SYLLABUS BASED ON CHOICE BASED CREDIT SYSTEM

M.Sc. (Botany)

SEMESTER SYSTEM

(Effective from the Session 2020-21)

UTKAL UNIVERSITY

VANI VIHAR, BHUBANESWAR-751004

ODISHA, INDIA

Preamble

The M. Sc. Botany course will be effective from the academic year 2020 –2021. It has been prepared keeping in view the unique requirements of M. Sc. Botany students and CSIR NET syllabus. The emphasis is to provide students the latest information along with due weightage to the concepts of classical botany so that they are able to understand and appreciate the current interdisciplinary approaches particularly in the field of research and innovation in the plant sciences and its role in societal development. Todays' plant science is a mixture of the traditional components with the modern aspects of biochemistry, molecular biology and biotechnology. Over the years, plant science (Botany) has shown enormous gain in information and applications owing to tremendous inputs from research in all its aspects. Thus the course content also lists new practical exercises so the students gets a hands on experience of the latest techniques that are currently in use. The four semester M. Sc. syllabus is a balanced, carefully-crafted course structure taking care of different aspects of plant science, namely plant diversity, cytogenetic, physiology, biochemistry, molecular biology, biotechnology, developmental biology, anatomy, taxonomy, ecology, economic botany and the impact of environment on the growth and development of plants. All these aspects have been given due weightage over the four semesters having special emphasis on some aspects in the last semester. Students should be encouraged to opt for one allied elective paper from other Life Sciences like Zoology and Biotechnology courses to increase interdisciplinary approaches of understanding and application. The course will also inspire students to pursue higher studies in botany, for becoming an entrepreneur and enable students to get employed in plant based industries. On the whole, the curriculum is a source of lot of information and is supported by rich resource materials. On behalf of Department of Botany, this new syllabus will cater the fundamental requirements for the students being employed in different sectors to serve the world as a whole.

M.Sc. COURSE IN BOTANY

P.G. Department of Botany, Utkal University, Vani Vihar, Bhubaneswar

(SEMESTER SYSTEM)

To be effective from the session 2020-2021 ***(Revised)***

Eligibility

Any student who has passed B.Sc. (Hons.) in Botany and with any other allied subjects such as Zoology, Life Science, Environmental Science, Microbiology, Biotechnology and Geography and having minimum of 50% marks in botany can take this course.

Admission

The candidates are to take admission after qualifying in an entrance test conducted by the department. The merit list will be prepared by taking 50% of marks in career plus 50% of marks secured by a candidate in the entrance test. The admission will be strictly as per the merit list in each category as per university norms.

Course and Regulation

1. The course is of two years duration with four semesters for theory, laboratory practical work.
2. First and second semesters have four (4) theory papers each and one (1) practical paper. Third semester has two (2) core papers, one (1) allied elective paper, one free elective paper to be opted from other department and one (1) practical paper. Fourth semester has one special paper having two (2) core elective papers, one (1) dissertation and one (1) seminar presentation. The candidate shall have to appear examination (both theory and practical / dissertation/seminar) at the end of each semester.
3. Each theory paper carries 100 marks.
4. Each practical paper carries 100 marks. In 4^{th} semester the dissertation paper carries 20 marks.
5. The semester system of examination will have internal system of evaluation as suggested by the Board of Studies approved by Teacher's council. For practical examination evaluation will be made by one external and one internal examiner together.

6. In order to pass a semester examination a candidate must have to secure a minimum of 40% marks in practical and 33% marks in aggregate of the theory papers in each semester. If the marks secured in a theory paper is less than 25% then the said mark will not be included in the aggregate.

7. If a candidate passes all the four semester examination he / she will be declared to have passed the M.Sc. examination in Botany.

(i) In first class securing 60% or more

(ii) In second class securing 48% or more but less than 60%

(iii) In third class securing 33% marks or more but less than 48% marks in aggregate of all the semester examinations taken together.

8. Attendance in each semester shall be strictly adhered to University Rules.

9. A candidate may repeat only once in one or more papers of any semester examination within a period of one year of the said semester examination. However, if the candidate does not clear the 1^{st}& 2^{nd} semesters, his/her result will not be published even after successfully completing the 3^{rd} and 4^{th} semester. In case a candidate is unsuccessful in 3^{rd} and 4^{th} semester, he shall appear in the immediate next examination of the next batch for the same semester. A candidate failing on any semester examination will be allowed to appear once only in the examination for that semester conducted for the next batch of students and also be allowed to continue to the next semester. A candidate not appearing the 1^{st} and 2^{nd} semester examinations will be considered to have discontinued his/her study and will not be allowed to appear the remaining semesters.

10. Merit list will be prepared as per University Rules, from among the students those who have cleared all semester examinations in 1^{st} chance in one time without repeat of any paper.

11. The candidates who have failed in one semester may be allowed to appear the same in the immediate next chance, following the due provision. However, he/she will be not given another chance to appear.

A. Core Papers:

1. Diversity of Life
2. Diversity of vascular plants
3. Cell and Molecular Biology of Plants
4. Plant Biochemistry
5. Plant Physiology
6. Cytogenetics, Plant Breeding and Biostaticstics
7. Biotechnology and Genetic Engineering of Plants
8. Plant Taxonomy, Ecology & Evolution
9. Plant Development, Reproduction and Economic Botany
10. Conservation Biology

Practical pertaining to above theory papers

B. Core Elective papers (optional):

1. Biochemistry and Molecular Biology
2. Plant Biotechnology
3. Cytogenetics
4. Environmental Biotechnology
5. Microbial Technology
6. Biosystematics

Practical pertaining to each theory core elective papers

C. Allied Elective Courses

Plant Physiology and Developmental biology

D. Free Elective Courses

1. Plants & Environment (A)

OR

2. Environmental Studies (B)

Outlines of M.Sc. (Botany) Syllabus

Semester-I	Core Papers Name	**Mark**	**Credit**
Core Papers:			
Paper-BOT-101	Diversity of Life	**100**	**06**
Paper-BOT-102	Diversity of Vascular Plants	**100**	**06**
Paper-BOT-103	Cell & Molecular Biology of Plants	**100**	**06**
Paper-BOT-104	Plant Biochemistry / SWAYAM Course on Biochemistry	**100**	**06**
Paper-BOT-105	Practical pertaining to Theory Papers – BOT-101, BOT-102, BOT-103, BOT-104	**100**	**06**
	TOTAL	**500**	**30**
Semester-II			
Paper- BOT-201	Cytogenetics, Plant Breeding & Biostaticstics	**100**	**06**
Paper- BOT-202	Biotechnology & Genetic Engineering of Plants	**100**	**06**
Paper- BOT-203	Plant Physiology	**100**	**06**
Paper- BOT-204	Plant Taxonomy, Ecology & Evolution	**100**	**06**
Paper- BOT-205	Practicals Pertaining to Theory Papers- BOT-201, BOT-202, BOT-203, BOT-204	**100**	**06**
	TOTAL	**500**	**30**
Semester-III			
Paper BOT-301	Plant Development, Reproduction and Economic Botany	**100**	**06**
Paper-BOT-302	Conservation Biology	**100**	**06**
Paper-BOT-303 (Free Elective Courses)	Plants & Environment (A) / Or Environmental Studies (B)	**100**	**06**
Paper-BOT-304 (Allied Elective Courses)	Plant physiology and Developmental biology	**100**	**06**
Paper-BOT-305	Advanced Practical	**100**	**06**
	TOTAL	**500**	**30**
Semester-IV			
Core elective papers (optional):	**Only One Special paper + Dissertation + Seminar presentation**		
Paper-BOT-401 (A)	Biochemistry and Molecular Biology -I	**100**	**06**
Paper- BOT-402 (A)	Biochemistry and Molecular Biology - II	**100**	**06**
Paper-BOT-401(B)	Plant Biotechnology -I	**100**	**06**
Paper- BOT-402 (B)	Plant Biotechnology -II	**100**	**06**
Paper-BOT-401 (C)	Cytogenetics -I	**100**	**06**
Paper- BOT-402 (C)	Cytogenetics -II	**100**	**06**
Paper-BOT-401 (D)	Environmental Biotechnology-I	**100**	**06**
Paper- BOT-402 (D)	Environmental Biotechnology-II	**100**	**06**
Paper-BOT-401 (E)	Microbial Technology-I	**100**	**06**
Paper- BOT-402 (E)	Microbial Technology-II	**100**	**06**
Paper-BOT-401 (F)	Biosystematics-I	**100**	**06**
Paper- BOT-402 (F)	Biosystematics-II	**100**	**06**
Paper-BOT-403	Dissertation	**200**	**12**
Paper-BOT-404	Seminar presentation	**100**	**06**
	TOTAL	**500**	**30**
	GRAND TOTAL	**2000**	**120**

Semester – I

DIVERSITY OF LIFE

PAPER-BOT-101 ***100 Marks/ 6 Credits***

Course Objectives: The paper aims to enhance the knowledge of students on diversity of microorganisms and lower plants, their classification, structure, life cycle and their significance.

UNIT-I

History and development of microbiology, Bergey's manual for classification of microbes, isolation, culture and maintenance of microorganisms, Microbial growth, Roles of microbes in agriculture and industry, Factors influencing growth of microbes.

UNIT-II

Structure and reproduction of Eubacteria, Cyanobacteria, Archaea, Actinomycetes, Mycoplasma, Rickettsiae, Spirochaetes, Virus, Viroids, Prions, Biofertilizers: cyanobacteria, *Rhizobium*, PSB, Mycorrhizae and *Azotobacter*. Plant diseases caused by viruses, bacteria, mycoplasma.

UNIT-III

Algae in diversified habitats (terrestrial, freshwater and marine), classification based on pigment, food reserve and flagella, thallus organization, reproduction. Life cycles in algae. Salient features of Chlorophyta, Bacillariophyta, Dinophyta, Phaeophyta and Rhodophyta, algal bloom and toxins, algae as food, seaweed cultivation.

UNIT-IV

Classification of fungi, structure and reproduction of Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes. Degeneration of sex in fungi, nutrition in fungi, heterothallism, heterokaryosis. Host-parasite relationship, fungal toxins and their mode of action.

UNIT-V

Origin, evolution and classification of Bryophytes, Ecological significance of bryophytes, structure and reproduction of Anthocerotales, Marchantiales, Jungermanniales, Sphagnales, and Polytrichales, Progressive sterilization of sporogenous tissues, evolution of gametophytes in bryophytes.

Learning Outcomes:

The course will impart theoretical knowledge on diversity of microorganisms, their life forms, economic importance and various plant diseases caused by them. Students will learn the basics of microbial techniques like isolation, culture and preservation of bacteria, algae and fungi. Students will learn about origin, evolution and reproductive strategies of bryophytes.

DIVERSITY OF VASCULAR PLANTS

PAPER- BOT-102 ***100 Marks/ 6 Credits***

Course Objectives: The paper aims to understand the evolutionary diversification, morphology, reproduction of extinct and present day vascular plants. students will also be exposured to paleobotany and palynology.

UNIT-I

Origin, evolution and classification of pteridophytes, General account of Psilophytales, fossil lycophytes, Sphenophytes, fossil ferns. Stellar evolution; Origin of heterospery, Heterospory and seed habit.

UNIT-II

Structure, reproduction and evolution of Psilopsida, Lycopsida, Sphenopsida and Pteropsida, soral evolution, origin, morphology and evolutionary significance of sporocarp.

UNIT-II

Evolution and classification of Gymnosperms, Geological time scale, fossilization process, General account of Pteridospermales, Cycadeoidales, Pentoxyllales, fossil Ginkgoales, Cordaitales and fossil Coniferales.

UNIT-IV

Structure and reproduction of Cycadales, Ginkgoales, Coniferales, Ephedrales, Welwitscilales, and Gnetales. Complexities and gametophytes in gymnosperm, Evolution of female gametophytes; variation in the structure of pollen grains. Angiospermic

UNIT-V

Paleobotany, Geological time scale, Basic concepts of continental drift, Fossilization process, Types of fossil, Dating of fossil, Fundamentals and applications of paleobotany

Palynology: Spore and pollen morphology, polarity, symmetry, ornamentation

Learning Outcomes:

Students will learn about evolution of gametophytes, sporophytes and conducting tissues of fossil and living pteridophyte as well as gymnosperm. Students will have knowledge on basics of paleobotany and palynology along with their applications.

CELL & MOLECULAR BIOLOGY OF PLANTS

PAPER*- BOT-103** ***100 Marks/ 6 Credits

Course Objectives:

The objective of the present course content is to provide a foundation and background of cellular structure, cell organelles in relation to their functions and regulatory mechanisms.

UNIT-I

Cell Wall: Structure & functions; biogenesis; growth.

Plasma membrane: Structure, models, electrical properties of membrane & functions; sites for ATPases, ion carriers, channels and pumps; receptors *Plasmodesmata:* Structure; role in movement of molecules & macromolecules; comparison with gap junctions.

UNIT-II

Chloroplast: Structure, genome organization, gene expression, RNA editing, nucleochloroplastic interaction. *Mitochondria*: Structure, genome organization, Biogenesis.

Other cellular organelles: Structure & functions of microbodies, golgi apparatus, Lysosomes, endoplasmic reticulum.

UNIT-III

Nucleus: Structure, nuclear pores, nucleosome organization, DNA structure, A, B & Z forms, replication, damage & repair. *Transcription*: Plant promoters & transcription factors, splicing, m-RNA transport, Nucleolus, t-RNA, micro-RNA.

UNIT-IV

Ribosomes: Structure, site of protein synthesis, mechanism of translation initiation, elongation & termination. Stability of proteins, Conformation of proteins (Ramachandran plot, secondary structure, domains, motif and folds). *Protein sorting*: Targeting of proteins to organelles, mechanism of sorting and regulation of target transport.

UNIT-V

Cell shape & motility: The cytoskeleton, organization & role of microtubules and microfilaments, motor movements, implications in flagellar & other movements. *Cell cycle and apoptosis*: Control mechanisms, role of cyclins & cyclin dependent kinases, retinoblastoma & E2F proteins, cytokinesis & cell plate formation, mechanism of programmed cell death.

Course Learning Outcomes:

The students will be learning about the structure and function of cell wall and plasma membrane, cell organelles such as chloroplast, mitochondria and others. Students will have knowledge on nuclear organization, DNA structure, replication and repair, transcription, translation and protein sorting. Understanding about regulatory mechanism of cell cycle and apoptosis of the students will be enhanced.

PLANT BIOCHEMISTRY

PAPER- BOT-104 ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on basic principles biophysics, fundamentals of biochemistry, structure and properties of various bio-molecules such as carbohydrates, proteins, lipids and enzymes.

UNIT-I

Principles of Biophysical Chemistry: Reaction kinetics: equilibrium and law of mass action, concept of reaction rates. Thermodynamics: Concept and Laws of thermodynamics, biological applications;

Fundamentals of Biochemistry: Proteolysis of water and hydrogen ion concentration, pH, Buffers;Solution and Colligative properties; *Stabilizing interactions*: Vanderwaals, Electrostatic, Hydrogen bonding and Hydrophobic interactions; *Metabolism and bioenergetics:* Generation and utilization of ATP, coupled reaction, group transfer, biological energy transducers.

UNIT-II

Carbohydrate: Structure, Physical & chemical properties, Biological activity of monosaccharide, oligosaccharide and polysaccharide

UNIT-III

Proteins: Amino acid Classification, structure and properties, Proteins : Primary, Secondary, tertiary and quaternary structure, determination of amino acid sequence, Protein folding.

UNIT-IV

Lipids: Classification, Structure, Physical and chemical properties of essential non essential fatty acids, triglycerides, phospholipids, wax.

Secondary metabolites: Importance of secondary metabolites, biosynthesis of terpenes, phenols and nitrogenous compounds and their roles.

UNIT-V

Enzymes: Nomenclature and Classification of enzymes, Enzyme kinetics: Michaelis-Menten equation and Briggs-Haldane modification; Determination of Km, Competitive, non-competitive and un-competitive inhibition of enzymes, Determination of inhibition constant. Mechanism of action of Chymotrypsin and Ribonuclease, Regulation of enzyme activity (covalent modification, feedback regulation and allosteric control)

Course Learning Outcomes:

Students will be learning about concepts of reaction kinetics, thermodynamics and their biological applications, fundamentals of biochemistry including metabolism and bioenergetics. Students will gain knowledge on structure and properties of carbohydrate, proteins, lipids and secondary metabolites. Students will learn the basics of enzyme kinetics and regulation of enzyme activity.

SWAYAM COURSE

Biomolecules: Structure Fuction in Health and Disease

COURSE LAYOUT

Week 1

Chemical bonds:Different types of Bonds, Bond energies,Bond Angles etc, Water:The molecule of life,Aqueous Solution,Acids & Bases,Measurements of pH, Henderson Haselbatch equation,Titration Curve & pK values,Buffers

Week 2

Amino acids, chirality, peptide bond and polypeptides,Structural levels of proteins and Stabilizing forces,Conformational properties of polypeptides and Ramachandran plot

Week 3

Turns, loops, Super secondary structures, motifs and domains in proteins,Structures and function of Fibrous Proteins,Structure and function of Actin and myosins

Week 4

Hemoglobin, Myoglobin and Oxygen binding,Role of Protein Structure in Health and Disease,Assessment 1

Week 5

Protein Seperation Techniques: Centrifugation & Chromatography,Protein sequencing

Week 6

Methods of structure determination of proteins : X-ray, NMR, CD etc,Clinical Proteomics

Week 7

Antigen-Antibody Complex and their Applications in Immunology,Protein-Ligand(Small Molecules including drugs) interaction

Week 8

Components of Nucleic Acids,Conformational parameters of Nucleic acids and DNA double helix,DNA Polymorphism

Week 9

Circular DNA,Supercoil DNA

Week 10

Interactions of small molecules (ions, drugs) with DNA,Different types and structures of RNA

Week 11

DNA-Protein interactions,Assessment 2

Week 12

Introduction to Carbohydrates,Structures of polysaccharides,Saturated and unsaturated fatty acids, Nomenclature of fatty acids and Essential and non-essential fatty acids

Week 13

Glycoproteins and Proteoglycons,Classification of Lipids: simple and compound lipids, phospholipids, Cholesterol,Micelles and Liposomes : Applications in biology and medicine

Week 14

Lipids: extraction, separation and analysis,Components and architecture of Cell membrane,Various membrane models including Fluid-mosaic model

Week 15

Cholesterol and its role in health and disease, Interrealtionship of Biomolecules : System Biology,Epigenetics and Human Diseases,Final Assessment

PRACTICALS PERTAINING TO THEORY PAPERS -BOT-101, BOT-102, BOT-103 & BOT-104

PAPER*- BOT-105** ***100 Marks/ 6 Credits

Course Objectives: Aim of the course is to impart knowledge on practical aspect of structure of microorganisms, lower plants and vascular plants. Practical skills on analysis of cell cycle, isolation and analysis bio-molecules along with understanding of their biochemistry will be given.

Semester-I (Diversity of Life, Diversity of Vascular Plants, Cell & Molecular Biology of Plants, Plant Physiology & Biochemistry)

Course Learning Outcomes:

Students will gain practical knowledge on microscopic examination microorganisms like bacteria, fungi, and algae. Students will be learning about gametophytic and sporophytic structures of bryophytes, pteridophytes and gymnosperm. Students will be able to isolate and quantify bio-molecule like DNA, RNA, protein, carbohydrate and lipids. Students will be able to identify different stages of cell cycle.

Reference books

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- Smith G M Crptogamic Botany Vol II Bryophytes and Pteridophytes Mc Graw Hill Publ.
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- Mehrothra, R.S. Plant Pathology -Tata McGraw Hill Publishing Co. New Delhi .
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- Vashishtha series for Algae. Fungi Bryophyta Pteridophyta and Gymnosperms S Chand Publ.
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- Boyer, R. (2004). Modern Experimental Biochemistry, 3rd Ed. Pearson Educational Publication, Singapore.
- Taiz, L. and E. Zeiger. 2002. Plant Physiology. 3rd Edition. Sinauer Associates, Inc., Sunderland, MA. 690 pp.
- David Freifielder (1995). Molecular cell biology - 2nd Edition, Narosa publishing House.
- Karp, G. Cell and Molecular Biology: Concepts and Experiments, 2000. John Wiley and Sons, New York.
- Benjamin Lewin, Genes VIII, 2004, Pearson Prentice Hall, New Jersey.
- Harvey Lodish, Arnold Berk, Paul Matsudaira, Chris A. Kaiser, Monty Krieger, Matthew P. Scott, S. Lawrence Zipursky, James Darnell. 2004. Molecular Cell Biology, Fifth Edition, W. H. Freeman and Company, New York.
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- Rangaswamy, D (1988) Disease of crop plants in India, Prentice Hall India, Ltd New Delhi.
- Asada, Y, Bbushnell, NR Ouchi. S, and vance, P (1982) Plant infection. The physiology and Biochemical basis, Springer Verlag, Berlin Nee York.
- Kosuge, T and Nester, EN (1984) Plant microbe interaction – molecular and genetic perspectives, MacMillan, New York.

Semester – II

CYTOGENETICS, PLANT BREEDING & BIOSTATISTICS

PAPER- BOT-201 ***100 Marks/ 6 Credits***

Course Objectives: The paper will deal with chromatin organization, structural and numerical alternation in chromosomes, genetics of prokaryotes and eukaryotic organelles, molecular cytogenetics and regulation of gene expression. Students will be taught about basics of statistical analysis and its application in biological studies.

UNIT-I

Chromatin organization: Chromosome structure, and Models, nucleolus, Euchromatin and heterochromatin, Chromosome banding, telocentric chromosome, isochromosome and B chromosome, Cell cycle, Molecular basis of cell division, Initiation of Meiosis Karyotype and its significance. *Genetic recombination and mapping*: Molecular basis of recombination, Role of Rec A and Rec BCD, physical mapping of genes on chromosomes, sex determination in plants.

UNIT-II

Structural and numerical alternation in chromosomes: Spontaneous and induced mutations, Physical and chemical mutagens, Chromosomal aberrations, Meiotic behaviour of deletion, duplication, inversion and translocation, Molecular basis of gene mutation, DNA damage and repair mechanisms, Euploids and aneuploids-classification, origin, induction, cytological features and genetic analysis, Role of polyploidy in evolution and practical significance in crop improvement. *Plant Breeding*: Method of plant breeding – introduction & selection (Pedegree, back cross, mass selection, bulk method), male sterility and heterosis breeding, mutation breeding.

UNIT-III

Genetics and Prokaryotes and Eukaryotic Oragnelles: Genetic transformation, transduction and conjugation in bacteria, Gene mapping in bacteria, Genetic recombination in bacteriophages and mapping of phage genome, Genetics of mitochondria and chloroplasts, Cytoplasmic male sterility, Transposable genetic elements.

UNIT-IV

Molecular cytogenetics: Nuclear DNA content, C-value paradox, nucleic acid denaturation and renaturation, *Cot* curve and its significance, introns and RNA splicing, Genetic code, Regulation of gene expression in prokaryotes and eukaryotes, Restriction mapping, RFLP, RAPD, AFLP, *in situ* hybridization, Flow cytometry.

UNIT-V

Statistical Methods: Sampling methods, Sampling distribution, parametric and non-parametric statistics, measures of central tendency and dispersion, mean, mode & median, Mean deviations coefficient of variance (CV).Standard deviations, Standard error of mean, probability distribution (normal, binominal and poison), confidence intervals, regression and correlation, tests of significance (t-test, and χ^2 test), analysis of variance.

Course Learning Outcomes: Students will learn about genetic recombination and mapping techniques, karyotype analysis, chromosomal aberrations, DNA damage and repair mechanism. Students will gain knowledge on plant breeding techniques for crop improvement. Students will have basic knowledge on regulation of gene expression, molecular markers and their application. Students will learn about sampling techniques, testing of hypothesis, correlation and regression.

BIOTECHNOLOGY & GENETIC ENGINEERING OF PLANTS

PAPER BOT-202 ***100 Marks/ 6 Credits***

Course Objectives: The paper will deal plant cell, tissue & organ culture, somatic hybridization and cybridization, recombinant DNA technology and genetic engineering of plants. Students will be taught about various instruments and techniques used in biological experiments.

UNIT-I

Plant cell, tissue & organ culture: History, scope and concept of cellular differentiations, totipotency, Fundamental aspects of morphogenesis: organogenesis and somatic embryogenesis, Clonal propagation, Artificial seeds. Androgenesis and production of haploids, Callus and cell suspension culture, Production of somaclonal variants, production of secondary metabolites in cultures, Cryopreservation.

UNIT-II

Somatic hybridization and cybridization: Factors affecting protoplast isolation, culture and plant regeneration, Protoplast fusion-chemical fusion & electrofusion mechanism & techniques, Selection of heterokaryotic fusion products, biochemical selection and physical selection (micromanipulation, flow cytometric characterization and cell sorting), Analysis of hybrids, Somatic hybrids and cybrids for crop improvement.

UNIT-III

Recombinant DNA technology: Gene cloning-principles, Cloning vectors-plasmids, phages, cosmids & phagemids; Artificial chromosomes, Polymerase Chain Reaction-principles, types and applications, RT-PCR; Genomic and c DNA libraries; Construction of recombinant DNA molecules and their mobilization into bacteria; Analysis of recombinant clones, DNA sequencing.

UNIT-IV

Genetic Engineering of plants: Methods for gene transfer to plants, *Agrobacterium* mediated and direct gene delivery, Gene tagging, detection of foreign gene and gene products; Southern blotting, Northern blotting and Western blotting; Chloroplast transformation, Gene targeting, Transgenic plants for crop improvement, possible ecological risks and ethical concerns.

UNIT-V

Biological methods: UV/Visible Spectrophotometry, Atomic Absorption Spectrophotometry fluorescence spectroscopy, NMR & ESR Spectroscopy, Mass Spectrometry, Electrophoresis, ELISA, Electron Microscopy–Scanning and transmission, Image processing, Chromatography. Centrifugation techniques, pH Electrode. Northern, Southern and Western Hybridization.

Course Learning Outcomes: Students will learn about clonal propagation, production of haploids, somaclonal variants, development of somatic hybrids and cybrids for crop improvement. Students will gain knowledge on recombinant DNA technology and agrobacterium mediated gene transfer for development of transgenic plants. Students will learn techniques like electrophoresis, blotting techniques, spectroscopy, chromatograph, ELISA etc.

PLANT PHYSIOLOGY

PAPER -BOT-203 ***100 Marks/ 6 Credits***

Course Objectives: The course aims to educate student on concepts membrane transport, translocation of water and solutes, photosynthesis, respiration, lipid and nitrogen metabolism, sensory photobiology, plant growth regulators and mechanism of flowering.

UNIT-I

Membrane transport and translocation of water and solutes: Uptake, transport and translocation of water, ion, solutes and macromolecules by membrane transport through xylem and phloem; transpiration and stomatal movement, mechanism of loading and unloading of photoassimilates.

UNIT-II

Photosynthesis: Photosynthetic pigments and light harvesting complexes, mechanism of electron transport, photoprotective mechanisms; CO_2 fixation: C_3, C_4 and CAM pathways, Photorespiration.

UNIT-III

Respiration and lipid metabolism: Glycolysis, TCA cycle, electron transport and ATP synthesis, alternate oxidase system, structure and functions of lipids, fatty acid biosynthesis, structure and function of carbohydrates.

UNIT-IV

Nitrogen metabolism: Biological nitrogen fixation, mechanism of nitrate uptake and reduction, nitrate and ammonium assimilation, amino acid biosynthesis.

Sensory Photobiology: Pigments as photoreceptors, structure, function and mechanisms of action of phytochromes, cryptochromes and phototropins, photoperiodism

Stress Physiology: Responses of plants to biotic (pathogen and insects) and abiotic (water temperature and salt) stresses. Metal toxicity, oxidative stress.

UNIT-V

Flowering and Senescence: Mechanism of flowering, Vernalization, biological clocks. Molecular mechanism of senescence and aging in plants.

Plant Growth regulators: Biosynthesis, storage, breakdown and transport of plant hormones; Mechanism of action, physiological effects and applications of plant growth regulators. Growth movement, measurement and indices.

Course Learning Outcomes: Students will learn about mechanism of membrane transport, transport through xylem and phloem, mechanism of photosynthesis, respiration and nitrogen metabolism. Students will gain knowledge on stress physiology, photoreceptors, flowering and senescence in plants.

PLANT TAXONOMY, ECOLOGY & EVOLUTION

PAPER- BOT-204 ***100 Marks/ 6 Credits***

Course Objectives: The course aims to add to understanding of the students about the nomenclature, classification and diversity of flowering plants. Students will be taught about ecosystem, population and community ecology. Students will be exposed to concepts of evolution and population genetics.

UNIT-I

Nomenclature : The species concept, delimitation of taxa and attribution of ranks, salient features of ICBN, relevance of taxonomy to conservation, herbarium and floras, herbarium methodology, important herbaria of the world. Phenetic and phylogenetic systems of classification, relative merits and demerits of major system of classification, cladistics in taxonomy, Molecular taxonomy.

UNIT-II

Taxonomic evidence: Morphology, palyonology, anatomy, embryology, cytology and Phytochemistry. *Range of floral structures*: Ranales, Rosales, Asterales, Scitaminae and Orchidales

UNIT-III

Physical and biotic environment, Biotic and abiotic interactions, concept of habitat and niche, niche width and overlap, fundamentals and realized niche, resource partitioning and character displacement, Population characteristic, population growth curves, population regulation, life history strategies (r and k selections), concept of metapopulation- Demes, Dispersal. Interdemic extinctions, age structure populations.

UNIT-IV

Community ecology: nature, structure and its attributes, levels of species diversity and its measurement. Edges and Ecotones, ecological succession: types, mechanism, changes involved in succession, climax concept. *Ecosystem Ecology:* Structure, function, energy flow, mineral cycling (C, N, P), Primary Production and decomposition, structure and functions of Indian ecosystems: terrestrial (forest and grassland) and aquatic (fresh water, marine and estuarine).

UNIT-V

Evolution: Lamark and Darwin concept of variation, adaptation and natural selection, evolution of prokaryotes, origin and evolution of eukaryotes, origin and development of major group of organisms in geological time scale, molecular evolution.

Population genetics: Populations, Gene pool, Gene frequency; Hardy-Weinberg Law; Adaptive radiation; Isolating mechanisms; Speciation; Allopatricity and Sympatricity; Convergent evolution; Sexual selection; Co-evolution.

Course Learning Outcomes: Students will learn about ICBN and rules for plant nomenclature, merits and demerits of major system of classification, Taxonomic evidence and range of floral structures of different orders. Students will gain knowledge on habitat, population characteristics, structure and attributes of community, ecological succession, structure and function of ecosystem. Students will learn about theories of evolution and maintenance of gene frequency in population.

PRACTICALS PERTAINING TO THEORY PAPERS - BOT-201, BOT-202, BOT-203, BOT-204

PAPER*- BOT-205** ***100 Marks/ 6 Credits

Course Objectives: Aim of the course is to impart knowledge on practical aspect of karyotype chromosomal aberrations, micropropagation, electrophoresis, spectrophotometry, identification of plants and community analysis.

Semester-II ***(Cytogenetics, Plant Breeding & Biostaticstics, Biotechnology & Genetic Engineering of Plants, Plant Physiology, Plant Taxonomy, Ecology & Evolution)***

Course Learning Outcomes:

Students will gain hand on training on identification of chromosomal aberrations, karyotyping, photosynthetic pigment isolation and quantification, aseptic techniques in clonal propagation, taxonomic identification of flowering plants, chromatographic techniques for separation of compounds and quantitative analysis of plant communities in various ecosystems.

Reference books

- Glick, B. R. and Pasternak (2003). Molecular Biotechnology: Principles and Applications of Recombinant DNA. ASM Press, Washington, D. C., USA.
- Kyte, L. and Kleyn, J. (1996). Plants From Test Tube to: an Introduction to Micropropagation, 3rd Ed. Timber press, Port land, USA.
- Pollard, W. J. and Walker (1990). Plant Cell and Tissue Culture Vol VI. Humana press Clifton, USA.
- Subramanyam N.S. (1995). Modern Plant Taxonomy, 1st Edition, Vikas Publication House Pvt Ltd. Publisher
- Sharma O.P. (2009). Plant Taxonomy, 2nd Edition Tata McGraw Hill Publisher
- Sambamurty, A. V. S. S. (2005). Taxonomy of Angiosperms. I. K. International Pvt.Ltd., New Delhi.
- Mitra, J.N. (1964). An Introduction to Systematic, Oxford & IBH Publishers, New Delhi, Calcutta-823pp
- Lawrence G.H. (1951) Taxonomy of Vascular Plants. 1st edition. Prentice Hall College Div Publishers, ISBN-13: 978-0023681905, 823 pp.
- Sharma, P.D. (1991)..Ecology and Environment. 10th ed. 2005. Rastogi Publications, ISBN, 8171339050, 9788171339051. 640 pp.
- M.C. Dash. (2004) Fundamentals of Ecology. 4th Edition Mc Graw Hill Education publishers. 504pp.
- Gomez, K. A. and Gomez, A. A. ((1984). Statistical Procedures for Agricultural Research, 2nd Ed. John Weley, New York.
- Kormondy, E. J. (1996). Concepts of Ecology, Prentice-Hall India, New Delhi.

- Odum, E. P. (1971). Fundamentals of Ecology, Saundas, Philadelphia, USA.
- Misra, B. N. and Misra, M. K. (1998). Introductory Practical Biostatistics, Naya prokash, kolkata.
- Smith, R. L. (1996). Ecology and Field Biology. Harper Collins, New York.
- Subrahmanyam, N. S. and Sambamurty, A. V. S. S. (2000). Ecology. Narosa, New Delhi.
- Kothari, A. (1997). Understanding Biodiversity: Life sustainability and Equity. Orient Longman, New york.
- Negi, S. S. (1993). Biodeiversity and its Conseravation in India. Indus Publishing Company, New Delhi.
- Simmonds, N. W. (1979). Evolution of Crop Plants. Longman, New York.
- Bewley, J.D. and Black, M. (1994). Seed: physiology of Development and Germination. Plenum, New York.
- Bhojwani, S.S. and Bhatnagar, S. P. (2008). The Embryology of Angiosperms. Vikas Publishing House, New Delhi.
- Raghavan, V (1997). Molecular Embryology of Flowering Plant. Cambridge University Press, Cambridge.
- Raghavan, V. (1999). Developmental Biology of Flowering Plants. Springer-Verlag, New York.
- K. Wilson and Walker J. Practical Biochemistry- Principles and Techniques. 5th Edn. Tata Mc. Graw Hill Publishers.
- P. Maheshwari (1950). Introduction to the Embryology and Angiosperms. Mc Graw Hill NY.

Semester – III

PLANT DEVELOPMENT AND REPRODUCTION, ECONOMIC BOTANY

PAPER- BOT-301 ***100 Marks/ 6 Credits***

Course Objectives:

Aim of the course is to educate students regarding differentiation of meristematic tissues, developmental biology, reproductive biology and economic botany of the flowering plants.

UNIT-I

Differentiation and Development: Difference between animal and plant cell development with unique features in plant cell development, use of mutants in seedling development; Molecular analysis of shoot apical meristem; root apical meristem & leaf growth, transition to flowering, vascular tissue differentiation of root, shoot & leaf, Floral development & homoeotic mutants in *Arabidopsis* & *Antirrhinum.*

UNIT-II

Developmental Biology: Molecular and cytological analysis of endosperm & fruit development, fruit ripening and its manipulation; polyembryony, apomixes, seed germination; seed dormancy, bud dormancy, types & programmed cell death in life cycle of plants, metabolic changes associated with senescence and its regulation. Influence of hormones & environmental factors on senescence.

UNIT-III

Male gametophyte: Structure of anthers, microsporogenesis, role of tapetum, pollen development, male sterility, male nuclei dimorphism and hybrid seed production, pollen germination, pollen tube growth and guidance, pollen storage, pollen allergy, pollen embryos.

UNIT-IV

Female gametophyte: Ovule development, megasporogenesis, organization of the embryo sac, structure of the embryo sac cells, floral characteristics, pollination mechanisms and vectors, breeding systems, structure of pistil. *Developmental Embryology:* pollen-stigma interactions, sporophytic and gametophytic self incompatibility (cytological, biochemical and molecular aspects), double fertilization, *in vitro* fertilization.

UNIT-V

Economic Botany: Origin and domestication of cultivated plants, world centres of diversity of domesticated plants, plant introduction and secondary centre origin, evolution and uses of food, forage, fodder, fibre and oil-yielding crops. Uses of medicinal and aromatic plants, Important firewood and timber yielding plants and nonwood forest products, plants used as avenue trees for shade, pollution control and aesthetics.

Course Learning Outcomes: Students will learn about plant cell development, differentiation of apical meristems & vascular tissues, flower development and its genetic regulation. Students will gain knowledge on development of fruit, senescence and its regulation, development of male and female gametophyte, pollen-stigma interactions and double fertilization. Students will learn about centre of origin of plants and various economic uses of domesticated and wild plants.

CONSERVATION BIOLOGY

PAPER -BOT-302 ***100 Marks/ 6 Credits***

Course Objectives:

Aim of the course is to educate students regarding biodiversity, resource conservation, biodiversity conservation strategies, intellectual property rights (IPR) and their protection.

UNIT-I

Concepts and concerns of biodiversity, biodiversity status, monitoring and documentation, major drivers of biodiversity changes, plant introduction, Invasion and its impact on biodiversity, biodiversity mapping

UNIT-II

Resource conservation: Survey and regeneration of bioresources, endemism and hot spots, endangered plants, red data book, convention of biological diversity.

Principles of conservation, extinction, environmental status of plants based on IUCN, Salient features of Biodiversity Act and rules. Strategies for resources conservation and management strategies.

UNIT-III

In situ conservation: International efforts and Indian initiatives; protected areas in India – Sanctuaries, national parks, biosphere reserves, wetlands and mangroves for conservation of wild biodiversity.

UNIT-IV:

Ex situ conservation: Principles and practices; botanical gardens, field gene banks, seed banks, cryobanks, general account of the activities of Botanical Survey of India (BSI), National Bureau of Plant Genetic Resources (NBPGR). ICAR, CSIR, DBT and ICRISAT.

UNIT-V

Intellectual Property Rights and their Protection: Sovereign Rights, copyrights, trademarks, trade secrets, patents, geographical indications, etc; Protection of plant variety and farmers right act; Indian patent act and amendments, patent filing; Patenting of biological materials.

Course Learning Outcomes: Students will learn about importance of biodiversity and drivers of biodiversity change, convention of biological diversity, IUCN categories of plants, Biodiversity Act and rules, Strategies for resources conservation and management, *in situ and ex situcoservation.* Students will gain knowledge on various types of IPR and their protection strategies.

Free Elective:

PLANTS AND ENVIRONMENT

PAPER -BOT-303 (A) ***100 Marks/ 6 Credits***

Course Objectives:

Aim of the course is to educate students regarding environment and the plants, plants for environmental protection, phytoremediation and phytomining, environmental pollution bioenergy and aerobiology.

UNIT-I

Environment and the plants: concept of environment and its components: atmosphere, hydrosphere, lithosphere and biosphere, physical and chemical environment. *Biogeography:* Major terrestrial Biomes (Vegetation types of the world and India), theory of Iceland Biogeography, Biogeographical zones of India.

UNIT-II

Plants for environmental protection: salt tolerant plants (Mangroves) and their role for environmental protection, nature and characteristics of mangroves and their distribution in India (Sundarban and Bhitarkanika), deforestation and afforestation, social forestry, agroforestry, waste land and mine reclamation.

UNIT-III

Phytoremediation and Phytomining: concept and definition of Phytoremediation and Phytomining, methods of phytoremediation: phytoextraction, rhizofiltration, phytodetoxification, phytovolatilization, role of hyperaccumulators, biomining and bioleaching.

UNIT-IV

Environmental pollution: Environmental pollution (Water, air and soil), urban air quality, green house effects, GHG emission and climatic changes, remote sensing and its application in plants and environment, Agro-meteorology.

Plants and pollution control: Bioindicators of water and air pollution: Algae and lichens as indicator plants, role of lichens on phytoair monitoring, insecticidal plants, plants as natural pesticides.

UNIT-V

Bioenergy and aerobiology: concept of biomass and bioenergy, energy plantation, petro plants, bioethanol and methane production, energy from solar and wind sources, rain water harvesting technology. Aerobiology: importance and scope of aerobiology, aerobiology and crop diseases, aerobiology and pollen allergy.

Course Learning Outcomes: Students will learn about components of environment, biogeography and biogeographical zones of India, mangroves and their role for environmental protection, phytoremediation and phytomining, methods. Students will gain knowledge on pollution of water, air and soil, remote sensing and its application in plants and environment, plants and pollution control, biomass and bioenergy, aerobiology and pollen allergy.

ENVIRONMENTAL STUDIES

PAPER-BOT-303 (B) ***100 Marks/ 6 Credits***

Course Objectives:

Aim of the course is to educate students regarding fundamentals of environmental studies and ecology, environmental pollution control and monitoring, natural resources and management, environmental hazards, risk and disaster management, environmental laws and awareness.

UNIT-I

Foundation courses of environmental studies and fundamentals of ecology: Definition, concept and scope of Environmental studies. Different components of the environment: Atmosphere, Hydrosphere, Lithosphere and Biosphere. Concept of ecosystem, its biotic and abiotic components, anthropogenic activities and ecosystem degradation. Environmental protection and sustainable development.

UNIT-II

Environmental pollution control and monitoring: Concept and definition of environmental pollution : Air, Water and Soil. Natural and anthropogenic sources of environmental pollutants. Methods of their monitoring and control.

UNIT-III

Natural resources and management: concept of natural resources, renewable and nonrenewable resources, mineral and water resources in India with special reference to Odisha and their exploitation, bioenergy resources, energy from biomass and biogas, energy plantation, petro plants, bioethanol and methane production, energy from solar and wind sources, rain water harvesting technology.

UNIT-IV

Environmental hazards, risk and disaster management: Environmental hazards: definition of hazard and disaster, environmental hazards: natural and technological hazards. Management of hazardous wastes, *Risk analysis:* concept of risk analysis types of models for risk analysis, their characteristics and salient features, guidelines for conducting risk analysis, *Disaster management:* concept of disaster management plan and the guidelines, disaster assistance.

UNIT-V

Environmental laws and awareness: Environmental laws: Environmental protection act, water act., air act., land requisition policies and acts, forest laws and wild life protection act, rehabilitation and resettlement policies, biomedical waste disposal act and municipality solid waste disposal act, *Environmental education and awareness:* environmental ethics and global imperatives.

Course Learning Outcomes: Students will learn about components of the environment, Concept of ecosystem, Environmental protection and sustainable development, sources, monitoring and control of environmental pollution, renewable and nonrenewable resources, environmental hazards and disaster management, environmental laws, environmental education and awareness.

Allied Elective:

PLANT PHYSIOLOGY AND DEVELOPMENTAL BIOLOGY

PAPER-BOT-304 ***100 Marks/ 6 Credits***

Course Objectives:

Aim of the course is to educate students of allied subjects regarding fundamental of plant physiology and development.

UNIT-I

Photosynthesis: Photosynthetic pigments and light harvesting complexes, mechanism of electron transport, photoprotective mechanisms; CO_2 fixation: C_3, C_4 and CAM pathways, Photorespiration.

UNIT-II

Sensory Photobiology: Pigments as photoreceptors, structure, function and mechanisms of action of phytochromes, cryptochromes and phototropins, photoperiodism

Flowering and Senescence: Mechanism of flowering, Vernalization, biological clocks. Molecular mechanism of senescence and aging in plants.

UNIT-III

Plant Growth regulators: Biosynthesis, storage, breakdown and transport of plant hormones; Mechanism of action, physiological effects and applications of plant growth regulators. Growth movement, measurement and indices.

UNIT-IV

Male gametophyte: Structure of anthers, microsporogenesis, role of tapetum, pollen development, pollen germination, pollen tube growth and guidance, pollen storage, pollen allergy.

UNIT-V

Female gametophyte: Ovule development, megasporogenesis, organization of the embryo sac, structure of the embryo sac cells, structure of pistil, *Developmental Embryology:* pollen-stigma interactions, sporophytic and gametophytic self incompatibility, double fertilization, *in vitro* fertilization.

Course Learning Outcomes: Students will learn about physiology of photosynthesis, flowering and senescence, mechanism of action of plant growth regulators, development of male and female gametophyte and the process of fertilization.

ADVANCED PRACTICALS

PAPER- BOT-305

Course Objectives: Aim of the course is to impart knowledge on advanced practical relating to plant embryology, tissue culture, microbiology, molecular biology and biochemistry.

1. T. S. / L. S. of Anther, Ovary and Ovule of angiosperms
2. Observation of permanent slides related to embryology
3. Microtome of RAM and SAM, material fixation, block preparation, section cutting and staining
4. *In-vitro* germination of pollen grains
5. DNA isolation and Purification, quality check in spectrophotometer and gel electrophoresis
6. PCR analysis
7. Tissue culture techniques, media preparation, different stages
8. Karyotype analysis, chromosomal anomaly, commet assay
9. Microbial culture, Gram staining, endospore staining, Micorrhiza fungi staining
10. Antimicrobial assay
11. Isolation, purification and algal culture
12. Quantitative analysis of protein, carbohydrate, chlorophyll, proline, sugar etc.
13. Phytochemical isolation, qualitative and quantitative analysis of phytochemicals by Spectrophotometer/TLC/HPLC etc
14. Protoplast isolation and fusion
15. Synthetic seed preparation/ immobilization technique

Course Learning Outcomes:

Students will gain hand on training on Microtome, germination of pollen grains, isolation and Purification DNA, PCR , electrophoresis, commet assay, antimicrobial assay Quantification of protein, carbohydrate, chlorophyll, proline, sugar etc., phytochemical analysis by TLC/ HPTLC, micropropagation and synthetic seed preparation.

Semester-III (Plant Development, Reproduction and Economic Botany,* Conservation Biology, *Plant Physiology and Developmental Biology, Plants and Environment / Environmental Studies)

Reference books

- Krishnamurthy, K.V. 2004. An advanced textbook on Biodiversity Principles and Practice. Oxford and IBH Publishing Co. Pvt. Ltd.
- Das, R. C., Baral. J. K., Sahu, N. C. and Misra, M. K. (1998). The Environmental Divide: The Dilemma of Developing Countries. A. P. H. Publication, New Delhi.
- Heywood, V. H. and Watson, R. T. (1995). Global Biodiversity Assessment. Cambridge University Press, UK.
- Hill, M. K. (1997). Understanding Environmental Pollution. Cambridge University Press, UK.
- Mason, C. F. (1991). Biology of Freshwater Pollution. Longman, New York.
- K.V. Krishnamurthy An Advanced Textbook on Biodiversity Principles and Practice, Oxford & IBH Publishing Co. Pvt. Ltd.
- Gomez, K. A. and Gomez, A. A. ((1984). Statistical Procedures for Agricultural Research, 2nd Ed. John Weley, New York.
- Misra, B. N. and Misra, M. K. (1998). Introductory Practical Biostatistics, Naya prokash, kolkata

Semester – IV

CORE ELECTIVE PAPER (OPTIONAL): A student has to select Paper-BOT-401 & BOT-402 from anyone of the followings Biochemistry and Molecular Biology / Biotechnology and Plant Genetic Manipulation / Cytogenetics and Cell Biology/ Environmental Biotechnology / Microbial Technology / Biosystematics

BIOCHEMISTRY AND MOLECULAR BIOLOGY-I

PAPER-BOT-401 (A) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student about various bio-molecules such as amino acid, proteins, enzymes, carbohydrate and lipid metabolism and basics of immunology.

UNIT-I

Amino acids: Classification, structure and properties, Proteins: Primary, Secondary, tertiary and quaternary structure, determination of amino acid sequence, Protein folding.

UNIT-II

Enzymology: extraction, assay and purification of enzymes; Enzyme kinetics: Michaelis-Menten equation and Briggs-Haldane modification; Determination of Km, Competitive, non-competitive and un-competitive inhibition of enzymes, Determination of inhibition constant. Mechanism of action of Chymotrypsin and Ribonuclease, Regulation of enzyme activity (covalent modification, feedback regulation and allosteric control), Industrial and clinical application of enzymes.

UNIT-III

Carbohydrate Metabolism: Regulation of Calvin cycle, HSK pathway, CAM pathway, Glycolysis, TCA cycle and oxidative pentose phosphate pathway, electron transport chain (Chloroplast and Mitochondrial), photophosphorylation and oxidative phosphorylation, Hydrolysis and biosynthesis of starch and sucrose.

UNIT-IV

Lipid Metabolism: Biosynthesis and hydrolysis of triacylglycerols, structural lipids of membrances, fatty acids; Oxidation of fatty acids; Gluconeogenesis. Cell signaling and signal transduction.

UNIT-V

Immune system: Lymphocytes and accessory cells, Immunoglobulins, MHC, Toll like receptors, mechanism of immune response and generation of antibody diversity, Effectors, complements, hypersensitivity and autoimmunity, AIDS and other immunodeficiency, vaccines, Hybridoma and Mabs, Immunological techniques (ELISA, RIA, western blot, immunoprecipitation, FISH and GISH.

Course Learning Outcomes:

Students will be learning about protein conformation, enzyme kinetics, regulation of enzyme activity, regulation of carbohydrate metabolism, oxidation of fatty acids, cell signaling and signal transduction. Students will gain knowledge on immunoglobulins, mechanism of immune response, vaccines and immunological techniques.

BIOCHEMISTRY AND MOLECULAR BIOLOGY-II

PAPER- BOT-402 (A) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on DNA replication, transcription, translation, gene regulation, genetic marker, antisense and ribozyme technology.

UNIT-I

DNA replication, Transcription: Enzymes and necessary protein in DNA replication, DNA damage, repair and recombination, Prokaryotic and eukaryotic transcription mechanisms, posttranscriptional modification of RNA, Nuclear export of m-RNA.

UNIT-II

Translation: Prokaryotic and eukaryotic translation, Regulation and posttranslational modification of proteins, protein import into nucleus, chloroplast, mitochondria and peroxisomes. Aminoacylation of tRNA, tRNA-identity, aminoacyl tRNA synthetase, and translational proof-reading, translational inhibitors.

UNIT-III

Gene Regulation: Regulation of gene expression in prokaryotes and eukaryotes (lac-operon, trp-operon, ara-operon, attenuation and anti-termination).

UNIT-IV

Genetic Marker: t-DNA and transposon tagging, targeted gene replacement, augmentation, gene knockout, vector engineering, gene correction and editing, molecular makers in genome analysis, (RFLP, RAPD and AFLP, ISSR and SSR and SNP).

UNIT-V

Antisense and Ribozyme technology: Molecular mechanism of antisense molecules, inhibition of splicing, polyadenylation and translation, disruption of RNA structure and capping. Biochemistry of ribozyme (hammer-head, hairpin and other ribozymes), designing of ribozymes. Applications of antisense and ribozyme technologies.

Course Learning Outcomes:

Students will be learning about DNA replication, DNA damage, repair and recombination, Prokaryotic and eukaryotic translation, regulation of gene expression in prokaryotes and eukaryotes, gene correction and editing, molecular makers in genome analysis, designing of ribozymes, applications of antisense and ribozyme technologies.

PLANT BIOTECHNOLOGY **-I**

PAPER-BOT-401 (B) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on plant cell, tissue & organ culture, somatic hybridization and cybridization, techniques in molecular biology, recombinant DNA technology, vector-mediated gene transfer to plants.

UNIT-I

Plant Cell, Tissue & Organ Culture: Micropropagation, Callus-mediated organogenesis, Adventitious organogenesis, Somatic embryogenesis, Synthetic seeds, Haploids through anther, microspore & ovary culture, Embryo rescue, Somaclonal variation, Cell suspension culture.

UNIT-II

Somatic Hybridization and Cybridization: Protoplast isolation and culture, chemical & electro fusion of protoplasts : Principle and techniques, Post-fusion selection, Characterization of somatic hybrids, Asymmetric hybrids & cybrids, Somatic hybrids and cybrids for crop improvement.

UNIT-III

Techniques in Molecular Biology . Genomic DNA & plasmid DNA isolation and purification, PCR, RNA isolation and m-RNA capture, RT-PCR, RACE($3^{'}5^{'}$), Gel extraction and purification of cDNA from agarose gel, DNA Sequencing : Maxam – Gilbert's methods, Sanger's method, Automatedsequencing. Protein analysis : SDS-PAGE, 2-D Gel electrophoresis. Pulse Field Gel electrophoresis, Mass spectrometry.

UNIT-IV

Recombinant DNA Technology: Cloning vectors (plasmids, lambda & M13 phage DNA, cosmids, phagemids, artificial chromosomes-YAC, BAC, PAC), Construction of recombinant DNA and expression cassettes, Mobilization of vectors into competent bacteria, Selection and analysis of recombinant clones, Genomic DNA and cDNA libraries

UNIT-V

Vector-mediated Gene Transfer to Plants: Plant virus vectors, Molecular basis of crown gall and hairy root diseases, Features of Ti and Ri plasmids of *Agrobacterium*, Mechanism of T-DNA transfer, Role of virulence genes, Hairy root cultures as source of pharmaceuticals, Vectors based on pTi & pRi, Binary and co-integrate vectors.

Course Learning Outcomes:

Students will be learning about micropropagation, microspore & ovary culture, embryo rescue, somaclonal variation and cell suspension culture, protoplast isolation, culture and fusion, DNA isolation and purification, RT-PCR, PCR, DNA Sequencing, SDS-PAGE, Cloning vectors Construction of recombinant DNA and expression, Mechanism of T-DNA transfer, Vectors based on pTi & pRi.

PLANT BIOTECHNOLOGY -II

PAPER-BOT-402 (B) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on transgenic plants, DNA based Markers, Genomics and Proteomics, DNA Microarray and Intellectual property Rights (IPR).

UNIT-I

Chemically-stimulated DNA uptake by Protoplasts (Liposome, Calcium phosphate precipitation, PEG). Physical methods (Electroporation, Ultrasonication, Silicon carbide fibers, Microlaser, Microinjection, Microprojectile bombardment). Transgenic monocots and dicots via direct gene transfer.

UNIT-II

DNA based Markers: Molecular markers based on DNA restriction-hybridization (RFLP), PCR (RAPD, SSR, STM, RAMP, SCAR, CAPS, SNP), and combination approach (AFLP), DNA finger printing, Characterization of genetic diversity and phylogenetic relationship, Identification and mapping of QTLs, gene tagging, Marker assisted selection for plant breeding.

UNIT-III

Genomics and Proteomics: Molecular genetic maps of major crop plant population, Physical maps using YACs, BACs and *in situ* hybridization, Whole genome sequencing and plant genome projects (*Arabidopsis*, rice, maize and legumes), Functional genomics, proteomics : Resolution & characterization of proteins, Post translational modifications, Protein chips, Protein-protein interactions.

UNITI-IV

DNA Microarray (Gene Chip) Technology: Concept and features, Oligonucleotides and cDNA-based chips, Hybridization and detection methods, Applications of microarrays in DNA sequencing, DNA sequence databases & protein sequence databases,

UNITI-V

Intellectual property Rights (IPR) and its protection: IPR forms of protection of Intellectual Property, Patenting of biological material, plant variety rights and protection. Farmer's and plant breeders rights, Terminator Seed Technology.

Course Learning Outcomes:

Students will be learning about chemical and physical method of DNA transfer, molecular markers, genetic maps, functional genomics and proteomics, gene chip technology.

CYTOGENETICS -I

PAPER-BOT-401 (C) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on genetic material, chromosome, polyploidy, DNA replication and repair, translation and post-translational modifications, techniques in molecular biology & recombinant DNA technology.

UNIT I

Historical developments of molecular biology; Nucleic acids as genetic material; Chemistry, structure and properties of DNA and RNA. Chromosome physical structure and karyotype analysis; Cytometry, Flow cytometry in karyotype analysis.

UNIT II

Polyploidy; Classification, cytological and genetical method of identification of autopolyploids and allopolyploids. Classification, method of production, identification and meiotic behaviour of aneuploids (Monosomics, Nullisomics and trisomics). Structural alteration in chromosome : Deletion, Duplication, Inversion & Translocation, hetrozygote.

UNIT III

DNA replication; DNA polymerases, topoisomerases, DNA ligase, etc; Molecular basis of mutations; DNA repair mechanisms; Extra chromosomal inheritance, Male sterility and incompatibility; Recombination in bacteria, fungi and viruses, tetrad analysis, functional genomics; DNA array, transcriptome, proteomics.

UNIT IV

Translation and post-translational modifications; Operon concept; Attenuation of *trp* operon; important features of gene regulation in eukaryotes; promoter, Gene concept, Gene regulation, Genes in development; Transcription process; RNA processing; Reverse transcriptase; RNA editing; Ribosomes structure and function; Genetic code; Aminoacyl tRNA syntheses

UNIT V

Techniques in Molecular Biology & Recombinant DNA technology: Genomic DNA & plasmid DNA, isolation and purification, PCR, RNA isolation and m-RNA capture, RT-PCR, RACE (3'/5'), Gel extraction and purification of cDNA from agarose gel, cloning vectors (plasmids, lambda & M13 phage DNA, cosmids, phagemids, artificial chromosomes - YAC, BAC, PAC), construction of recombinant DNA and expression cassettes, Mobilization of vectors into competent bacteria, Selection and analysis of recombinant clones, Genomic DNA and cDNA libraries. DNA Sequencing: Maxam - Gilbert's methods, Sanger's method, Automatedsequencing. Protein analysis: SDS-PAGE, 2-D Gel electrophoresis, Pulse Field Gel electrophoresis, Mass spectrometry.

Course Learning Outcomes:

Students will be learning about structure and properties of DNA and RNA, autopolyploids and allopolyploids, structural alteration in chromosome, DNA replication and repair mechanisms, gene regulation in eukaryotes, DNA isolation and purification, RT-PCR, PCR, DNA Sequencing.

CYTOGENETICS -II

PAPER-BOT-402 (C) *100 Marks/ 6 Credits*

Course Objectives:

The course aims to educate student on Cell cycle, Recombinant DNA technology, transcription and translation, inheritance of quantitative traits, antisense RNA & ribozyme technology.

UNIT I

Cell cycle, Regulation, Call division, Structural and numerical changes in chromosomes; Nature, structure and replication of the genetic material; Organization of DNA in chromosomes, Variation of chromosome number, B-chromosomes, Physical mapping of chromosome, *In situ* hybridization - concept & Techniques.

UNIT II

Recombinant DNA technology; Genetic fine structure analysis. Split genes, Transposable genetic elements, Overlapping genes, Pseudogenes, Oncogenes, Gene families; An overview of some recent discoveries in the field of genetics; Cell signaling.

UNIT III

Structure of mRNA, rRNA & t RNA, replication of RNA. Splicing, transport of RNAs, RNA editing. Extra chromosomal inheritance, Ribosome: Structure biogenesis. Protein synthesis: Mechanism of translation (initiation, elongation and termination). Post translational modification, protein targeting to organelles. Regulation of protein synthesis at transcription and translation level in prokaryotes & eukaryotes.

UNIT IV

Inheritance of quantitative traits; Concepts in population genetics; Genes and behavior; Genetics and crop evolution; Crop breeding techniques, Male sterility and incompatibility; Recombination in bacteria, fungi and viruses, tetrad analysis. Marker Assisted Selection (MAS), QTL mapping, PCR techniques; RAPD, SSR, ISSR, EST; AFLP; RFLP markers, Genetic map.

UNIT V

Antisense RNA & Ribozyme Technology: Regulatory RNA (micRNA) in prokaryotes, antisense RNA, construction of antisense expression vectors, analysis of antisense clones, Ribozyrne, applications of antisense RNA and Ribozyme technology, Transposons and Gene tagging: Transposable genetic elements in bacteria. Class I & II genetic elements in eukaryotes, Transposon, gene tagging.

Course Learning Outcomes:

Students will be learning about cell cycle and its regulation, Genetic fine structure analysis. Split genes, replication of RNA and splicing, post translational modification, population genetics, antisense RNA technology and its application.

ENVIRONMENTAL BIOTECHNOLOGY-I

PAPER-BOT-401(D) *100 Marks/ 6 Credits*

Course Objectives:

The course aims to educate student on environmental biotechnology, atmospheric chemistry and air pollution, soil pollution, water pollution and their control, aquaculture technology and application.

UNIT-I

Environmental Biotechnology: Scopes and issues, Ecosystem functioning, Ecosystem approach in Environmental management; Environmental Impact Assessment (EIA), Environmental Management Plan (EMP)

UNIT-II

Atmospheric chemistry and air pollution: Composition of air, major regions of atmosphere, photochemical reactions, photochemical smog, sources and types of air pollutants, acid rain, ozone depletion, green houses gases. *Air pollution and its control*: Sampling and analysis of air pollution from ambient air and point sources, technological methods of air pollution control, particulate emission control, gas emission control, Role of plants in air pollution control.

UNIT-III

Soil pollution and control: Soil structure and soil profile, Physico-chemical properties, soil conservation, soil pollution and its control, soil remediation and disposal. *Solid waste processing technology*: Solid wastes sources and composition, classification, aerobic and anaerobic composting, reactor and non-reactor composting, biogas generation, vermiculture, Solid waste reuse, management of urban and industrial solid waste.

UNIT-IV

Water pollution and control: Surface water resources surface water degradation, eutrophication, waste water collection and treatment, physical, chemical and biological processes, measurement of water pollution, anaerobic sludge treatment. *Waste water treatment processes*: Development of treatment processes, oxidation, nitrification, denitrification, secondary treatment plants, wastewater recycling, recycling, algae-fish and duck weed system, waste water as resources, batch reactor.

UNIT-V

Aquaculture technology: Waste water use in aquaculture, algal species for culture, culture systems, autotrophic – heterotrophic cultivation. Open cultivation systems, photobioreactors, harvesting and preservation, bioaugmentation. Remote sensing and its application.

Course Learning Outcomes:

Students will be learning about Environmental Impact Assessment (EIA), Environmental Management Plan (EMP), major regions of atmosphere, technological methods of air pollution control, Soil structure and soil profile, soil remediation and disposal, Waste water treatment processes and Waste water use in aquaculture.

ENVIRONMENTAL BIOTECHNOLOGY-II

PAPER-BOT-402 (D) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on biodegradation of organic pollutants, bioremediation of metal, energy management, biodiversity monitoring and management, environmental management system and biotechnological methods in environmental monitoring.

UNIT-I

Biodegradation of organic pollutants: Degradation of industrial pollutants, measurement of biodegradability: aerobic and anaerobic degradation, degradation of pesticides, hydrocarbon removal, molecular basis of pesticide removal, Bioaccumulation.

UNIT-II

Bioremediation of metal: Biomining and bioleaching, biosorption, phytochelation, phytoextraction, rhizofiltration, phytovolatilization, Roles of metalophores, phytoremediation of organics, biotransformation of toxic metal pollution.

UNIT-III

Energy management: biomass, bio energy and biofuels, energy plantation, petroplants, hydrocarbon from higher plants, methane, bioethanol and biohydrogen generation. *Biodiversity monitoring and management*: Concept and definition, quantification, *in situ* and *ex situ* conservation measures, Biosphere reserve, biodiversity conventions and legislation (Rule). Biotechnology for biodiversity conservation. Forest resources, types and management.

UNIT-IV

Environmental management system: role and objectives of EMS, Core elements of EMS, Development of EMS, Case studies of Enterprise functions, Overseas and Involvement, Role of Microorganisms in Environmental Management, Nutrient limitation, Symbiotic partners and symbiosis.

UNIT-V

Biotechnological methods in environmental monitoring: Bioassay, selection of test batteries, methods, Gel documentation, immunoassay, biosensor in environmental analysis. Community study and application of remote sensing. Mathematical tools for model building, modeling elements, components of mathematical model, system variables and forcing functions, model testing and validation, use of models as experimental tools.

Course Learning Outcomes:

Students will be learning about degradation of pesticides and hydrocarbons, Biomining and bioleaching, phytoremediation, bio energy and biofuels, *in situ* and *ex situ* conservation measures, role, objectives and core elements of EMS, bioassay, biosensor and mathematical tools for model building.

MICROBIAL TECHNOLOGY-I

PAPER-BOT-401 (E) ***100 Marks/ 6 Credits***

Course Objectives:
The course aims to educate student on microbial culture, immunology, soil microbiology, microbes in metal recovery, molecular techniques and industrial microbiology.

UNIT-I
History and milestones in the development of microbiology, classification of microorganisms, Microbial culture methods: isolation, purification, growth, maintenance and preservation of microbes, axenic and synchronous culture, batch and continuous culture. Metabolic groups of bacteria, ultra-structure and composition of bacterial cell wall, cell inclusions and nucleic acids, reproduction, bacterial metabolism.

UNIT-II
Immune system, Lymphocytes and accessory cells, Immunoglobulins, mechanism of immune response and generation of antibody diversity, Effectors, complements, auto-immunity, AIDS and other immune-deficiency, Hybridoma and Mabs, Immunological techniques: detection of molecules using ELISA, RIA, western blot, flow-cytometry.

UNIT-III
Soil microbiology: surface and deep surface microbes, water microbiology : microbes of freshwater and marine habitats; aero microbiology : microbes in atmosphere, microbial activity and biogeochemical cycle. Wastewater microbes, microbial aspects of waste water treatment, biofilm structure and development, microbial interaction in biofilm, degradation of industrial pollutants and organic carbon, pesticide, hydrocarbon removal by microbes.

UNIT-IV
Microbes in mining and bioleaching of metals, Bioaccumulatioin and its characteristics, determination of biodegradability, microbial transformation of metals, wasteland reclamation, biogas, composting, non-reactor and reactor composting method.

UNIT-V
Isolation of DNA, Restriction modification of DNA, Agarose gel electrophoresis, PCR in environmental microbiology, DGGE, Microbial finger printing of environmental samples. r RNA sequencing, Ribotyping. Fermenter,design of bioreactor, batch and continuous fermentation, downstream processing, industrial production of organic acids, alcohol, enzymes and antibiotics.

Course Learning Outcomes:
Students will be learning about classification of microorganisms and microbial culture methods, immunoglobulins and mechanism of immune response, immunological techniques, soil, water and aero microbiology, microbes in mining and bioleaching of metals, isolation of DNA, Agarose gel electrophoresis, PCR, fermenter and industrial application.

MICROBIAL TECHNOLOGY-II

PAPER-BOT-402 (E) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on role of microbes in soil fertility, Microbial nutrition, industrial microbiology, Microbial interaction and microbes as plant pathogen.

UNIT-I

Microbes in soil fertility: Nutrient metabolism, organic nitrogen transformation, phosphate solubilization, microbial association in soil. Lignocellulotytic and cellulolytic microbes, catabolic degradation. Biofertilisers: Types, methods of production, stain improvement, application and economics of *Rhizobium, Azotobactor, Azospirllum,* Mycorrhiza, Cyanobactria.

UNIT-II

Microbial nutrition (Photo-autotrophs, chemo-lithotrophs, photo-organotrophs, chemoorganotrophs), photosynthetic pigments of bacteria, symbiotic and asymbiotic nitrogen fixation by bacteria; nitrification and denitrification .

UNIT-III

Fermenter, design of bio-reactor, batch and continuous fermentation, down stream processing, industrial production of organic acids, alcohol, enzymes and antibiotics. Microbes in food: Principles of food preservation, contamination and food spoilage, microbiology of milk, processing and milk products, single cell protein-yeast, *Chlorella, Spirulina,* mushroom cultivation, microbial technology for pigments; biohydrogen and biodiesel.

UNIT-IV

Microbial interaction: microbe-microbe, plant microbe and animal-microbe interaction, proto-cooperation, parasitism, commensalism, competition, neutralism and mutualism, microbial contribution to animal nutrition, pathogenic and non-pathogen interaction in plants.

UNIT-V

Plant disease development, host-parasite relation, biochemical basis of pathogenic invasion, disease resistance, phyto- immunity, microbial toxins, biocontrol of diseases.

Course Learning Outcomes:

Students will be learning about microbial nutrient metabolism, biofertilizers, nutritional types of microbes, nitrogen fixation, bio-reactors, downstream processing and microbes as food, microbe-microbe, plant microbe and animal-microbe interaction.

BIOSYSTEMATICS-I

PAPER-BOT-401 (F) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on plant systematic, International Code of Botanical Nomenclature (ICBN), plant identification, herbarium and evolutionary trends in some plant orders.

UNIT-I

Systematics: scope and components, criteria of classification of flowering plants, types of classification, critical evaluation of Bentham & Hooker's system of classification and its application in herbarium methodology, comparative accounts of classificatory systems - Bentham Hooker, Hutchinson, Cronquist, Takhtajan, Dahlgren, Thorne and APG.

UNIT-II

Development of International Code of Botanical Nomenclature (ICBN), frame work of ICBN, nomenclature of taxa according to their ranks, typification, effective and valid publication, choice, retention and rejection of names and epithets, principle of priority and its limitations, names of hybrids, orthography of names and epithets.

UNIT-III

Plant identification, methods of plant identification - Botanical keys for identification of angiospermic plants, types of botanical keys and methods of preparation, limitation of botanical key, use of computers for identification, taxonomic literature: flora, monograph, manuals, journal and indices.

UNIT-IV

Herbarium concept, historical development, function and management, role of herbarium in plant identification, herbarium methodology, important herbaria of the world with special reference to Central National Herbarium, Indian botanical gardens and famous botanical gardens of the world.

UNIT-V

Evolutionary trends in Ranales, Rosales, Umbellales, Asterales, Lamiales, Microspermae and Scitaminae.

Course Learning Outcomes:

Students will be learning about microbial nutrient metabolism, biofertilizers, nutritional types of microbes, nitrogen fixation, bio-reactors, downstream processing and microbes as food, microbe-microbe, plant microbe and animal-microbe interaction.

BIOSYSTEMATICS-II

PAPER-BOT-402 (F) ***100 Marks/ 6 Credits***

Course Objectives:

The course aims to educate student on cytotaxonomy, chemotaxonomy, molecular taxonomy, numerical taxonomy and floristic studies.

UNIT-I

Cytotaxonomy : biological species concept, population concept, genetics of population, chromosome number, karyotype, levels of polyploidy, structural alteration and hybridity as major consideration of taxonomic significance, biosystematic categories, apomictics and their taxonomic problems, limitation of cytogenetic criteria in taxonomy.

UNIT-II

Chemotaxonomy : historical account of chemotaxonomic study, uses of chemical criteria in plant taxonomy, primary metabolites, secondary metabolites and semantides, use of phytochemical criteria such as flavonoides, alkaloids, terpenoides, oils etc. in taxonomy, use of serology in taxonomy.

UNIT-III

Use of palynological data in taxonomy, pollen characters as taxonomic value. Molecular taxonomy : application of molecular markers for identification of species, phylogeny and establishment of genomic relationship in resolving taxonomic problems.

UNIT-IV

Numerical taxonomy : concepts, characters and attributes, OUT's, cluster analysis, Origin of cultivated plants, wild relatives of major crop plants in India, germplasm conservation: *in situ* and *ex situ* conservation, role of gene banks, taxonomy of cultivated plants and bybrids.

UNIT-V

Floristic studies: methods, collection of materials, documentation of data, housing of materials, Endemism: concepts and types of endemism, hotspots, brief account of floristic studies in Odisha - post, present and future.

Course Learning Outcomes:

Students will be learning about chromosome number, karyotype, levels of polyploidy, uses of chemical criteria in plant taxonomy, application of molecular markers for identification of species, characters and attribute of numerical taxonomy, cluster analysis, methods, collection of materials and documentation of data for floristics study.

DISSERTATION

PAPER-403 **200 Marks (12 Credits)**

Course Objectives:

The course aims to develop the skill of experimental design, critical thinking and scientific writing.

Semester-IV *(Biochemistry and Molecular Biology, Biotechnology and Plant Genetic Manipulations, Cytogenetics and Cell Biology, Environmental Biotechnology, Microbial Technology, Biosystematics).*

Course Learning Outcomes:

Students will learn how to design experiments, think critically and write dissertation. The course will be a preliminary training to do research.

SEMINAR PRESENTATION

PAPER-404 **100 Marks (6 Credits)**

Course Objectives:

Objective of the course is to enable to students for public speaking and presentation of a scientific topic.

Semester-IV *(Biochemistry and Molecular Biology, Biotechnology and Plant Genetic Manipulations, Cytogenetics and Cell Biology, Environmental Biotechnology, Microbial Technology, Biosystematics.*

Course Learning Outcomes:

Students will acquire the skill of public speaking, content development for presentation and discussion with audience.

BIOCHEMISTRY AND MOLECULAR BIOLOGY

Reference books

- Nelson, D.L., Cox M.M. (2008) Lehninger Principles of Biochemistry, 5th edn. Macmillan Publisher. 1158 pp.
- Zubay G.L. (1983) Biochemistry, 4th edition, 1999. Addison-Wesley publishers, 1268pp.
- Voet, D. and Voet, JG. (2004) Biochemistry. 3rd edition John Wiley and Sons publisher; New York. 1616 pp. ISBN: 978-0471193500.
- Stryer L. (2002). Biochemistry, 5th Revised edition, W.H.Freeman & Co publisher, 1050 pp. ISBN: 978-0716746843.
- Palmer, T. and Bonner, P.L. (2007). Enzymes: Biochemistry, Biotechnology, Clinical Chemistry, 2nd edn, Woodhead Publishing, ISBN: 9781904275275, 432 pp.
- Goodwin T. W. and Mercer E. I. (1990). Introduction to Plant Biochemistry, Second Edition, Pergamon Publisher, 660 pp.
- Lea PJ and Leagood RC (1999) Plant Biochemistry and Molecular Biology. Wiley, San Diego.
- David Freifielder (1995). Molecular cell biology - 2nd Edition, Narosa publishing House.
- Karp, G. Cell and Molecular Biology: Concepts and Experiments, 2000. John Wiley and Sons, New York.
- Benjamin Lewin, Genes VIII, 2004, Pearson Prentice Hall, New Jersey.
- Harvey Lodish, Arnold Berk, Paul Matsudaira, Chris A. Kaiser, Monty Krieger, Matthew P. Scott, S. Lawrence Zipursky, James Darnell. 2004. Molecular Cell Biology, Fifth Edition, W. H. Freeman and Company, New York.
- Buchanan, B. B., Grissem, W. and Jones, R. L. (2000). Biochemistry and molecular biology of plants. American Society of plant physiologists, Rockville, USA
- Trevor Palmer (1991) Understanding enzymes. 3rd edition. E. Horwood publisher, ISBN: 9780139282508, 399 pp.
- Mathews, C. K., Van Holde, K. E. and Ahern, K. G. (2000). Biochemistry, Addison-Wesley Publishing Company, San Francisco, USA.
- Goodwin, T. W. and Mercer, E. I. (1985). Introduction to Plant Biochemistry, 2nd ed. Pergamon, Oxford.
- Richard A.Goldsby, Thomas J. Kindt & Barbara A. Osborne. Kuby Immunology (4th Ed.). W.H.Freeman and Company
- Sawhney , R Singh Introductory Practical Biochemistry Narosa Publishing House Pvt Ltd
- Sadasivam S and Manickam A 1996. Biochemical methods. 2nd edn. New Age International, ISBN: 9788122409765. 256 pages

BIOTECHNOLOGY AND PLANT GENETIC MANIPULATIONS

Reference books

- Brown T. A. (2001). Gene Cloning and DNA Analysis. Blackwell Science, London.
- Glick, B. R. and Pasternak (2003). Molecular Biotechnology: Principles and Applications of Recombinant DNA. ASM Press, Washington, D. C., USA.
- Gardner, Simmons, Snustad (2006). Principles of Genetics. 8th Ed. John Wiley & Sons, 740 pages, ISBN: 9788126510436
- Colin Rutledge & Bjorn Kristiansen Basic Biotechnology (2nd Ed.) Cambridge University Press
- Winnacker E - L, (2003). From Genes to Clones. Panima, New Delhi.
- Kumar.H.C. 1992. Text book on Biotechnology. East west press. New York.
- Walker.J.M and Gingold. W.B. 1989. Molecular Biology and Biotechnology. 2nd edition. Royal Society of chemistry, London.
- Keshav Trehan.1990. Biotechnology. Wiley Eastern/td. New Delhi.
- Smith, J. E. (2004) Biotechnology, 3rd edition, Cambridge University Press
- Satyanarayana U. (2005), Biotechnology. **Books** and Allied (P) Ltd, Kolkata. 2nd edn. 2008.

CYTOGENETICS AND CELL BIOLOGY

Reference books

- Lewin B. 2010. *Gene IX.* Peterson Publications/ Panima.
- Malacinski GM & Freifelder D. 1998. *Essentials of Molecular Biology.* 3rd Ed. Jones & Bartlett Publishers.
- Nelson DL & Cox MM. 2007. *Lehninger's Principles of Biochemistry.* W.H. Freeman & Co.
- Primrose SB. 2001. *Molecular Biotechnology.* Panima.
- Watson JD, Bakee TA, Bell SP, Gann A, Levine M & Losick R. 2008. *Molecular Biology of the Gene.* 6th Ed. Pearson Education International.
- Klug WS & Cummings MR. 2003 *Concepts of Genetics.* Peterson Education.
- Russell PJ. 1998. *Genetics.* The Benzamin/Cummings Publ. Co.
- Strickberger MW.1990. *Genetics.* Collier MacMillan.
- Tamarin RH. 1999. *Principles of Genetics.* Wm. C. Brown Publs.
- Uppal S, Yadav R, Subhadra & Saharan RP. 2005. *Practical Manual on Basic and Applied Genetics.* Dept. of Genetics, CCS HAU Hisar.

ENVIRONMENTAL BIOTECHNOLOGY

Reference books

- Evans G.G., Furlong J. (2011). Environmental Biotechnology: Theory and Application, John Wiley & Sons, 290 pp.
- Levitt J. (1980). Responses of Plants to Environmental Stresses: Chilling, freezing, and high temperature stresses second edition, published in Academic Press, ISBN: 9780124455016, 497 pp.
- R.K. Sinha and R. Sinha, 2008, Environmental Biotechnology. Aavishkar Publisher Distributors.
- Raskin, I (1999). Phytoremediation of Toxic Metals: Using Plants to Clean Up the Environment. Wiley-Interscience, New York.
- Tsao, D. T. (2003) Phytoremediation (Advances in Biochemical Engineering / Biotechnology), Springer, New York.
- Walker, D. (1992). Energy, Plants and Man, 2nd Ed. Packard Publishing Limited, Chichester U. K.
- Willey, N. (2007). Phytoremediation: Methods and Reviews (Methods in Biotechnology). Humana Publication, New York.
- Santra S.C. (2001). Environmental Science.1st Edn. New Central Book Agency, Kolkata.
- Mohapatra P.K. (2006). Textbook of Environmental Biotechnology. I.K. Int. Publ., New Delhi, India. 515 pp.
- Vinod Soni and Vinay Sharma. Text Book of Environmental Biotechnology, Aavishkar publishers.
- Santra S.C. New Frontiers of Environmental Biotechnological Applications, ENVIS Centre on Environmental Biotechnology publisher.
- Nathanson J. A. Basic Environmental Technology (4th Ed.). Prentice-Hall India Pvt. Ltd.
- Hans-Joachim Jordening, Josef Winter Environmental Biotechnology Concepts & Application. Willey-VCH
- Kaiser Jamil Bioindicators & Biomarkers of Environmental Pollution & Risk Assessment. Oxford & IBH Publishing Co Pvt. Ltd.

MICROBIAL TECHNOLOGY

Reference books

- Pelczar,Jr. Chan, B.C.s and Krej, N.R. 1993. Microbiology. MC Graw Hill-Inc. New Delhi.
- Prescott,L.M, Harley, J.P and Klein, D.A 1998. Microbiology W M C Brown Publishers. New Delhi.
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- Bisen, P.S. (1994). Frontiers in Microbial Technology. CBS. Publishers. New Delhi.

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- Freeman, J.E.1982. Advances in microbiology. Ed. Subba Rao, (N.S) Oxford and IBH Co. New Delhi.
- Kosuge, T, Nester, EN (1984) Plant microbe interaction-molecular and genetic perspectives, MacMillan, New York.
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- Kumar H.D. Environmental Technology & Biosphere Management. Oxford & IBH Publishing Co. Pvt. Ltd
- Talaro K.P. Foundation in Microbiology basic Principles (Fifth Ed.). McGraw Hill
- Bauman R.W., Microbiology. Pearson publishers

BIOSYSTEMATICS

Reference books

- Conway, G. and Barbier, E. (1994). Plants, Genes and Agriculture. Jones and Bartlett, Boston, USA.
- Heywood, V. H. and Wyse Jackson, P. S. (1991). Tropical Botanical Gardens, Their role in Conservation and Development. Academic press, San Diego, USA.
- Takhtajan, A. L. (1997). Diversity and Classification of Flowering Plants. Columbia University Press, New York.
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