REVISED COURSE STRUCTURE FOR M.Sc. BOTANY, DEPARTMENT OF BOTANY, UNIVERSITY OF DELHI, DELHI - 110007 (2009-10 onwards)

CORE PAPERS (SEMESTERS I AND II)

I. SEMESTER I (Session: July 21 - Nov 14)

1. CELL AND MOLECULAR BIOLOGY

Introduction to modern tools and techniques of cell biology: advances in light and electron microscopy, techniques supplementing microscopy (cytochemistry, microprobe analysis, x-ray diffraction, etc.), Cell fractionation and visualization/characterization of various cell fractions.

Cell components and their functions: Dynamic structure, functions and biogenesis of cell wall and plasma membrane; new insights in structure and function of cytoplasmic cell organelles and biopolymers; nucleus; its components, chromatin structure in eukaryotes, condensation and packaging of DNA in prokaryotes, their dynamic state and role in gene regulation; structure and function of plant cytoskeletal genes and gene products; protein sorting and intracellular trafficking.

Cell multiplication and turnover: cell cycle and apoptosis

Gene structure, regulation and expression in eukaryotes: Gene and promoter architecture, cistrons, regulatory sequences, enhancers and their mechanism of action, DNA replication; transcription - RNA polymerases, transcription factors, Introns, RNA splicing, alternative splicing, RNA stability - cap structure and function, polyadenylation; translation, post-translational modifications.

Organellar genomes: Organization and function of mitochondrial and chloroplast genomes, diversity and evolution of organelle genomes, chloroplast protein targeting to different compartments, mitochondrial DNA and male sterility, transfer of genes between nucleus and organelles.

PRACTICALS:

1. To exemplify the use of phase contrast and fluorescence microscopy in plant biology by studying phase objects and autofluorescent specimens or those stained with fluorochromes, such as, carbofluorescein diacetate, aniline blue, calcofluor white, Evans blue and neutral red.
2. Isolation and purification of nuclei and their staining with Feulgen stain or DAPI.
3. Isolation of mitochondria and their visualization with Janus green B and mitotracker.
4. Isolation of chloroplasts and determination of number of chlorophyll molecules per chloroplast.
5. Comparing the effect of some physical and chemical factors on the efficiency of photosynthetic electron transport.
6. To study the effect of inhibitors and uncouplers on the activity of succinic dehydrogenase, a marker enzyme of mitochondria.
7. *In situ* visualization of microfilaments and microtubules by fluorescent labeling.
8. *In silico* analysis (sequence comparison) of mitochondrial and chloroplast genes for identification of the loci for interspecific discrimination.
9. Molecular characterization of GUS-actin constructs in *Arabidopsis thaliana* using microscopy and PCR.
10. Multiple sequence alignment and ontology based database searches on selected plant cytoskeletal genes to deciphering the molecular phylogeny of cytoskeleton genes.
11. Immunostaining of nuclei, chloroplast and/or mitochondria.

SUGGESTED READINGS:

1. Alberts B, Johnson A, Lewis J, Raff Martin, Roberts K and Walter P. (2007) Molecular Biology of the Cell. Garland Publ., New York.
2. Bonifacino JS, Dasso M, Harford JB, Liipincott-Schwartz J and Yamada KM. (2004) Short Protocols in Cell Biology. John Wiley & Sons, New Jersey.
3. Bregman AA (1987) Laboratory Investigations in Cell Biology. John Wiley & Sons, New York.
4. Hawes C and Satiat-Jeunemaitre B (2001) Plant Cell Biology: Practical Approach. Oxford University Press, Oxford.

5. Hirt RP and Horner DS (2004) Organelles, Genomes and Eukaryote Phylogeny: An evolutionary synthesis in the age of genomics. CRC Press.
6. Karp G. (2008) Cell and Molecular Biology: Concepts and Experiments. John Wiley & Sons.
7. Lodisch H, Berk A, Kaiser CA, Krieger M, Scott MP, Bretscher A, Ploegh H and Matsudaire P (2008) Molecular Cell Biology. WH Freeman & Co., New York.
8. Ruzin SE (1999) Plant Microtechnique and Microscopy. Oxford Univ. Press, Oxford.
9. Wischnitzer S. (1989) Introduction to Electron Microscopy. Pergamon Press, New York.

2. GENETICS AND CYTOGENETICS

Microbial Genetics: Viral and bacterial genomes and derived vectors; Recombination in viruses and bacteria (transformation, conjugation and transduction); Fine structure of gene; Prokaryotic gene regulation; Fungal genetics – mating types and genetic exchange, heterokaryosis, parasexual cycle.

Mendelian and Non-Mendelian Inheritance: Meiosis; Chromosome theory of inheritance; Mendelian laws; Gene interactions; Organelle inheritance.

Eukaryotic Genome: Evolution, structure and organization; Gene regulation.

Recombination in Eukaryotes: Linkage and crossing over: basic concepts, linkage maps, correlation of genetic and physical maps, molecular markers and construction of linkage maps; Molecular mechanism of recombination; QTL mapping.

Mutation: Basic concept, spontaneous and induced mutations, allele theory, physical and chemical mutagens; Molecular basis of mutations; Transposons and their use in mutagenesis and gene tagging in plant systems; Oncogenes and cancer.

Concepts in: Developmental genetics; Behavioral genetics; Population genetics and Quantitative genetics.

Cytogenetics: Chromosome: Structure and nomenclature, centromere and telomere; Sex determination: mechanisms, sex chromosomes; Chromosomal aberrations: Duplications,

deficiencies/deletions, inversions, interchanges/translocations; Role of chromosomal aberrations in crop evolution; Ploidy changes: Haploids, polyploids and aneuploids; Genome analysis in crop plants; Molecular Cytogenetics: FISH, GISH, FIBER-FISH, Flow Cytogenetics, Flow karyotyping, Applications of molecular cytogenetics

PRACTICALS:

1. Preparation of mitotic and meiotic spreads and analysis of various stages of cell division (*Phlox, Allium* and *Rhoeo*).
2. Extraction of genomic DNA from plants by CTAB method.
3. Analysis of molecular polymorphism in parental lines and derived mapping population using different types of molecular markers.
4. Construction of a linkage map using available data.
5. Mutagenesis experiments in *E. coli*.
6. Experiments in *Neurospora* / *Drosophila* genetics.

SUGGESTED READINGS:

1. Acquaah G (2007). Principles of Plant Genetics and Breeding, Blackwell Publishing Ltd. USA.
2. Allard RW (1999). Principles of Plant Breeding (2nd Edition), John Wiley and Sons.
3. Hartl DL and Jones EW (2007). Genetics – Analysis of Genes and Genomes, 7th edition, Jones and Barlett publishers.
4. Hartwell LH, Hood L, Goldberg ML, Reynolds AE, Silver LM, Veres RC (2006). Genetics – From Genes to Genomes, 3rd edition, McGraw Hill.
5. Lewin B (2008). Genes IX, Jones and Barlett Publishers.
6. Singh RJ (2002). Plant Cytogenetics, 2nd edition, CRC Press.
7. Smartt J and Simmonds NW (1995). Evolution of Crop Plants (2nd Edition) Longman.
8. Strickberger MW (2008). Genetics, 3rd Edition, Pearson (Prentice Hall).
9. Weising K, Nybom H, Wolff K and Kahl G (2005) DNA Fingerprinting in Plants: Principles, Methods and Applications, 2nd ed. Taylor and Francis Group, Boca Raton, FL.

3. PHYSIOLOGY AND BIOCHEMISTRY

Protein structure: Hierarchical structure of proteins; folding; ticketing; degradation; purification, detection and functional characterization; sequence alignments; molecular motors and pumps.

Enzymes and bioenergetics: Application of principles of thermodynamics in biology; origin and evolution of biocatalytic reactions; significance of ribozymes; abzymes; artificial enzymes; enzyme technology; regulation of enzymatic activity; evolution of electron transport chain and its coupling to ATP synthesis; bioelectricity, photosynthesis and respiration.

Signal Transduction: Overview, second messengers, receptors and G-proteins, phospholipid signaling, role of cyclic nucleotides, calcium-calmodulin cascade, diversity in protein kinases and phosphatases, specific signaling mechanisms and their regulation, e.g. simple and hybrid type of two-component sensor-regulator system in bacteria and plants (examples of chemotaxis, osmosensing, ethylene and cytokinin signaling), quorum sensing.

Sensory Photobiology: Structure, function and mechanisms of action of phytochromes, cryptochromes and phototropins; stomatal movement; scotomorphogenesis and photomorphogenesis.

Molecular Basis of intercellular and intracellular uptake and transport of water, ions and macromolecules: Apoplastic and symplastic transport mechanisms, role of aquaporins and transporter proteins, structure-function relationship of inward and outward ion channels, dual action of ATPases/pumps and modulation of their activity, specialized mechanisms for phosphorus and iron uptake, monitoring of ion channel activity.

Plant hormones and other growth regulators: Concept of hormones as chemical messengers, techniques for detection and quantitation of plant hormone, classical approaches and use of mutants in understanding hormone actions, hormones in defense against abiotic and biotic stresses, synthetic regulatory compounds and their uses.

Physiology of plant reproduction: Reproductive strategies in higher plants and their significance. Sexual and non-sexual modes. Flowering as a multi-organ function, floral

induction, evocation and development. Regulation of flowering by light and temperature. Role of circadian rhythm. Involvement of hormones. Genetic, molecular and biotechnological aspects. Manipulation of flowering and floriculture. Vegetative propagation with special reference to epiphyllous budding.

PRACTICALS:

1. In vivo assay for nitrate reductase in leaf tissues.
2. Comparative assessment of methods for protein quantitation.
3. Study of enzyme kinetics for determination of Km value, nature of inhibition – competitive/non competitive.
4. Study of enzyme kinetics for effect of time/ enzyme concentration/ pH.
5. Extraction of proteins from plant tissue and their quantitative (Bradford's) and qualitative (SDS, PAGE gel) analysis.
6. Detection of phosphoproteins in plant (*Brassica*) extract by pro Q diamond staining.
7. Qualitative and quantitative analysis of photosynthetic pigments and anthocyanins by spectrophotometric and chromatographic techniques.
8. PAGE analysis of pigment-protein complexes from chloroplasts.

SUGGESTED READINGS:

1. Ainsworth C (2006) Flowering and its Manipulation, Annual Plant Reviews, Vol. 20. Blackwell Publishing, Oxford, U.K.
2. Brown TA. (2002) Genomes, BIOS Scientific Publishers Ltd, Oxford, UK.
3. Buchanan B, Gruissem G and Jones R. (2000) Biochemistry and Molecular Biology of Plants, American Society of Plant Physiologists, USA.
4. Davies P J. (2004) Plant Hormones: Biosynthesis, Signal Transduction, Action. 3rd Edition, Kluwer Academic Publisher, Dordrecht, The Netherlands.
5. Jordan BR. (2006) The Molecular Biology and Biotechnology of Flowering, 2nd Edition, CAB International, Oxfordshire, U.K.
6. Lodish H, Berk A, Kaiser CA and Krieger M. (2008) Molecular Cell Biology, 6th Edition, W.H. Freeman and Company, New York, USA.
7. Nelson DL and Cox MM. (2004) Lehninger Principles of Biochemistry, 4th Edition, W.H. Freeman and Company, New York, USA.

8. Taiz L and Zeiger E. (2006) Plant Physiology, 4th Edition, Sinauer Associates Inc. Publishers, Massachusetts, USA.

4. RECOMBINANT DNA TECHNOLOGY AND PROTEOMICS

Principles and tools of recombinant DNA technology: Restriction and nucleic acid modifying enzymes; restriction mapping; Principles of gel electrophoresis; choice of vectors; plasmids, phages, cosmids, plant viruses, synthetic DNA vectors; cDNA and genomic libraries; Isolation of specific genes from bacteria and higher plants; cloning; PCR and its applications; Principles of DNA sequencing.

Proteomics: Comparative account of translation in prokaryotes and eukaryotes, post translational modifications, Use of vectors for over-expression of proteins, Protein extraction/purification techniques viz., electrophoresis and column chromatography, Introduction to proteome and proteomics and its relevance/significance in the post genomic era, Proteomics as a tool for plant genetics, breeding and diversity studies.

PRACTICALS:

1. *E. coli* growth curve
2. Preparation of competent cells and transformation of *E. coli* (chemical/electroporation method)
3. Plasmid DNA isolation, quantification and agarose gel electrophoresis.
4. Restriction digestion, elution and cloning in *E. coli*.
5. PCR
6. Preparation of protein extracts from *E. coli*, quantification and SDS-PAGE analysis.
7. Inducible expression of proteins in *E. coli*
8. ELISA
9. Southern Hybridization
10. Yeast transformation
11. RNA extraction and preparation of cDNA.

SUGGESTED READINGS:

1. Buchanan B, Gruissem G and Jones R (2000). Biochemistry and Molecular Biology of Plants, American Society of Plant Physiologists, USA.
2. Harlow and Lane D (Eds.) (1988). Antibodies – A Laboratory Manual; Cold Spring Harbor Laboratory, USA.
3. Lieber DC (2006). Introduction to Proteomics: Tools for New Biology; Humana Press, NJ.
4. Pennington SR, Dunn MJ (Eds.) (2002). Proteomics: From Protein Sequence to Function, BIOS Scientific Publishers, United Kingdom.
5. Sambrook J and Russell DW (2001). Molecular Cloning – A Laboratory Manual, Vols I – III, Cold Spring Harbor Laboratory, USA.
6. Singer M and Berg P (1991). Genes and Genomes: A Changing Perspective; University Science Books, CA, USA.

II. SEMESTER II (Session: Jan 05 – April 30)

1. DEVELOPMENTAL BIOLOGY

Section A: Plant Diversity

Algae: Habitat diversity, thallus organization, cell structure and reproduction.

Archegoniatae: Comparative morphology and developmental anatomy of Hepaticae, Anthocerotae and Musci; comparative anatomy of vegetative organs of Pteridophytes; study of stem apex, leaf initiation and early leaf ontogeny in ferns; development of long and short shoots, origin and pattern of development of cortex, pith and procambium in conifers.

Vascular plants: Meristems; patterns of cell fate, determination and lineage in root and shoot; leaf growth and differentiation; secondary growth; wood development and its diversity; cambial variants; ultrastructure and control of xylem and phloem differentiation; secretory ducts and laticifers; flower, seed and fruit anatomy; patterns of evolution in seed; anatomical adaptations for special habitats, biotic and abiotic stresses; Applications (in brief) of anatomical studies in systematics, archaeology, climate studies, pharmacology, forensic sciences and biomedical research.

Section B: Reproductive Biology

Development of flower: Transition to flowering - vegetative to reproductive evocation, floral homeotic mutations in *Arabidopsis*, *Antirrhinum* and *Petunia*, axis development in flower, gender expression in monoecious and dioecious plants.

Developmental biology of male and female gametophytes: Regulation of anther and ovule development, microsporogenesis and microgametogenesis, megasporogenesis and megagametogenesis, male sterility- mechanisms and applications, pollen embryogenesis.

Pollen-pistil interaction: *In vivo* and *in vitro* pollen germination, pollen tube growth and guidance, double fertilization, self-compatibility mechanisms, incongruity.

Embryogenesis and seed development: Polarity during embryogenesis, pattern mutants, *in vitro* fertilization, endosperm development, apomixis, polyembryony, somatic embryogenesis.

PRACTICALS:

1. Study of thallus structures of different groups of algae through preparation of whole mounts and sections.
2. Study of morphology and anatomy of thalloid and leafy forms of Bryophytes; Study of Protonema
3. Study of fern gametophyte and soral variations
4. Comparative anatomy of conifers and gnetales.
5. Study of apical meristems with the help of dissections, whole mount preparations, sections and permanent slides.
6. Origin and development of epidermal structures (trichomes, glands and lenticels).
7. Study of xylem and phloem elements using maceration, staining, light and electron micrographs (xerophytes, hydrophytes and halophytes).
8. Study of secretory structures (nectaries and laticifers).
9. Study of secondary growth (normal and unusual) of selected woods with the help of wood microtome and permanent slides.
10. Study of the stages of pollen and ovule development in the wild and mutant plants using permanent slides, electron micrograph and available phenotypes.

11. Pollen *in vitro* germination methods: Sitting drop culture, suspension culture, surface culture.
12. Correlation between fertility (stainability), viability (TTC and FDA staining) and germinability (*in vitro*) of pollen grains.
13. Assessment of stigma receptivity by localizing peroxidases, non-specific esterases and phosphatases.
14. Aniline blue fluorescence method to localize pollen tubes to study different aspects of pollen-pistil interaction.
15. Use of DNA fluorochromes to localize nuclei during pollen and ovule development.
16. Study of post-fertilization stage with the help of permanent slides and electron micrographs.
17. Dissection of embryo and endosperm.

SUGGESTED READINGS:

1. Anderson RA (2005) Algal Culturing Techniques. Physiological Society of America. Elsevier Academic Press, USA.
2. Bhatnagar SP and Moitra A (2005) Gymnosperms. New Age Interactive (P) Ltd. Publishers, New Delhi.
3. Carlquist S (2001). Comparative Wood Anatomy, Springer-Verlag, Germany.
5. Cutler DF (1978). Applied Plant Anatomy, Longman, United Kindom
6. Cutter EG (1978) Plant Anatomy, Part I & II, Edward Arnold, United Kingdom.
7. Dickinson WC (2000). Integrative Plant Anatomy, Harcourt Academic Press, USA.
8. Fahn A (1974) Plant Anatomy, Pergmon Press, USA & UK.
9. Fosket DE. (1994) Plant, Growth and Development: A Molecular Approach, Academic Press.
10. Fritsch FE (1935, 1945). The Structure and Reproduction of Algae Vols. I and II. Cambridge University Press, Cambridge, UK.
11. Hopkins WG. (2006). The Green World: Plant Development, Chelsea House Publication
12. Howell SH. (1998) Molecular Genetics of Plant Development, Cambridge University Press.
13. Leyser O and Day S (2003) Mechanism of Plant Development, Blackwell Press
14. Mauseth JD (1988). Plant Anatomy, The Benjamin/ Cummings Publisher, USA
15. Nair MNB (1998). Wood Anatomy and Major Uses of Wood, Faculty of Forestry, University of Putra Malaysia, Malaysia.

16. Parihar NS (1993) An Introduction to Embryophyta: Vol I – Bryophyta, Vol II – Pteridophyta, Central Book Dept. Allahabad.
17. Raghavan V (2000) Developmental Biology of Flowering Plants, Springer, Netherlands
18. Raghavan V (1997). Molecular Embryology of Flowering Plants. Cambridge. University Press.
19. Richards AJ (1986) Plant Breeding System, George Allen and Unwin.
20. Shivanna KR (2003) Pollen Biology and Biotechnology, Science Publishers.

2. SYSTEMATICS, EVOLUTION AND ENVIRONMENTAL SCIENCE

Systematics and Evolutionary Biology: History of developments in taxonomy: Linnaean to post-Linnaean era; Systematics - concepts and components; Botanical Nomenclature; Evolutionary ecology-concepts and principles; Microevolution - theory and concepts; Species and speciation; Phylogenetic systematics; Macroevolution - inferring phylogenies; Diversity and classification of flowering plants; Taxonomic evidence - structural and biochemical; Molecular systematics; Diversity and classification of flowering plants; Biological diversity-concepts and applications; Diversity- patterns, indices and applications.

Environmental Science: Introduction to Environmental Science and Sustainability, Environmental laws, Ecosystems and living organisms, Major ecosystems of the world and India, Human health and environmental change, Population issues, the search for fuels, natural resources and their management, applications of GIS and RS technology in environmental studies, the future of planet earth.

PRACTICALS:

1. Live plants/ Herbarium specimens of the following families will be provided in the class for description and identification (classification based on APG II, 2003): Basal Angiosperm and Magnoliids: Monocots: Commelinids: Basal Eudicots and Caryophyllids: Ranunculaceae, Rosids: Asterids.
2. Techniques in molecular systematics.
3. Phylogenetic analyses using PAUP.
4. Local flora study

5. Basics of GIS, Remote sensing data – visual and digital interpretation for vegetation types, delineation of ecosystems using RS and GIS technology, temporal dynamics and models.

SUGGESTED READINGS:

1. Angiosperm Phylogeny Group (2003) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. Botanical Journal of the Linnaean Society 141: 399-436.
2. Cracknell AP, Hayes L (2009) Introduction to Remote Sensing. CRC Press, Boca Raton, USA (Special Indian Edition)
3. Crawford DJ (2003) Plant Molecular Systematics. Cambridge University Press, Cambridge, UK.
4. Cronquist A (1981). An integrated system of classification of flowering plants. Columbia University Press, New York.
5. Hollingsworth PM, Bateman RM and Gornall RJ (1999). Molecular systematics and Plant Evolution. Taylor and Francis, London.
6. Judd WS, Campbell CS, Kellogg EA, Stevens PA and Donoghue MJ (2002) Plant Systematics: A Phylogenetic Approach. Sinauer Associaes, Inc., Massachusetts.
7. Nei M and Kumar S (2000) Molecular Evolution and Phylogenetics. Oxford University Press, New York.
8. Raven PH, Begr LR, Hassenzahl DM (2008) Environment. 6th edition. John Wiley & Sons, Inc., New York.
9. Semple C and Steel MA (2003) Phylogenetics. Oxford University Press, Oxford.
10. Simpson MG (2006) Plant Systematics. Elsevier, Amsterdam.
11. Stuessy TF (2008) Plant Taxonomy: The systematic Evaluation of Comparative Data. Columbia University Press, New York.
12. Swafford DL (2001) PAUP*. Phylogenetic analysis using parsimony (* and other methods), version 4. Sinauer Associates, Sunderland.

3. PLANT BIOTECHNOLOGY AND RESOURCE UTILIZATION

Plant tissue culture: History, concepts of cell differentiation and totipotency; pathways for *in vitro* regeneration: organogenesis, somatic and gametic embryogenesis; protoplast isolation, culture and regeneration; somatic hybridization; Applications: micropropagation, meristem

culture, embryo rescue, synseed production, somaclonal and androclonal variations, cryopreservation and germplasm storage.

Principles, methods and applications of genetic transformation: *Agrobacterium* biology and biotechnology; Plant - *Agrobacterium* interactions; Direct gene transfer methods: particle bombardment, electroporation, PEG-mediated and floral-dip; marker and reporter genes; case studies of transgenic traits in plants; marker-free transgenics; transgene silencing; environmental, social and legal issues.

Plant resource utilization: World centres of primary diversity and secondary centres of cultivated plants; crop domestication genes; Uses and introduction to current research paradigms in major cereals, oilseeds, legumes, medicinal plants, forest trees and non-alcoholic beverages.

PRACTICALS:

1. Preparation of different types of standard tissue culture media.
2. Establishment of aseptic cultures following appropriate sterilization procedures using seeds.
3. Preparation of competent cells and *Agrobacterium* transformation by electroporation.
4. *Agrobacterium tumefaciens*-mediated transformation of tobacco.
5. Visualization of GFP or YFP in transgenic *Arabidopsis*.
6. Morphological and histochemical features of major cereals, oilseeds, legumes, forest trees, non-alcoholic beverages and medicinal plants.
7. Analysis of crude extracts from medicinal plants using HPLC.
8. Evaluation of a transgenic phenotype (viz., Herbicide resistance) under containment conditions in the field.

SUGGESTED READINGS:

1. Adrian S, Nigel WS, Mark RF (2008). Plant Biotechnology: The genetic manipulation of Plants, Oxford University Press.
2. Buchanan B, Gruissem G and Jones R (2000) Biochemistry and Molecular Biology of Plants, American Society of Plant Physiologists, USA.

3. Butenko RG (2000) Plant Cell Culture, University Press of Pacific.
4. Davies PJ (2004) Plant Hormones, Kluwer Academic Publishers, Netherlands.
5. Halford N (2006) Plant Biotechnology - Current and future applications of genetically modified crops, John Wiley and Sons, England.
6. Wickens GE (2004) Economic Botany: Principles and Practices, Springer, ISBN 978-0-7923-6781-9.

4. PATHOGENS AND PESTS OF CROP PLANTS

General characteristics of plant pathogenic organisms and pests including viruses, bacteria, fungi, insects and nematodes with reference to the following:

- Life cycles
- Nature of disease(s) and damage caused
- Host range
- Control mechanisms based on genetics, chemical treatments, biological control and genetic engineering.

Case studies of economically important causative agents with specific references to crop plants:

- Plant-virus interactions with emphasis on potyviruses and horticultural crops.
- Plant-bacterial interactions with emphasis on *Erwinia* sp. and potatoes.
- Plant-fungus interactions with emphasis on *Magnaporthe* sp. and rice.
- Plant-nematode interactions with emphasis on *Meloidogyne* sp. and tomato.
- Plant-Insect interactions with emphasis on *Pieris* sp. and crucifers.

PRACTICALS:

1. Methods of sterilization; Media preparation (selective media); inoculation procedures.
2. Characterization of disease symptoms and identification of pathogenic organisms.
3. A study on effects of various formulation and doses of BTk on growth and development of selected pest species.
4. Isolation and identification of rhizosphere soil fungi, seed borne fungi
5. Isolation and estimation of DNA from fungus

6. Biochemical markers of enhanced resistance
   (i) Estimation of total phenols and O-didhydroxyphenols in sugarcane and groundnut
   (ii) Estimation of activity of Phenylalanine ammonia lyase in healthy and diseased leaves of sugarcane
   (iii) Estimation of deoxyribonuclease and ribonuclease enzymes produced by virus infected and healthy leaves of tobacco
7. Research paper discussions.

SUGGESTED READINGS:

1. Agrios GN (2005) Plant Pathology, 5th Edition.
2. Buchanan B, Gruissem G and Jones R (2000) Biochemistry and Molecular Biology of Plants", American Society of Plant Physiologists, USA.

OPTIONAL PAPERS (SEMESTERS III AND IV)

III. SEMESTER III (classes: July 21 – Nov 14)

Two papers from options 1 – 4 and two papers from options 5 – 8 are to be selected

1. ALGAE, ENVIRONMENT AND HUMAN WELFARE

Diversity and distribution of the algae: Thallus organization, cell structure and reproduction in various groups. *Chlamydomonas* and *Porphyra* as modern experimental systems.

Classification: Molecular taxonomy – recent developments in algal classification, special emphasis on emerging trends in molecular phylogeny and inter relationship of principal groups of algae. The following groups will be covered: Cyanophyta, Chlorophyta, Phaeophyta and Rhodophyta.

Algal Biotechnology: Historical perspectives, algal culturing techniques in the laboratory, tissue and cell culture studies in seaweeds, cryopreservation, aquaculture (micro and macro algae cultivation), bioremediation, recent developments and future of algal biotechnology; Algal biofuels – algal biodiesel, bio-ethanol and biological hydrogen production; Algae in global warming – carbon capture by algae.

Industrial Phycology: Products, processes and applications, seaweeds polysaccharides like Agar, Carrageenan and Alginates. Bioactive compounds from algae: Bio-fertilizers; Algae in bioengineering, photo-bioreactors and raceway ponds.

PRACTICALS:

Practicals would be based on the theory syllabus and would broadly include the following:

1. Study of diversity of freshwater and marine algae.
2. Raising of pure culture.
3. Phytoremediation experiments
4. Microtechniques

SUGGESTED READINGS:

1. Andersen RA (2005). Algal Culturing Techniques. Physiological Society of America. Elsevier Academic Press, USA.
2. Cole KM and Sheath RG (1990). Biology of the Red Algae. Cambridge Univ. Press, Cambridge.
3. Fritsch FE (1945). The Structure and Reproduction of Algae. Vol. II. Cambridge Univ. Press. Cambridge, London.
4. Isabella A. Abbott, George J and Hollenberg (1993). Marine Algae of California. Stanford University Press. USA.
5. Lee RE (1989). Phycology. Vol. II. Cambridge Univ. Press. Cambridge, USA.
6. Sahoo D & Qasim SZ (Eds), (2002). "Sustainable Aquaculture". APH Publishing Corporation, New Delhi, India.
7. South GR and Whittick A. (1987). Introduction to Phycology. Blackwell Scientific Publications. London.
8. **Journals**: Journal of Applied Phycology, Journal of Phycology, European Journal of Phycology, Phycologia, Botanica Marina.

2. MICROBES AND MICROBIAL TECHNOLOGY

General Microbiology: Diversity of the microbial world – Microbial taxonomy and phylogeny; Microbial nutrition, growth and metabolism; Genetics of bacteria and their viruses.

Agricultural Microbiology: Agriculturally important microorganisms; Biological nitrogen fixation; Mycorrhizae, microbial mineralization, Biocontrol of plant diseases, Plant growth promoting rhizobacteria (PGPR).

Environmental Microbiology: Microbes and quality of environment; Distribution and implications of microbes in air – bio-aerosols, microbial flora of water, water pollution, drinking water and domestic waste treatment systems; Microbial pesticides, Biotransformations: microbial degradation of pesticides and toxic chemicals, biodegradation of the agricultural residues, bioremediation of contaminated soils and water. Microbes in nanotechnology, biosensors; Microbes in extreme environments.

Food and Industrial Microbiology: Recent developments in food and industrial microbiology – Fermentation, fermented foods, fermenter design and growth processes, food spoilage, methods of food preservation; Microbes in recovery of metal (bioleaching) and oil, Recombinant-DNA technology; Cell and enzyme immobilization, microbial enzymes of industrial interest; Novel medicines from microbes.

PRACTICALS:

1. Determination of colony forming units (CFUs) using haemocytometer, dimensions of microbes using ocular- and stage-micrometer.
2. Differential staining of bacteria using Gram-stain; Endospore staining using Malachite Green; Methods for measurement of bacterial growth.
3. Isolation and estimation of bacterial proteins; Study of amylase and protease activity in bacteria.
4. Estimation of phosphate solubilizing capacity of microorganisms; Characterization of Plant Growth Promoting Rhizobacteria – Production of ammonia, IAA, siderophores, HCN, antibiotics, antifungal metabolites.
5. Isolation of *Rhizobium* from root nodules.
6. Isolation, identification and enumeration of AM fungal spores from soil.
7. Isolation of bacterial nucleic acids from soil to study microbial diversity of unculturables.

SUGGESTED READINGS:

1. Prescott L, Harley J, Klein D (2005) Microbiology, 6th edition, Mc Graw-Hill.
2. Singh VP and Stapleton RD (Eds.) (2002) Biotransformations: Bioremediation Technology for Health and Environmental Protection. "Progress in Industrial Microbiology Vol. 36", Elsevier Science.
3. Subba Rao NS (1982) Advances in Agriculture Microbiology, Butterworth-Heinemann.
4. Subba Rao NS and Dommergues YR (Eds.) (2001) Microbial Interactions in Agriculture and Forestry Vol. 2, Science Pub. Inc.
5. Waites MJ, Morgan NL, Rockey JS, Higton G (2001) Industrial Microbiology: An Introduction, Wiley-Blackwell.

3. ADVANCES IN ARCHEGONIATAE

Bryophytes: Vegetative and reproductive innovations of early land plants, Role of bryophytes in ecosystem dynamics and in the global carbon budget, bryophyte association with microorganism and animals, Symbiotic fungal associations in early land plants, Poikelohydry, Desiccation tolerance. Bryogeography and conservation. Hormonal regulation of gametophyte development in bryophytes. Breeding system, population ecology and population genetics, Anisospory and sexual dimorphism.Biologically active compounds in Bryophytes. Cytogenetics of bryophytes, Molecular genetic studies of moss species with special reference to *Physcomitrella patens*, Expression of genes under stress conditions.

Pteridophytes: Morphological diversity and evolution of vegetative organs in Pteridophytes, Diversity of Ferns - an ecological perspective, Genetics and reproductive biology of ferns, Culture of fern gametophyte for experimental investigation, photomorphogenesis, Model system in *Ceratopteris*, *Trichomanes*, *Osmunda*, *Marsilea*.

Gymnosperms: Evolution of pollination mechanisms and embryogeny of gymnosperms: propagation of conifers using plant tissue culture approaches, advances in synthetic seeds technology of conifers, somatic embryogenesis and plantlet regeneration; Acclimatization and adaptive responses of conifers to environmental stresses. Drought tolerance and cold

hardiness, stimulation of reproductive growth seed and seedling ecology, litter decomposition rate, Conifer plantation as seed trap, impact of coniferous forest on human life.

PRACTICALS:

1. Study of structural modification in Marchantiales, Jungermanniales, Isobryales and Hypnobryales.
2. Regeneration experiments, Effect of light, sugars and pH on regeneration.
3. Growth forms, water-holding capacity.
4. Effect of bryophyte extract on the growth of microbes.
5. Pollution Monitoring
6. Systematics in bryophytes and Pteridophytes.
7. Cytological studies on bryophytes and ferns
8. Evolution of reproductive pathways in Gymnosperms
9. Spore viability test. Male and female cone and pollen study in gymnosperms.

SUGGESTED READINGS:

1. Shaw AJ and B Goffinet (2000) Bryophyte Biology. Cambridge University Press.
2. Geissler and Greene SW (1982) Bryophyte Taxonomy, methods, practices and floristic exploration. J Cramer, Germany.
3. Dyer AF (Ed) (1979) The experimental Biology of Ferns. Academic London.
4. Richardson DHS (1981) The Biology of mosses. John Wiley & Sons, Inc New York.
5. Bhatnagar SP and Moitra A (1996) Gymnosperms. New Age International (P) Limited, Publishers, New Delhi
6. Singh Hardev (1978) Embryology of Gymnosperms. Encyclopedia of Plant Anatomy. Vol X Gebruder Borntraegrl, Berlin, Stuttgart.

4. PRINCIPLES OF ECOLOGY *

UNIT I

Introduction to ecology, evolutionary ecology, environmental concepts – laws and limiting factors, ecological models. Characteristics of population, population size and exponential growth, limits of population growth, population dynamics, life history pattern, fertility rate and age structure, population growth. Competition and coexistence, intra-specific interactions, inter-

specific interactions, scramble and contest competition model, mutualism and commensalism, prey-predator interactions.

UNIT II

Nature of ecosystem, production, food webs, energy flow through ecosystem, biogeochemical cycles, resilience of ecosystem, ecosystem management. The biosphere, biomes and impact of climate on biomes

UNIT III

Environmental Stresses and their management, global climatic pattern and variations over time, global climatic changes and global warming, atmospheric ozone, acid and nitrogen deposition, coping with environmental variations. Environmental pollutants- air, water and soil pollution, chemical fate and transport in air, water and soil. Use of fertilizer, pesticides and other chemicals in agriculture and hygiene and their disposal. Chemical usage and disposal from industry and pollution. Impact of chemicals on biodiversity of microbes, animals and plants. Bioindicator and biomarkers of environmental health. Biodegradation and bioremediation of chemicals, environmental issues, policies and regulations

UNIT IV

Biodiversity – assessment, conservation and management, biodiversity act of India and related international conventions. Sustainable development, natural resource management in changing environment. Molecular ecology, genetic analysis of single and multiple population, phylogeography, molecular approach to behavioural ecology, conservation genetics.

PRACTICALS**:**

Habitat studies:

1. Physical and chemical characters of soil
2. Assessing influence of light, temperature and moisture on plant germination and growth/animal behavior and growth
3. Assessing influence of soil nutrient status on plant germination and growth

Community/ecosystem studies:

1. Assessment of density, frequency and abundance of plants/animal in a community using various techniques i.e. transect, quadrate etc.
2. Comparison of stands/communities and ordination

3. Profile diagrams
4. Biomass and reproductive allocation under various environments
5. Nutrient uptake and budget for various communities/Food chain assessment
6. Decomposition of various organic matters and nutrient release mechanisms/role of arthropods and other micro-, and macrofauna in decomposition
7. Understanding ecosystem succession by studying various stages of vegetation/community assemblages development
8. Molecular techniques in laboratory.
9. Insect diversity in soil

Landscape studies:

4. Principles of GIS and RS technology
5. Interpretation (visual and automated) of remote sensing information for landscape differentiation

SUGGESTED READING

(Books meeting the needs of Botany, Zoology and Environmental Biology programs)

1. Conklin, A.R. Jr. 2004. Field Sampling: Principles and Practices in Environmental Analysis. CRC Press.
2. Fahey, T.J. and Knapp, A.K. 2007. Principles and Standards for Measuring Primary Production. Oxford.
3. Grant, W.E. and Swannack, T.M. 2008. Ecological Modeling. Blackwell.
4. Wilkinson, D.M. 2007. Fundamental Processes in Ecology: An Earth system Approach. Oxford.

5. EVOLUTIONARY BIOLOGY *

Introduction: Evolutionary Biology before Darwin, Darwin, after Darwin. Evolutionary synthesis. Fact and theory.

Biological diversity: Species and classification. Phylogenetic trees, reading and using trees. Tree of Life. The fossil record. Geological fundamentals. Phylogeny and the fossil record. Evolutionary trends. Rates of evolution. The geography of life. Major patterns of distribution. Historical biogeography, phylogeography. Genetic diversity: Genes, genomes, mutations,

karyotypes. Sources of phenotypic variation. Genetic variation in populations. Variation among populations.

Microevolution: Genetic drift, sampling, coalescence. Founder effects. Neutral theory of molecular evolution. Natural selection. Adaptation in action. Experimental studies. Levels of selection. Genetical theory of natural selection. Fitness, modes and models of selection. Evolution of phenotypic traits, Conflict and co-operation. Species and speciation. Reproductive success. Co-evolution.

Macroevolution: Inferring phylogenies. Gene trees, species trees. Patterns of evolutionary change. Adaptive radiation. Evolution and development.

Biodiversity: Estimating changes in biodiversity. Taxonomic diversity through the Phanerozoic. The future of biodiversity.

PRACTICALS:

1. Biological diversity - Interspecific variation: Species. Phylogenetic trees, reading and using trees. Floral evolution and MADS-box. Angiosperm fossil record. Biogeography. Morphometrics (Computer exercises).
2. Biological diversity - Intraspecific variation: Phenotypic morphological variation: Intraspecific variation in size and shape of leaves. Statistical analysis (distribution, mean, mode, median, standard deviation). Measurment error. Genetic variation: Intraspecific variation in Arabidopsis or other material [mutants].
3. Microevolution: Phenotypic variation and the environment: Intraspecific variation (e.g., stomatal size and density in sun and shade leaves). Hypothesis testing. t-test. Genetic variation: Computer simulations. Fitness measurements: in field, laboratory.
4. Macroevolution: Inferring Phylogenies, comparative analyses. Field, laboratory and computer exercises.

SUGGESTED READINGS:

1. David Briggs, Stuart Max Walters (1997). Plant Variation and Evolution, Cambridge University Press.
2. Douglas J. Futuyma (1998). Evolutionary Biology (3rd Edition), Sinauer Associates.

3. Mark Ridley (2003) Evolution (3rd edition), Blackwell.
4. Roderic D. M. Page, Edward C. Holmes (1998). Molecular Evolution: A Phylogenetic Approach, Blackwell.
5. Scott R, Freeman and Jon C. Herron (2003). Evolutionary Analysis, Prentice Hall.

6. BIOINFORMATICS, COMPUTATIONAL BIOLOGY AND BIOSTATISTICS# **

Bioinformatics and Computational Biology:

1. **Databases** - NCBI, EMBL, DDBJ, Genbank, Pubmed, Patent databases, TAIR, PDB, ATIDB).
2. **Online tools** - BLAST, ORF finder, Primer3, protein motif and structure prediction tools; Vector NTI, DNASTAR.
3. Bioinformatics in genome sequencing and annotation.
4. Fundamentals of computer programming.
5. Programming in PERL.
6. Introduction to *in silico* drug design and molecular modeling.

Biostatistics:

1. **Introduction**: The scope of biostatistics; Classification of study design, Observational studies and Experimental studies (uncontrolled studies, trials with external controls, cross-over studies, trials with self controls, trials with independent concurrent controls).
2. **Exploration and presentation of data**: Scales of measurement, Tables, Graphs, Histograms, Box and Whisker plots, Frequency polygon, Scatter Plots.
3. **Descriptive statistics**: measures of central tendency, measures of dispersion, rates and proportions.
4. **Probability**: Definition, mutually exclusive events and addition rule, independent events and multiplication rule. Sampling: Reasons for sampling, methods of sampling, SRS, Systematic, Stratified, Cluster, NPS. Probability distribution: Binomial, Poisson, Gaussian, Standard normal distribution. Drawing inferences from data: Confidence intervals, Confidence limits, Hypothesis tests, Types of errors, P-values.
5. **Estimating and comparing means**: Decision about single mean (normal population and non-normal population), decision about single group, decision about paired groups, decision

about two independent groups, equality of population variances, computer-aided illustration for comparison of means.

6. **Comparing three or more means**: ANOVA – one way, two way, A priori comparison, Posterior or Post Hoc comparison, randomized block design, LSD, Kruskal-wallis one way ANOVA.
7. **Estimating and comparing proportions**: Proportion in single group, Comparing two independent proportions, Risk ratios v/s χ^2, comparing proportions in more than two groups, comparing proportions in paired groups, χ^2 as goodness of fit.
8. **Correlation and Regression**: Pearson's correlation coefficient, Spearman's rho, Linear regression, Least Square method, Predicting with regression equation, Comparing two regression lines, Dealing with nonlinear observation, Common errors in regression, Comparing correlation and regression.
9. **Statistical methods for multiple variables**: Multiple regression, Predicting with more than 1 variable, Statistical test for regression coefficient, Role of R and R^2 in multiple regression, Confounding variable (ANACOVA), Predicting categorical outcomes – logistic regression, discriminant analysis.

PRACTICALS:

Bioinformatics:

Combined with theory lectures.

Biostatistics:

1. Contingency table, frequency table
2. Simple bar chart, stem and leaf plot
3. Histogram, Box and whisker plot
4. Scatter plot
5. One sample t-test, independent t-test, paired t-test
6. Wilcoxon rank-sum test, Mann-Whitney U
7. One way ANOVA, 2 way ANOVA, Kruskal-Wallis test
8. Correlation, linear regression, ANACOVA.

SUGGESTED READINGS:

1. Attwood TK and Parry-Smith DJ (2004) Introduction to Bioinformatics, Pearson Education (Singapore) Pvt. Ltd.
2. David Edwards (Ed.) (2007) Plant Bioinformatics: Methods and Protocols, Humana Press, New Jersey, USA.
3. Kulas JT (2008) SPSS Essential: Managing and Analyzing Social Science Data. John Wiley & Sons, New York.
4. Pagano M, Gauvreau K (2007) Principles of Biostatistics. Thomson India Edition, New Delhi.
5. Randal Schwartz, Tom Phoenix and Brian d Foy (2005) Learning Perl (4th edition), O'Reilly & Associates, ISBN: 0-596-10105-8.
6. Rex A. Dwyer (2004) Genomic Perl: From Bioinformatics Basics to Working Code, Cambridge University Press, 1st South Asian Edition.
7. Rosenkrantz WA (2009) Introduction to Probability and Statistics for Science, Engineering and Finance. CRC Press, Boca Raton.

7. GENOMICS AND PROTEOMICS

Genomics: Genome sequencing strategies and programs, new technologies for high-throughput sequencing, methods for sequence alignment and gene annotation; Approaches to analyze differential expression of genes - ESTs, SAGE, microarrays and their applications; gene tagging; gene and promoter trapping; knockout and knock-down mutants; dynamic modulation of protein structure and function; Comparative genomics of model plants and related crop species; Recombination-based cloning techniques; RNAi and gene silencing, genome imprinting, small RNAs and their biogenesis, role of small RNAs in heterochromatin formation and gene silencing, genomic tools to study methylome and histone modifications.

Proteomics: Analysis of proteins by different biochemical and biophysical procedures like CD (Circular Dichroism), NMR, UV/Visible and fluorescent spectroscopy, protein identification and analysis on ExPASy server, other protein related databases, 1-D and 2-D gel electrophoresis for proteome analysis, Sample preparation, gel resolution and staining; Mass spectrometry based method for protein identification like PMF (protein mass fingerprinting) and LCMS; Image analysis of 2D gels: Data acquisition, spot detection & quantitation, gel matching, data analysis, presentation, databases, conclusions; DIGE (Differential In Gel Electrophoresis), alternatives to 2-DE for protein expression analysis; Analysis of post-translational modifications

and protein-protein interactions; protein chips and arrays, future directions in proteomics, scope of functional proteomics.

PRACTICALS:

1. Gateway cloning
2. Real-time PCR
3. Northern and Western Blotting
4. Bioluminescence imaging
5. Phage titration, Phage library amplification
6. Site-directed mutagenesis
7. 2D electrophoresis
8. Differential staining procedures including MS-compatible staining
9. Gel filtration chromatography for desalting
10. Native molecular weight determination
11. Immunoprecipitation for antibody quantification

SUGGESTED READINGS:

1. Buchanan B, Gruissem G, and Jones R (2000) Biochemistry and Molecular Biology of Plants, American Society of Plant Physiologists, USA.
2. Hammes GD (2005) Spectroscopy for the Biological Sciences; Wiley Interscience, USA.
3. Harlow and Lane D (Eds.) (1988) Antibodies – A Laboratory Manual; Cold Spring Harbor Laboratory, USA.
4. Lieber DC (2006) Introduction to Proteomics: Tools for New Biology; Humana Press, NJ.
5. Pennington SR, Dunn MJ (Eds.) (2002) Proteomics: From Protein Sequence to Function, BIOS Scientific Publishers, United Kingdom.
6. Sambrook J and Russell DW (2001). Molecular Cloning – A Laboratory Manual, Vols I – III, Cold Spring Harbor Laboratory, USA.
7. Singer M and Berg P (1991). Genes and Genomes: A Changing Perspective; University Science Books, CA, USA.

8. IMMUNOLOGY *#

Fundamentals of Immunology: Basic principles and overview of immunity, antigens and antibody production, cellular interactions in the immune system, Innate immunity, Complement, antibody structure and antigen recognition, Immunoglobulin genes, Ig/TCR gene rearrangement and generation of diversity, Introduction to Immunogenetics & the MHC, Antigen recognition by T cells, TCR, Co-receptors & MHC structure, antigen processing and presentation.

Immunity in Health & Disease: Immune response to infectious diseases, Immunodeficiency and AIDS, Hypersensitivity, transplant rejections, autoimmunity, vaccines, evolution of the immune system.

PRACTICALS:

1. Animal tissue culture
2. Demonstration of antibody production in mice and estimation of antibody titre.
3. Antibody purification by affinity chromatography
4. Immunoprecipitation
5. Immunoelectrophoresis

SUGGESTED READING:

1. Kuby Immunology; by Richard A. Goldsby, Thomas J. Kindt, Barbara A. Osborne, Janis Kuby, W. H. Freeman Publishing (4e-6e).

***# - TO BE OFFERED BY FACULTY FROM THE DEPARTMENT OF ZOOLOGY / GUEST FACULTY.**

IV. SEMESTER IV (Session: Jan 05 – April 30)

Three papers are to be selected from options 1 - 8; Possible combinations include: 2,3,4 / 1,3,4 / 1,7,8 / 2,5,6

1. IN VITRO TECHNOLOGIES AND INDUSTRIAL APPLICATIONS

(To provide students with an overview of plant tissue culture techniques, their potential in the production of propagative material and interaction with industries)

- Micropropagation (via organogenesis and embryogenesis) of floricultural, agricultural and pharmaceutical crops: Orchids, Chrysanthemum, Gerbera, Carnation, Anthurium, Bamboos, *Spilanthes, Stevia, Psoralea*, Chickpea and elite tree species of national importance.
- Production of virus free plants through meristem culture in orchids and fruit trees.
- Germplasm conservation *in vitro.*
- Variations: Somaclonal and gametoclonal variations, spontaneous, genetic and epigenetic variations.
- Culture systems: Differentiated, undifferentiated, physiological, biochemical and molecular role of minerals and growth regulators in understanding differentiation of organs under *in vitro* conditions.
- Problems in Plant Tissue Culture: contamination, phenolics, recalcitrance.
- Problems in establishment of regenerated plants in nature: hardening, association of mycorrhiza and rhizobia.
- Factors responsible for *in vitro* and *ex vitro* hardening.
- Use of bioreactors in secondary metabolite production and scale up automation of plant tissue culture.
- Recent applications of tissue culture techniques and biotechnology in the introduction of economically important traits in horticultural, agricultural and medicinal plants.
- Interactions, training and workshops in Biotech industries and placements.

PRACTICALS:

1. Development of regeneration protocols employing direct and indirect organogenesis / somatic embryogenesis in economically important horticultural and/or medicinal plants.
2. Control of phenolics in recalcitrant tissues under culture conditions.
3. Study of various physico-chemical factors (pH, light, hormones, etc.) on in vitro growth and development of tissues or organs, rooting of regenerants, in vitro and ex vitro hardening, potting and acclimatization in natural conditions.
4. Shoot-tip meristem culture for raising virus-free plants in tomato / tobacco.
5. *Agrobacterium rhizogenes* mediated development of hairy root cultures.

6. Isolation of bioactive compounds from medicinal plants using column chromatography and TLC.
7. Preparation of synthetic seeds for germplasm conservation using somatic embryos or other propagules.

SUGGESTED READINGS:

1. Herman EB (2008) Media and Techniques for Growth, Regeneration and Storage 2005-2008. Agritech Publications, New York, USA.
2. Pierik RLM (1999) *In Vitro* Culture of Higher Plants. Kluwer Academic Publishers.
3. Prakash J & Pierik RLM (1991) Horticulture - New Technologies and Applications (Current Plant Science and Biotechnology in Agriculture). Kluwer Academic Publishers.
4. George EF, Hall MA and Geert-Jan De Klerk (2008). Plant Propagation by Tissue Culture (3rd Edition), Springer, Netherlands.
5. **Journals**: Plant Cell, Tissue and Organ Culture, Plant Cell Reports.

2. REPRODUCTIVE BIOLOGY OF FLOWERING PLANTS

Modes of Reproduction: An overview

Flower development: Regulation of floral architecture and diversification; Floral organogenesis; Pollination regulation of flower development.

Male gametophyte: Sporophyte-gametophyte interaction during micro- and megasporogenesis; interaction of mitochondrial and nuclear genes; male specific cytokinesis; tapetal development and pollen-coat formation; asymmetric division, cell fate and polarity; sperm dimorphism; male germ unit: cytology and 3-d structural organization; pollen biotechnology; manipulation of sperm cells; male-sterility; induction; mechanism of action and breeding; transformation of pollen; embryogenic development of pollen grains.
Female gametophyte: Regulation of pistil and ovule development; megasporogenesis and megagametogenesis: developmental pathways, gene function and organization.

Pollen-pistil interaction and double fertilization: Pollen tube guidance; recognition and rejection reaction, barriers to gene flow; signal transduction at the level o f stigma style and

ovules, double fertilization: origin, mechanism and *in vitro* fertilization; preferential fertilization; pistil activation and ovule penetration.

Plant-pollinator interactions and breeding systems: Plant-pollinator interaction: floral display, attractants and rewards, pollen load, temporal details and foraging behaviour, pollinator and pollination efficiency, physicochemical aspects of pollination; pollination energetics, gene flow, applied pollination ecology; phenology; mating systems: diversity and quantitative estimation; differential reproductive success; resource allocation; pollen:ovule ratio; sibling rivalry, ovule abortion.

Fruit biology: Development biology and diversity of fruit types, fruit abortion in relation to resource allocation, dispersal and gene flow.

Seed biology: Embryogenesis and embryonic pattern formation; endosperm development and differentiation; ultrastructure and cytology; seed development: pattern, regulation of gene expression and imprinting; agamospermy and parthenocarpy, pseudogamy and autonomous development of endosperm; Embryo and endosperm culture.

PRACTICALS**:**

1. Study of developmental aspects of reproduction using *Arabidopsis* mutants.
2. Isolation of embryo sacs and visualization of post-fertilization stages with the help of fluorescence and confocal microscope.
3. Study of micro- and megasporogenesis using Nomarski interference microscope.
4. Microtomy of resin-embedded and wax-embedded material.
5. Determination of mating systems using Isozymes/DNA markers.
6. Study of pollination syndromes and plant-pollinator interaction.
7. Measuring floral sex allocation based on biomass.
8. Assessment of floral rewards: quantitative and qualitative analysis of nectar and pollen.
9. Assessment of attraction of insects to artificial flowers and determining pollination energetics.
10. Demonstration of in-situ expression of anther/ovule specific genes.
11. Induction of somatic embryos using a suitable plant material.

12. Study of types of embryo sacs during apomictic development by employing ovule-clearing method.

SUGGESTED READINGS:

1. Barrett SCH (2008) Major Evolutionary Transitions in Flowering Plant Reproduction. Univ. of Chicago Press.
2. Faegri K & van der Pijl L (1979) The Principles of Pollination Ecology. Pergamon Press, Oxford. 291 pp.
3. Harder LD & Barrett SCH (2006) Ecology and Evolution of Flowers, Oxford Univ. Press.
4. O'Neill SD & Roberts JA (2002) Plant Reproduction, Sheffield Academic Press.
5. Raghavan V (1997) Molecular Embryology of Flowering Plants, Cambridge Univ. Press.
6. Raghavan V (2000) Developmental Biology of Flowering Plants, Springer Verlag, New York.
7. Richards AJ (1986) Plant Breeding System, George Allen and Unwin, UK.
8. Scott RJ and Stead AD (2008) Molecular and Cellular Aspects of Plant Reproduction. Society for Experimental Biology, Seminar Series 55.
9. Shivanna KR and Johri BM (1985) The Angiosperm Pollen: Structure and Function. New Delhi, India: Wiley-Eastern.
10. Shivanna KR and Rangaswamy NS (1992) Pollen Biology: A Laboratory Manual, Springer-Verlag, Berlin.
11. Shivanna KR (2003) Pollen Biology and Biotechnology. Enfield, New Hampshire, U.S.A.: Science Publishers.

3. MOLECULAR INTERACTIONS OF PLANTS WITH SYMBIONTS, PATHOGENS AND PESTS

This paper aims is to introduce various aspects of molecular and biochemical interactions of plants with symbionts, pathogens and pests at an advanced level.

1. Introduction to biotic interactions with plants.
2. Recent advances in plant-fungi, plant-insect and plant-nematode interactions: Stages of pathogenesis, Structural and biochemical host defense mechanisms against pathogens and pests, Basal resistance, Systemic acquired resistance, Induced systemic resistance,

Gene-for-gene concept, Cloning of resistance genes (R genes) and avirulence genes (Avr genes) from plants and pathogens, Induced responses to herbivory, Genetic engineering for the production of resistance plants to pathogens and pests.

3. Recent advances in symbiotic interaction with plant with special references to mycorrhiza and plant interaction.
4. Recent advances in parasitic interaction between plants and parasitic plants.

PRACTICALS:

1. Study on susceptible and resistance interactions at cellular and biochemical levels between plants and pathogens, and between plant and pests.
2. Investigation of infection cycle of a plant parasitic nematode (e.g., root knot nematode, *Meloidogyne incognita*) in susceptible and resistant tomato roots in the absence and presence of resistance genes (Mi gene).
3. Estimation of activity of phenylalanine ammonia lyase in healthy and disease leaves.
4. Detection of plant viruses from infected leaf tissues using ELISA and Western Blot.
5. Computer-based study of a multigene family pathogenicity gene from the Nem databases.
6. Field visit to show diseases on crop plants

SUGGESTED READINGS:

Plant-nematode interactions:

1. Williamson VM, Kumar A (2006) Nematode resistance in plants: the battle underground. *Trends in Genetics* 22: 396–403.
2. Davis EL, Hussey RS, Baum TJ (2004) Getting to the roots of parasitism by nematodes. *Trends in Parasitology* 20: 134–141.
3. Plant Nematology (2006) Edited by Perry and Moens, CABI.

Plant virology and insect-plant interactions:

4. Induced responses to herbivory by R Karban and IT Baldwin (1997) Chicago University Press, Chapter 3, pg47-100.
5. Mathew's Plant Virology by Roger Hull (2001) Academic Press, NY.

Plant-fungi interactions:

6. *Plant resistance mechanisms (SAR, ISR)* - Strange RN, (2003) Introduction to Plant Pathology, John Wiley & Sons, USA.

7. *Signal transduction; Molecular diagnostics; Transgenic approaches for crop protection* - Dickinson M, (2003) Molecular Plant Pathology, Bios Scientific Publishers, London.

4. ADVANCED GENETICS AND PLANT BREEDING

Origin and history of crop plants: Plant domestication - morphological, agronomic and genetic features accompanying domestication of plants, agro-biodiversity, genetic erosion.

Biological diversity and genetic variation: Kinds and patterns of variation, variation and variability; genetics, utilization and analysis of genetic variation; qualitative and quantitative traits and their genetics, polygenic inheritance, partitioning of genotypic variance, inbreeding heterosis, recent development in quantitative genetics. Variation in population, genetic structure of population.

Genetic system and breeding methods: Reproduction and breeding systems in plants. Recombination, genetic control and manipulation of breeding systems including male sterility and apomixis. Selection and breeding strategies for self-pollinated, cross-pollinated and clonally propagated crop plants, breeding for crop quality, biotic and abiotic stresses, gene pyramiding for multi-trait incorporation.

Sources of variation: Plant genetic resources-genetic consideration on PGR management and conservation, utilization of gene pools in breeding programs; Access and ownership of PGR-changing paradigms and their implications. Chromosome manipulation, induced mutations, polyploidy, somatic hybridization, somaclonal variation, novel sources of variation**;** molecular markers and construction of linkage maps; QTL mapping; map-based cloning, synteny, MAS (marker assisted selection), tagging of agronomically important traits.

Plant genome and crop improvement: Cytogenetics and its role in evolution and improvement of crops such as wheat, maize, sugarcane, *Brassica* etc.; location and mapping of genes on chromosomes, molecular cytogenetics. Genome analysis – modern approaches,

biochemical and molecular tools for the analysis of plant genome including protein and DNA based techniques; structural and functional genomics in relation to crop improvement.

World food demand vis-à-vis availability: Food availability – International and Indian scenario, national and international agencies for agricultural R&D, green revolution, IPR and post-CBD changing paradigms.

PRACTICALS:

1. FISH for rDNA
2. Molecular markers: SSR, Intron-polymorphisms, CAPS, AFLP, RAPD.
3. Analysis of morphological and molecular diversity in different cultivars/varieties of a crop plant.
4. QTL mapping (Theoretical using available data)

SUGGESTED READINGS:

1. Acquaah G (2007). Principles of Plant Genetics and Breeding, Blackwell Publishing Ltd. USA.
2. Allard RW (1999). Principles of Plant Breeding (2nd Edition), John Wiley and Sons, ISBN 0471023094, 9780471023098.
3. Hartl and Jones (2007). Genetics – Analysis of Genes and Genomes, 7th edition, Jones and Barlett publishers.
4. Hartwell, Hood, Goldberg, Reynolds, Silver, Veris (2006). Genetics – From Genes to Genomes, 3rd edition, McGraw Hill.
5. Lewin B (2008). Genes IX, Jones and Barlett Publishers, ISBN-10: 0763740632.
6. Ram J. Singh (2002). Plant Cytogenetics, 2nd edition, CRC Press.
7. Simmonds (1995). Evolution of Crop Plants (2nd Edition) Longman.
8. Strickberger (2008). Genetics, 3rd Edition, Pearson (Prentice Hall).

5. AGRICULTURAL ECOLOGY – PRINCIPLES AND APPLICATIONS

Ecological experimentation in agriculture; basic chemical process-carbon cycle; Climate and adaptation of agricultural crops; Physical factors affecting crop-water; Energy flow in

agroecosystems; Soil type and classification; soil properties and environmental factors; Nitrogen in agroecosystems; fertilizer elements in the environment; Macro and micronutrients and their availability to crops; Decomposition: beneficial soil organisms; Plant succession and competition.

Weed ecology and management; Distribution and sampling of agricultural pests; introduction to insects; Population dynamics; pesticides and the environment; Traditional knowledge systems and agrodiversity management; Plant disease and environment; integrated pest management; plant-parasitic nematodes; Host plant resistance and conservation of genetic resources; Cropping systems and agro-ecosystems in the landscape; crop rotation and cover crops; Intercropping; conservation tillage; Mulches and organic amendments; Dry-land agriculture, irrigation and salinity; Tropical agro-ecosystems; intensive agriculture; Impact of GMOs on crop biodiversity and agroecology; Impact of agricultural policies on crop biodiversity and agroecology; Human population growth; sustainable agriculture; Agroecology: the future perspective.

PRACTICALS:

1. Soil sampling and analysis for macro and micro nutrients
2. Plant water requirement assessment
3. Assessment of fertilizer inputs on crop growth
4. Assessment of planting density on crop growth
5. Impact of salinity on crop growth
6. Ecological foot print analysis

SUGGESTED READINGS:

1. Gliesmann, S.R. (2006). Agroecology: The Ecology of Sustainable Food Systems. Technology & Engineering.
2. Gliesmann, S.R. (2006). Field and Laboratory Investigations in Agroecology. Technology & Engineering.
3. Paul A. Wojtkowski, P.A. (2004). Landscape agroecology, Haworth Press, Inc., New York. 330 pp.

4. Warner, K.D. (2007). Agroecology in Action: Extending Alternative Agriculture Through Social Networks. The MIT Press, Cambridge, Massachusetts, USA, 291 pp.

6. ADVANCED PLANT SYSTEMATICS

Plant systematics: The Components of systematics, Major objectives of systematics; Relevance to society and science.

Taxonomic History: Natural systems to cladistics: Natural systems; Phyletic systems; Phenetics; Cladistics.

Botanical Nomenclature: Kinds of names; International Code of Botanical Nomenclature, Names according to rank; Citation of authors; Priority; Type method; Naming a new species; Legitimacy; Synonyms.

Classification: The components of classification; Characters and their states; Sources of characters; Evaluation of characters.

Systematic evidence: Morphology, Anatomy and ultrastructure; Embryology; Palynology; Cytology; Phytochemistry.

Molecular Systematics: Plant genomes: nuclear, mitochondrial, chloroplast; Molecular markers; Generating molecular data: restriction site mapping, gene sequencing; Analysis of molecular data: alignment of sequences, methods of phylogeny reconstruction.

Phylogenetics: The nature of phylogeny; How we depict phylogeny?; The importance of homology, Polarizing characters of homology; Rooting Trees; The problem of homoplasy.

The plant systematics community: Professional organizations; Work environment; Activities; The role of field studies; The role of the herbarium.

Introduction to the angiosperms: General characteristics; Evolutionary history; Basal angiosperms and Magnoliids; Basal monocots; Petaloid monocots; Commelinids; Basal eudicots and Caryophyllids; Rosids; Asterids.

PRACTICALS:

1. Live plants/ Herbarium specimens of the following families will be provided in the class for description and identification (classification based on APG II, 2003):
   - Basal Angiosperm and Magnoliids: Nymphaeaceae, Magnoliaceae
   - Basal Monocots: Araceae, Alismataceae
   - Petaloid monocots: Liliaceae, Smilacaceae, Alliaceae, Orchidaceae
   - Commelinids: Arecaceae, Poaceae, Cyperaceae
   - Basal Eudicots and Caryophyllids: Ranunculaceae, Caryophyllaceae
   - Rosids: Euphorbiaceae, Rosaceae, Fabaceae, Cucurbitaceae
   - Asterids: Solanaceae, Lamiaceae, Apiaceae, Asteraceae
2. Writing exercise
3. Nomenclature exercise
4. Classification exercise
5. Cladogram construction and analysis
6. Techniques in molecular systematics

SUGGESTED READINGS:

1. Angiosperm Phylogeny Group 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. Botanical Journal of the Linnaean Society 141: 399-436.
2. Crawford, D.J. 2003. Plant Molecular Systematics. Cambridge University Press, Cambridge, UK.
3. Cronquist, A. 1981. An integrated system of classification of flowering plants. Columbia University Press, New York.
4. Judd, W.S., C.S. Campbell, E.A. Kellogg, P.F.Stevens and M.J. Donoghue 2002. Plant Systematics: A phylogenetic Approach. Sinauer Associates, Inc., Massachusetts.
5. Maheshwari, J.K. 1963. The Flora of Delhi, CSIR, New Delhi.
6. Nei, M. and S. Kumar 2000. Molecular Evolution and Phylogenetics. Oxford University Press, New York.
7. Radford, A. E., W.C. Dickison, J.R. Massey and C.R. Bell 1974. Vascular Plant Systematics. Harper and Row, New York.
8. Semple, C. and M.A. Steel 2003. Phylogenetics. Oxford University Press, Oxford.

9. Simpson, M.G. 2006. Plant Systematics. Elsevier, Amsterdam.
10. Stuessy, T.F. 2009. Plant Taxonomy: The systematic Evaluation of Comparative Data. Columbia University Press, New York.

7. CONTEMPORARY CONCEPTS AND METHODS IN CELL BIOLOGY

Infective particles and life forms: prions, viroids, origin and evolution of various life forms, cell theory vs. cell body concept, multicellularity vs. supracellularity.

Cell Wall: temporal and spatial dynamism in structure, structural and functional roles, *in planta* and *ex planta* uses, cell wall biotechnology

Biological membranes: from PLP model to Dynamically Structured Mosaic Model, transport through membranes, membranes as sites and routes of intra- and inter-organism and environment interactions

Cytoplasmic components: Endomembranes, organellar architecture, protein sorting and vesicular traffic

Biopolymers: Structural and functional aspects of cytoskeleton and associated motor molecules, their role in cell organization and movement, interaction among cytoskeletal elements, genomics, proteomics and bioinformatics of plant cytoskeleton; cytoskeleton in agro-biotechnology

Nucleus: detailed structure of nuclear pore complex and nuclear lamina, nuclear transport; chromatin subunit structure: from DNA to metaphase chromosome, histone code, states of chromatin during replication and transcription, heterochromatization as a method of gene regulation

Cell turnover: cell division, cell cycle controls, breakdown of cell cycle control: cancer vs. plant tumors, programmed cell death.

Cells to tissues: Cell polarity, cell fate determination, integration of plant cells in tissues.

Introduction to methods in plant cell biology: optical and electron microscopy, fluorescent probes, flow cytometry, transient expression, microinjection and micromanipulation, electrophysiological methods, plant histology, immunocytochemistry, *in situ* hybridization, cell fractionation and organelle isolation

PRACTICALS:

Would be based on the above topics. These could be in real time if facilities are available or could be virtual experiments.

SUGGESTED READINGS:

Books:

1. Alberts B, Johnson A, Lewis J, Raff Martin, Roberts K and Walter P. (2007). Molecular Biology of the Cell. Garland Publ., New York.
2. Bonifacino JS, Dasso M, Harford JB, Liipincott-Schwartz J and Yamada KM. (2004). Short Protocols in Cell Biology. John Wiley & Sons, New Jersey.
3. Bregman AA. (1987). Laboratory Investigations in Cell Biology. John Wiley & Sons, New York.
4. Buchanan et al. 2002. Biochemistry & Molecular Biology of Plants 1st edition, American Society of Plant Physiologists: Chapter 4, pp. 160-201 & Chapter 5, pp. 202-256.
5. Hawes C and Satiat-Jeunemaitre B. (2001). Plant Cell Biology: Practical Approach. Oxford University Press, Oxford.
6. Karp G. (2008). Cell and Molecular Biology: Concepts and Experiments. John Wiley & Sons.
7. Lodish H, Berk A, Kaiser CA, Krieger M, Scott MP, Bretscher A, Ploegh H and Matsudaire P (2008). Molecular Cell Biology. WH Freeman & Co., New York.
8. Ruzin SE (1999). Plant Microtechnique and Microscopy. Oxford Univ. Press, Oxford.
9. Wischnitzer S. (1989). Introduction to Electron Microscopy. Pergamon Press, New York.

Research papers / Reviews:

1. Aguzzi, A. et al. (2007) Molecular mechanisms of prion pathogenesis. Ann. Rev. Path.: Mech. Dis. 3: 11-40.
2. Baluska F. et al. (2004) Eukaryotic cells and *cell bodies:* cell theory revised. Ann. Bot. 94: 9-32.

3. Boxma, B. et al. (2005) An anerobic mitochondtion that produces hydrogen. Nature 434: 74-79.
4. Delwiche CF (1999). Tracing the thread of plastid diversity through tapestry of life. Amer. Nat. 154:S164-177.
5. Dobson CM (2005). Structural biology: prying the prions. Nature 435: 747-749.
6. Gruenbaum Y. et al. (2003). The nuclear lamina and its functions in the nucleus. Int. Rev. Cytol. 226: 1-62.
7. Meagher, B. et al. (1999) "The evolution of new structures: clues from plant cytoskeletal genes. TIG, 15:7, 278-284.
8. Moerschbacher B. (2002). The plant cell wall – structural aspects and biotechnologoical developments. Pp. 445-477. In: Oksman-Caldentey, K-M. and Barz, W.H. Plant Biotechnology and Transgenic Plants. Marcel Dekker, Inc. New York.
9. Raven JA and Allen JF (2003). Genomics and chloroplast evolution: what did cyanobacteria do for plants? Genome Biol. 4(3): Art No. 209.
10. Rose A. et al. (2003). The plant nuclear envelope. Planta. 218: 327-336.
11. Smith and Raikhel (1999). Protein targeting to the nuclear pore: what can we learn from plants?" Plant Physiol. 119:1157-1163.
12. van der Giezen et al. (2005) "Mitochondrion-derived organelles in protists and fungi". Int. Rev. Cytol. 244:175-225.
13. Vereb, G. et al. (2003) Dynamic, yet structured: the cell membrane three decades after the Singer-Nicolson model. Proc. Nat. Acad. Sci. USA 100: 8053-8058.
14. Wasteneys GO and Yang Z (2004) New views on plant cytoskeleton. Plant Physiol. 136: 3884-3891.

8. TOPICS IN PLANT PHYSIOLOGY AND BIOCHEMISTRY

Stress physiology: Plant responses to abiotic stresses, mechanisms of abiotic stress tolerance, water deficit and drought tolerance, salinity stress, metal toxicity, freezing and heat stress.

Oxidative and nitrosative stress and antioxidative strategies: Nitrosative and oxidative stress - causes and effects, nitric oxide biosynthesis and metabolism, NO mediated signaling, markers of nitrosative stress, NO crosstalk with other hormones, antioxidant mechanisms.

Secondary metabolites and their biotechnological aspects: Natural products (secondary metabolites), their range and ecophysiological functions. Overview of terpenoidal, alkaloidal, and phenolic metabolites and their biosynthesis. Molecular approaches and biotechnological applications. Metabolic engineering in the production of pharmaceuticals.

Physiology of seed development, maturation, dormancy and germination: Hormonal regulation of seed development, events associated with seed maturation, factors regulating seed dormancy, mechanisms of mobilization of food reserves during seed germination.

Fruit development and ripening: Stages of fruit development and their regulation, biochemical and related events during fruit ripening in chimacteric and non-climacteric fruits, physiology and biochemistry of fruit abscission, post-harvest changes, production of transgenic fruits.

Programmed cell death (PCD): Concept of PCD and its types in plants during vegetative and reproductive stages. Developmental and stress-induced PCD. Plant senescence and its characteristics. Leaf and flower senescence. Altered metabolism during senescence and its regulation. The oxidative stress and the anti-oxidative strategies. Hormonal modulations. Environmental, genetic and molecular regulations.

Sensory physiology: Biochemical and biophysical mechanisms of sense of touch, electric self-defence, taste, light, explosion, sleeping and rhythms. Stimuli that trigger rapid movements; movements based on mechanical forces; mobility triggered by sense of touch, taste and electricity; motors driving movements in the living world; actin-myosin motors; photo-sensing; chemistry of excitability; neurotransmitters in plants.

Chemical defence: Biochemical mechanisms of plants' chemical war against other plants and animals. Plant responses to herbivory; constitutive defence mechanisms; induced phytochemical responses; biochemical mechanisms of allelopathty.

PRACTICALS**:** Based on the above topics.

NOTE: These papers/contents are subject to change from time to time in order to keep the courses of reading updated in light of recent developments in the areas of plant sciences.

SUGGESTED READINGS:

Journals: Annual Review of Plant Biology, Critical Reviews in Plant Science, Current Opinion in Plant Biology, Trends in Plant Science.

9. DISSERTATION

(Mandatory; assigned after the second semester)