic pathways in plants.

COURSE LEARNING OUTCOMES:

- Students will acquire knowledge about embryogenesis from zygotic development and functional perspectives of different histogens.
- Students will also know about root, shoot and leaf development and the key molecular mechanisms involved during development.
- During this course students will learn about transformation of shoot apical meristem into inflorescence and floral meristem and the involvement of hormone florigen during juvenile to adult transition.
- This course will also highlight students about floral organogenesis and their possible molecular mechanisms along with distortion of development during gene mutation.
- Students will have complete understanding of the two major cellular processes viz. photosynthesis and respiration and the pathways associated with them.
- Students will gain knowledge regarding the lipids as a source of energy and also how they are synthesized.
- Students will also get aware of nucleotide and protein biosynthesis and amino acid families and their biosynthesis.

GROUP A: PLANT DEVELOPMENT		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. **Embryogenesis:** Structure of embryo sac; Different stages of *Arabidopsis* embryogenesis; Origin of polarity; Development of body plan; Position dependent signalling during embryogenesis.
2. **Shoot and root apical meristem development:** Organization of root and shoot apex; Genes controlling apical-basal and radial patterning; Sequence of gene expression during shoot apex development; Maintenance of stem cell population by transcriptional feedback loop; Genes involved in organogenesis of root tip.

3. **Leaf development:** Establishment of leaf polarity; Genes involved in leaf development; Differentiation of epidermal cell types; Stomatal cell fate and trichome initiation; Venation patterns and hormonal interplay.
4. **Control of flowering:** Photoperiodism and control of Florigen; Critical day length**;** Molecular mechanism of phase change and floral evocation; Genes controlling floral organ identity.
5. **Gametophytes, Fruit and Seed development:** Male and Female gametophyte development; Development of pollen tube and fertilization; Self incompatibility; Endosperm development; Fruit ripening; Seed maturation and desiccation tolerance.

GROUP B: PLANT METABOLISM		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. **Photochemistry and photosynthesis:** General concepts; photosynthetic pigments and light harvesting complexes; photo-oxidation of water; mechanisms of electron and proton transport; Benson-Calvin cycle; CO_2 concentrating mechanisms.
2. **Respiration:** Overview of plant respiration; glycolysis; TCA cycle, electron transport systems and ATP synthesis; alternative oxidase system.
3. **Lipid metabolism:** Fatty acid biosynthesis and breakdown; synthesis of storage and membrane lipids.
4. **Nucleotide and protein biosynthesis:** Purine and pyrimidine biosynthesis, de novo and salvage pathways; regulation and degradation; Transcription, translation, post-transcriptional and post-translational modifications.
5. **Amino acid biosynthesis:** Ketoglutarate and oxaloacetate families.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Study of apical meristems with the help of dissections and permanent slides.
2. Development and diversity of epidermal structures of leaves: trichomes and glands.
3. Pollen in vitro germination methods: sitting drop and suspension culture.
4. Dissection of embryo and endosperm of monocot and dicot seeds.
5. Assessment of seed viability by staining with TTC.
6. Assessment of superoxide content of developing seedling under desiccation.
7. Comparative anatomy of C3, C4 and CAM plants.
8. Demonstration of photolysis of water.
9. Estimation of ATP synthesis.
10. Estimation of rate of respiration of different plant parts.
11. Quantification of total fats.
12. Estimation and in situ localization of ROS.

DISCIPLINE SPECIFIC ELECTIVE – III / IV / V

Discipline Specific Elective (DSE-III/IV/V) courses in 3rd Semester will be provided as a choice to the students for developing specialization in eight (08) specific topics in Botany. DSE-III and DSE-IV are theoretical papers and DSE-V is practical paper. The students are allowed to choose only one (01) specific combination of papers enlisted below for the DSE papers (DSE-III/IV/V):

*** Any One (01) paper to be selected out of Eight (08) papers**

(A) Genetics and Bioinformatics

(B) Microbiology

(C) Molecular Plant Pathology and Fungal Biotechnology

(D) Plant Biochemistry

(E) Plant Genetics and Molecular Breeding

(F) Plant Physiology and Pharmacognosy

(G) Advanced Pteridology and Palaeobotany

(H) Taxonomy of Angiosperms and Biosystematics

The Course Objectives and Course Learning Outcomes for the papers are as follows:

(A) GENETICS AND BIOINFORMATICS

COURSE OBJECTIVES:

Genetics is the study of genes, the fundamental unit of heredity. The importance of studying genetics is enormous. Sydney Brenner once said that in the present century all biology would be gene-centred and all biologists would be geneticists. Though the study area of Genetics is manifold, still the main concern of Genetics is the study of heredity and the information of life imprinted in DNA. On the other hand Bioinformatics is rather an interdisciplinary field mainly concerning with the development of methods and software tools for understanding biology. Bioinformatics has particularly become important after the advent of various genome projects. Therefore Genetics with Bioinformatics would be an integrated field for studying the misery of life.

COURSE LEARNING OUTCOMES:

- Students will learn the concepts of gene in pre-DNA era.
- Students will gain knowledge on the laws of genetic inheritance, gene pyramiding, and also about population genetics.
- Students will gain knowledge on the different types of recombination and genetic markers.
- Students will get detail information of PCR, its variants and their applications.
- Students will have in depth knowledge on the use of different bioinformatics tools, homology modeling, etc.

(B) MICROBIOLOGY

COURSE OBJECTIVES:

The course aims to increase understanding of the students with about the mechanism of genetic recombination and advantage of this process in genetic engineering. Students will also learn about the modern day chemotherapy and few concepts of immunology. The course aims to increase the understanding of the students about the importance of microbes in industry. The student will be taught role of microorganisms in production of antibiotics, alcohols, enzymes etc. The students will gain knowledge about the recent advances in the field of industrial microbiology. The course aims to increase the understanding of the students about the importance of microbes in environmental and agricultural microbiology. The student will be taught role of microorganisms in maintaining the functioning of ecosystem. The students will also gain knowledge about the possible roles of microorganisms in bioremediation. The students will also gain knowledge about the diversity of microorganisms in extreme environments.

COURSE LEARNING OUTCOMES:

- Students will be able to understand and appreciate role of genetic recombination in bacteria.
- Students will develop theoretical skills of medical microbiology and understand the molecular mechanisms underlying the gene cloning.
- Students will be able to understand and appreciate fermentation technology.
- Students will develop practical skills in microbiological techniques and appreciate the versatile role of microbes in day to day products.
- Students will be able to understand and appreciate role of microbes in sustainable environment.
- Students will also develop both theoretical and practical knowledge regarding study of microbial diversity from extreme environment.
- Students will be able to appreciate the resourceful part of microbes in overcoming major environmental problems of the world.

(C) MOLECULAR PLANT PATHOLOGY AND FUNGAL BIOTECHNOLOGY

COURSE OBJECTIVES:

This course aims to give an overall knowledge of fungal biotechnological developments with special reference to agriculture and environment. Details of the molecular biological concepts are given to the students to study, analyze, and control of plant diseases. Developments of immunology, molecular techniques of defense genes, and classical aspects of plant virology, mycology and also of other pathogens are taught. Students are given knowledge in transgenics, biocontrol product formulations, mushroom cultivation etc. Concept of plant health clinic/seed health clinic also given to the students. Genomics, proteomics and use of bioinformatics in host-pathogen interaction are also taught in this paper.

COURSE LEARNING OUTCOMES:

- Students will understand molecular events of host-pathogen interaction.
- Students will learn how to prepare biocontrol products.
- Students will learn different diagnostic techniques applied in pathology and will also be able to diagnose plant disease for proper recommendation of control measures.
- Students will learn basics of research and publications in molecular as well as classical plant pathology.

(D) PLANT BIOCHEMISTRY

COURSE OBJECTIVES:

This course aims to aims to acquaint the students with the fundamentals and recent advances in the field of Plant Biochemistry. The course attempts to teach the students with some fundamental topics like calvin cycle, starch biosynthesis, sucrose transportation, signaling to advances in the tools and techniques required for the evaluation of genome and proteome.

COURSE LEARNING OUTCOMES:

- Students will have a complete understanding of the structural and functional details of the photosynthetic apparatus, in depth knowledge of the calvin cycle and CO_2 concentrating pathways that leads to the synthesis of sucrose and starch.
- Students will gain knowledge about the details of starch biosynthesis and sucrose transportation in plants.
- Students will gain knowledge of the mechanism of protein sorting and degradation, nitrogen and sulfur metabolism, hormonal control of plant growth, photoperiodism and the role of phytochrome, flower and fruit development.
- Students will have an in depth knowledge of plant signaling mechanisms and the pathways associated with it, secondary metabolites and the major pathways of their biosynthesis, and the mechanisms controlling the regulation of genome expression.
- Students will gain knowledge regarding the major instruments used in the field of biochemistry and learn some basic aspects of computational biochemistry.

(E) PLANT GENETICS AND MOLECULAR BREEDING

COURSE OBJECTIVES:

Students will gain knowledge about the theory and practices of plant genetics and molecular breeding. They will understand the basic principles of inheritance of qualitative and quantitative characteristics. Quantitative characteristics mainly governed by many genes which are polygenic inheritance or QTL based trait expression. Breeding is the subject where students can have knowledge about the improvement of crop varieties by applying the basic & fundamental aspects of genetics and breeding methods. Conventional breeding process has some drawbacks which can be rectified by using the modern technique of molecular breeding which is molecular marker based breeding technique. Student will learn about modern technique of molecular breeding – which include MAB/ MAS/ GWAS for QTL mapping and identification to develop new climate resilient crop varieties (mainly rice). Students can have some ideas about the Green Revolution, how it was started in 1960s by using the Mendelian genetic inheritance principle in the breeding programme to improve the crop varieties.

COURSE LEARNING OUTCOMES:

- Students will understand about pre-breeding (interspecific hybridization) for introgression of genes/QTLs from wild relatives. Wild relatives are the reservoir of many important traits such as Abiotic/Biotic stress tolerance.
- Students will also learn the technique for increasing the genetic base of crop varieties in terms of yield & quality of crop plant (especially in Rice).
- The students will understand the controversy of GM Crops and its ethical issues and ecological concern.
- Students will gain knowledge on crop improvement because food grain production must be increased to feed more than nine billion people by 2050.

(F) PLANT PHYSIOLOGY AND PHARMACOGNOSY

COURSE OBJECTIVES:

The course is designed for delivering comprehensive knowledge about different classes of secondary metabolites and new generation plant hormones with their prospective uses in the field of medicine and agriculture. The course will also deal with different aspects of advance topics and the techniques of modern research in plant physiology and pharmacognosy. The chapters are designed to equip students acquainted with vast and dynamic area of plant science research associated with molecular mechanism of signal perception and transduction, membrane transport, gene expression, green nano-techniques for therapeutic purposes, proteomics, bio-separation techniques and identification of bio-molecules through spectroscopic analysis.

COURSE LEARNING OUTCOMES:

- Students will learn the metabolite flux in plants and their homeostasis, compartmentation and augmentation with programs of differentiation.
- Students will acquire knowledge about phenolics, alkaloids, glycosides and terpenoids; their biosynthesis in plants and ecological significance.
- Peptides and brassinosteroids are now emerging field of plant hormone research. Through this chapter students will achieve knowledge molecular mechanism of new phytohormone research.
- Students will be learning perception and processing of external information by cells through signal transduction mechanism and their functional translation through gene expression an editing.
- Students will understand the action and pharmacology of herbal drugs, their channelling inside the cells and specific nano-carriers for precise targeting of herbal drugs.
- Students will know the stress mitigation measures by plants and molecular interaction with environment.
- Students will recognize the quality control attributes of herbal drugs as per international guidelines.
- Students will learn chromatographic techniques of separation of biomolecules which will help them independent during research designing.
- Also, the students will acquire different techniques of spectroscopy for understanding the nature of biomolecules in modern phytochemical research.

(G) ADVANCED PTERIDOLOGY AND PALAEOBOTANY

COURSE OBJECTIVES:

The course aims to provide an insight of the various physiological, biochemical and molecular changes associated with the diversification of land plants and the mechanisms of their adaptive strategies. The course also focuses on the role of different species in the ecosystem and bioprospecting.

COURSE LEARNING OUTCOMES:

- Students will learn about the role of various growth hormones in lower groups of plants and their regulatory mechanisms.
- Students will learn about the interactions of various lower groups of plants with micro-organisms and the strategies followed by them in conduction of water and photosynthates.
- Students will gain knowledge regarding stress tolerance mechanisms of bryophytes nad pteridophytes with special regards to dessication and will also be learning about bryophyte and pteridophyte model plants.

(H) TAXONOMY OF ANGIOSPERMS AND BIOSYSTEMATICS

COURSE OBJECTIVES:

This course aims to introduce the students to elaborate and advanced concepts of ICN, taxonomy and systematics, evolutionary inference among the taxa, biodiversity conservation, important families, their classification and role of taxonomic evidences, application of barcode markers in delineating species boundary, traditional knowledge and biodiversity conservation.

COURSE LEARNING OUTCOMES:

- Students will learn about the role of ICN in Plant Taxonomy.
- Students will gain knowledge on the usage of taxonomic evidences as delineate factor for angiosperms and their classification
- Students will understand the concepts of are phonetic and cladistics.
- Students will be able to understand the concept of molecular systematics and get acquainted with the preparation of phylogenetic trees and understand the importance in modern biology.
- Students will learn the concept of Ethnic knowledge and Biodiversity conservation.

DISCIPLINE SPECIFIC ELECTIVE - III		
COURSE CODE: - -		
COURSE NAME: DSE-III		
Credit: 2	**Full Marks: 42 (T) + 8 (CE)**	**Total lecture hours: 64**

(A) GENETICS AND BIOINFORMATICS

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Genetic and physical mapping of a genome: Recombination and genetic marker viz. microsatellite/ mini-satellite markers, RFLP, RAPD, SNPs, FISH & Chromosome painting, clone counting, physical mapping, sequencing and annotation. CpG islands, isochore and gene densities.
2. Concept of Genomics, Proteomics and Transcriptomics; The Human genome project and its importance; Functional and comparative genomics.
3. Host-pathogen interaction, ecological impacts of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbes and nutrient cycles; microbial communication system; bacterial quorum sensing.
4. Genetic basis of plant-microbes symbiosis; significance of Rhizobium-legume symbiosis; Actinorhizal symbiosis.
5. Molecular cloning: Recombinant DNA techniques, construction of genomic DNA and cDNA libraries, screening of libraries
6. Evolution of Protein and Genetic Code: Protein or nucleic acid first? The RNA world, Evolution of Protein synthesis, Evolution of genetic code, Genetic drift, Ecogeographic rules: Subspecies concepts, Clines and hybrid zones, Tracing ancestor-descendant relationships, Phenetics and cladistics.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Computer hardware and software-concept and applications; Introduction to Windows, UNIX and Linux; Perl and Python programming
2. Different types of biological databases: sequence, structural, genomic and pathway interaction databases. Information retrieval from biological databases; overview of sequence analysis.
3. Different types of file formats used in bioinformatics analysis; Genome annotation. Nucleotide and protein sequence analysis, sequence alignment and applications. Phylogenetic analysis.
4. Introduction to protein structure prediction and analysis; drug designing and discovery, plant based drug designing

(B) MICROBIOLOGY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Transcription:** Organization of transcriptional units Mechanism of transcription of prokaryotes-Structure and function of RNA polymerase, RNA processing (Capping, polyadenylation, splicing, introns and exons).
2. **Translation:** Ribonucleoprotein, Salient features of genetic code, structure of mRNA, rRNA, tRNA. polycistronic mRNA in bacteria, translation mechanism in bacteria, Post-translational modification.
3. **Regulation of gene expression in prokaryotes:** Control of gene expression. Positive gene regulation, negative gene regulation and attenuation, using the *lac*, *gal*, *trp*, *ara* and *tol* operons, with emphasis on recent advances.
4. **Gene cloning:** Plasmid biology (Types; Detection and purification; Replication); Genetic engineering (Splicing of DNA; Insertion of DNA into vector; Detection of recombinant molecules; Expression of cloned genes; PCR and Its variants.
5. **Chemotherapy:** General principles; classification of antibiotics; Chemistry, mode of actions, and antimicrobial spectra of antibacterial and antifungal antibiotics; Mechanism of antibiotic resistance in prokaryotes.
6. **Immunology:** Immunoglobulin classes; Formation and structure of Immunoglobulin G; Antibody-antigen reactions; Immunodiagnostics.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Introduction to industrial microbiology:** Sources of industrially important microbes, strain development, types of fermentation and fermenters, process optimization, and recent developments in fermentation technology.
2. **Production of antibiotics:** penicillin, streptomycin; Amino acids: Glutamic acid, Lysine etc.

3. **Production of alcohols and organic acids:** Alcohol Production - Malt- Beverages, Production of Beer, Production of Wines, Distilled Beverages or Liquors, Vinegar Production, Organic Acids - Citric, Lactic, Acetic, Propionic.
4. **Production of enzymes:** Extracellular – amylase, protesases, pectinases, lipase, cellulases
5. **Food microbiology and fermented products:** Vegetables, fruits, milk, fermented and non-fermented milk products, fresh meats, poultry and non-dairy fermented foods.

(C) MOLECULAR PLANT PATHOLOGY AND FUNGAL BIOTECHNOLOGY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Resistance genes:** Gene for gene concept; features of cloned resistance genes; R gene specificity, TIR domain, NBS Domain, other R gene domains.
2. **Signalling in plant disease resistance mechanisms:** Different types of signals; Interplay of downstream signaling pathways; NPR1 independent pathways.
3. **Genetic engineering of plants for disease resistance:** organization of genes controlling disease resistance; methods of gene transfer; strategies for development of transgenics.
4. **Mushroom:** theory and cultivation techniques of: *Agaricus* sp, *Volvariella* sp, *Pleurotus* sp. and *Calocybe indica.*

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Molecular diagnostics:** Nucleic acid based techniques such as pathogen specific marker; hybridization technique; PCR based techniques; gene array based techniques; quantitative PCR.
2. **Production of industrially important enzymes:** alfa-amylase, cellulose, laaccase, pectinase, and protease from filamentous fungi.
3. **Fungal Protoplasts:** isolation, Fusion, Regeneration and reversion, Genetic manipulation of industrially important fungi: Strain improvement.
4. **Management of plant diseases:** Cultural, chemical and biological control.

(D) PLANT BIOCHEMISTRY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Basic Chemistry:** Structure of atom and molecules; electronic theory of valency; atomic and molecular orbitals, hybridization; electrophilic and nucleophilic substitution reactions; dipole

moments, electron displacements (inductive, electromeric, mesomeric effects); resonance; hydrogen-bonding; types of organic reactions - carbocations, carbanions and free radicals.

2. **Plant growth and regulation:** Embryogenesis - gene expression, role of transcription factors; auxin mediated growth; cell wall biosynthesis; Phytohormones, brassinosteroids, jasmonic acid, salicylic acid - chemistry, metabolism and mode of action.
3. **Sensory photobiology:** Photoperiodic pathway, phytochrome - structure, physico-biochemical properties, mode of action, phytochrome gene family; cryptochrome and blue light responses, physiological activities, xanthophyll cycle.
4. **Flower and fruit development:** Photoperiodism, vernalization; floral meristems, floral organ identity, genetic control of flowering, ABC model; hormonal control of fruit development, physiology and biochemical changes during ripening, genetic regulation.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Molecular biology of photosynthetic system:** Organization of chloroplast genome in higher plants; chloroplast gene expression and protein synthesis; structure and function of light receptors and reaction centers; plant pigments - types, structural differences and applications.
2. **Calvin cycle and its regulation:** Gene organization, expression and regulation; RUBISCO - folding and assembly, activation, regulation; photorespiration.
3. **CO2 concentrating cycles:** Operation of C4 pathway, variants, regulation; CAM as survival mechanism, gas exchange phases and regulation regulation.
4. **Sucrose and starch metabolism:** Sink-source concept, relation with hexose monophosphate junction; sucrose synthesis, storage, transport - phloem loading and unloading; regulation; structure and function of transitory starch; synthesis pathways, branching and debranching enzymes, regulation; starch transportation and degradation; starch-sugar interconversion.

(E) PLANT GENETICS AND MOLECULAR BREEDING

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Molecular plant breeding: Introduction; tools of molecular breeding; application of molecular markers and functional markers system in plant breeding, identifying markers and trait associations; molecular markers used in model crop rice.
2. Rice breeding in the post genomic era-application in crop improvement program; Green Revolution-its implications in Food security in India and in Asia.
3. Quantitative Genetics and QTLs Mapping: Quantitative characteristics; polygenic inheritance, statistical methods for analysing quantitative traits, heritability- broad sense and narrow sense and genetic advance.

4. Development of mapping population - RIL/NIL/double haploid including CSSL/BIL lines; QTLs mapping, and artificial selection; QTL mapping by linkage analysis and by association analysis (GWAS); molecular markers and construction of linkage map; map based cloning.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Marker Assisted Breeding: Molecular markers as new efficient tools in breeding, MAS for tagging of agronomically important traits; trait integration-theory and practice, foreground and background selection,
2. Concept of graphical genotypes, elimination of linkage drags, breeding informatics, SEG-Map.
3. Advanced Breeding techniques: Whole-genome sequencing (WGS), GBS, genome function, SNP discovery, allele mining, 3k RGP and phylogenomics for crop improvement.
4. Transgenic technology for crop improvement: GM crops and traits, Golden rice, Bt-brinjal; Bt-cotton, Bt toxin (Cry protein) gene structure analysis and expression for insect resistance.
5. Genome editing with CRISPR-CAS9 technology; advantages and ecological concern of GM crops.

(F) PLANT PHYSIOLOGY AND PHARMACOGNOSY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Regulation of secondary metabolites**: Characteristic features and origin of secondary metabolites; Regulation of enzyme amount and activity in secondary metabolism; Compartmentation and turnover; Integration of metabolism in programs of differentiation and development, Transcriptional control of secondary metabolite regulation.
2. **Plant Phenolics and Flavonoids:** Properties, Structural diversification, and Occurrence; Classification; Biosynthetic Origin; Phenyl Propanoid Pathway; Flavonoids: Major Classes and variation in hydroxylation; Isoflavones: Biosynthesis of Rotenone; Anthocyanins; Enzymology and regulation of Phenyl Propanoid pathway; Vacuolar transport and glycosylation; Therapeutic implications.
3. **Alkaloids**: Classification, Occurrence physico-chemical and biological properties; Pyrrolidine, Piperidine, Isoquinoline, Quinolizidine, Tropane and Indole alkaloids - their distribution and biological function; Qualitative and quantitative detection of alkaloids.
4. **Cyanogenic Glycosides and Glucosinolates**: Structure, biological properties, metabolism, and physiological role of Cyanogenic glycosides and Glucosinolates.
5. **Chemistry and pharmacology of herbal drugs:** Classification of active plant constituents and phytotherapeutic properties; Routes of drug administration; Adsorption, metabolism, and fate of drugs; Mechanism of drug action and tolerance; Basic concept and application of network medicine, Determination of *in silico* ADMET properties.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Drought and Heat Stress Physiology**: Drought resistance strategies; Osmotic adjustment; Adaptation of CAM plants under drought stress; ABA signalling and drought tolerance; Heat stress and heat shock; Temperature affecting membrane stability; HSP mediated thermo tolerance and signalling pathways.
2. **Chilling, Salinity and Flood Stress:** Chilling and freezing tolerance; Transcription factors regulating cold-induced gene expression; Salinity stress; Strategies of salt tolerance; Hypoxic and anoxic stress; Strategies for submergence tolerance and oxygen deficit.
3. **Chromatographic Techniques and Application**: Introduction, History, Classification and Types; Basic principles of Column Chromatography: Partition, Ion-Exchange, Gel Permeation and Affinity system; Normal and Reverse Phase system; Detection of compounds; Chromatogram, Solute retention and capacity factor; Column efficiency; Peak resolution; HPLC and GLC; Applications of Chromatography.
4. **Principles and Application of Mass Spectroscopy**: Mass Spectrometry and Spectrum -Basic Principles; Detection of Mass Spectrum; Components of Mass Spectrometer; Ionization methods in MS; MALDI and APCI; Mass analysers; Type of peaks and fragmentation rules; Determination of molecular mass; Application of Mass Spectrometry.
5. **UV-Visible Spectrophotometry:** Electromagnetic Radiation; Properties of EM wave; Principles of Spectroscopy; Molecular orbital; Electronic transitions; Lambert Beer's Law; Chromophore and Auxochromes; Absorption and intensity shifts; Instrumentation of UV-Visible Spectrophotometer and applications.

(G) ADVANCED PTERIDOLOGY AND PALAEOBOTANY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. History of pteridophyte classification; any molecular classification.
2. Ecological diversity and pteridophytes, Pteridophytic flora of India, endangered pteridophytes and their conservation.
3. Cytogenetics of Ferns, Nature of Ferns Breeding systems, genetic load. I. Analysis of species complexes. II. Polyploidy (Origin of polyploidy, Polyploidy in Homosporous and Heterosprous Ferns, Geographical distribution of polyploids).

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Culture of fern gametophytes, photomorphogenesis in fern gametophytes. Biochemical and Physiological aspects of Gametophyte differentiation and development. Gametophyte types. Mating systems in Ferns. Antheridogen and its mechanism of action in sex expression.

2. Shoot apical meristem. Leaf origin and development. Root apical meristem of sporophyte.
3. Fern ecology: Tolerance of desiccating conditions, sporophyte-sporophyte interactions, sporophyte-prothallus interactions, prothallus-prothallus interactions.

(H) TAXONOMY OF ANGIOSPERMS AND BIOSYSTEMATICS		
GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. International Code of Nomenclature (ICN): Principles, articles, recommendations and special provisions; application of code with problems; nomenclature of cultivated and hybrid plants.
2. Taxonomic hierarchy. Biocode and Phylocode
3. Latest amendments of Code. Description of New taxa.
4. Survey of Taxonomic Literature: Dictionaries, Indices, Monographs, Manuals, Floras, Journals, and taxonomic websites; Genebank.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Herbaria and virtual herbarium; role of Botanic Gardens in the 21st Century.
2. Taxonomic evidences: Palynology, Embryology, Micromorphology, Phytochemistry, DNA
3. Remote sensing & GIS.
4. Homology & Analogy; Convergence & parallelism; homoplasy, phylogenetic hypothesis.
5. Analysis of data; commonly available software, construction of dendrograms.

DISCIPLINE SPECIFIC ELECTIVE - IV		
COURSE CODE: - -		
COURSE NAME: DSE-IV		
Credit: 2	**Full Marks: 42 (T) + 8 (CE)**	**Total lecture hours: 64**

(A) GENETICS AND BIOINFORMATICS		
GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Protein sequencing – principle and methods. MS/MS techniques for protein identification.
2. Basic principles of genetic engineering; Applications of recombinant DNA in agriculture and medicine; Restriction endonucleases, Modification methylases and other enzymes needed in genetic engineering.

3. Cloning vectors; Plasmids and plasmid vectors, Phages and Phage Vectors, phagemids, cosmids, artificial chromosome vectors (YAC, BAC), Animal virus derived vectors - Cloning strategies & screening of recombinant clones.
4. Molecular cloning: Recombinant DNA techniques, construction of genomic DNA and cDNA libraries, screening of libraries
5. Expression strategies for heterologous genes
6. Use of transposons in genetic analysis: Transposon tagging and its use in identification and isolation of genes.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Drug Discovery, Drug Development, Source of Drugs, Structural effects on drug action
2. Drugs Derived from Natural Products, Existing Drugs as a Source for New Drug Discovery, screening for New Drug Leads, Modern "Rational Approach" to Drug Design, Approaches to Lead Optimization
3. Receptor Theory, Receptor Complexes and Allosteric Modulators, Second and Third Messenger Systems, Molecular Biology of Receptors, Receptor Models and Nomenclature, Receptor Binding Assays, Lead Compound Discovery of Receptor agonists and antagonists.
4. Docking and virtual screening, Molecular Dynamics and binding free energy methods.

(B) MICROBIOLOGY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Issues and scopes of environmental biotechnology:** Microorganisms and Environment- Physiological state of microorganisms in the environment, nutrient cycling process, carbon cycle, nitrogen cycle, sulphur cycle.
2. **Bioleaching of metals:** Characteristics of commercially important microbes, mechanisms of bioleaching, Biobeneficiation of gold ores. Microbially enhanced oil recovery.
3. **Biodegradation of organic pollutants:** Xenobiotics, Mechanisms and factors affecting biodegradation; Bioremediation, Biostimulation and Bioaugmentation. *In situ* and *ex situ* bioremediation technologies. Bioremediation of oil spills; Phytoremediation; Use of GMO in bioremediation.
4. **Waste water treatment:** Waste water characterization and its significance: COD, BOD, Inorganic constituents, solids, biological components. Primary, secondary and tertiary treatment of waste water.
5. **Microbial diversity in extreme environments:** Occurrence, diversity, adaptations and potential applications of oligotrophs, thermophiles, psychrophiles, barophiles, organic solvent and radiation tolerants, metallophiles, acidophiles, alkaliphiles and halophiles.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Introduction to industrial microbiology:** Sources of industrially important microbes, strain development, types of fermentation and fermenters, process optimization, and recent developments in fermentation technology.
2. Production of antibiotics and alcohols.
3. **Production of enzymes:** Extracellular – amylase, protesases, pectinases, lipase, cellulases
4. **Food microbiology and fermented products:** Vegetables, fruits, milk, fermented and non-fermented milk products, fresh meats, poultry and non-dairy fermented foods.

(C) MOLECULAR PLANT PATHOLOGY AND FUNGAL BIOTECHNOLOGY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Pathogenicity and Disease Development-factors; induced resistance, virulence and pathogenecity factors.
2. Molecular aspects of host pathogen interactions - PR proteins, Phytoalexins, Degradation of phytoalexins, systemic resistance mechanism.
3. Defense related enzymes: Occurrence, properties, isolation, purification, biochemical and immunological characterization, induction, possible functions.
4. Detection and identification of pathogens by Immunological techniques. ELISA, Immuno-fluorescence, ISEM etc.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Plant-pathogen interactions; Type III secretary system in Bacteria-Plant interaction. Concept of PTI; ETI; PAMP/MAMP/DAMP etc. in modern Plant pathology.
2. Plant viruses: movement and interactions with plants; Transmission and cross protection, Transgenics through RNAi and VIGS; Tissue culture-mediated and *in planta* transformation.
3. Mycorrhizae in plant disease, agriculture and forestry.
4. Plant pathology in practice- Plant Health Clinic and Plant Doctor Concept. Brief idea of fungal, bacterial, and viral genomics.

(D) PLANT BIOCHEMISTRY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Plant signaling:** Overview; receptors; G-proteins and phospholipid signaling; role of cyclic nucleotides calcium-calmodulin cascade; diversity and role of protein kinases; sucrose sensing mechanism; abiotic stress related signaling - ROS generation, role of transcription factors, SOS pathway, heat shock proteins, anti-freeze proteins; stress induced genes and proteins; genetic engineering for stress tolerance.
2. **Secondary metabolites:** Overview, classification, functions; major biosynthetic pathways; biosynthesis of terpenoids, alkaloids, phenols; compartmentations and sequestration of metabolites, long distance transport; metabolic engineering.
3. **Genome expression and regulation:** RNA polymerases and transcription cycle, RNA splicing and editing; mRNA transport; Genetic code - basic principles and exceptions; proteins biosynthesis; gene regulation, operon concept, post transcriptional gene silencing, concept of RNAi - miRNA and siRNA; post translational regulation, ribozymes, Genetic imprinting.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Electrophoresis and chromatography:** Capillary electrophoresis, microchip electrophoresis, gel electrophoresis, IEF, 2D gel electrophoresis, DIGE, iTRAQ; High-performance liquid chromatography, adsorption chromatography, partition chromatography, ion-exchange chromatography, molecular (size) exclusion chromatography, affinity chromatography, gas chromatography.
2. **Spectroscopic Technique:** Ultraviolet and visible light spectroscopy, Fluorescence spectroscopy, Luminometry, Light scattering, Atomic spectroscopy, Nuclear magnetic resonance, X-ray diffraction.
3. **Other Techniques:** Preparative and analytical centrifuge; Protein purification, characterisation and functional analysis; DNA-protein, RNA-protein and protein-protein interaction; DNA and protein microarray; GFP tagging.
4. **Computational Biochemistry:** Sequence alignment, local and global, multiple sequence alignment; concept of databases with examples; protein sequence analysis, ExPASy proteomic tools, prediction of physiochemical properties, secondary structures, hydrophobicity; CATH, SCOP and VAST; phylogenetic analysis based on DNA, RNA and proteins; molecular modelling.

(E) PLANT GENETICS AND MOLECULAR BREEDING

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Breeding for Biotic and Abiotic stress Resistance: Genetic basis and breeding for resistance to diseases and insect pests.
2. Genetic and physiological basis of abiotic stress tolerance- flood, drought, salinity, cold for climate ready crop varieties and breeding for nutritional quality (Nutragenomics).
3. Proteomics and Transcriptomics: Principles and Techniques of proteomics and transcriptomics analysis and application in plant breeding.
4. QTLs (genes) analysis and Molecular mechanism of action associated with following QTLs in rice (*Saltol; Pstol, Sub1*).
5. Biofortification of rice-Nutritional security; global science and development; HarvestPlus.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Genomics: Structural and functional genomics, comparative genomics- and synthetic biology; reverse-genetics: dissecting biological processes by inhibiting gene expression; and Epigenomics.
2. Alien gene transfer and evolution of major crop plants: Methods of alien gene transfer for crop improvement with rice as Model crop. Overview of intragenesis and cisgenesis. Generation Challenge program; Crop Diversity and conservation strategies.
3. Plant Genetic Resources and their Regulatory System: Origin of crop plant, plant domestication, agro-biodiversity, Conservation and utilization of plant genetic resources. CBD, and ITPGRFA, Intellectual Property Rights; Plant Variety Protection and Farmers' Rights Act (PPV&FR act 2001, India); Biological diversity act 2021; Food security Act 2013.
4. Nature positive agriculture- for sustainable development.

(F) PLANT PHYSIOLOGY AND PHARMACOGNOSY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Terpenoids:** Classification, occurrence, and biological properties; Biosynthesis and metabolic regulation; Health benefits and ecological significance of terpenoids; Chemical nature of volatile oil and their role in aromatherapy.
2. **Steroids and Saponins**: Chemical nature, biological distribution, occurrence, biosynthesis and physiological function and ecological role of Saponins and sapogenins; Sterols, steroids, steroidal alkaloids. Pharmacological action of steroids and saponins.

3. **Natural product based nanomedicine**: Herbal Drug nanoparticles; Nanoparticles Classification; Novel Drug delivery System: Nano Carriers for Herbal Therapy; Polymeric Nanoparticles; Metallic Nanoparticles; Green synthesis and characterization of Metallic Nanoparticles; Solid-Lipid Nanoparticles and Nanostructured Lipid Carriers; Liposomes and Micro-emulsions; Carbon Nanotubes.
4. **Quality control of herbal drugs:** Herbal technology; Organoleptic, Microscopic, Biological, Chemical and Physical attributes; Pharmacopoeia; Guidelines for the assessment of herbal medicines; Drug adulteration; Determination of microbial contamination and Aflatoxin; Identity, purity, and strength of herbal drugs; Detection of pesticide and heavy metals; TLC profile and chemical fingerprint.
5. **Proteomics and Mass Spectroscopy**: Basic Concept of Proteomics; SDS-PAGE and Isoelectric Focusing; 2-D Gel Electrophoresis; Tandem Mass Spectrometry; Peptide Mass fingerprinting; Determination of peptide sequences.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. **Hormone like action of plant peptides**: Identification of peptide signals; post-translational modification and function of peptides; Physiological role of Systemin, Phytosulfokine, Clavata, RALF and ENOD40 peptides; Determining therapeutic and nutraceutical action of plant peptides.
2. **Signal perception and transduction**: Overview; Receptors; Quantitative Ligand binding; G-proteins and Phospholipid signalling; Cyclic nucleotides; Role of Protein Kinases; Diseases associated with G-Protein signalling; Receptor Tyrosine Kinases (RTKs); RAS and other Proto-oncogenes; JAK-STAT Pathway; Integrins; Toll Gate Receptors; Lipid Hormone Signalling; COX targets.
3. **Transport across membrane and drug action**: Types of transport (Simple Diffusion, Passive-Facilitated Diffusion); Active transport – Primary and Secondary Group Translocation; Transport ATPases; Drug Action and potential role of Transporters; Transporters in Pathogens as Drug Gateways or Targets; Nernst Equation and Equilibrium Potential
4. **Regulation of gene expression in plants:** Plant Gene structure and Expression; Regulatory Mechanisms- control of Transcription; Post-transcriptional control of gene expression; Eukaryotic Promoter; Transcription Factors and Enhancers; DNA-binding Motifs; Chromatin Remodelling.
5. **Infra-Red and NMR Spectroscopy for metabolite detection:** Molecular Vibrations-Stretching and Bending; Classification of Infra-Red region; Harmonic Oscillation; Instrumentation of IR Spectrophotometer; -OH and –CH stretching; Use of IR spectra; Nuclear Spin states; Principles of NMR; Chemical shift; Proton NMR; Spin-spin coupling; NMR Instrumentation and application in biological field.

(G) ADVANCED PTERIDOLOGY AND PALAEOBOTANY

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Antiquity of life; Major events in the Precambrian- early life forms, Indian records, stromatolites and palaeoecology.
2. Applied Palaeobotany Life as fuel maker, sources of natural fossil fuels, Peat, coal and its varieties, constitution of coal, Coal Palynology, coal maceral, Petroleum – its origin, migration and concentratiohn, palynology in oil exploration.
3. Environmental changes during Permian, Permo-Carboniferous floral proviences. Early Paleozoic and Lower Carboniferous flora of India. Origin and relationships of Cycads, Bennettites, Ginkgos and Glossopterids. Distribution of Glossopteris flora in time and space.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Brief concept of mass extinction: evidence in the geological record: plants versus animals; floral changes across the Cretaceous – Tertiary boundary.
2. Palaeopalynology of peat, lignite and coal. Artificial classification of spore.
3. Different aspects of palynology and their applications.

(H) TAXONOMY OF ANGIOSPERMS AND BIOSYSTEMATICS

GROUP A		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Pre Linnaean and post Linnaean Classification systems.
2. Phenetic versus cladistics; APG IV (2016) System.
3. Concise accounts of the phylogeny of Basal Angiosperms, Magnoliids, Eudicots, Core eudicots.

GROUP B		
Credit: 0.84	**Full Marks: 21 (T)**	**Total lecture hours: 32**

1. Endemism and Invasive species - in Indian perspective
2. Migration, dispersal and discontinuous distribution of plants
3. Biodiversity Conservation: IUCN categories, Effects of Rio de Genero world summit, CBD, Biodiversity Conservation Hotspots, India as a Megadiversity country; Ramsar sites, Methods conservation. protected areas in India.

4. Traditional knowledge: Ethnobotanical resources in India; documentation and utilization of ethnic knowledge. Traditional methods of conservation; sacred groves.

DISCIPLINE SPECIFIC ELECTIVE - V		
COURSE CODE:		
COURSE NAME: DSE-V		
Credit: 2	**Full Marks: 42 (P) + 8 (CE)**	**Total lecture hours: 64**

(A) GENETICS AND BIOINFORMATICS		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 32**

1. Isolation of microbes from root nodules of leguminous plants. Biochemical and molecular. characterization of isolated bacteria. 16s amplification with suitable primers and sequencing.
2. Identification of microbes with the help of 16s sequences.
3. Calculation of codon usage indices of different microbes.
4. Comparative genomics through Codon Usage analysis and related software.
5. Sequence alignment of different genomic sequences and Phylogenetic analysis.
6. Evolution study of prokaryotic and eukaryotic organelles through different software.
7. Homology modelling, Ligand structure and ADME property assessment, Molecular docking.

(B) MICROBIOLOGY		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 32**

1. Study of physiological and biochemical activities of bacteria (hydrolysis of starch, lipid, protein and urea; degradation of cellulose and pectin; catalase; β-galactosidase; nitrate reduction; Voges-Proskauer reaction; indole production; liquefaction of gelatin; citrate utilization; fermentation/oxidation of sugars).
2. To assess the quality of milk by methylene blue reduction test.
3. Study of bacterial growth curve and determination of generation time.
4. To determine the effect of pH and temperature on microbial growth.
5. Isolation of bacterial genomic and plasmid DNA.
6. Study of fermentors and bioreactors (through photographs/slides/field visit).
7. Assay of antibiotics using tube dilution, well diffusion and agar dilution methods.
8. Detection and enumeration of indicator and index organisms for foodborne pathogenesis.

(C) MOLECULAR PLANT PATHOLOGY AND FUNGAL BIOTECHNOLOGY		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 32**

1. Isolation of bacterial, fungal, and nematode plant pathogens of crop plants.
2. Assessment of foliar infection by Sinha and Das' method/ Stover's method/ any other.
3. Study of diseases of plants available: (10 diseases to be studied)
4. Detection and identification of pathogens by Immunodiffusion/ immunoelectrophoresis/ ELISA/ Immunofluorescence.
5. Detection and identification of virus pathogens by PCR
6. Molecular identification of fungi/ bacteria by 18S/16S rRNA studies.
7. Scanning electron microscopy (Demonstration)/ Immunosorbent–Elecctron Microscopy (Demonstration)
8. Column chromatography
9. SDS-PAGE analysis of Healthy and infected plant proteins
10. Extraction and estimation of defense related enzymes; On-Gel assay of enzymes.
11. BLASTn analysis and phylogenetic study.
12. Fluorescence microscopy.

(D) PLANT BIOCHEMISTRY		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 32**

1. Isolation of chloroplast and determination of Hill activity.
2. Protein extraction, precipitation by salting out, desalting by dialysis.
3. Protein purification by gel filtration/ ion exchange column.
4. SDS-PAGE analysis of the proteins and determination of molecular weights.
5. Assay of antioxidative enzyme (peroxidase/ catalase) activities following abiotic stresses.
6. Isozyme analysis by PAGE.
7. Separation of pigments by TLC and their identification.
8. Genomic DNA extraction from plants, quantification and gel electrophoresis.
9. Extraction, estimation and UV-spectral analysis of carotene and lycopene pigments.
10. Separation and detection of secondary metabolites through TLC.

(E) PLANT GENETICS AND MOLECULAR BREEDING		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 32**

1. Plant genomic DNA isolation and fractionation on 1% agarose gel electrophoresis and visualization on UV-Trans-illuminator after staining with ethidium bromide.
2. Floral biology in self and cross pollinated species, selfing and crossing techniques. Selection methods in segregating populations and evaluation of breeding material.
3. Agro-morphological trait analysis according to PPV&FR Act 2001 in rice breeding lines.
4. Analysis of variance (ANOVA); Estimation of heritability and genetic advance; Maintenance of experimental records.

5. SSR marker- PCR amplification and analysis of SSR marker specific traits in rice crop.
6. DNA sequence analysis of Whole genome sequence- Model Crop Rice.
7. Gramene web-based genomic data analysis for marker trait association analysis
8. Nucleic acid and protein sequence alignment for phylogenetic analysis.
9. Divergence of Codon uses in Model Plant Rice using CodonW software.
10. Rice Pan-Genome and Rice Var Map2 database and applications in crop improvement

(F) PLANT PHYSIOLOGY AND PHARMACOGNOSY		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 32**

1. Assay of Peroxidase enzyme activities following abiotic stresses.
2. Extraction and estimation of carotene and lycopene pigments.
3. Solvent extraction of plant metabolites through Soxhlation and refluxing and determination of extractive values
4. Determination of fluorescence and ash value of powdered drugs.
5. Determination of free radical scavenging (DPPH and $ABTS^{+}$) activities of plant extracts.
6. Determination of superoxide scavenging activity of an extract.
7. Measurement of lipid peroxidation.
8. Qualitative phytochemical analysis of powdered drug.
9. Determination of metal chelating activity of plant drug.
10. Separation and detection of flavonoids through TLC and demonstration of chemical fingerprint under UV light.
11. Green synthesis of nanosilver and determining their role in leaf preservation.
12. Isolation, purification, and identification of *Solanum* alkaloids.
13. Extraction and estimation of ortho-dihydric phenol and flavonoids.
14. Synthesis of metallic nano-chitosan through Ionotropic Gelation method.
15. Determination of antimicrobial activity of phytochemicals.
16. Demonstration of isozyme analysis of POX, NOX, or SOD under adverse physiological conditions.

(G) ADVANCED PTERIDOLOGY AND PALAEOBOTANY		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 32**

1. Phytochemical Studies of different parts of the sporophyte of ferns and Gymnosperms and their qualitative and quantitative analysis with respect to different properties.
2. Comparative studies of scales on rhizome and rachis, epidermal features--trichomes hair and stomata of fronds of pteridophyte.
3. Meiotic studies of different ferns from developing sporangium.
4. Developmental study on fern gametophyte following in vitro culture method.
6. Studies of tracheid's and vessels through maceration process of ferns and gymnosperms.
7. Techniques of Fossil collection and process of studies of different types of mega and micro fossils from prepared specimen.

(H) TAXONOMY OF ANGIOSPERMS AND BIOSYSTEMATICS		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 32**

1. Seasonal collection of local flora, processing, Herbarium management.
2. Phenology of some common weeds.
3. Anatomical and Micro-morphological study of various angiosperms.
4. Identification of plants by matching.
5. Comparative study among various taxa of different angiospermic plants (fresh and dry), their identifications using literature and preparation of artificial keys.
6. Phytosociological studies; Biological Spectrum; Determination of Diversity Indices (Shannon-Wiener, Species Richness & β-diversity).
7. Use of GPS and demonstration on the use of at least one remote-sensing software
8. Preparation of temporary and permanent pollen slides, description of common palynomorphs, preparation of identification keys.
9. Ethnobotanical survey in a forest village/ village market.
10. Use of modern instruments in molecular taxonomy.
11. Identification of secondary metabolites and pigments.

GENERAL ELECTIVE - I		
COURSE CODE: - -		
COURSE NAME: GE-I *		
Credit: 4	**Full Marks: 75 (T) + 25 (CE)**	**Total lecture hours: 96**

*** Any One (01) paper to be selected out of Two (02) papers.**

(A) Rice Breeding, Organic Farming & Tissue Culture (or)

(B) Nanobiology, Bioseparation Techniques & Drug designing and Bioinformatics

(A) RICE BREEDING, ORGANIC FARMING & TISSUE CULTURE

GROUP A: RICE BREEDING		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

COURSE OBJECTIVES:

The course attempts to familiarize the students with the techniques for the improvement of crop varieties mainly in rice through conventional breeding process.

COURSE LEARNING OUTCOMES:

- Students will learn the plant hybridization technique and method to develop progeny lines in rice.
- Students will develop the skill to select promising breeding lines from the progeny populations.
- Students will also know about the mapping population used for QTL mapping and cloning purposes.

1. Rice breeding for global food security-overview and implications.
2. Biology of rice plant-rice gene pool and species complexes; wild rice as a source of many genes for biotic/abiotic resistance/tolerance respectively.
3. Reproduction systems – floral biology – pollination – fertilization; Ecological interaction, intraspecific and interspecific gene transfer in rice plant.
4. Germplasm Conservation - Gene Bank; geographic origin of rice species
5. Rice grain composition and quality parameters - nutritional value.
6. Rice cultivation and cropping patterns - breeding objectives and milestones; insect pests/diseases.
7. Global status of rice cultivation and trade related issues.

GROUP B: ORGANIC FARMING		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

COURSE OBJECTIVES:

Organic farming can be defined as an integrated farming system that strives for sustainability, enhancement of soil fertility and biological diversity. This course attempts to inculcate the importance and scope of organic farming in the present era of climate change.

COURSE LEARNING OUTCOMES:

- ❖ Students will gain an insight in to the chemical-free fertilizer system.
- ❖ Students will get to know about the different types of organic farming.
- ❖ Students will get to learn about the various types of organic manure.

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1. Introduction, Need, concept and key components of Organic Farming, Different concepts of organic farming – Natural farming, Biodynamic farming, Perma culture and Zero Budget Farming.
2. Stages in agricultural development – History of alternative agricultural development, effects of Green Revolution.
3. Types of farming – pure organic farming, integrated farming system, mixed farming; developing organic farms, importance of biofertilizers.
4. Benefits of Organic Fertilizer, Role of Microorganisms in Organic Fertilizer and their management.
5. Storage transportation, Social and market aspect of organic farming.
6. Organic manure – FYM, rural compost, city compost, animal wastes, vermi-compost, Green manure – Processing and ecological aspect, Liquid manure.

GROUP C: TISSUE CULTURE		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

COURSE OBJECTIVES:

Plant tissue culture is an important technique used by several branches of plant sciences according to their requirements. This course aims to introduce students to the fundamental principles of plant tissue culture.

COURSE LEARNING OUTCOMES:

- ❖ At the end of the course, students will be able to know the basic technique of tissue culture and their applications in different fields of applied agriculture and industry.

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1. Introduction to plants tissue culture. Design of a plant tissue culture Laboratory. Equipments, Instruments, Glassware and Plasticware.
2. Tissue Culture media (composition and preparation). Initiation and maintenance of callus. Suspension culture, single cell culture and somaclonal variation.
3. Organogenenesis: somatic embryogenesis. Embryo culture and embryo rescue.
4. Shoot tip culture and virus free plant development.
5. Methods of Micro-propagation and their application.

(B) NANOBIOLOGY, BIOSEPARATION TECHNIQUES & BIOINFORMATICS

GROUP A: NANOBIOLOGY

Credit: 1	Full Marks: 25 (T)	Total lecture hours: 32

COURSE OBJECTIVES:

Nanobiology is acclaimed to play vital roles in different field starting from agriculture to medical sciences. The course attempts to introduce the students with the emerging field of nanobiology.

COURSE LEARNING OUTCOMES:

- ❖ Students will gain knowledge on the different types of nanomaterials used in human welfare.
- ❖ Students will get to know about the synthesis approaches of nanomaterials.
- ❖ Students will get to learn about the present and futuristic applications of nanomaterials.
- ❖ Students will learn about the application of biosensors.

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1. **Introduction to nanomaterials:** Zero-dimensional, one-dimensional and two-dimensional nanostructures, size dependent properties; Synthesis of nanomaterials - bottom-up and top-down approaches; homogeneous and heterogeneous nucleation; nanoparticle stabilization.
2. **Nanobiotechnology:** Introduction; Natural nanoparticles; DNA nanotechnology - DNA nanotubes and their applications; nanoparticles for biological assays, drug delivery; surface modification of nanoparticles – rationale and applications.
3. **Engineered nanoparticles:** Physical and chemical characters; effect of engineered nanoparticles in biological systems; engineered NPs in therapeutics, cell targeting, gene delivery, bioimaging, drug encapsulation and release, agriculture.
4. **Biosensors:** Classes of biosensors; carbon nanotube-based sensors – methodology, application of CNTs-based biosensors.

GROUP B: BIOSEPARATION TECHNIQUES

Credit: 1	Full Marks: 25 (T)	Total lecture hours: 32

COURSE OBJECTIVES:

The course attempts to introduce the different analytical techniques that are being used for studying the structure and function of cellular macromolecules and metabolites.

COURSE LEARNING OUTCOMES:

- ❖ Students will know about the methods of cell disruption.
- ❖ Students will attain the technical skill to isolate and separate biomolecules from cellular extracts.
- ❖ Students will gain knowledge on the advances in the chromatographic and electrophoretic techniques for the separation of biomolecules.

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1. **Introduction to Bioseparation Process:** Role and importance of Bioseparation; Problems and requirements of bioproducts purification; Properties of Biomolecules and biological activity; Analysis of purity-Process economics
2. **Removal of Insoluble Components**: Cell disruption methods for intracellular products: Physical, chemical, and mechanical; Biomass and particulate debris separation techniques - flocculation - sedimentation - centrifugation and filtration methods.
3. **Isolation of Products:** Aqueous two-phase extraction - supercritical extraction Precipitation: Methods of precipitation with salts - organic solvents and polymers - Membrane based separations: Micro and ultrafiltration
4. **Chromatographic separations**: Basic principles; Types of chromatographic system: Gel permeation, Ion exchange, Affinity, Reverse phase, and hydrophobic interaction chromatography; Resolving power of chromatographic column; TLC, GC and HPLC: Design and configuration of Equipments and their applications, metabolite fingerprinting
5. **Electrophoretic separation techniques**: Separation of DNA, RNA, and Proteins; Capillary Electrophoresis; Isoelectric focusing and 2D gel electrophoresis, Isozyme analysis, Application of electrophoretic system

GROUP C: DRUG DESIGNING AND BIOINFORMATICS		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

COURSE OBJECTIVES:

The course attempts to introduce the students with the basics and advances in the field of computer-aided drug designing.

COURSE LEARNING OUTCOMES:

- ❖ Students will learn the basics and significance of computer-aided drug designing.
- ❖ Student will gain knowledge on the bioinformatics softwares and tools for drug discovery, molecular docking and simulation studies.

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1. Homology modelling: related servers and software. Validation of a model
2. Structure based phylogeny and its implications
3. Protein modelling: introduction; force field methods.

SEMESTER-IV

CORE COURSE - IX		
COURSE CODE: - -		
COURSE NAME: GENETIC ENGINEERING AND GM CROPS & GENOME BIOLOGY AND EVOLUTION		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

COURSE OBJECTIVES:

This course aims to introduce the students to the subject of genetic engineering for making them aware about the mechanism of gene transfer without considering the species barrier. Bacterial gene can be transfer to plant or vice versa. Students also can know about the mechanism of transgenic plant development for GM-Crop production. Students will also learn about the fundamentals of genome biology and evolutionary perspectives of living organisms.

COURSE LEARNING OUTCOMES:

- Students will acquire knowledge about the tools and techniques of recombinant DNA technology.
- Students will learn about the development of transgenics, their applications and ethical issues related to their use.
- Students will be exposed to the concept of gene silencing and gene knockouts.
- Students will gain knowledge regarding the concept and different tools used in bioinformatics, about the different DNA and protein databases.
- Students will be learning the concepts of metabarcoding, small RNAs and non-coding RNAs.
- Students will also be gaining knowledge in the advances in nucleotide sequencing techniques.

GROUP A: GENETIC ENGINEERING AND GM CROPS		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. **Recombinant DNA Technology:** Overview and fundamental techniques of rDNA technology; Restriction enzymes; DNA ligase, Cohesive and blunt end ligation.
2. **DNA Hybridization techniques:** Northern, Southern, Western and Colony hybridization.
3. **Basic biology of plasmid and phage vectors:** Plasmids; Bacteriophages; pBR322, pUC19 and Phagemids; Lambda vectors; Cosmids; YACs; BACs; Expression vectors; pMal; GST; pET; Protein purification; His-tag; GST-tag; Ti and Ri as vectors.
4. **Gene cloning strategies:** Introduction; principles of gene cloning and methods; insertion of foreign DNA into host cells; transformation.
5. **Gene transfer to plants:** Overview, Ti vector based Agrobacterium mediated gene transfer and viral vectors; selectable marker and reporter genes; direct gene transfer to plant cell. Control of transgene expression in plants; transgene analysis- silencing and targeting.
6. **Transgenic technology for crop improvement:** GM crops and traits, Golden rice, Bt-brinjal; Bt-cotton, Bt toxin (Cry protein) gene structure analysis and expression for insect resistance.

GROUP B: GENOME BIOLOGY AND EVOLUTION		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. Introduction, nucleotide substitution rates, origins of new genes, Chloroplast genome evolution; transfers of mitochondrial and chloroplast genes to the nucleus, Horizontal gene transfer between species, Gene duplication, fates of duplicated genes, gene families, polyploidy, Transposable element evolution.
2. Genome and transcriptome sequencing approaches- SANGER, Illumina, Hiseq, MIseq, Chip-seq, RNA seq.
3. Metabarcoding and amplicon sequencing- importance, population diversity, rarefaction curve.
4. Small RNAs and other non-coding RNAs evolution and their significance.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Isolation of plant genomic DNA and purity check.
2. Restriction digestion of the plasmid DNA and fractionation in agarose gel electrophoresis.
3. In vitro gene cloning through PCR amplification.
4. Protein analysis using SDS-PAGE gel electrophoresis
5. Demonstration of GM Golden rice (GR1 & GR2) development history.
6. Calculation of codon usage indices of different prokaryotic and eukaryotic organism,
7. Comparative genomics through Codon Usage analysis and related software
8. Sequence alignment of different genomic sequences and Phylogenetic analysis.
9. Evolution study of prokaryotic and eukaryotic organelles through different software.

CORE COURSE - VIII		
COURSE CODE: - -		
COURSE NAME: ECOLOGY AND BIOSTATISTICS		
Credit: 4	**Full Marks: 50 (T) + 25 (P) +25 (CE)**	**Total lecture hours: 96**

GROUP A: ECOLOGY		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. Origin of life (including aspects of prebiotic environment and molecular evolution), Concepts of evolution, Theories of organic evolution, Mechanisms of speciation and extinctions; Hardy-weinberg genetic equilibrium, genetic polymorphism and selection; Origin and evolution of economically important microbes, plants and animals.
2. Concepts and dynamics of ecosystem, components, food chain and energy flow, productivity and biogeochemical cycles; Types of ecosystem: Grassland and Savannas, Shrubland and Deserts,

Tundra and, Taiga. Temperate forests, Tropical forests, Lakes and Ponds, Freshwater wetlands, Streams and Rivers, Oceans, Estuarine and Mangrove.

3. Population ecology (Basic characteristics with examples, life table, survivorshipcurves, growth curves) and biological control; Community structure and organization; Environmental pollution; Sustainable development; Economic importance of microbes, plants and animals.
4. Interactions between environment and biota; Concept of habitat and ecological niches; Limiting factor; Energy flow, food chain, food web and trophic levels; Ecological pyramids and recycling, biotic community-concept, structure, dominance, fluctuation, succession, N, P, C and S cycles in nature.
5. Ecosystem dynamics and management; Stability and complexity of ecosystems; Environmental impact assessment, Principles of conservation; conservation strategies; cryopreservation, Sustainable development. Ethical issues related to new-crops and introduction of transgenics. Climate change.

GROUP B: BIOSTATISTICS		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

1. **Sampling and Data structure:** Sampling methods, experimental design – completely randomized design, incomplete block design, split plot, factorial experiments, etc.; Univariate, bivariate and multivariate data; data sources; classification of data, data presentation – textual, tabular, graphical; levels of measurement – nominal, ordinal, ratio, interval.
2. **Measures of central tendency and dispersion:** Arithmetic mean, Geometric mean, Harmonic mean, Median, Mode, Quartile; Range; Variance, Mean deviation, Standard deviation; Dispersion and Skewness, Moments, Kurtosis.
3. **Correlation and Regression analysis:** Correlation – types; Karl Pearson's correlation coefficient, Rank correlation; Regression equations.
4. **Probability:** Introduction; Random variables and expectation, Discrete probability distribution - Binomial and poisson distribution; continuous probability distribution.
5. **Tests of hypothesis:** Basic concepts, simple and composite hypotheses, Null and alternative hypothesis, Type-I and Type-II errors, critical region, significance level; Parametric and non-parametric tests- Student's t-distribution, F test, Sign test, Chi-square, etc.; p-value and its interpretation; Analysis of variance (Anova)- Bivariate & multivariate.

GROUP C: PRACTICAL		
Credit: 1	**Full Marks: 25 (P)**	**Total lecture hours: 32**

1. Estimation of dissolved oxygen content.
2. Estimation of dissolved carbonate & bicarbonate content.
3. Determination soil pH.
4. Study of ecological characters of plants.
5. Determination of a population growth curve from given data.
6. Ecological studies of grassland/herbland.
7. Ecological studies of a wetland.

8. Measurements of central tendency.
9. Measures of dispersion.
10. Determination of tests of significance: Chi square test, t-test.
11. Determination of relationship between variables using correlation and regression analysis.
12. Analysis of variance; one way, two way

DISCIPLINE SPECIFIC ELECTIVE - VI		
COURSE CODE: - -		
COURSE NAME: DSE-VI		
Credit: 2	**Full Marks: 42 (T) + 8 (CE)**	**Total lecture hours: 64**

Discipline Specific Elective – VI course will be provided as a choice to the students for developing research-based aptitude and technical skills in eight (08) Special paper titles in Botany. The students are required to carry **'DISSERTATION WORK'** related to the Special paper selected in the 3rd Semester DSE papers (DSE-III/IV/V). The final topic of Dissertation to the students to be given by the respective faculty members which shall fall within the following specializations:

(A) Genetics and Bioinformatics

(B) Microbiology

(C) Molecular Plant Pathology and Fungal Biotechnology

(D) Plant Biochemistry

(E) Plant Genetics and Molecular Breeding

(F) Plant Physiology and Pharmacognosy

(G) Advanced Pteridology and Palaeobotany

(H) Taxonomy of Angiosperms and Biosystematics

The Course Objectives and Course Learning Outcomes is as follows:

COURSE OBJECTIVES:
The course is designed to train the students with conducting research-oriented experimentations, conducting literature survey, writing articles, and so on.

COURSE LEARNING OUTCOMES:
- ❖ Students will learn how to design experiments.
- ❖ Students will develop research aptitude that will motivate them to pursue Ph.D. course.
- ❖ Students will gain knowledge to conduct literature review, write research proposal and manuscript.
- ❖ Students will develop technical expertise to use scientific instruments.

DISSERTATION SUBMISSION		
Credit: 1.68	**Full Marks: 42 (P)**	**Total lecture hours: 64**

The Dissertation work is required to be submitted by the students at the time of term-end examination which will be evaluated for its experimental design, technical quality and overall presentation of the work.

DISSERTATION - SEMINAR		
Credit: 0.32	**Full Marks: 8 (IA)**	**Total lecture hours: 64**

The Dissertation work will be assessed on the basis of Seminar presentation followed by Viva-voce on the topic presented.

GENERAL ELECTIVE - II		
COURSE CODE: - -		
COURSE NAME: GE-II *		
Credit: 4	**Full Marks: 75 (T) + 25 (CE)**	**Total lecture hours: 96**

*** Any One (01) paper to be selected out of Two (02) papers.**

(A) Climate Change, Stress Physiology & Sustainable Development (or)

(B) Biodiversity, Plant Treaty & IPR

(A) CLIMATE CHANGE, STRESS PHYSIOLOGY & SUSTAINABLE DEVELOPMENT

GROUP A: CLIMATE CHANGE		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

COURSE OBJECTIVES:

Global climate change is an alarming issue. The course therefore attempts to present the students with recent status and concerns regarding the issue of climate change. The course will also introduce the threats climate change possess on plant system, different bodies involved in dealing with the threats, etc.

COURSE LEARNING OUTCOMES:

- The students will get to learn about the factors that contribute to global warming.
- The students will learn about the initiatives at the national and international level to save the biodiversity from the negative impacts of climate change,
- The students will also gather knowledge regarding the GIS and remote sensing techniques that plays an essential role in monitoring climate change.

1. Greenhouse gases and Global warming, Greenhouse gases and its sources, Enhanced greenhouse gas effect, Global warming and Greenhouse gases policy issue, Effects and causes of global warming.
2. Aerosols, Sources of aerosols Direct and indirect effects, Production mechanisms of aerosols, Trends in aerosols, Radiative forcing and GHGs-Definition, concept and processes.
3. International response to climate change, history of IPCC and UNFCCC, The climate change convention, National and local government responses, Adaptive response and mitigation activity.
4. Climate change impacts on forests and transportation, Forest dispersion and shifting, Forest fires, Ecophysiological Responses, Tree Responses to Temperature and Water Availability, Plant Responses to Increased CO_2 Concentration, Biodiversity and related Adaptation mechanisms and strategies.
5. GIS & Remote Sensing, Introduction to Remote Sensing and GIS techniques, satellites, Sensors, Platforms and Resolutions, Infrared and Microwave Remote Sensing, principles and Applications, GIS applications based on models outputs and GIS databases, Remote sensing technologies to monitor climate change processes (vegetation biomass, monitoring flooding, soil moisture and depth, surface micro topography etc.).

GROUP B: STRESS PHYSIOLOGY		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

COURSE OBJECTIVES:

This course attempts to introduce the students to stress physiology which deals with the responses of plants against abiotic stresses like drought, temperature, salinity, etc. This course also attempts to focus on the strategies for improving the stress tolerance of plants.

COURSE LEARNING OUTCOMES:

- The students will get to know about the various responses of plants subjected to abiotic stresses.
- The students will know about the adaptive mechanisms which play an important role in stress tolerance.
- The students will learn about the role of phytohormones in stress responses.

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1. **Response of plants to abiotic stress**: Acclimation and adaptation; Abiotic stresses affecting plant productivity; Compromising vegetative and reproductive development; Interactions between biotic and abiotic stresses.
2. **Water and Plants**: Cohesive and adhesive properties of water, water potential differences in the soil-plant-air continuum. Development of water deficits. Transpiration and its regulation in stomatal functions.
3. **Drought Stress:** Physiological processes affected by drought; Drought resistance mechanism: Escape, dehydration postponement (drought avoidance), dehydration tolerance and characteristics of resurrection plants; Osmotic adjustment and osmoprotectants; Water use efficiency as a drought resistant trait.
4. **Flood Stress:** Water logging and flooding injury; Hypoxic and anoxic stress; Strategies for submergence tolerance and oxygen deficit.
5. **Stress due to high temperature:** Heat stress and heat shock; Temperature affecting membrane stability; HSP mediated thermo-tolerance and signalling pathways

6. **Low temperature stress:** Chilling and freezing stress, frost and cold injury effects on physiological process, crucial role of membrane lipids; Transcription factors regulating cold-induced gene expression
7. **Salinity:** Species variation in salt tolerance; Salinity effects at Cellular and whole plant level; Salt tolerance in Glycophytes and Halophytes; Strategies of salt tolerance.
8. **Stress and plant hormones:** Oxidative stress; Relative Oxygen Species (ROS); Role of scavenging systems; ABA, Jasmonic Acid signalling and stress tolerance.

GROUP C: SUSTAINABLE DEVELOPMENT		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

COURSE OBJECTIVES:

This course attempts to present the students with the concept of sustainable development goals of the United Nations. The course also highlights the process and strategies for attaining food security for the ever-increasing population in a sustainable manner.

COURSE LEARNING OUTCOMES:

- The students will learn about the concept of sustainability, their significance in environmental and economic development.
- The students will get to know about the government policies, EIA and EMP that aims to achieve development in a sustainable way.
- The students will learn about the factors threatening food security and the strategies for ensuring the same.

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1. Introduction: Concept of sustainability, factors governing sustainable development; linkages among sustainable development, environment and poverty; Determinants of sustainable development.
2. Environmental assessment: National environmental policy act, Environmental Impact Assessment (EIA), Project categories based on environmental impacts, Impact identification methods, Environmental Impact Assessment process.
3. Environmental management: Trends and policies, Environmental Management Plan (EMP); Milestones in environmental management, Achievements in Environmental Management, Millenium Development Goals (MDGs), Sustainable Development Goals (SDGs).
4. Food security: Sustainable food supply and end of hunger; Farm systems; Factors threatening the food system; Sustainable global food supply.

(B) BIODIVERSITY, PLANT TREATY & IPR

GROUP A: BIODIVERSITY

Credit: 1	Full Marks: 25 (T)	Total lecture hours: 32

COURSE OBJECTIVES:
The course will focus on the importance of biodiversity, the present status of biodiversity on earth and the recent concerns regarding biodiversity conservation.

COURSE LEARNING OUTCOMES:
- The students will learn about the concept of hotspots, megadiversity country.
- The students will gain information on the different meetings and conventions to protect world biodiversity.
- The students will know about the concept of gene pool and strategies for ecology restoration.

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1. Biodiversity and its conservation: Definition, types, importance of biodiversity and threats to biodiversity. Concept and basis of identification of 'Hotspots'; hotspots in India. Measures of biodiversity.
2. Strategies for biodiversity conservation: in situ, ex situ and in vitro conservation. National parks, Sanctuaries, Protected areas and Sacred groves in India.
3. Concepts of gene pool, biopiracy and bio-prospecting. Concept of restoration ecology. IUCN Threatened categories, Extinct, Rare, Endangered flora of India.
4. Endemism, Convention on Biodiversity (1992), Kyoto Protocol, 1997.

GROUP B: PLANT TREATY

Credit: 1	Full Marks: 25 (T)	Total lecture hours: 32

COURSE OBJECTIVES:
Students will be taught about the Biodiversity on the blue planet, source of food, shelter and clothing. Exchange of plant varieties between countries and their access benefit sharing (ABS) norms according to the international regulations.

COURSE LEARNING OUTCOMES:
- Students will know the basic principles of sustainability of earth, role of biodiversity to maintain peace and harmony among the human populations, and green and clean environment for sustainable development.
- Students will learn how to transfer plant genetic material between two countries through international plant treaty (ITPGRFA) following SMTA rules.

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1. Plant Genetic Resources and their Regulatory System: Origin of crop plant, plant domestication, agro-biodiversity, Conservation and utilization of plant genetic resources; Genetic Resources for Food Security.

2. CBD, and ITPGRFA, Intellectual Property Rights; Plant Variety Protection and Farmers' Rights Act (PPV&FR act 2001, India); Biological diversity act 2021; Food security Act 2013.
3. International Regulation of Genetic Resources and Agrobiodiversity. Nagoya Protocol in relation to Agrobiodiversity Conservation; Nagoya Protocol on ABS; WTO/TRIPS; UPOV; FAO-IT; INGER.
4. Germplasm exchange is a risky Affair; Biosecurity in the regime of CBD and WTO to ensure Agricultural Diversity; Climate change and role of Crop diversity.

GROUP C: IPR		
Credit: 1	**Full Marks: 25 (T)**	**Total lecture hours: 32**

COURSE OBJECTIVES:

The course attempts to introduce the students with the concept of patent, trademark, copyright, GI. The course will also present the students with the laws governing the process of patent filing the significance of protecting novelty.

COURSE LEARNING OUTCOMES:

- ❖ The students will be able to know about patentability, its significance and the laws governing the same.
- ❖ The students will gather information on the importance of patent, trademark, GI tagging etc.
- ❖ The students will learn about the recent topics such as biopiracy, cyber squatting and so on.

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1. Introduction to Intellectual Property Rights Concept and Theories Kinds of Intellectual Property Rights Economic analysis of Intellectual Property Rights Need for Private Rights versus Public Interests Advantages and Disadvantages of IPR.
2. Copyright law and practices, Copyright Act, 1957 Terms of Copyright conditions for grant of copyright, extent of rights exception to copyright protection, fair use provision, assignment and licensing, Copyright in Literary, Dramatic and Musical, Works, Sound Recording, Cinematograph Films, Copyright in Computer Programme, Author Special Rights, Right of Broadcasting and performers.
3. Historical development of the concept of trademark and trademark law-National and International Introduction to Trademarks Need for Protection. Kinds of trademarks Concept of well known trademark.
4. IPR and Climate change Patents and Biotechnology, Traditional knowledge and IPR Bio piracy Domain Name Disputes and Cyber squatting.

SUGGESTED READINGS

BIOSTATISTICS

1. Fundamentals of Biometry – L.N.Balaam
2. Fundamentals of Biostatistics – I.A. Khan and A.Khanum,Ukaaz Publications
3. Principles of Biometry- C.M.Woolf
4. Statistical Methods – G.W.Snedecor and W.G.Cochran

BRYOLOGY

1. Bryophyta - N.S.Parihar , Central Book Depot, Allahabad
2. Bryophye Ecology – A.J.E.Smith (Ed)
3. Bryophytes – P.Puri, Atma Ram & Sons Publishers, N.Delhi
4. Cryptogamic Botany, Vol.II – G.M.Smith
5. Liverworts of the Western Himalayas and Punjab Plain – S.R.Kashyap

CYTOLOGY AND GENETICS

1. Genetics : PJ Russell. Benjamin Cummings Pub. Inc. USA.
2. Principles of Genetics: Snustad and Simmons, John Wiley and Sons, USA
3. Concepts of Genetics: Klug and Cummings, Pearson Education, USA
4. Genome 3: T.A. Brown, Pearson Education, USA
5. Principles of Gene Manipulation and Genomics: Primrose and Twyman, Blackwell Scientific, Oxford.
6. Plant chromosome: Analysis; Manipulation and Engineering: Sharma & Sharma, Harwort Academic Pub. Australia
7. The Science of Genetics: Sauders College Publishing, Fort Worth, USA
8. Genetics: Principles and Analysis, Hartl and Jones, EW Jones & Bartlettt Pub, USA.
9. Gene IX: Lewin, B. Oxford University Press, USA.
10. Essential Genes, Lewin, B. Pearson Education.
11. Functional Genomics: A practical Approach. Hunt And Rick, Oxford University Press.
12. Genetic Engineering: An Introduction to Gene Analysis and Exploitation in Eukaryotes: Kingsman &Kingsman, Blackwell Scientific .Pub. Oxford.
13. Molecular Biotechnology: Glick & Pasternock, Indian Edition.
14. Molecular Cloning: A Laboratory Manual, Sambrook & Russel, CSHL press, N.York.
15. DNA Cloning: A Practical Approach, Glover & Hames, IRL press, Oxford.
16. Methods in Enzymology, Guide to molecular Technique, Vol. 152. Berger & Kimmel, Academic Press, San Diego.
17. DNA Science: A first course in recombinant Technology, Mickloss & Freger, CSHL Press, NY.
18. Recombinant DNA Technology: Watson, Academic Press.

ECOLOGY

1. Basic Ecology –E.P. Odum , Saunders Publication

2. Fundamentals of Ecology-E.P. Odum , Saunders Publication
3. Elements of Ecology – R.L. Smith & T.M. Smith , Benjamin/ Cummings Publishers
4. Air pollution and Plant Life –M.T. reshow , Willy Interscience
5. Concepts of ecology- E.J. Kormondy, Prentice-Hall of India
6. Fundamentals of Ecology- M.C. Dash , Tata McGraw Hill
7. Environmental Science-S.C. Santra , New Central Book agency(P) Ltd. Kolkata.
8. Biology of Fresh water pollution-C.F. Mason , Longman Publishers

GENETIC ENGINEERING

1. Fundamental Molecular Biology ; Allison LA; 2007
2. Recombinant DNA, Watson et al ; 5th Ed; 2006
3. Techniques for Engineering Genes ; Curell BR et al;2004
4. Techniques for Molecular Biology ; Tagu D & Moussard C; INRA; 2006
5. Gene Cloning and DNA Analysis ; 5th Ed ; Brown TA ; 2006
6. Analysis of Genes and Genomes ; Reece RJ ; Wiley; 2004
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