Syllabus
M.Sc. Botany
University of Calcutta
2015.

The Regulations for two years M.Sc. course in Botany, Calcutta University

1. The University of Calcutta shall provide instructions leading towards course for M.Sc degree in Botany. A candidate who has passed the three year B.Sc. examination with Honours (Major) in Botany will be eligible for admission to this course on the basis of merit.

2. The duration of the course shall be two academic years and the examination for the M.Sc degree in Botany shall be held in four semesters over a total of 1000 marks. The duration of the semester shall be as follows:

1st Semester July - December

2nd Semester January - May

3rd Semester July - December

4th Semester January - May

3. The course shall comprise a total credit of 72 (seventy two), evenly distributed over the four semesters. The courses shall be grouped as core and optional and will carry credits according to the number of theoretical classes required, study hours and laboratory hours.

Semester wise distribution of courses:

	Courses	**No. of courses**	**Marks**	**Credits**
1st Semester	Core courses	4	260	18
2nd Semester	Core Courses	4	260	18
3rd Semester	Core Courses	4	260	18
4th Semester	Optional Course Project	3	195 25	13 05
TOTAL			**1000**	**72**

6. Grading of students' performance (as per CU rules)

Marks	**Numerical grade points**	**Grades**
75-100	5.50-6.00	Outstanding (O)
65-74	4.50-5.49	Good (A+)
60-64	4.00-4.49	Fair (A)
55-59	3.50-3.99	Satisfactory (B)
50-54	3.00-3.49	Average (C)
0-49	Below 3.00	Fail (F)

The following multiplication factors will have to be used for the calculation of the extract grade point:

Marks between	**Multiplication factor/marks added to minimum grade point bracket**
76-100	0.02
66-74	0.11
61-64	0.1225
56-59	0.1225
51-54	0.1225
0-49	0.061

Award of Grades:

6 (six) points grade system will be followed. On the basis of the results of each course, grade will be given according to the following computation. For example, if a student scores 64% in theory and 68% in practical in a 3-credit course (2+1), his/her grade point for the course will be as follows:

Grade point= {2x (4+0.1225x4)+(4.5+0.11x3)}/ (2+1)= 4.60

For a credit course with no practical component, for example a 2-credit course, if a student scores say, 59%, then the grade point will be:

Grade point= {2x(3.5+0.1225x4)}/2= 3.99

Average grade point for a Semester:

The computation of average grade point of a student in a semester will be worked out as follows:

N^{th} Semester

Course	**Credits**	**Grade Scored**
1	2+1	5.65
2	2+1	5.33
3	2+0	3.99
4	2+0	5.05
5	3+1	4.22
6	3+1	4.46
Average grade point		**4.76**

Average grade point= (5.65x3)+(5.33x3)+(3.99x2)+(4.22x4)+(4.46x4)=4.76

Cumulative grade point average over four semesters:

Working out simple average, cumulative grade point average will be obtained over four semesters.

Significance of grades:

On the basis of the cumulative results of the student's performance, the following grades will be given in each semester as well as over four semesters.

Numerical grade points	**Grades**	**Class**
5.50-6.00	Outstanding (O)	First (I)
4.50-5.49	Good (A+)	First (I)
4.00-4.49	Fair (A)	First (I)
3.50-3.99	Satisfactory (B)	Second (II)
3.00-3.49	Average (C)	Second (II)
Below 3.00	Fail (F)	Fail

7. A candidate shall be eligible for appearing at the examination provided he/she prosecutes a regular course of studies in Botany maintaining percentage of attendance as specified by the University.

8. Examinations would be held after the completion of curriculum at the end of each semester. However, evaluation of the practical will be based on continuous assessment as well as on the final Viva-Voce examination of the students on the experiments.

9. If a student gets 'F' in a particular course, he/she shall be deemed to have failed in that course only and shall be required to repeat that course in a subsequent semester when offered. A student can attempt a maximum number of two times to clear a particular course, failing which he/she shall be dropped from the rolls of the University on the advice of the concerned Dean of the Faculty.

10. If a student is dropped from the University rolls because of failure to clear a particular course, he/she may apply for readmission in the beginning of the next academic session along with the fresh applicants.

11. A student securing a cumulative grade point average of B or above shall be considered as secured at least 55% of marks and will be eligible to appear at the National Eligibility Test (NET) or other national level selection tests.

12. Paper setters for each paper will include both internal and external examiners appointed on the recommendations of the Board of Post-graduate Studies in Botany.

13. There shall be at least one external paper setter for each theoretical paper appointed by the authority for this process.

14. The external paper-setters may be from other universities/faculty members of premier research institutions.

15. The students will be required to prepare and submit a report on project work performed during 4^{th} semester. A panel of examiners, comprising of both internal and external examiners, shall evaluate the Project work.

17. For each of the semester-end examination, there shall be a board of moderators for the theoretical papers.

Orientation of courses in four semesters for M.Sc in Botany

1st Semester

Core courses		*Marks(*Theo.+Prac)	*Credits*
Bot C11	Phycology	40+ 25	2.5+2
Bot C12	Microbiology	40+ 25	2.5+2
Bot C13	Plant Anatomy and Developmental Biology	40+ 25	2.5+2
Bot C14	Cell and Molecular Biology	40+ 25	2.5+2
	Total	160 (Theoretical) + 100 (Practicals) = 260	10 (Theoretical) + 8 (Practicals) = 18

2nd semester

Core courses		*Marks(Theo.+Prac)*	*Credits*
Bot C21	Bryophytes,Pteridophytes and Gymnosperms	40+ 25	2.5+2
Bot C22	Palaeobotany and Palynology	40+ 25	2.5+2
Bot C23	Taxonomy of Angiosperms	40+25	2.5+2
Bot C24	Genetics and Genomics	40+ 25	2.5+2
	Total	160 (Theoretical) + 100 (Practicals)	10 (Theoretical) + 8 (practicals)
		= 260	= 18
			= 260

3rα Semester

Core courses		*Marks(Theo.+Prac)*	*Credits*
Gen C31	Mycology and Plant pathology	40+ 25	2.5+2
Gen C32	Plant Physiology and Biochemistry	40+25	2.5+2
Gen C33	Phytochemistry and Pharmacognosy	40+ 25	2.5+2
Gen C34	Plant Biotechnology	40+ 25	2.5+2
	Total	160 (Theoretical) + 100 (Practicals) = 260	10 (Theoretical) + 8(practicals) = 18

4th Semester

Optional courses		*Marks(Theo.+Prac)*	*Credits*
Bot O 41#	Ecology and Environmental Botany	50+ nil	2
Bot O42#	Integrative Plant Biology	50+nil	2
Bot O43	Special Paper	70+25	6+3
Bot O44	Project work	Nil +25	5
	Total	170Theoretical) + 50 (Practicals) = 220	10 (Theoretical) + 8 (Practicals) = 18
Total Marks/Credits		**650 (Theoretical) + 350 (Practical) = 1000**	**40 (Theoretical) +32 (Practical) = 72**

Choice based Credit Course

Bot O 43 Special paper:

1. **Advanced Cell Biology**
2. **Molecular and Applied Phycology**
3. **Microbiology**
4. **Molecular Mycology and Plant Pathology**
5. **Phytochemistry and Pharmacognosy**
6. **Palaeobotany and Palynology**
7. **Plant Biotechnology**
8. **Plant Genetics and Genomics**
9. **Plant Physiology, Biochemistry and Molecular Biology**
10. **Taxonomy and Biosystematics**

Detailed Syllabus for two years M.Sc Course in Botany, CU - 2015

First Semester

Bot C11: Phycology~ 40 marks; 2.5 credits, 40 Lecture hours

Algal Classification and Phylogeny- Old Classical system and modern poly phasic approach;Biome classification and algal phylogeny, Symbiosis theory-Primary, Secondary and Tertiary endosymbiosis, molecular markers.
Biodiversity and Conservation of Algae: Algal diversity of different habitat, importance of conservation; *in situ* and *ex situ* conservation.
Evolution of Algae: Evolution at morphological and ultra structural level, horizontal gene transfer and evolution of algal chloroplast.
Cyanobacteria: Protoplasmic structure, genome and genetic properties; heterocyst, ultra structure,- biochemistry of *nif* gene regulation; ecology-Cyanobaterial bloom, cyanotoxin and cyanophages. **General overview of algal divisions:** Diagnostic characters of major algal divisions-
Glaucophyta-Principle characteristics and primitive features
Dinophyta- Cell structure; heterotropism, Red-tides and Toxins.
Chlorophyta-Cell division pattern, ultra structure of flagella; classification and phylogeny
Bacillariophyta-Ultra structure and developmental patterns of diatom frustules
Phytoplankton Ecology- A brief introduction to the organisms; types; physical factors (light,heat) and chemical environment: carbon, nitrogen, phosphorous, red field ratio; Phytoplankton Dynamics-Nutrient Uptake models.
Economic application of microalgae- Bioactive chemicals from microalgae, nutraceuticals, pigments, polysaccharides, lipids.
Mass production of micro-algae- Culturing techniques and photo bioreactor based production; down stream processing.

Practicals: 25 marks; 2 credits

1. Algal Diversity study(Fresh water) Cyanobacteria, chlorophyta, Euglenophyta,Bacillariophyta
2. Identification of seaweeds from different divisions-chlorophyta, Phaeophyta, Rhodophyta
3. General Principles of culturing algae in laboratory and growth curve determination
4. Demonstration of mass cultivation in photobioreactor
5. Collection of local flora and submission(at least 10 voucher)

Suggested readings:

1. Phycology (4th Edition) R.L. Lee, Cambridge University Press, 2008.
2. Algae- An introduction to Phycology- C Van den Hoek, DG Mann, HM Janes, Cambridge University Press,1995.
3. Hand Book of Microalgal culture. Ed by A. Richmond. Blackwell Publishing House,2003
4. Algae- Anatomy, Biochemistry and biotechnology-L. Barsanti & P. Gualtieri. Taylor & Francis,2006.
5. Molecular Biology of Cyanobacteria- DA Bryant. Kluwer Academic Publisher,1995.
6. Photosynthesis in Algae- W. D. Larkman, E. Douglass & J A Raven, Kluwer Academic Publishers.
7. Algal Ecology- Fresh Water Benthic Ecosystems. Ed by R. J Stevenson, ML Bothwell, R.L. Lowe, Academic Press, 1996.
8. Ecology of Cyanobateria-Their diversity in time and space- B A Whittan,M Potts. Kluwer Academic Publishers.
9. Origin of algae and their plastids.Ed. D Bhattacharya, Springer Wien,New York
10. The Biology of Blue Green Algae- NC Carr & BA Whitton,Berkley: University of California Press,1973.
11. Algae- LE Graham & W. Lee Wilcox.Prentice Hall,2000.

Bot C12: Microbiology ~ 40 marks; 2.5 credits, 40 Lecture hours

Methods in Microbiology
Culture of microorganisms; Methods for isolating pure cultures, types of culture, enrichment culture techniques, maintenance and preservation of pure cultures. Control of microorganisms: physical and chemical methods.
Microbial Diversity and Extremophilies
Phototrophic bacteria; Chemolithotrophic bacteria; Spirochetes; Rickettsias; Chlamydias; Mycoplasmas; Myxobacteria and Extremophiles (thermophilic, halophilic, acidophilic and alkalophilic bacteria).
Growth and Differentiation
Bacterial growth: definition, growth parameters, measurement of growth, synchronous growth, growth kinetics, factors affecting growth. Batch and continuous culture. Differentiation: endospore formation- cytological, physiological and genetic aspects, germination; life cycle of Caulobactor.
Microbial Metabolism
Outlines of biosynthesis of peptidoglycan, major amino acids and proteins. Regulatory mechanisms in bacteria-induction, repression, feedback inhibition, catabolite repression and attenuation; Manipulation of biochemical regulatory mechanisms for overproduction of metabolites. Nitrogen metabolism: ammonification, nitrification, denitrification and nitrogen fixation.
Bacterial Genetics
Organisation and replication of genetic material in bacteria: chromosome and plasmid;, gene transfer mechanisms: conjugation, transformation and transduction. Recombination in bacteria.
Medical Microbiology
Pathogenic properties of bacteria: toxins and extracellular enzymes; brief account of major human disease and their bacterial pathogens. Principles of chemotherapy, general account of chemotherapeutic agents, sulfa drugs and antibiotics.
Fundamentals of Immunology
History of immunology, innate and acquired immunity, humoral and cell mediated immunity, organ and cells involved in immunity, T cells and B cells; antigens: characteristics and types, adjuvants. Immunoglobins: types, structure and properties.
Viruses and acellular microbes
Nomenclature and classification, distinctive properties of virus, morphology and ultrastructure, capsid and their arrangements, types of envelopes and their composition, viral genome, their types and structure, virus related agents (viriods and prions). Viral replication: lytic and lysogenic.

Practicals ~ 25 marks; 2 credits

Based on theory papers

Bot C 13: Plant Anatomy and Developmental Biology *~ 40 marks; 2.5 credits, 40 Lecture hours*

Plant Developmental biology
Basic concepts of development; Gametogenesis, potency, commitment, specification, determination and differentiation, morphogenetic gradients, cell fate and cell lineages; positional information, pattern formation and morphogenesis.

Fertilization and early development in plants; Gametophyte development and fertilization, post-fertilization changes, axis and pattern formation in Arabidopsis, organization of shoot and root apical meristem, leaf development and phyllotaxy; transition to flowering-vegetative to reproductive evocation, floral homeotic mutations in Arabidopsis, Antirrhinum and Petunia, floral meristems and floral development. Approaches to study genes involved in plant development in Arabidopsis and maize.

Plant Anatomy:

Differentiation of primary and secondary plant bodies: Origin and development of sclereids, fibres and their control of differention; vascular cambium; factors influencing cambial activity.
Physiological plant anatomy: Anatomical response to mineral deficiency; response of plants to wounding and invasion by microorganism; Kranz leaf anatomy and photosynthesis; Hydraulic engineering-principle and water flow.
Plant anatomy in systematic and evolution: Phylogeny of xylem and phloem elements; wood anatomy, nodal anatomy, mineral inclusion in systematic and evolution.
Ecological anatomy: Leaf and wood anatomy in ecological perspective; anatomical response to pollutants.
Reproductive plant anatomy: Floral vasculature; development of pollen grains; structure of floral nectarines, endosperm and seed coat.
Applied plant anatomy: Application of anatomical studies in climatology, genetics and plant breeding, biomedical research and forensic science.

Practicals ~ 25 marks; 2 credits

1. Cell types- trichomes, sclerides, tracheids, vessel members and sieve tube elements.
2. Secretary structures and cell inclusions- nectaries, glandular hairs, oil glands, salt glands, resin canals, laticifers, phytoliths, cystolith and crystals.
3. Nodal anatomy- unilacunar, trilacunar, multilacunar.
4. Anatomy of bark and lenticels.
5. Wood anatomy from TS, TLS, RLS of woody plants.
6. Study of shoot apical organization in pteridophytes, gymnosperms and angiosperms.
7. Ecological leaf anatomy: sun and shade leaves, xeromorphic leaves, succulent leaves, halophyte leaves, hydromorphic leaves.

Suggested readings:

1. Comparative Plant Anatomy - Carlquist, S. (1961)
2. An Introduction to Plant Anatomy - Eames, A.J. and MacDaniels, L.H. (1947).
3. Anatomy of Seed Plants - Esau, K. (1977).
4. Plant Anatomy (4th Edition) - Fahn, A. (1990).
5. Physiological Plant Anatomy - Haberlandt, G. (1914).
6. An Introduction to Plant Structure and Development - Charles B. Beck (2010).
7. Integrative Plant Anatomy - Dickison, W.C. (2000).
8. Plant Anatomy - Mauseth, J.D. (1988).
9. Plant Anatomy (Part-I- Cells and Tissues) - Cutter

Bot C14: Cell and Molecular Biology *~ 40 marks; 2.5 credits, 40 Lecture hours*

Cell structure and function

Plasma Membrane: Structural models, Composition and dynamics, Biogenesis and assembly, transport of small molecules.
Cell walls: Bacterial and eukaryotic cell walls
Nucleus: Internal organization, nuclear envelope, NPC, macromolecular transport and rRNA processing

Mitochondria: Origin, evolution, biogenesis and genetic systems.
Chloroplast: Origin, evolution, biogenesis, chloroplast genome
Cytoskeleton: Structure and organization of actin, intermediate filament and microtubules

Cell Regulation

Cell cycle: Eukaryotic cell cycle, regulations of cell cycle
Cell signaling: Signaling molecules and their receptors, functions of cell surface receptors (G-protein coupled receptor, receptor PTK, cytokine and non-receptor PTK), second messengers
Cell interactions: Cellular adhesions, junctional proteins and receptors

Genetic Information

Deoxyribonucleic acid: Structure and properties of DNA (hyperchromocity, melting and reassociation, Cot curve, unique and repetitive sequence)
DNA replication: Mode of replication in prokaryotes and eukaryotes, machineries of replication
Ribonucleic acid: Structure and properties of RNA, types of RNA, m RNA processing-G capping, intron splicing (including *cis-trans* and alternate splicing), polyadenylation, RNA editing,
Transcription: Transcription in prokaryotes and eukaryotes (initiation, elongation and termination), transcription factor binding sites and factors
Protein synthesis: Machineries involved in translation process, process of translation in prokaryotes and eukaryote

Practicals *25marks; 2credits*

Subcellular fractionation of plant tissues and isolation of cellular organelles.
Isolation of plant genomic DNA, purity estimation by UV spectroscopy, agarose gel electrophoresis.
Extraction & estimation of total protein from plant tissue, SDS-PAGE

Suggested readings

1. Molecular Cell Biology, Lodish H et al., - Freeman
2. The World of the Cell, Becker WM et al., - Benjamin Cummings
3. Essential Cell Biology, Alberts B et al., - Garland
4. Molecular Biology of the Cell, Alberts B et al., - Garland
5. Genes IX, Lewin B – Pearson
6. Molecular Cell Biology, Lodish H et al., - Freeman
7. Cell and Molecular Biology, De Robertis and De Robertis – Lippincott and Wilkins
8. Genomes, Brown TA - Garland

Second Semester

Bot C21: Bryophytes, Pteridophytes and Gymnosperms *~ 40 marks; 2.5 credits, 40 Lecture hours*

Bryophyta

1. General habit, habitat, distribution, biogeography & conservation, growth forms, life forms (for general identification from field).
2. Outline of recent classification of Bryophytes.
3. Comparative morphology and developmental anatomy of Liverwort, Hornwort and Mosses.
4. Sporophyte organization and its evolutionary significance in bryophytes (peristome structure and its significance in classification of mosses) .
5. Ecological significance: colonization, succession and role of bryophytes in ecosystem.

6. Bryophyte as site-specific bio-indicator and phytoremediator for environmental pollution.
7. Metabolic chemistry of bryophytes and its taxonomic implication.
8. Cytogenetics & Reproductive Biology.

Pteridophyta

1. Introduction; outline of systematic treatment of pteridophytes; distribution of extant groups in time and space.
2. Early land plants; vegetative and reproductive organography, evolutionary significance of the members of Zosterophyllopsida, Trimerophytopsida, Isoetales and Sphenophyllales.
3. Stomatal types and development; evolution of stele; ecology, karyology and affinity of Ophioglossaceae, Osmundaceae, Cyatheaceae, Polypodiaceae, Salviniaceae.
4. Types of spore, induction of spore germination, gametophyte types, biochemical aspects of gametophyte differentiation; antheridogens- chemical nature and mode of action; determination of femaleness in free sporing heterosporous plants; phytochemistry of pteridophytes.
5. Diversity of ferns in an ecological perspective; insect, microorganism- pteridophyte interactions, endangered and endemic pteridophytes and their conservation.
6. Cytogenetics and reproductive biology of ferns: polyploidy, apospory, apogamy, apomixes and hybridization; genetic variability in fern population- genetic load.

Gymnosperms

1. Concept of progymnosperms and its evolutionary significance.
2. Introduction; outline of systematic treatment; distribution of extant taxa in time and space.
3. Brief account of extinct cycadales, Coniferales with emphasis on evolutionary aspects.
4. Vegetative morphology and reproductive biology (pollination mechanism, embryology) of extant Cycadales, Coniferales, Ginkgoales, Taxeles and Gnetales.
5. Karyology and phytochemistry of important taxa, biotechnogy of important taxa; endangered and endemic taxa and their conservation.

Practicals : *25marks; 2credits*

Bryophyta

Work out the vegetative and reproductive structures of representative genera from Liverwort, Hornwort and Mosses..

Pteridophyta

1. Study of general habitat, external and internal morphology of vegetative and reproductive structures (spore types and soral anatomy etc.) of the following taxa:
   Psilotum, Lycopodium japonicum, L. serratum, L. cernuum, Selaginella monospora, Isoetes coromandelina, Equisetum diffusum, Botrychium, Angiopteris, Osmunda, Lygodium, Dicranopteriis, Oleandra, Nephrolepis, Asplenium, Blechnum, Adiantum, Christella, Cyathea/ Alsophila/ Hemitelia, Microsorum, Phymatosorus, Ceratopteris and Salvinia.
2. External morphological features of the following taxa:
   Tmesipteris, L. squarrosum, L. Selago, Ophioglossum, Schizaea, Marattia, Cibotium, Drynaria, Acrostichum, Selaginella bryopteris, Pteris vittata, Pyrrosia, Helminthostachys, Cheilanthes and Onychium.

Gymnosperms

1. Study of general habit, external and internal morphology with special reference to their male and female reproductive structures, pollen grains, *Cycas, Ginkgo, Pinus, Cryptomeria ,Thuja, Araucaria, Podocarpus, Cephalotaxus, Ephedra, Gnetum.*

2. Study of leaf and wood anatomy of the following taxa: *Abies, Cryptomeria, Cupressus, Araucaria, Taxus and Gnetum.*
3. Study of External morphology of the following taxa : *Zamia ,Encephalartos, Tsuga, Taxodium, Cunninghamia, Juniperus, Callitris, Agathis, Welwitschia, Sequoia and Metasequoia.*

Bot C22: Palaeobotany and Palynology ~ 40 marks; 2.5 credits, 40 Lecture hours

Basic geological information related to palaeobotany
Sedimentary rocks; Taphonomy; dating the pages of eath history; nomenclature and reconstruction of fossil plants; Stratigraphy; Basic concepts of continental drift and plate tectonics.
Origin and evolution of plant life forms:
The earliest environments; Brief idea of Origin of life; first prokaryotes; evolution of eukaryotes; geological records of algae (stromatolites, diatoms, dinoflagellates), fungi (endomycorrhiza and epiphyllous fungi), bryophytes and their ecological significance.
The colonization of land:
Environmental changes before terrestrialization, land adaptive features, evolution of land plants- different evidences, biogeographical distribution of early land plants (Silurian- early Carboniferous), earliest trees in the fossil record.
Emergence of seed plants:
Preovules, hydrasperman reproduction; evolution of closed carpel; evidences from the ovulate fructification of Glossopteridales, Corystospermales, Caytoniales, Bennettitales, Pentoxylales.
Appearance of Angiosperms:
Evidence for the first angiosperms: leaves, flowers and pollen grains; place of origin and radiation; cladistic and molecular biological approaches on phylogeny of angiosperms.
Past life as source of energy:
Organic deposits of commercial value- coal, petroleum- their origin and depositional environment; coal and petroliferous basins of India.
Palynology:
Branches of palynology; Spore, pre-pollen and pollen morphology, wall chemistry, exine ornamentation, evolution of aperture types.
Applied palaeobotany and palynology:
i)Fundamentals of palaeofloristics, palaeogeography, palaeoecology and palaeoclimatology; Application of neopalynology and paleopalynology.
ii)Ancient DNA and other fossil biomolecules and their potential in evolutionary research; stable isotopes and tree ring in reconstruction of palaeoclimate.

Practicals : 25marks; 2credits

1. Types of fossils and modes of preservation
2. Techniques of study of plant fossils:
Thin section method (demonstration and study of prepared slides), peel techniques (demonstration and study of prepared peel sections); maceration of peat, lignite, coal: (demonstration).
3. Systematic study of fossil plants through ages-
Precambrian biota: Stromatolites.
Early land plants*: Aglaophyton*, Cooksonoids, Rhyniophytes, Zosterophylls.
Palaeozoic Pteridiphytes: Lepidodendrids, Sphenopsids, Filicopsids.
Palaeozoic Gymnosperms: Lyginopteridaceae, Medullosaceae, Glossopteridaceae, Cordaitaceae.
Mesozoic Gymnosperms: Peltaspermaceae, Williamsoniaceae, Cycads, Gingkoaceae, Pentoxylaceae.

Tertiary and Quaternary angiosperms including plant remains from Holocene archaeological sites.
4. Acetolysis method (demonstration); study of morphology of modern spores and pollen grains; pollen analysis of honey.
5. Study of macerated sample (to be supplied) of peat, lignite and coal. Quantitative and qualitative study of palynomorphs. Interpretation of data on stratigraphic age and environment of deposition.

Suggested Readings:

1. Kumar R. 2011. Fundamentals of Historical Geology and Stratigraphy of India. New Age International Publishers. 254 p.
2. Bhattacharyya, K., M.R.Majumdar, S.G.Bhattacharyya. 2011. A Textbook of Palynology. New Central Book Agency (P) Ltd. 352 p.
3. Jones, T.P. and N.P. Rowe. 1999. Fossil Plants and Spores: modern techniques. The Geological Society, London. 396 p.
4. Cleal, C.J., and B.A.Thomas. 1999. Plant Fossils. The History of Land Vegetation. Woodbridge, Boydell Press, Woodbridge, VA. 128p.
5. Meyen, S.V. 1987. Fundamentals of Palaeobotany. Chapman & Hall, New York. 432 p.
6. Stewart, W.N., and G.W. Rothwell. 1993. Palaeobotanmy and the Evolution of Plants, 2nd ed. Cambridge University Press, New York. 521 p.
7. Taylor, T.N., E.L. Taylor and M. Krings. 2009. Palaeobotany- The Biology and Evolution of Fossil Plants. Elsevier. 1230 p.
8. Thomas, B.A., and R.A. Spicer. 1987. The Evolution and Palaeobiology of Land Plants. Croom Helm, London (Dioscorides Press, Portland, OR). 309 p.
9. Willis, K.J., and J.C. McElwain. 2002. The Evolution of Plants. Oxford University Press, New York, 378 p.
10. Surange, K.R., R.N. Lakhanpal and D.C. Bharadwaj. 1974. Aspects and Appraisal of Indian Palaeobotany. Birbal Sahni Institute of Palaeobotany, Lucknow. 674 p.
11. Moore, P.D., J.A. Webb and M.E. Collinson. 1991. Pollen analysis. 2nd Edition. Oxford (Blackwell Scientific Publications). 216 p.
12. Brasier, M.D. Microfossils. George Allen and Unwin, London, 193 p.
13. Erdtman, G. 1969. Handbook of Palynology. Munksgaard, Copenhagen.
14. Levin, H.L. 1981. Contemporary Physical Geology. 579 p.
15. Holmes Arthur. 1978. Holmes Principles of Physical Geology. 3rd Edition, 730 p.
16. Senger, R. 1999. Encyclopedia of Palaeontology. Fitzroy Dearborn Publ.

Bot C23 Taxonomy of Angiosperms ~ 40 marks; 2.5 credits; 40 lecture hours

1. Introduction: Systematics, Taxonomy, Classification, Identification, Nomenclature.
2. International Code of (Botanical) Nomenclature (ICBN/ICN): History, aims and principles, brief knowledge of rules and recommendations with selected examples.
   Proposed Bio Code and PhyloCode.
3. Tools of Taxonomy: Field collection methods, Herbarium, Botanic Gardens and their importance in teaching and research, GIS (Geographical Information System) in Botany, Brief knowledge of Taxonomic literature.
4. Data sources of Taxonomy: Anatomy, embryology, palynology, cytology and phytochemistry.
5. Species concept.
6. Numerical Taxonomy (Phenetic methods): Definition, Principles, Steps of studies, Merits and Demerits.
7. Cladistics: A brief account.
8. Major systems of classification and their merits and demerits: Cronquist's system (1981), Takhtajan's System (1997), APG Classifications.
9. Angiosperms diversity: Salient features, phylogeny and evolutionary trends in Magnollidae, Hamamelidae, Caryophyllidae, Asteridae, Alismatidae, Commeliniidae, and Liliidae (*sensu* Cronquist, 1981), concept of palaeoherbs and eu-dicots (tricolpates).

10. Biodiversity: Concept, levels, values, hotspots and hottest hotspots, megadiversity centers of world, loss of biodiversity, IUCN threat categories, *in situ* and *ex situ* conservation measures.
11. Ethnobotany: Concept, importance, methods of study.

Practicals: 25marks; 2credits

1. Workout of plant specimens and description of vegetative and reproductive characters from representative families locally available.
2. Training in using local floras and other literature and herbaria for identification of specimens described in the classes.
3. Study of various taxa of a genus, location of key characters and preparation of keys at species level.
4. Field excursion for familiarization with and study of vegetation type(s) and flora(s) of areas outside the state, and in the local areas, and training in collection and preservation methodologies.

Bot C 24: Genetics and Genomics~ 40 marks; 2.5 credits, 40 Lecture hours

Basic concepts in Plant Genetics: Discoveries in classical and molecular genetics; Extension of Mendelism: Allelism; gene-environment interaction; penetrance and expressivity; epistasis, pleiotropy, continuous and discontinuos variations; complementation test for alleles; linkage, crossing over and cytogentic mapping
Genetic Integrity and Diversity – Physical and chemical basis of equational separation of chromosomes; Recombination, Mechanisms and genetic control of recombination; Evolutionary significance of recombination. Mutagenesis: Molecular basis of spontaneous and induced mutations; Transposon mutagenesis, *In vitro* mutagenesis, Site-directed mutagenesis, Structure and function of transposable elements and their role in evolution.
Population Genetics-- Definition of populations, Gene frequency in a population, genetic equilibrium, Hardy-Weinberg principle, barriers to gene flow and mechanism of speciation, Using highly polymorphic DNA sequences in DNA typing, Inbreeding and genetic consequences of self-pollination in plants.
Genome organization in Eukaryotes – types of genomes, genetic features of eukaryotic nuclear genomes; development of gene concept, gene replication, organization of structural and functional elements of chromosome:- centromere, telomere heterochromatin and telomerase, sex chromosomes in plants; special chromosomes in different eukaryotes ;genome duplication and alterations and their role in evolution; Genes and gene number; Law of constancy and C-value paradox.
Genomes and Comparative Genomics –Nuclear, mitochondrial and chloroplast genomes of Eukaryotes: physical features and genetic content; Concept: mapping and sequencing of genomes: *Arabidopsis*, rice and tomato genomes; Genome annotation; Synteny; Gene search and comparison tools.
Functional Genomics -- Approaches to analyze differential expression of genes - ESTs, SAGE, microarrays and their applications; Principles in reverse genetics: Gene tagging; Gene trapping; Gene silencing; Knockout mutants; Transcriptome; Ribotype concept; concept, methodology and applications of proteomics.

Practicals: 25marks; 2credits

1. Phases of division of meiotic cell: chromosome pairing in diploids, polyploids and structural hybrids
2. Mitosis: staining techniques and karyotype analysis
3. Analysis of genetic polymorphisms using molecular markers
4. Physical mapping of DNA
5. RNA isolation, cDNA preparation, gene amplification

Suggested Reading

1. Klug, Cummings, Spencer and Palladino (2014) Concepts of Genetics 10th Edition; Pearson Publishers
2. Watson, Baker, Bell, Gann, Levine, Losick (2014) Molecular Biology of the Gene 7th Edition; Pearson Publishers
3. Hartwell, Hood, Goldberg, Reynolds (2014) Genetics: From Genes to Genomes; Mc Graw Hill Publishers
4. Griffiths, Wessler, Carroll, Webley (2013) Introduction to Genetic Analysis 10th Edition
5. Jahier J. Techniques in Plant Cytogenetics; Oxford and IBH Publishers
6. Brown TA (2006) Genomes 3; Wiley-Liss Publishers
7. Snustad DP and Simmons MJ (2013) Principles of Genetics; John Wiley and Sons

Third Semester

Bot C 31: Mycology and Plant Pathology~ 40 marks; 2.5 credits, 40 Lecture hours

Mycology

1. Introduction to Mycology; Major Groups of Fungi; Fungal life cycles, Fungal Phylogeny and Evolution.
2. Fungal physiology, nutrition, and growth
3. Fungal cytology.
4. Cell cycle in Yeast; Molecular mechanism of asexual and sexual reproduction.
5. Applied mycology: Overview; Fungi in fermentation technology; mycorrhiza in agriculture; Bioremediation; mushroom production;

Plant Pathology

1. Principles of Plant Pathology.
2. Mechanism of penetration and the process of disease development: Specificity, recognition, penetration, toxin production, altered plant metabolism during disease.
3. Mechanism of disease resistance; stress signaling.
4. Major Fungal, Bacterial and Viral diseases of crop plants.
5. Epidemiology of plant diseases; Principles and practices of disease control; Integrated disease management.
6. Molecular methods for detection of plant pathogens.

Practical: 25marks; 2credits

1. Sterilization and incubation- principles and uses of instruments.
2. Culture media and their preparation.
3. Preparation of stabs, slants and pouring of plates.
4. Isolation of fungi from water/soil/air by culture plate technique.
5. Isolation of pathogen from diseased tissues.
6. Preparation of pure culture and sub culturing.
7. Inoculation of tuber and fruit.
8. Morphological and reproductive structure of some macro and micro fungi.
9. Symptomology and histopathology of some common diseases with diagnostic characteristics.
10. Isolation of fungal DNA and PCR based analysis.
11. Fungal tissue- culture; Preparation of spawn and cultivation of *Pleurotus.*
12. Identification of specimens from field trip.

Gen C 32 Plant Physiology and Biochemistry ~ 40 marks; 2.5 credits; 40 lecture hours

1. Plant water relationship, physicochemical properties of water.
2. Ion uptake mechanism of individual cell and roots, interaction between ions, ion competition, antagonism and synergism, Ion transporters: Different types, structure and function
3. Phloem translocation: symplastic and apoplastic flow of solvents, phloem loading and unloading, Validity of Münch's Pressure Flow Mechanism, Phloem sap composition, P-proteins, Sucrose transporters – structures and types.
4. Photosynthesis: Genes and polypeptide components of photosynthetic complexes , Linear and Cyclic electron transport in chloroplast, generation of proton gradient and ATP synthesis ,Water to Water Cycle , bioenergetics of light reaction, CO2 concentrating mechanism in plants, regulation of C3,C4 and CAM cycles.
5. Respiration: metabolic regulation of glycolysis, acetyl CoA, Krebs cycle, gluconeogenesis and glyoxylate cycle. Complexes and mechanism of electron transport in mitochondria, generation of proton gradient and ATP synthesis.
6. Nitrogen metabolism: structure and function of nitrogenase. Mechanism of nodule formation and establishment of microaerobic environment for the bacteroids, *nif* genes and *nod* genes ---organization and function.
7. Structure and mechanism of action of auxin, gibberellins, cytokines, ethylene and abscisic acid. Biosynthesis of ethylene, Gibberellins and abscisic acid.
8. Physiology of flowering: Photoperiodism and transduction of Photoperiodic signal leading to Floral Bud Initiation (FBI), Phytochrome - chemistry and photo-morphogenetic responses. Cryptochrome and blue light responses; Vernalization – Effect of low temperature on FBI
9. Dormancy and generation of seeds: orthodox and recalcitrant seeds, types of seed dormancy, breaking of dormancy, biochemical changes during dormancy, hormonal regulation of dormancy and germination.
10. Carbohydrate- classification, structure.
11. Lipid metabolism: oxidation of fatty acids and biosynthesis of fatty acids.
12. Protein -structure, Ramachandran plot, structure of amino acids.
13. Enzymes: Types, mechanism of enzyme action, enzyme kinetics, enzyme inhibition.
14. Senescence: Types, causes of senescence, physiology of senescence, senescence promoters, Whole plant senescence and organ senescence, hormonal and environmental control of senescence, programmed cell death in life cycle of plants.

Practicals : 25marks; 2credits

1) Assay of Catalase,Peroxidase,Ascorbic acid oxidase and Urease activity.
2) Complexometric method of analysis of Calcium & Magnesium.
3) Colorimetric estimation : IAA.
4) Isolation of chloroplast and assay of Hill activity.
5) Tetrazolium test of seed viability

Bot C33: PHYTOCHEMISTRY AND PHARMACOGNOSY~ 40 marks; 2.5 credits, 40 Lecture hours

1. Introduction, history, scope.
2. Classification and pharmacological action of plant drugs.
3. Origin of secondary metabolites – a brief account of acetate pathway, mevalonate and deoxyxylulose phosphate pathways, shikimate pathway
4. Carbohydrates – starch, cellulose derivatives, gums.
5. Glycosides, general account, biosynthesis, glycosidal drugs
6. Cyanogenic glycosides and glucosinolate compounds.
7. Alkaloids, definition, properties, classification, alkaloidal drugs – *Datura stramonium*, *Atropa belladona*, opium, *Cinchona*, tea, ergot, *Rauvolfia, Holarrhena, Catharanthus* – alkaloidal constituents, uses, allied drugs.
8. Phenolic compounds produced by plants, types, biological activity, drugs – Senna, Aloe, Hypericum, Capsicum.
9. Steroidal compounds, different types, biological activity and pharmaceutical importance
10. Volatile oils, composition, drugs – clove, *Mentha, Eucalyptus, Foeniculum, Cinnamomum,* citronella
11. Resins, different types, uses
12. Lipids
13. Antibiotics and vitamins
14. Hallucinogenic, allergenic and other toxic plants
15. Pesticides (plant and microbial origin)
16. Methods of extraction, isolation and characterisation of secondary metabolites.
17. Chemical races.
18. Quality control of plant drugs.

Practicals : *25marks; 2credits*

1. Choice of solvent for extraction of alkaloids, phenols.
2. 2Chemical tests for the detection of alkaloids, phenols, anthraquinones, cardenolides, anthocyanins, betacyanins, carotenoids.
3. Extraction and chromatographic detection of some common plant drugs.
4. Study of unorganized drugs – starches, gums, resins etc.

Bot C34: Plant Biotechnology~ 40 marks; 2.5 credits, 40 Lecture hours

Plant tissue culture: Introduction; Surface sterilization; Nutrient medium; Cyto-differentiation; Plant regeneration; Organogenesis; Embryogenesis; Micropropagation (introductory); Protoplast culture and application; Haploid culture; Apomixis and application of haploidy and DH populations in crop improvement; *In vitro* fertilization.

Recombinant DNA technology: Principles and methods of recombinant DNA technology- expression of cloned genes in *E. coli*, cloning in yeast: transformation in yeast, yeast artificial chromosome (YAC), retrovirus like vector (Ty) in yeast/shuttle vector.

Genetic transformation: Vector construction; *Agrobacterium* system, *en-planta* transformation; system; Direct gene transfer system; Protoplast transformation system (Electroporation and PEG); Screenable and selectable markers and their uses; Chloroplast transformation; Marker-free methodologies; Gene stability, Inheritance and Differential expression of transgenes in plants.

Molecular breeding for abiotic stress tolerance: Stress regulated genes expression; Osmotic stress signaling; Application in salt, cold and drought tolerance in plants.

Molecular breeding for Biotic stress tolerance: Fungal resistance; Bacterial resistance; Virus resistance; Transgenes pyramiding.
Pest management in crop plants: Bio-pesticides, Built-in plant protection (*Bt* technology); Safety and environmental issues; Integrated Pest Management (IPM).
Weed management: Implications of herbicide resistant crops
Bio-fortified crops: Concept of bio-pharming; Improvement of micronutrients in food crops; Iron and pro-vitamin A-enriched rice, Vitamin E-maize, Protein improvement in rice and potato etc.; Renewable Bio-fuel production in plants.
Bio-and Food-safety, Intellectual Property Rights and Ethical Issues: Intellectual property rights (IPR); Patents, trade secrets, copyright & trademarks; Plant genetic resources; Plant
Economic and social impact of Biotech-crops: *Ex-ante* analysis and commercial release of GM-crops.

Practicals : 25marks; 2credits

1. **Plant tissue culture techniques:** Media preparation; Surface sterilization; Embryo rescue & *in vitro* germination; Shoot bud multiplication for initiation of micropropagation; Callus culture induction.
2. **Plant Transformation system:** (Demonstration)
3. **Molecular Biology tools:** PCR, Gel electrophoresis, Isolation of plasmid and genomic DNAs (Demonstration).

Fourth Semester

Bot O41: Ecology and Environmental Botany ~50 marks; 2 credits; 48 lecture hours

1. The Environment: Physical, biotic, and abiotic.
2. Habitat and Niche: Concept, types, resource partitioning.
3. Population ecology: Characteristics of a population; population growth curves; life history strategies (r and k selection).
4. Community Ecology: Nature of communities; community structures; edges and ecotones.
5. Ecological Succession: Types; mechanisms; changes involved in succession; concepts of climax.
6. Ecosystem: Structure and function; energy flow and mineral cycling (CNP); forest, grassland and aquatic ecosystems.
7. Major Biomes of the world.
8. Environmental Pollution and its effects on plants.
9. Sustainable Development;
10. Biodiversity: Definition, levels, value, Hotspots (Indian), major threats.
11. Conservation: Principles; major approaches to management; Biosphere Reserves; wetland conservation.
12. Bioremediation: Definition, importance, methods, ecology of bioremediation; brief knowledge of phytoremediation.
13. Greenhouse effect and Global warming; Ozone depletion.
14. Ecological Adaptation in Hydrophytes, Xerophytes, Mesophytes, and Halophytes.
15. International Biological Programmes; Man and Biosphere Programmes.
16. Geographical Information System (GIS).

Suggested Readings

Odum, E. P. 1971. Fundamentals of Ecology. W.B Sounders Co., Philadelphia.
Odum, E. P. 1997. Ecology: A Bridge Between Science and Society. Sinauer Associates.
Chapman, J. L. & Reiss, M. J. 1999. Ecology Principles and Applications. Cambridge University Press, U. K.
Sharma, P. D. 2009. Ecology and Environment. Rastogi publicatios, Meerut.

Ambasht, R. S. 1990. A Text Book of Plant Ecology. Students' Friends & Co. Varanasi.
Dhaliwal, G. S., Sngha, G. S. and Ralhan, P. K. 1998. Fundamentals of Environmental Science. Kalyani Publishers.
Kaushik, A. and Kaushik, C. P. 2014. Perspective in environmental studies. New Age International (8) Ltd. Publishers, New Delhi.

Bot O42: Integrative Plant Sciences ~50 marks; 2 credits; 48 lecture hours

1. Principles of Phylogenetics: Systematics
2. Advanced Paleoecology
3. Evolutionary Genetics
4. Comparative genomics and transcriptomics
5. Epigenetics – inheritance beyond the DNA sequence
6. Plant cell & tissue culture and its application
7. The stem cell concept in plant development
8. The plant immune system and response to stress
9. Systemic acquired resistance in plants
10. Biophysical phenomena, instrumentation and biostatistics
11. Sustainable Plant Systems
12. Green nanotechnology
13. Drug discovery from plants
14. Toxicology
15. Challenges in Plant Science

Bot O 43 Advanced Cell Biology~70 marks; 6 credits; 70 lecture hours

Organization of nuclear genomes: Chromosomes and higher order chromatin structure, organization of centromere and telomeres, chromatin modification and gene expression, transposable elements
Protein sorting and transport: System involved in sorting(ER, golgi,), cargo selection and sorting, transport and docking
Cell signaling pathways: Mode of functioning of cAMP pathway, Hedgehog, wnt, Notch, NF-kB signaling,PI-3/Akt-mTOR, MAPK pathways, JAK-STAT and TGF-b pathways
Cell renewal: Checkpoints of cell cycle progression ,roles of inhibitor proteins, growth factors and regulators(DNA damage checkpoints)
Cell death: Types (apoptosis, necrosis, autophagy, PCD) and mechanisms of cell death, roles of factors involved
Cytoskeleton and cellular motility: Functions of actin, IF and microtubule, microtubule motor proteins, cell movement
Mutation: Types and molecular basis, genetic basis of complementation, chromosomal aberration, structural basis of DNA mutagenesis, oxidative DNA damage and mutagenesis, in vitro mutagenesis
DNA repair and damage response: Mechanism in DNA repair in prokaryotes, lower eukaryotes and plants, identification and molecular characterization of repair enzymes
Cancer: Characteristics of tumour cells, transformed cell lines, oncogene vs. tumour suppressor genes, immunocytochemistry, strategies for combating cancer

Epigenetics Epigenetic marks and their maintenance, epigenetic controls in whole- plant processes,techniques to study epigenetic mechanisms such as restriction landmark genome scanning, sodium bisulphite based DNA sequencing, chromatin immunoprecipitation coupled microarrays.
Molecular Evolution: Evolution of gene structure, protein domains, Ribozyme and RNA world, micro RNA, si RNA and importance of RNAi in differentiation and evolution, evolution of major phyletic lines, antiquity of introns, molecular clock

Practicals (based on theory papers) ~ 25 marks; 3 credits

Bot O 43: Molecular and Applied Phycology ~ 70 marks; 6 credits; 70 lecture hours

1. Latest development in Classification and Phylogeny- Molecular systematic of Cyanobacteria and Chlorophyta.
2. Modern Biology of Cyanelles- Phylogenetic analysis and molecular genetics.
3. Application of Phylogeny- Evolutionary Process, Application in classification, Ecological application, Environmental genomics, monitoring harmful algae.
4. Algae in biotic associations: algae in food web, algae as parasites or pathogen, algae as epibionts, algae in mutualistic symbiosis.
5. Algal Light Harvesting complex: Phycobiliproteins, Carotenoids and xanthophylls, Chromatic adaptation, Structure and regulation of Light Harvesting genes, optical monitoring of signature pigments.
6. Targeted genetic modifications in cyanobacteria and algae.
7. Freshwater Wetland and Marine Ecology: Algal assemblages and bio films, sampling and biomass estimation, Physical factors, Limiting nutrients, Conceptual models
8. Algae as bio indicator- Fossil algae as indicator- lake sediment analysis; Monitoring of water quality, Practical implication of algal indices.
9. Industrial production of Microalgal cell mass and secondary products from major industrial species- *Nostoc, Haematococcus, Porphyridium.*
10. Technological application of algae- heterotrophic production; Microalgae in human and animal nutrition; micro-algae in novel food products; Pharmaceuticals and gelling agents from algae; Microalgae in aquaculture, Biodisel, Hydrogen, Methane production and CO_2 sequestration by algae, Phyco-nanotechnology.

Suggested Readings:

1. Phycology (4^{th} Edition) R.L. Lee, Cambridge University Press. 2008.
2. Algae- An introduction to Phycology C Ven den Hoek, DG Mann, HM Janes, Cambridge University Press.1995
3. Algae- Anatomy, Biochemistry and Biotechnology L Barsanti & P. Gualtieri. Taylor and Francis, 2006.
4. Handbook of Microalgal Culture. Ed. A. Richmond. Blackwell Publishing, 2003.
5. Algal Ecology- Fresh Water Benthic Ecosystems Ed. R.J. Stevensom, M.L. Bothwell, R.L . Lowe. Academic Press, 1996.
6. The Molecular Biology of Cyanobacteria D.A. Bryant. Kluwer Academic Publisher, 1995.
7. Photosynthesis in Algae W.D. Larkman, E. Douglass & J a raven, Kluwer Academic Publishers.
8. Ecology of Cyanobacteria - Their diversity in Time and Space B.A. Whittan, M Potts. Kluwer Academic Publishers.
9. Origin of Algae and their Plastids. Ed. D Bhattacharya. Springer Wien, NewYork.
10. The Biology of Blue Green Algae- NG Carr & BA Whitton. Barkley: University of California Press, 1973.
11. Algae LE Graham & W Lee Wilcox. Prentice Hall, 2000

Bot O 43: Plant Cell and Tissue Culture ~70 marks; 6 credits; 70 lecture hours

1. **Basic concept of plant *in vitro* technology**: History of *in vitro* plant biology; Organization of a tissue culture laboratory; Equipment and supplies; Basic techniques; Medium components; Medium preparation; Differentiation/ Regeneration.
2. **Organogenesis**: Organogenesis process; Mechanism of action of plant hormones; Multiple hormonal control on organogenesis; Mechanisms of morphogenesis; Genetic control of morphogenesis.
3. **Embryogenesis**: Major processes in Embryonic development; Role of phyto-hormones in embryogenesis; Somatic Embryogenesis-Structural and developmental ontogeny, Physiological, Biochemical and molecular aspects of somatic embryogenesis; Synthetic seeds and its application.
4. **Haploid and Triploid culture**: Androgenesis; Gynogenesis; Endosperm culture; Techniques and Applications in crop improvement.
5. **Protoplast culture and somatic hybridization:** Isolation, Purification and Culture of Protoplasts; Protoplast fusion and Somatic Hybridization, Principle and scope; Nuclear and Cytoplasmic hybrids; Selection of hybrids; Regeneration; Applications & Limitations.
6. **Micropropagation**: Methods and stages of clonal propagation; Strategies for virus-free plant production; Assessment of clonal fidelity using different types of markers; Field evaluation; Packaging technology & Transport methods.
7. **Somatic cell genetics**: Somaclonal variation; Genotypic and Phenotypic variations in cell cultures and in regenerated plants; Types & Origin of chromosomal mutation in cultured plants; Genetic basis of somaclonal variation; Applications in crop improvement.
8. **Germplasm preservation**: Concept of Biodiversity and role of *in situ* and *ex situ* conservations of germplasms; Cryopreservation, Principle, Techniques and Applications.
9. **Genetic manipulations in plants**: Strategies and Methods of genetic manipulations in plants; *Agrobacterium*-mediated gene transfer; Genetic elements and engineering of *Ti* and *Ri* plasmids; Direct gene transfer – electroporation, particle bombardment and other alternative methods; Role of markers in plant transformation; Application of plant transformation for productivity and performance; Molecular farming, benefits and risks; Transgene stability and gene silencing; Strategies to avoid gene silencing and improve gene expression in transgenic plants.
10. **Production of secondary metabolites by cell and organ cultures:** Secondary product formation and storage in plants; Manipulation of biosynthetic capacity of secondary metabolites in cell cultures; Factors determining the accumulation of secondary metabolites by plant cells and organ cultures; Strategies for improvement of metabolite production; Screening and selection of variant cell lines with increased secondary product level; Biotransformation using plant cell cultures; Transformed cell and root cultures for production of secondary metabolites; Metabolic engineering for production of secondary metabolites; Bioreactors and Commercial applications.

Practicals (based on theory papers) ~ 25 marks; 3 credits

Suggested Readings

1. Plant Tissue Culture: Theory and Practice: By SS Bhojwani and MK Razdan
2. Plant Tissue Culture: Techniques and Experiments: By RH Smith
3. Plant Cell and Tissue Culture: By S Narayanaswamy

4. *In Vitro* Culture of Higher Plants: RLM Pierik
5. Plant Cell and Tissue Culture: By IK Vasil & TA Thorpe
6. Molecular Biotechnology: Principles and Applications of Recombinant DNA: By BR Glick & JJ Pasternak.
7. Biotechnology in Agriculture and Forestry 8: Plant Protoplasts and Genetic Engineering I: By YPS Bajaj
8. Biotechnology in Agriculture and Forestry 9: Plant Protoplasts and Genetic Engineering II: By YPS Bajaj
9. *Agrobacterium*: From Biology to Biotechnology: By T Tzfira & V Citovsky
10. Molecular Cloning: A Laboratory Mannual: By J Sambrook, EF Fritsch & T Maniatis

Bot O 43: Plant Physiology, Biochemistry and Molecular Biology ~70 marks; 6 credits; 70 lecture hours

1. Biological thermodynamics- Relationship between energy and entropy, Equillibrium constant and Free energy change, overview on metabolic flow in plants, oxidation-reduction reactions, oxidation number, redox potential, dissociation constant, Energy conservation-phosphoryl group transfer, hydrolysis of ATP, phosprorylation potential, ATP cycle-ATP generation mechanisms in chloroplast and mitochondria.
2. Nitrate assimilation in plants, structure, function and regulation of nitrate assimilation enzymes, nif genes, nod genes - structure, function and regulation.
3. Physiology and molecular biology of abiotic stress, biotic stress, reactive oxygen species and their protection mechanisms, role of polyamines in stress physiology.
4. Senescence and its regulation, Programmed cell death (PCD): Types, developmental and.Molecular Biology of PCD, fruit ripening.
5. Pumps, carriers and channels - Structure and function, energetics of active transport,
   a. isophore and ionophore; Vacuoles – origin,structure and function.
6. Uptake and metabolism of sulphur in plants.
7. Floral induction and development - Hormonal control, molecular genetics of floral development and floral organ differentiation; Effect of low temperature on floral bud initiation (FBI) through silencing of FLC gene.
8. Protein targeting - Protein transport in cell organelles, common features of the transport mechanism, chaperon, chaperonin and protein folding, protein glycosylation and its significance.
9. Signal molecules, signal perception and transduction in plants;MAP-kinase,Ca-calmodulin complex – role in plant signaling.
10. Protein purification, characterization, methods for the determination of amino acids
    a. sequences in proteins, protein folding pathways and Levinthal Paradox.
11. Biosynthesis of carotenoids, amino acids, biological significance of carotenoids.
12. Gene tagging, Recombinant DNA technology,Transposon and mobile elements.
13. Genetic markers,types and application
14. RNAi technology, application for trait improvement
15. Proteomics applied to functional genomics
16. Metabolomics study,profiling,application
17. Molecular characterization of transgenic event, Intellectual property rights
18. Metabolic engineering – An overview.

Practical 25 marks; 3 credits

1) Reducing and non-reducing sugar estimation from sugar sample.
2) Seperation of amino acids and sugar by cation exchange resin chromatography.
3) Estimation of nitrogen by Kjeldal method.

4) Extraction of fat from plant materials
5) Estimation of sap value from oil samples.
6) Colorimetric estimation of Phosphorus, reducing sugar.
7) Determination of Km value of Urease
8) Practical on Molecular Biology.

Bot 043: Phytochemistry and Pharmacognosy ~70 marks; 6 credits; 70 lecture hours

1. Origin of secondary metabolites – detailed account of acetate pathway: fatty acids and polyketides; mevalonate and deoxyxylulose phosphate pathways: terpenoids and steroids; shikimate pathway
2. Turnover and degradation of secondary metabolites – physiological and developmental aspects - compartmentation of secondary metabolism.
3. Phytochemistry, biosynthesis and sources of drugs:
   (i) Phenols and phenolic glycosides : structural types, biosynthesis, importance (simple phenolic compounds, tannins, anthraquinones, coumarins and furanocoumarins, flavones and related flavonoid glycosides, anthocyanins, betacyanins, stilbenes, lignins and lignans).
   (ii) Steroids, sterols, saponins, withanolides, ecdysones, cucurbitacins: Biosynthesis, commercial importance.
   (iii) Miscellaneous isoprenoids – iridoids, sesquiterpenes, diterpenoids, triterpenoids, tetraterpenoids, polyterpenoids.
   (iv) Alkaloids – Different groups, biosynthesis, bioactivity.
   (v) Volatile oils, aromatherapy
   (vi) Resins and balsams
   (vii) Lipids: nutritional and medical uses
   (viii) Carbohadrates: nutritional contribution, disease prevention
4. Enzymes, proteins and amino acids as drugs
5. Vaccine, toxins and toxoids, antitoxins, immune globulins, antiserums
6. Vitamins
7. Antibiotics – chemical nature, mode of action.
8. Pharmacological action of plant drugs – tumour inhibitors, hypoglycaemic, antihepatotoxic, antiprotozoal, antiviral, immunomodulators, PAF antagonists, antioxidants, phytoestrogens and others; role of different enzyme inhibitors
9. General methods of phytochemical analysis – extraction, isolation (different chromatographic techniques, principles), characterisation, immunoassay.

11. Plant metabolomics: a general idea and applications
12. Tissue culture and biotechnology for production of secondary metabolites - microbiological conversion – metabolic engineering
13. Ethnopharmacology

Practicals (based on theory papers) ~ 25 marks; 3 credits

BOT O 43: Plant Genetics and Genomics ~70 marks; 6 credits; 70 lecture hours

Genetic analysis and an overview of Genomics:
Overview of genetic analysis; Epistasis analysis, genetic analysis of pathways; suppressor/enhancer screens; forward and reverse genetics; Evolution of the concept of the Gene; Complex gene-protein relationships.

Genomics an overview; correlated genetic, cytological, physical maps of chromosomes in plants; map position based cloning of genes; RNA and protein assays of genome function; evolution of genome in cereals.

Regulation of gene expression:
Chromatin modification and genome expression. Various protein motifs involved in DNA protein interactions during eukaryotic transcription; chromatin remodeling, different modes of mRNA, tRNA splicing; general discussion on various snRNPs; capping, polyadenylation and other processing events in eukaryotes, RNA editing; discussion on ribozyme; RNA interference: mechanism and enzymology regulation of gene expression by miRNP pathway; plant virus interactions and silencing of RNA.

Molecular Breeding:
Development of hybrid and evaluation of combining ability, prediction of double cross hybrid performance; production of hybrids using cytoplasmic male sterile parental line, detection of DNA polymorphisms using molecular markers, quantitative trait loci (QTL), QTL mapping using molecular markers, markers assisted breeding.

Transposon tagging of plant genes:
Ac/Ds transposable elements of corn; Cloning of maize Ac/Ds elements; molecular features of the maize Ac/Ds system; Transposon tagging; Cloning of the tomato Cf-9 gene by transposon tagging.

Genes controlling flower development in plants:
Genes that are implicated in flower development, commitment to flowering, floral organ identity; Cloning of genes involved in flowering induction and flower organ development; Analyzing gene expression by *in situ* hybridization; Expression analysis of floral commitment genes and floral organ determining genes.

Plant metabolic engineering:
Advancement of metabolic engineering through pathway gene discovery, case study of phenylpropanoid pathway; Manipulating structural genes to change pathway enzymes to augment metabolite production ; Identification of transcriptional factors controlling pathways of metabolism. Gene discovery in plant metabolism; Genetic characterization of molecular mechanism driving plant natural product biosynthesis; Combinatorial Biochemistry and Metabolomics.

Genomics and proteomics:
Genomic tools; Sequencing technology, sequencing strategies, sequence databases (ESTs, BAC ends, genomic etc.), annotation of sequence data, Using TAIR (BAC contigs in areas of interest, obtaining their sequences), the annotation process, BLAST searches, DNA microarrays for global gene expression studies, Computer tools: BLAST searches, multiple alignments, phylogenetic trees. Importance of proteomics in post genomics era; studying the proteome; interactive session: virtual proteomics; analyzing a protein; application of proteomics. Plant Genome Informatics. Plant Proteomics and Gene Expression Profiling.

Quantitative and evolutionary genetics
Quantitative inheritance: traits controlled by many loci; location and significance of polygenic inheritance; QTL mapping with molecular markers; population statistics; heritability; partitioning of the variance; measurement of heritability; quantitative inheritance in plants. Quantifying heritability; testing for fit to Hardy- Weinberg equilibrium; extension of H-W equilibrium – multiple alleles; multiple loci; Non-random mating, inbreeding and population analysis.

Evolutionary Genetics:
Evolutionary forces: processes that change allelic frequencies; models for population genetics; The ribonucleic acid and ribonucleic protein worlds. The DNA world; the evolution of major phyletic lines; Evolution by Genome Duplication; Evolution of Protein Domains; Evolution and introns; Evolution and Horizontal gene transfer : Evolution and transposable elements. Molecular clock.

Practicals (based on theory papers) ~ 25 marks; 3 credits

Suggested Reading

1. Russel PJ (2013) iGenetics- A Molecular Approach; Pearson Publishers
2. Krebs, Goldstein and Kilpatrick (2014) Lewin's Genes XI; Jones and Bartlett Learning Publishers
3. Lodish, Berk, Kaiser, Krieger, Bretscher, ploegh, Amon et al, Molecular Cell Biology 7th edition; WH Freeman Publishers
4. Pua E-C and Davey M-J (2014) Plant Developmental Biology-Biotechnological Perspectives Vol-2; Springer Publishers
5. Hendrick PW (2011) Genetics of Populations; Jones and Bartlett Learning Publishers
6. Fedoroff (2013) Plant transposons and Genome Dynamics in Evolution; Wiley-Blackwell Publishers
7. Brooker, Genetic Analysis and Principles 3rd edition; Mc Graw Hill Publishers
8. Rapley and Harbron (2012) Molecular Analysis and genome discovery 2nd Edition; Wiley-Blackwell Publishers
9. Weaver R, Molecular Biology, 3rd edition; Mc Graw Hill Publishers

Bot O 43 : Palaeobotany and Palynology ~70 marks; 6 credits; 70 lecture hours

1. Brief introduction to physical geology related to Palaeobotany; types of rock, classification of sedimentary rock, tectonic features: fold, fault, taphonomy.
2. Outline of stratigraphy, Uniformitarianism and superposition, gaps in the time record, code of stratigraphic nomenclature, Biostratigraphy, Lithostratigraphy, Chronostratigraphy, stratigraphic correlation.
3. Antiquity of life; Major events in the Precambrian- early life forms, Indian records, stromatolites and palaeoecology.
4. Brief account of structural diversity of Fossil algae, fungi and bryophytes.
5. Evolutionary theories and the plant fossil record; mechanisms driving evolutionary change.
6. Environmental changes during Permian, Permo-Carboniferous floral proviences. Early paleozoic and lower Carboniferous flora of India. Origin and relationships of cycads, bennettites, ginkgos and glossopterids.
7. Distribution of Glossopteris flora in time and space, vegetative and reproductive organography of *Glossopteris* plant.
8. Enigma of angiosperm origin: reasons for the late arrival in the fossil record, Pre-Cretaceous angiosperm.
9. Origin of mangrove vegetation with special reference to palaeocostline reconstraction; evolution of plants using the C_4 and CAM photosynthetic pathway: the first grasses.
10. Brief concept of mass extinction: evidence in the geological record: plants versus animals; floral changes across the Cretaceous – Tertiary boundary.
11. Biotic interactions: Plant animal intereaction and their co evolution in the fossil record.
12. Palaeopalynology of peat, lignite and coal. Artificial classification of sporae-dispersae, role of palaeopalynology and microfossils in oil exploration, identification of isobotanical line, source rocks and palaeoshoreline; kerogen.
13. Coal petrology- Depositional facies, Diagenesis, Lithification, Microlithitypes, reflectance, fluorescence study (brief), Application of coal petrology (brief).
14. Microfossils- geological occurance, structure and palaeoecology of Acritarchs, Dinoflagellates, Hystrichosphaerids, Radiolaria, Microforaminifera, Ostracods, Silicoflagellates, Diatoms, *Botryococcus*, Coccolithophores.

15. Palaeobotany- Palaeopalynology of quaternary sediments in understanding global warming, climate changes, eustatic sea level change, coastal evolution with special reference to Bengal Basin.
16. Ancient DNA and other fossil plant biomolecules: Extraction, characterization and potential in evolution and climate research; fossil evidence of physiological and developmental mechanism-polar auxin flow.
17. Application of palaeobotany in geological investigations, plate tectonics, palaeoenvironment and palaeogeography; NLR, CLAMP, stable carbon isotopes and Co-existance approach for reconstruction of palaeoclimate, determination of pCO_2 concentration.
18. Archaeobotany: study of plant economy from Palaeolithic to Historic age; vegetation dynamics and palaeoclimatic reconstraction through phytolith analysis.
19. Mega-Milo floristic divisions of Indian Gondwana.
20. Deccan- intertrappean flora and palaeoecological consideration.
21. Siwalik flora: Dynamics of vegetation and climate in the Himalayas.
22. Pleistocene flora- palaeobotany and palynology with special reference to Kashmir.
23. Different aspects of Neopalynology and their applications: Melittopalynology, Aeropalynology, Archaeopalynology, Forensic Palynology, Copropalynology, Entomopalynology; Natural traps of pollen grains and their importance.

Practicals ~ 25 marks; 3 credits

1. Physical Geology: types of rocks, Tectonic features: Fold, Fault, environmental features of deposition: BIF, Varved sediments. Geological maps showing sedimentary basins of India.
2. Modes of preservation.
3. Pre-Cambrian, Palaeo-Meso-Cenophytic plants: Stromatolites, Oncolith, Thallophytes to angiosperms (Gondwana, Euramarian, Cathaysian); Microfossils- Carboniferous to Quaternary, fossil algae, fungi, acritarch, dinoflagellates, *Botryococcus*, hystrichosphaerid, Fossil salt glands *Heliospermopsis*, phytoliths.
4. Anatomical study of fossils through ages (peel section) Carboniferous- Quaternary (Northern and Southern Hemisphere).
5. Thin section method- thin section of wood.
6. Peel- technique- Coal ball, Coalified compression.
7. Palynological techniques- Acetolysis methods, study of living spores and pollen with different apertural types and ornamentation pattern.
8. Study of aerospora using natural trap; pollen analysis of cattle dung and insect gut content.
9. Maceration techniques- i. Peat ii. Lignite iii. Coal iv. Shale v. Clay vi. Sandstone vii. Heavy liquid separation- study of fossil spores, pollens, other microfossils of Palaeozoic, Mesozoic, Cenozoic age. Camera lucida drawing, measurement and tally mark counting of biota, palynogram, histogram.
10. Comparative study of miofloral assemblazes and statistical analysis; correlation of miofloral assemblazes.
11. Transfer technique; preparation of cuticle for study of venetion pattern, pCO2 concentration and epiphyllous fungi.
12. Project work.

Bot O 43 : MICROBIOLOGY ~70 marks; 6 credits; 70 lecture hours

Microbial Systematics

Classical approaches to bacterial taxonomy, chemo-taxonomic characteristics (peptidoglycan, lipids, fatty acids and proteins) and genotypic characteristics (DNA-base composition, -fingerprinting, -relatedness; RNA-sequence analysis, DNA-RNA hybridization); bacterial phylogeny.

Medical

Normal microbiota of human body; host-parasite relationship in baterial pathogenecity: non-specific mechanisms of host defense, mechanism of bacterial virulence, genetics of bacterial virulence; chemotherapy: antibiotics (origin, classification, chemistry and mode of action); semisynthetic antibiotics; antibiotic resistance in bacteria, mechanism of antibiotic resistance.

Immunology

Theories of antibody production, antibody diversity; antigen-antibody reactions; immunoassay methods and their applications, major histocompatibility complex (structure and function), complement system and complement activation; monoclonal antibodies (production and applications).

Virology

Cultivation of viruses, methods for detection and assay, phage typing, major human viruses: HIV, Hepatitis B and C, their salient properties, diagnosis, prevention and treatment. Viral vaccines, interferon and antiviral drugs.

Microbial Ecology

Population interactions (microbe-microbe interactions, plant-microbe interactions, animal-microbe interactions), quorum sensing; microbial consortia; bacterial biofilms- formation and applications; biogeochemical cycling of carbon, nitrogen, phosphorous and sulphur.

Environmental Microbiology

Biological treatment of wastes and pollutants: solid wastes disposal, treatment of liquid wastes; Biodegradation of environmental pollulants: petroleum hydrocoarbons and xenobiotics. Bioremediation of heavy metals; Bioleaching and recovery of metals.

Microbes in Agriculture

Biological nitrogen fixation, nitrogenase and alternative nitrogenase system, nif genes; degradation of cellulose, hemicellulose and lignin, production of biofertilizers (mass production of Rhizobium and Azotobacter); Microbial control of insects. Use of viruses in agriculture.

Food Microbiology

Food produced by microbes: Fermented foods (fermented dairy products, alcoholic beverages, vinegar, fermented vegetables), microbial cells as food. Food as substrate for microorganism, food borne disease; contamination and spoilage of food (meat and meat products, fish, fruits and vegetables, milk and milk products), methods of food preservation (physical and chemical).

Practicals (based on theory papers) ~ 25 marks; 3 credits

Bot O 43 : Molecular Mycology and Plant Pathology ~70 marks; 6 credits; 70 lecture hours

Molecular Mycology

1. Nutrient sensing and uptake in fungi.
2. Regulation of carbohydrate and nitrogen compound metabolism.
3. Genetic control of vegetative growth, asexual and sexual development
4. Genome organization in fungi.
5. Extra chromosomal inheritance in fungi.
6. Principles and general methods of fungal genetic engineering.
7. Retroposon and retrotransposon in fungi.

8. Regulation of protein synthesis in fungi.
9. Heat shock protein and chaperon.
10. Signal transduction pathway.
11. Control of cell cycle in yeast; genetic manipulation of brewing yeast.
12. Medical mycology: General account of cell mediated and humoral immunity.
13. Mushroom in modern medicines: Mushroom nutraceutials.

Plant Pathology

1. Molecular basis of plant-pathogen interaction- physiology and genetics of plant-pathogen interaction; genetics of pathogenicity; gene for gene hypothesis and its molecular explanation; resistance genes and avirulent genes.
2. Molecular biology of disease resistance- Plant chemicals (phenolics) involved in resistance: Phytoalexins; pathogenesis related (PR) proteins; systemic acquired resistance (SAR).
3. Host specific and non specific toxin and molecular basis of their roles in pathogenicity.
4. Crown gall tumerogenesis- nature of tumor; the Ti plasmid and its use as a transformation vector.
5. Development of disease resistant variety by mutation breeding and recombinant DNA technology.
6. Laboratory and Analytical techniques in plant pathology.
7. Molecular diagnoses of plant pathogens- DNA-DNA hybridization; PCR amplification and finger printing; protein profiling by gel electrophoresis (SDS-PAGE); immunological assays.
8. Biological control by biotechnological methods- use of hyper-parasite, hypo-virulence plasmids and recombinant DNA technology.

Practical (Based on theory papers) ~ 25 marks; 3 credits

Bot O 43: Taxonomy and Biosystematics ~70 marks; 6 credits; 70 lecture hours

1. History of taxonomy in India.
2. Brief knowledge of Botanical Survey of India (B.S.I), Central National Herbarium (CAL), and Acharya Jagadish Chandra Bose Indian Botanic Garden in relation to taxonomic studies.
3. Taxonomic Literature.
4. International Code of (Botanical) Nomenclature (ICN/ICBN including Nomenclature of Cultivated and Hybrid plants).
5. Concept of Characters in Taxonomy.
6. Evolutionary concepts: monophyly, paraphyly, polyphyly, plesiomorphy, apomorphy, anagenesis, stasigenesis, cladogenesis, homology, analogy, homoplasy, parallelism and convergence, synapomorphy and symplesiomorphy.
7. Biosystematics: Objectives, methods of study, categories, relationship with classical taxonomy.
8. Data Sources in Taxonomy: Seedling morphology, Leaf architecture, Nodal Anatomy, Serology, SEM & TEM Characters, and Molecular taxonomy including DNA barcoding.
9. Centers of origin and diversity of cultivated plants (proposed by N. I. Vavilov) and Indian centers of wild plant genetic resources; Role of IBPGR and NBPGR.
10. Floristic regions of world; Vegetation of India: classifications; description and composition of Himalayan, peninsular and desert vegetation.
11. Biodiversity: Bioprospecting, Biopiracy, Seed and Gene Banks, Biodiversity Act, IK and TK, PBR (People's Biodiversity Register), Role of National Biodiversity Authority (NBA) and West Bengal Biodiversity Board in biodiversity management.

12. Conservation: principles, causes of threats and categories of threatened plants (IUCN), methods of assessment, strategies of conservation-*in situ* and *ex situ*; concept and types of protected areas; role of botanic gardens.
13. Palynology: branches; applications; structure, types and evolution of pollen grains.
14. GIS and Remote Sensing and their applications in Botany.
15. Characters, phylogeny and evolution: Amentiferae, Fagales, Zingiberales and Orchidales.

Suggested Readings:

1) Datta, S. C. 1988. Systematic Botany. Wiley Eastern Limited, New Delhi.
2) Davis, P. H. and Heywood, V. H. 1963. Principles of Angiosperm Taxonomy. Princeton, NJ: Van Nostrand.
3) Johnes, S. B. and Luchsinger, A. E. 1987. Plant Systematics. McGraw-Hill. London.
4) Judd, W. S., Campbell, C. S., Kellogg, E. A., Stevens, P. F., Donoghue, M. J. 2008. Plant Systematics – A Phylogenetic Approach. Sinauer Assoociates, Inc., Sunderland, Massachusetts USA.
5) Lawrence, G. H. M. 1964. Taxonomy of Vascular Plants. Oxford & IBH Publishers, Calcutta.
6) Naik, V. N. 1984. Taxonomy of Angiosperms. Tata McGraw-Hill Publishing Company Limited, New Delhi.
7) Radford, A. E. 1986. Fundamentals of Plant Systematics. Harper & Row, London.
8) Simpson, M. G. 2010. Plant Systematics. Elsevier Academic Press, Amsterdam.
9) Singh, G. 2012. Plant Systematics – Theory and Practice. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.
10) Sivarajan, V. V. 1991. Introduction to the Principles of Plant Taxonomy. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.
11) Sokal, R. R. and Sneath, P. H. A. 1973. Numerical taxonomy: the principles and practice of numerical classification. W. H. freeman, San Francisco.
12) Stace, C. A. 1989. Plant Taxonomy and Biosystematics. Arnold Publishers, United Kingdom.
13) Stuessy, T. F. 2008. Plant Taxonomy – The Systematic Evaluation of Comparative Data. Columbia University press, New York.