UNIVERSITY OF CALCUTTA

Notification No. CSR/ 38 /17

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in exercise of his powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 15.05.2017 approved the **Revised Regulations and Syllabus for M.Sc.** course of study in **Botany** under this University, as laid down in the accompanying pamphlet.

The above shall be effective from the academic session 2017-2018 and onwards.

SENATE HOUSE
KOLKATA-700073
The 13th June, 2017

(Prof Dr. Rajagopal Dhar Chakraborti)

Registrar

M.Sc. Regulations and Syllabus

In BOTANY

University of Calcutta

2017

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	20
2nd Semester	Core Courses	4	260	20
3rd Semester	Core Courses Optional Course Choice based Courses	2 1 2	130 20 100	10 1.5 08
4th Semester	Core Courses Optional Course Supportive Dissertation	2 1 1 1	130 20 20 60	10 1.5 1.5 7.5
TOTAL			**1000**	**80**

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

Marks	**Numerical grade points**	**Grades**
75-100	5.00-6.00	Outstanding (O)
65-74	4.50-4.99	Excellent (A+)
60-64	4.00-4.49	Very Good (A)
55-59	3.75-3.99	Good (B+)
50-54	3.50-3.74	Fair (B)
40-49	3.00- 3.49	Satisfactory (C)
00-39	****	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**
75-100	0.02
65-74	0.11
60-64	0.1225
55-59	0.1225
50-54	0.1225
40-49	0.061
00-39	***

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
5.00-6.00	Outstanding (O)	First (I)
4.50-5.99	Excellent (A+)	First (I)
4.00-4.49	Very Good (A)	First (I)
3.75-3.99	Good (B+)	Second (II)
3.50-3.74	Fair (B)	Second (II)
3.00-3.49	Satisfactory (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	Microbiology	40+ 25	2.5+2.5
Bot C12	Phycology	40 + 25	2.5+2.5
Bot C13	Bryophytes,Pteridophytes and Gymnosperms	40 + 25	2.5+2.5
Bot C14	Cell Biology	40 + 25	2.5+2.5
	Total	**160 (Theoretical) + 100 (Practical)**	**10 (Theoretical) + 10 (Practical)**
		= 260	**= 20**

2nd Semester

Core courses		*Marks(Theo.+Prac.)*	*Credits*
Bot C21	Palaeobotany and Palynology	40 + 25	2.5+2.5
Bot C22	Taxonomy of Angiosperms	40 + 25	2.5+2.5
Bot C23	Phytochemistry and Pharmacognosy	40 + 25	2.5+2.5
Bot C24	Genetics and Genomics	40 + 25	2.5+2.5
		40 + 25	2.5+2.5
	Total	**160 (Theoretical) + 100 (Practical)**	**10 (Theoretical) + 10 (Practical)**
		= 260	**= 20**

3rd Semester

Core & other courses		*Marks(Theo.+Prac.)*	*Credits*
Bot C31	Mycology and Plant pathology	40+ 25	2.5+2.5
Bot C32	Plant Physiology and Biochemistry	40+25	2.5+2.5
Bot-O-I	Optional Paper I	20 + 0	1.5+0
OA	*Choice based credit course (CBCS 1)	50+0	4+0
OB	*Choice based credit course (CBCS 2)	50+0	4+0
	Total	**200 (Theoretical) + 50 (Practical)**	**14.5 (Theoretical) + 5 (Practical)**
		= **250**	**=19.5**
	Dissertation (To be Contd in Sem IV)		

4th Semester

Optional& other courses		*Marks(Theo.+Prac.)*	*Credits*
Bot C41	Plant Anatomy and Developmental Biology	40 + 25	2.5+2.5
Bot C42	Plant Biotechnology	40 + 25	2.5+2.5
Bot C 43	Ecology	20 + 0	1.5+0
Bot-O-II	Optional Paper II	20+0	1.5+0
	Dissertation (Contd from Sem III)	60	7.5

	Total:	120 (Theoretical) + 50 (Practical)+60 (Dissertation)	8 (Theoretical) + 5 (Practical) +7.5(Dissertation)
		= **230**	= 20.5
	Grand Total Marks/Credits	**640 (Theoretical) +300 (Practical)+60 (Dissertation)**	**42.5 (Theoretical) +30 (Practical) +7.5 (Dissertation)**
		= 1000	**=80**

C – Core course; O – Optional course; S – Supportive course

***Appendix-I**

Optional PapersBot OP:

Optional Paper I (any 1 of the following)

1. **O-I-A: Applied Virology**
2. **O-I-B: Molecular and Applied Phycology**
3. **O-I-C: Molecular and Applied Mycology**
4. **O-I -D: Molecular Plant Physiology**
5. **O- I -E: Advanced Cell Biology**
6. **O- I -F: Advanced Paleobotany and Palynology**
7. **O- I -G: Advanced Phytochemistry and Pharmacognosy**
8. **O- I-H: Taxonomy and Biosystematics**

Optional Papers II(any 1 of the following)

1. **O-II-A: Microbial Biotechnology**
2. **O-II-B: Plant protection**
3. **O-II-C: Green Nanotechnology**
4. **O-II-D: Plant Molecular genetics**
5. **O-II-E: Plant Molecular Biology**
6. **O-II-F Molecular stress biology**
7. **O-II-G: Immunology**
8. **O-II-H: Instrumentation and Biostatistics**

The students will have to choose one optional paper each in semester III and IV from the given list of optional papers. There is no limit on number of students for any optional paper.

Detailed Syllabus for two years M.Sc. Course in Botany, CU - 2016

First Semester

Bot C11: Microbiology: Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section A (GENERAL MICROBIOLOGY)

Microbial taxonomy: Basis of bacterial classification: analysis of phenetic, genetic and phylogenetic characteristics; polyphasic approaches to bacterial taxonomy. Salient features of major bacterial groups according to Bergey's Manual of Systematic Bacteriology.

Methods in microbiology: Types of culture media, isolation of pure cultures, enrichment culture techniques, maintenance and preservation of bacterial cultures. Control of microorganisms: physical and chemical methods.

Growth and differentiation: Measurement of growth, growth kinetics, synchronous growth, and continuous culture. Physico-chemical factors influencing bacterial growth. Differentiation: sporogenesis- physio-biochemical and genetic aspects, *Caulobacter* differentiation.

Section B (MICROBIAL PHYSIOLOGY)

Photosynthesis and fermentative metabolism: Bacterial photosynthesis (anoxygenic and oxygenic): antennae complex and reaction centre, chemosynthesis. Bacterial fermentative pathways: lactic acid, propionic acid, mixed and butanol fermentation.

Biosynthetic pathways: Biosynthesis of peptidoglycan and extracellular polysaccharides and polyesters.

Nitrogen metabolism: ammonification, nitrification, denitrification and nitrogen fixation. Nif genes: functions and regulation. Metabolism of amino acids: amino acid biosynthesis pathways: aspartate, and glutamate family, regulation and overproduction.

Section C (MICROBIAL GENETICS)

Genetic analysis of bacteria: Conjugation: molecular mechanism of gene transfer and regulation. Conjugation mapping, Plasmids: types, function and application. Transformation: Natural transformation and competence; molecular mechanism of transformation. Transduction: Generalized and specialized transduction-T4, T7 and lambda phages. Lysogenic phages: genome organization and its regulation.

Transposons: Types of bacterial transposons. Detection, regulation and molecular mechanism of transposition in bacteria.

Gene regulation: Positive and negative gene regulation and attenuation, *lac*, *gal*, *trp*, and *ara*operons and their applications. Quorum sensing. CRISPR-CAS discovery, mode of action and application.

Section D (APPLIED MICROBIOLOGY)

Environmental microbiology: Distribution and implications of microbes in air and water, waste water treatment systems; Microbial production of pesticides; degradation of xenobiotics Bioremediation of heavy metals.

Medical microbiology: Human microbiome, host pathogen interaction, pathogenicity of bacteria invasiveness and toxigenicity, genetics of bacterial virulence, constitutive and inducible host defense mechanism, acquired immunity and immune systems.

Chemotherapy: Principles of chemotherapy, general mode of action of various chemotherapeutic agents: Sulfa drugs, antibiotics- classification and mode of action. antibiotic resistance, vaccines and antivirals.

Section E (VIROLOGY)

General Virology: Virus classification. General properties and ultra-structure. Viral genome organizations. Cultivation of viruses, methods for detection and assay. Virus related agents: viriods, prions and prion hypothesis.

Bacteriophages: General classification and properties, genome organization. Phage therapy and typing. Genetic analysis of phages – complementation and recombination tests with phages.

Plant viruses: Tobacco mosaic virus: capsid assembly, genome organization and replication.

PRACTICALS

1. Basic microbiological techniques: preparation of media, sterilization, slant and stab preparation. Pouring of plates and pure culture by streak and pour plate method.
2. Qualitative and quantitative analysis of soil or water microbiota, characterization of selected pure culture isolates by gram staining, simple and negative staining, endospore staining and physio-biochemical features (extraceullar enzymes, antibiotic sensitivity/production).
3. Determination of bacterial growth and growth kinetics under batch cultivation (turbidimetric and cell count method)
4. Bacterial transformation: Competent cell preparation, transformation, screening of transformed isolates.
5. Plasmid isolation and gel electrophoresis.
6. Bacteriophage titration, purification and quantification.
7. Isolation of antibiotic producing organism from soil and their sensitivity assay against standard laboratory strains of bacteria.
8. Enrichment and isolation of nitrogen fixing bacteria from soil and their characterization.

SUGGESTED READINGS:

1. General Microbiology by R.Y. Stanier, JL Ingrahm, ML Wheelis and PR Painter.
2. Microbiology: Fundamentals and Applications by RM Atlas.
3. General Microbiology by HG Schlegel
4. Microbial Physiology by A G Moat and Foster
5. Fundamental Bacterial Genetics by N Trun and J Trempy
6. Bacterial Genetics by Snyder
7. Microbial Genetics by Maloy, J E Cronan and D Friefelder
8. Introduction to Modern Virology by NJ Dimmock, A J Easton and K N Leppard
9. Basic Virology by EK Wagner, MJ Hewlett, DC Bloom and D Camerini.
10. Principles of Fermentation Technology by P F Stanbury, A Whitaker and SJ Hall.
11. Microbiology by Prescott L, Harley J, Klein D.
12. Microbial Interactions in Agriculture and Forestry Vol. 2, NS Subba Rao and YR Dommergues.

Bot C12: Phycology: Theory (40 marks; 2.5credits, 40 Lecture hours)

Section A (CLASSIFICATION, PHYLOGENY AND EVOLUTION)

Classification and Phylogeny: Classical system and modern polyphasicapproach;Biome classification and algal phylogeny, Symbiosis theory-Primary, Secondary and Tertiary endosymbiosis, molecular markers for phylogenetic study .

Evolution of Algae: Evolution at morphological and ultra structural level, horizontal gene transfer and evolution of algal chloroplast.

Section B (GENERAL OVERVIEW OF MAJOR DIVISIONS)

Cyanoprokaryotes: Protoplasmic structure, genome and genetic properties; Heterocyst- ultra structure and biochemistry ,*nif* gene regulation.

Diagnostic characters of major algal divisions-

Glaucophyta-Principle characteristics and primitive features , phylogenetic significance.

Dinophyta- Cell structure; Heterotrophic nutrition; Red-tides.

Chlorophyta- Cell division pattern, ultra structure of flagella; classification and phylogeny.

Bacillariophyta- Classification; Ultra structure and developmental patterns of diatom frustules- Role of Frustulene protein.

Section C (ALGAL ECOLOGY)

Biodiversity and Conservation of Algae: Algal diversity of different habitat, importance of conservation: *in situ* and *ex situ* conservation.
Patterns in Wetlands: Algal assemblages in Wetlands; Role of Algae in Wetlands; Conceptual models of Wetlands.

Algal Bloom - Bloom formation and Eutrophication; Harmful algal blooms and toxin production; Bloom control measures.

Section D (PHYTOPLANKTONS)

Definition;Types of Phytoplanktons:On the basis of cell size,habitat.
Community pattern analysis :Species Diversity, Species richness, Species evenness.
Ocean acidification and Climate change effects on phytoplankton
Phytoplankton Dynamics - Physical factors (light, heat, temperature) ; chemical environment: carbon, nitrogen, phosphorous; Nutrient requirements with reference to Redfield's ratio (1963) and Brezinski ratio (2005); Biological carbon pump;Phytoplankton nutrient uptake models (Monod's model and Droop's cell quota model),

Section E (ALGAL BIOTECHNOLOGY)

Microalgae in Human welfare –Nutraceuticals; Pharmaceuticals; Biofertilizers; Bio-fuel ; CO_2 sequestration and pollution control.
Targeted genetic modifications:Genome shuffling and evolutionary engineering -*Chlamydomonas reinhardtii* as model organism; Application of synthetic biology in algae.
Mass production of micro-algae- Culturing techniques and photo bioreactor based production; Down stream processing.heterotrophic production;

PRACTICALS

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 as voucher specimens(at least 10 vouchers)

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.An Introduction to Phytoplanktond:Diversity and Ecology .R.Pal and A.Choudhury,Springer.

Bot C13: Bryophytes, Pteridophytes and Gymnosperms: Theory (40 marks; 2.5 credits, 40 Lecture)

(*Bryophyte: 13 marks, Pteridophyte; 14 marks, Gymnosperms: 13 marks*)

Section A (GENERAL OVERVIEW ON BRYOPHYTES)
:

General habit, habitat, distribution, biogeography, growth forms, life forms and colonization; Recent trend for classification of Bryophytes and outline on a recent classification system of (liverworts, hornworts and mosses); Comparative morphology and developmental anatomy of gametophytes & sporophyte of Liverwort, Hornwort and Mosses; Evolutionary significance; vegetative reproduction and cytogenetics of bryophytes.

Section B (ROLE OF BRYOPHYTES IN ECOLOGY& ECOSYSTEM DYNAMICS)

Poikilohydry, desiccation tolerant, vulnerability, succession dynamicity, as bio-indicator and as phytoremediator; Metabolic chemistry of br

Section C (GENERAL OVERVIEW ON PTERIDOPHYTES)

Introduction; outline of systematic treatment of pteridophytes; molecular systematic and chemosystematic considerations; distribution of extant groups in time and space; evolutionary significance of the members of Zosterophyllopsida, Trimerophytopsida, Lycopsida and Sphenopsida; Evolution of vegetative organs in Pteridophytes: study of shoot apex, leaf initiation and early leaf ontogeny in ferns; stomatal types and development; origin and evolution of sporangium; evolution of stele; Diversity of ferns in an ecological perspective; characteristics and affinity of Ophioglossaceae, Osmundaceae, Cyatheaceae, Polypodiaceae, Salviniaceae; insect, microorganism – pteridophyte interaction; endangered and endemic pteridophytes and their conservation.

Section D (PHYTOCHEMISTRY& CYTOGENETICS OF PTERIDOPHYTES)

Reproductive biology and cytogenetics of Pteridophytes: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 sporingheterosporous plants; polyploidy, apospory, apogamy, apomixis and hybridization; genetic variability in fern population- genetic load.

Section E (GENERAL FEATURES OF PROGYMNOSPERMS, GYMNOSPERMS AND THEIR CLASSIFICATION)

Concept of progymnosperms and its evolutionary significance; General characters and different systematic treatments of Gymnosperms as proposed by Sporne (1974), Gifford and Foster (1989), S.P. Bhatnagar and AlokMoitra (1996), Distribution of extant taxa in time and space.

Comparative account among different groups of living genera, their applications and conservation

Comparative account of sporophyte and gametophyte of Cycadales, Coniferales, Ginkgoales, Coniferales, Taxales and Gnetales with emphasis on evolutionary aspects, Pollination mechanism and embryology of extant Cycadales, Coniferales, Ginkgoales, Coniferales, Taxales and Gnetales. Karyology, phytochemical and biotechnological approach of important taxa. Biotic interactions (algae, microbes and insects) of Gymnosperms, Economic importance in pharmaceuticals and food supplements, Endangered and endemic taxa and their conservation.

PRACTICALS

Bryophyte

1. Workout on structural modification in Marchantiales, Jungermanniales, Anthocerotales, Isobryales and Hypnobryales, Funariales &Dicranales (depending on availability of the specimen).

2. Workout on different types of peristome structure for classification on mosses.

Pteridophyte

1. Study of external and internal morphology of vegetative and reproductive structures (spore types and soral anatomy etc.) of species of:

   Lycopodium, Selaginella, Equisetum,Drynaria, Lygodium,Diplopterygium, Dicranopteris, Phymatosorus, Oleandra, Nephrolepis, Asplenium, Blechnum, Adiantum, Pteris, Cyathea/ Alsophila/Hemitelia,Christella, Microsorum, *Phymatosorus*, and*Salvinia*

2. External morphological features of the following taxa:

   Psilotum/Tmesipteris, Isoetescoromandelina, Ophioglossum, Schizaea, Marattia, Cibotium, Ceratopteris, ,Acrostichum, Dryopteris, Cheilanthes, Woodwardia and *Onychium.*

Gymnosperm

1. Study of external morphology of the following taxa:

   Zamia, Encephalartos, Tsuga, Taxodium, Ginkgo, Cunninghamia, Callitris, Cedrus, Araucaria, Podocarpus, Thuja, CupressusTaxodium, Juniperus, Cryptomeria, Gnetum, Ephedra and*Welwitschia, Agathis, Sequoia* and*Metasequoia.*

2. Study of general habit, external and internal morphology leaf and wood anatomy with special reference to male and female reproductive structures, pollen grains:

Cycas, Zamia, Pinus, Cedrus, Cupressus, Cryptomeria, Thuja, Araucaria, Cephalotaxus.

SUGGESTED READINGS

Bryophyte

1. INTRODUCTION TO BRYOPHYTES, Cambridge University Press, Edited by Alain Vanderpoorten and Bernard Goffinet.
2. BRYOPHYTE BIOLOGY, 2nd Edition, Bernard Goffinet, Edited by A. Jonathan Shaw.
3. BRYOPHYTE ECOLOGY, edt. A. Smith, Springer Science &Business,Media, 2012.
4. BRYOPHYTE ECOLOGY. Glime, J. M. Houghton: Michigan Technological Univ., 2007.
5. BRYOPHYTES AND LICHENS IN A CHANGING ENVIRONMENT.Bates, J. W., and A. M. Farmer, eds. Oxford: Clarendon, 1992.
6. HANDBOOK OF INDIAN MOSSES, H. C. Gangulee,Amerind Pub. Co., 1985.
7. BIOLOGY OF BRYOPHYTES, eds R.N. Chopra and P.K. Kumra, New age International publisher, 2005.

Pteridophyte

1. Dyer A. F. (1979). *The Experimental Biology of Ferns.* Academic Press, London.
2. Gifford E. M, Foster A.S. (1989). *Morphology and evolution of Vascular plants,* (3rd Edn). W H. Freeman & Co.
3. Kubitzki K. (1976). *The families and Genera of Vascular plants:Vol. I Pteridophytes.*Vikas Publishing House.
4. Rashid A. (1976). *An Introduction to Pteridophytes*. Vikas Publishing House.
5. Sporne K.R. (1986). *Morphology of Pteridophytes.* Hutchinson University Library, London.
6. Surange K.R. (1966). *Indian Fossil Pteridophytes.* Council of Scientific and Industrial
7. Research.
8. Louis J.D. (1977). *Evolutionary patterns and processes in ferns:* Advances in Botanical Research. Scott. Studies in Fossil Botany. Haffner publications.
9. Smith, G.M. (1976). *Cryptogamic Botany Vol. II.* Tata McGraw Hill, Publishing Co. Ltd. New Delhi.
10. Chandra S. & Srivastava M. (2003). *Pteridology in the New Millennium*. Khuwar Acad. Publishers
11. Stewart W.N. &Rothwell G.W. (2005).*Paleobotany and the Evolution of Plants*, (2nd Edn.) Cambridge University Press.
12. Sharma O.P. (2006). *Text book of Pteridophyta*. Macmillan India Ltd., New Delhi.

13. Ranker T.A. &Haufler C.H. (2008). *Biology and Evolution of Ferns and Lycophytes.* Cambridge University Press.
14. Eames E.J. (1983). *Morphology of vascular Plants.* Standard University Press.

Gymnosperms

1. The Morphology of Gymnosperms. K.R.Sporne
2. Morphology of Gymnosperms. John M. Coulter and Charles J. Chamberlain
3. Gymnosperms. S.P.Bhatnagar and AlokMoitra
4. The Gymnosperms. C. Biswas and B.M. Johri
5. Morphology and Evolution of Vascular Plants. Ernest M. Gifford, Adriance S. Foster
6. The Families and Genera of Vascular Plants. K.U.Kramer, P.S. Green (Edited by Kubitzki)

Bot C14: Cell Biology: Theory: 40 marks; 2.5 credits, 40 Lecture hours

Section A (MODERN TOOLS AND TECHNIQUES IN CELL BIOLOGY)

I. Advances in light and electron microscopy (Fluorescence microscopy)

II. Cell fractionation and visualization /characterization of various cell fractions

Section B (CELL STRUCTURE)

I. Cell wall, Plasma membrane-structural model, composition & dynamics, biogenesis and assembly, transport of small molecules (Physical structure of fluid membrane bilayer, membrane lipids, membrane proteins, pumps, carriers and channels).

II. Nucleus: internal organization, chromatin structure, condensation and packaging of DNA, nuclear envelop, nuclear pore complex and macromolecular trafficking (Organization of nucleus, nuclear matrix, nucleolus, structure of nuclear envelope, nuclear lamina, nuclear pore complex, nuclear transport; chromosome organisation, centromere-overview, variation in organisation among species; telomere- structure and structural proteins; DNA packaging, histone variants, modification, heterochromatin and euchromatin, controlling the influence and spread of heterochromatin, imprinting).

Section C (CELL ORGANELLE)

I. Mitochondria ,Chloroplast: origin, evolution, biogenesis & genetic system
II. Structure of Golgi apparatus, Lysosome, Peroxisome , endoplasmic reticulum.
III. Protein sorting and transport: Chaperon and protein folding, protein cleavage, glycosylation, attachment of lipids, targeting protein to Endoplasmic Reticulum, Golgi Apparatus, lysosome, Mitochondria and Chloroplast; protein folding and processing in ER and golgi, smooth ER and lipid synthesis, export, mechanism of vesicular transport.

IV. Cytoskeleton : structure and organization of actin, microtubule and intermediate filament, assembly and disassembly, associated proteins and motors, function

Section D (CELL REGULATION)

I. Cell cycle-Eukaryotic cell cycle, checkpoints and regulations of cell cycle

II. Cell interaction-Cellular adhesions, junctions and junction proteins

Section E (GENETIC INFORMATION)

I. DNA replication : Unit of replication, enzymes involved, replication origin and replication fork, fidelity of replication, extrachromosomal replicons.

II. RNA synthesis and processing : transcription factors and machinery, formation of initiation complex, transcription activator and repressor, RNA polymerases, capping, elongation, and termination, RNA processing, RNA editing, splicing, and polyadenylation, structure and function of different types of RNA, RNA transport; translation-machineries and process.

PRACTICAL

i. Staining nucleus with DAPI/Et Br and studying under fluorescence microscope
ii. Staining mitochondria with Janus green B and studying under fluorescence microscope
iii. Isolation of plant genomic DNA, purity estimation by UV spectroscopy, and visualization by agarose gel electrophoresis.
iv. Isolation of protein from plant samples and electrophoresis by SDS-PAGE
v. Determination of antigen concentration by sandwich Eliza method.

Suggested Books:

1. The World of the Cell- Becker WM et al., - Benjamin Cummings
2. Cells- Benjamin Lewin, Lynne Cassimeris, Vishwanath R. Lingappa, George Piopper Jonesand Bartlett Publishers 3rd edition.
3. Molecular Cell Biology-Lodish H et al., - Freeman
4. Essential Cell Biology, Alberts B et al., - Garland
5. Molecular Biology of the Cell, Alberts B et al., - Garland
6. Cell and Molecular Biology: Concepts and Experiments. By Gerald Karp Wiley 7th edition
7. Cell and Molecular Biology, De Robertis and De Robertis – Lippincott and Wilkins
8. Cell and Molecular Biology- Phillip Sheeler; Donald E. Bianchi Published by John Wiley & Sons 3rd edition
9. Genes IX- Lewin B – Pearson
10. Genomes- Brown TA - Garland
11. Molecular Biology of the Gene- Watson et al. Pearson 7th edition
12. Fundamental Molecular Biology- By Lizabeth A. Allison. Wiley-Blackwell 2nd edition
13. The biophysical Chemistry of nucleic acids and proteins-Creighton

14. The physical and chemical basis of molecular biology-Creighton
15. Principles of Biochemistry-Nelson et al
16. Lewin's Cell- Plopper, George (edtd)
17. Principles of Mol. Biology-Tropp, Burton
18. Cell Biology-Pollard
19. The Cell: a molecular approach-Cooper
20. Molecular Biology-Clarke, David
21. Molecular Biology-Weaver

Second Semester

Bot C21: Palaeobotany and Palynology Theory : (40 marks; 2.5 credits, 40 Lecture hours)

Section A (BASIC GEOLOGICAL INFORMATION RELATED TO PALAEOBOTANY)

Sedimentary rocks; Taphonomy; dating the pages of earth history; Laws of Uniformitarianism and Superposition; outlines of Stratigraphy; Basic concepts of continental drift and plate tectonics; evolutionary theories and plant fossil record.

Section B (ORIGIN AND EVOLUTION OF EARLY LIFE FORMS AND COLONIZATION OF LAND)

The prebiotic environments; antiquity of life; first prokaryotes and evolution of eukaryotes; geological records and ecological significance of algae (stromatolites, diatoms, dinoflagellates), fungi (endomycorrhiza, epiphyllous fungi), bryophytes and early ferns (Palaeozoic).

Environmental changes before terrestrialization, fossil evidences for land adaptation, evolution of land plants- evidences, earliest trees in the fossil record.

Section C (EMERGENCE AND DIVERSIFICATION OF SEED PLANTS)

Preovules, hydrasperman reproduction; evolution of closed carpel- evidences from the ovulate fructifications of Glossopteridales, Corystospermales, Caytoniales, Bennettitales and Pentoxylales.

Enigma of angiosperm origin- fossil leaves, flowers and pollen grains as evidences; nature and distribution of earliest angiosperms; reasons for late arrival; cladistic and molecular biological approaches on phylogeny of angiosperms; first grasses.

Section D (PALYNOLOGY)

Branches of palynology; Spore, pre-pollen and pollen morphology; evolution of aperture types; Palaeopalynology of Bengal Basin peat and Indian lower Gondwana coal; Non-pollen palynomorphs.

Section E (APPLIED PALAEOBOTANY AND PALYNOLOGY)

Fundamentals of palaeofloristics, palaeogeography, palaeoecology and palaeoclimatology; ii) Ancient DNA and other fossil biomolecules, stable isotopes, tree ring, speleothem and their potential in evolutionary and palaeoclimatological research iii) Fossil fuels-origin and depositional environment, role of microfossils in oil exploration iv) phytoliths in reconstruction of palaeovegetation and palaeoclimate.

PRACTICALS

1. Study of fossil types and modes of preservation.

2. Techniques of studying plant fossils: Thin section method (demonstration and study of prepared slides); peel techniques (demonstration and study of prepared peel sections); preparation of leaf cuticle (demonstration) for study of micromorphological parameters and epiphyllous fungi.

3. Systematic study of fossil plants through ages

Precambrian biota: Stromatolites.
Early land plants: Aglaophyton, Cooksonioids, Rhyniophytes, Zosterophylls.
PalaeozoicPteridophytes: 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 samples.

4. Acetolysis method (demonstration); study of morphology of modern spores and pollen grains; pollen analysis of honey.

5. Study of macerated samples (to be supplied) of peat, lignite and coal. Qualitative and quantitative (using tally mark counting of palynomorphs and subsequent pollen diagram/ histogram preparation) studies of palynomorphs. Inference on floristic composition, environment of deposition and stratigraphic age of sediments studied.

6. Extraction of phytoliths from modern plant materials followed by their study from already macerated soil samples.

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. BirbalSahni 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.
17. Traverse, A. 1988. Paleopalynology, 600p.
18. Stach, E. *et al*. 1982. Coal petrology, 535p.

Bot C22Taxonomy of Angiosperms: Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section A (CLASSIFICATION, CLADISTICS AND ANGIOSPERM DIVERSITY)

Major systems of classification: basis, merits and demerits: Cronquist (1981); Takhtajan's System (1997), basis of APG Classification, brief idea about APG IV (2016). Concepts of palaeoherbs and eu-dicots (tricolpates). Cladistics: A brief account: definition and application. Angiosperms diversity: Salient features, phylogeny and evolutionary trends in Magnollidae, Asteridae, Alismatidae, and Liliidae (*sensu*Cronquist, 1981).

Section B (INTERNATIONAL CODE OF [BOTANICAL] NOMENCLATURE [ICN/ICBN])

Principles, latest changes: overview; Status, typification, and priority of names; effective publication: new provisions; valid publication: general provisions; Names of new taxa (species); new combinations; names at new rank; replacement names; rejection of names. Proposed BioCode and PhyloCode.

Section C (DATA SOURCES AND TOOLS OF TAXONOMY)

Data sources in Taxonomy: Embryology, Palynology, Anatomy, Molecular taxonomy–DNA barcoding. Tools of Taxonomy: Application of GIS and GNSS (Remote Sensing) in Botany.

Section D (SPECIES, BIOSYSTEMATICS ANDNUMERICAL TAXONOMY)

Species concept. Biosystematics: Objectives, steps, categories, relationship with classical taxonomy. Numerical Taxonomy (Phenetic methods): Definition, Principles, methods, merits and demerits.

Section E (BIODIVERSITY, CONSERVATION AND ITK)

Concept, levels, importance of biodiversity, hotspots and hottest hotspots, megadiversity centers of world, loss of biodiversity, IUCN threat categories: methods of assessment; strategies of *in situ* and *ex situ* conservation; CITES and TRAFFIC; General idea about Red Data Book. Ethnobotany and Traditional Knowledge: Concept, history, importance of ethnobotany, and development of Ethnobotany in India.

PRACTICALS:

1. Workout of plant specimens and description of vegetative and reproductive characters from representative families locally available.
2. Training in identification of specimens described in classes using relevant literatures and herbaria.
3. Study of various taxa of a genus, determining 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. Submission of at least 50 herbarium specimens of common plants.

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. SinauerAssoociates, 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) Stace, C. A. 1989. Plant Taxonomy and Biosystematics. Arnold Publishers, United Kingdom.
12) Stuessy, T. F. 2008. Plant Taxonomy – The Systematic Evaluation of Comparative Data. Columbia University press, New York.

Bot C23: Genetics and Genomics: Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section A (BASIC CONCEPTS IN GENETICS AND GENETIC ANALYSES)

Discoveries in Classical and Molecular Genetics; Extensions of Mendelism; Allelism; Gene-environment interactions; Penetrance and Expressivity; Epistasis; Pleiotropy; Continuous and Discontinuous Variations; Overview of Genetic Analysis: Epistasis analysis, genetic analysis pathways, complementation test for alleles, Linkage and Crossing over; gene mapping methods, LOD score.

Section B (GENETIC INTEGRITY AND DIVERSITY)

Organization of structural and functional elements of chromosome; Physical and Chemical bases of equational separation of chromosomes; Recombination: Homologous and non homologousrecombinations: mechanisms and genetic control, Genetic control of chromosome pairing in wheat; evolutionary significance of recombination; Mutagenesis: Molecular basis of spontaneous and induced mutations, transposon mutagenesis; Structure and function of transposable elements and their role in evolution; Transposon tagging of plant genes: Molecular features of Ac/Ds transposable elements in maize and its cloning.

Section C (QUANTITATIVE AND EVOLUTIONARY GENETICS)

Quantitative Inheritance: traits controlled by many loci; significance of polygenic inheritance; Heritability and Variance: measurement of heritability and partitioning of variance; quantitative inheritance in plants; Population Genetics: defining populations; gene frequency in a population; genetic equilibrium; Hardy Weinberg principle: barriers to gene flow and mechanism of speciation; testing for fit with H-W equilibrium; extensions of H-W equilibrium in cases of multiple alleles, multiple loci, non-random mating, inbreeding; using highly polymorphic DNA segments in DNA typing of plants; Inbreeding and genetic consequences of self-pollination in plants; Evolutionary Genetics: concepts of evolutionary forces that change allelic frequencies; molecular clock concept

Section D (GENOME ORGANIZATION AND GENE REGULATION IN EUKARYOTES)

Types of genomes, nuclear, mitochondrial and chloroplast genomes in eukaryotes, Physical and genetic features of eukaryotic nuclear genomes, C-value paradox. Genome size and chromosome number in phylogenetic analysis in plants.
Chromatin modification and genome expression: chromatin remodeling Epigenetic control of gene expression in plants. Genomic imprinting.
Mapping(using RFLP, RAPD and AFLP)and sequencing of genomes (using Sanger's method and Next gen sequencing), strategies for genome sequencing, genome annotation, synteny, gene search and comparison tools. QTL mapping, positional cloning.

Section E (FUNCTIONAL GENOMICS AND PROTEOMICS)

Approaches to analyze differential expression of genes, ESTs, SAGE, microarrays. Forward and reverse genetic approaches. Gene tagging, gene trapping. Mutant types: lethal, conditional, biochemical, loss of

function, gain of function, germinal and somatic mutants and insertional mutagenesis, studying the proteome, analyzing a protein, proteins sequencing methods, detection of post translational modification of proteins, application of proteomics, comparative genomics, BLAST searches and multiple sequence alignment, Reconstruction methods used in molecular phylogeny.

PRACTICALS:

1. Preparation of stains and staining techniques for chromosome analysis.

2. Karyotype analysis in diploids and polyploids.

3. Phases of division in PMC: chromosome pairing in diploids and polyploids.

4. Study of genetic variation using random and gene-specific molecular markers: molecular phylogeny reconstruction

5. Restriction mapping to locate the position of non polymorphic restriction sites.

6. Differential expression of a gene by semiquantitative RT PCR

7. Genetic Analysis (online practical)

SUGGESTED READINGS

1. Klug Cummings, Spencer and Palladino (2015), Concepts of Genetics, 11th edition Pearson publishers

2. Russel PJ (2012), Genetics: A Molecular Approach, 3rd edition, Pearson publishers

3. Singh Ram J (2016), Plant Cytogenetics, 3rd Edition, CRC Press

4. Hartwell, Goldberg, Fischer, Hood, Aquadro (2015), Genetics: From Genes to Genomes, 5th Edition McGraw Hill publishers

5. Brown TA (2006) Genomes3, 3rd edition, Garland Science Publishers

6. Primrose and Twyman (2006), Principle Of Gene Manipulation And Genomics, 7th edition, Wiley publishers

7. Hartl DL (2014), Essential Genetics: a Genomics perspective, 6th edition, Jones and Barlett Educational Publishers

8. ThiellementHerve (2007), Plant proteomics: Methods and Protocols, Springer publishers

9. Mertens and Hammersmith (2015) Genetics Laboratory Investigations, 14th Edition, Pearson publishers

10. Brooker R. (2015), Genetics: Analysis and Principles, 5th edition, McGraw-Hill Publishers

Bot C24: Phytochemistry and Pharmacognosy: Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section A (INTRODUCTION /CLASSIFICATION/ PHARMACOLOGICAL ACTIONS OF PLANT DRUGS)

Introduction, history, scope.

Classification and pharmacological action of plant drugs: drugs acting on nervous system; heart, circulation & blood; gastrointestinal tract; nasal and respiratory system; urinary and reproductive system; skin and mucous membranes; steroidal and nonsteroidal anti-inflammatory drugs; malignant diseases; antibacterial, allergies, vitamins; Hallucinogenic, allergenic and other toxic plants, pesticides etc.

Section B (ORIGIN OF SECONDARY METABOLITES)

Acetate pathway (fatty acids and polyketides), mevalonate and deoxyxylulose phosphate pathway (for production of terpenoids and steroids), shikimate pathway (phenols, amino acids etc.): a brief account.

Section C & D (PHYTOCHEMISTRY/ PHARMACEUTICAL IMPORTANCE)

Carbohydrates – sugar alcohols, starch, cellulose derivatives, gums and mucilages.

Glycosides: general account, biosynthesis, glycosidal drugs**;** Cyanogenic glycosides and glucosinolate compounds.

Alkaloids: definition, properties, classification, alkaloidal drugs – *Daturastramonium*, *Atropabelladona*, opium, *Cinchona*, tea, ergot, *Rauvolfia*, *Holarrhena*, *Catharanthus* – alkaloidal constituents, uses.

Phenolic compounds produced by plants: types, biological activity, drugs – Senna, Aloe, Hypericum, Capsicum.

Steroidal compounds: different types, biological activity and general pharmaceutical importance

Carotenoids: chemistry, types, apocarotenoids, bioactivities.

Volatile oils: composition, drugs – clove, *Mentha*, *Eucalyptus*, *Foeniculum*, *Cinnamomum*, citronella

Resins: chemistry, different types, uses

Lipids: fatty acids, nomenclature, fats, fixed oils, waxes

SECTION V (METHODS RELATED TO PHYTOCHEMICAL ANALYSIS & QUALITY CONTROL)

Methods of extraction, separation, isolation (Chromatographic techniques) and characterisation of secondary metabolites (Spectroscopic techniques).

Quality control of plant drugs: Classical and modern approaches.

PRACTICALS:

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

SUGGESTED READINGS

1. Bruneton J., 1999. Pharmacognosy, Phytochemistry, Medicinal Plants, Intercept Ltd., Paris.
2. Dewick P.M., 2002. Medicinal Natural Products: A biosynthetic approach, John Wiley & Sons Ltd.
3. Evans W.C., 2002, Trease and Evan's Pharmacognosy, W.B. Saunders.
4. Harborne, J.B., 1998. Phytochemical Methods, Chapman and Hall.
5. Houghton P.J. and A. Raman, 1998. Laboratory handbook for fractionation of natural extracts, Chapman and Hall.
6. Kokate C.K., 1991. Practical Pharmacognosy, VallabhPrakashan, Delhi.
7. Samuelsson G., 1999. Drugs of naural origin: A text book of Pharmacognosy, Apotekarsocieteten, Swedish Pharmaceutical Society, Swedish Pharmaceutical Press, Stockholm, Sweden.
8. Tyler V.E., L.R. Brady and J.E.. Robbers, 1988. Pharmacognosy, Indian Edition, K.M. Varghese Company, Bombay.
9. Vickery M.L. and B. Vickery, 1981. Secondary Plant Metabolism, The MacMillan Press Ltd.
10. Wallis T. 1967. Text Book of Pharmacognosy, J & A Churchill, London.

11. Wagner H., S. Bladt and E.M. Zgainski (Translated by A. Scott) 1984, Plant Drug Analysis, Springer-Verlag.

12. Vermerris Wilfred & Nicholson Ralph, 2006, Phenolic compound Biochemistry

Third Semester

Bot C31: Mycology and Plant Pathology: Theory (40 marks; 2.5 credits, 40 Lecture hours)

MYCOLOGY (20 marks,20 Lectures)

Section A (INTRODUCTION TO MYCOLOGY)

Classification of the kingdom Mycota beyond G. C. Ainsworth (1973) system; Phylogeny and evolution of fungi.

Mechanisms behind the spore dispersal in fungi; Physiology of spore dormancy, germination and growth; Nutrient sensing and uptake. An overview of the central metabolic pathways in yeast. Heat shock proteins. Signal transduction pathways.

Section B (FUNGAL CYTOLOGY AND GENETICS)

Morphogenesis: Control of cell types and shape in fungi. Mitosis and meiosis in fungi. Parasexual cycle; Sex Pheromones (hormones) in fungi; Genetic control of asexual and sexual reproduction. Retroposon and retrotransposon in fungi.Extra-chromosomal inheritance in fungi.

Section C (**APPLIED MYCOLOGY AND PLANT – PATHOGEN INTERACTION)**

In Industry: Production of alcohol and organic acids. In Medicine: Types of metabolites used in medicine and production of antibiotics. As bio-fertilizers: Ecto and Endomycorrhizae. As human and animal parasites. As food: Nutritional and medicinal value of edible mushrooms; Fungal protein (Yeast and *Fusarium*).

PLANT PATHOLOGY (20 Marks ,20 Lectures)

Section D (PLANT PATHOGEN INTERACTION)

Classification of plant diseases; Biochemical and molecular basis of pathogenesis: Signalling in appresorial development, Role of chemical weapons in pathogenesis (enzymes, toxin and growth regulators); Genetics of pathogenecity. Plant diseases epidemiology: Elements of epidemics, Measurement of Plant diseases, Patterns of epidemics and pathogens factors. Computer simulation of epidemics, Disease Forecasting.

Section E (PLANTS DEFENSE STRATEGIES)

Concept on structural and biochemical plant defense; Defense through the production of secondary metabolites; Classification of elicitors and its receptors; Role of calcium binding proteins in plant defense. Hypersensitive reactions, Role of Reactive oxygen species in hypersensitivity.
Signaling mechanism behind the development of localized and systemic acquired resistance in plant. Pathogenesis related proteins and innate immunity in plants.

Section F (PLANT DISEASES AND ITS PROTECTION STRATEGIES)
A brief concept of diseases and disorders of plants; Diagnosis of plant diseases – from field to molecular diagnosis system;
General overview on different strategies of diseases management systems. Mechanism of action of chemicals used to control plant diseases, resistance of pathogen to chemicals, restrictions on chemical control of plant diseases;
Biopesticide and its mode of action with special reference to induced systemic resistance. Control of plant diseases through transgenic approaches.
Integrated control of plant diseases - General account (importance and basic principles).

PRACTICALS
1.Introduction to basic Mycological Techniques and Laboratory Safety; Methods of sterilization, media preparation and culturing.
2.Isolation of fungi from water/soil/air by culture plate technique.
3.Isolation of pathogen from diseased tissues.
4.Morphological and reproductive structure of some macro- and micro-fungi.
5.Symptomology and histopathology of some common diseases with diagnostic characteristics.
6.Isolation of fungal DNA and PCR based analysis.
7.Fungal tissue- culture; Preparation of spawn and cultivation of *Pleurotus.*
8.Identification of specimens from field trip.

SUGGESTED READINGS
1.Introduction to Fungi- John Webster and Roland W.S. Weber
2.Introductory Mycology -Alexopoulos C.J., C.W. Mims and M. Blackwell
3.The Mycota- Esser, K. and Bennet J. W. (Eds.)
4.An Introduction to Mycology - Mehrotra, R.S. and Aneja, K.R.
5.Fundamentals of Mycology -Burnett, J. H.
6.Chemical fungal taxonomy - Frisvad, J.C. Bridge, P.D. and Arora, D.K.
7.The Filamentous Fungi - Smith, J.E.
8.Fungal Nutrition and Physiology - Garraway, M. O. and Evans, R. C.
9.Mushroom Biology - Miles, P.G. and Chang, S.T.
10.Mycorrhizae Verma - A. and Hock, B.
11.Ectomycorrhizal Fungi - Cairney, J.W.G. and Chambers, S.M.

12.Industrial mycology - Berry, R.
13.Plant Pathology - Agrios, G.N.
14.Plant Pathology - Mehrotra, R.S.
15.Annual Review of Phytopathology - APS Press
16.Biotechnology in Plant Disease Control- Cheet,I.
17.Post infectional defense mechanisms - Mahadevan, A.
18.Pathogenesis and host specificity in plant diseases. Vol. III.-Rudra P. Singh, Uma S. Singh &
19.Keiisuke Kohmoto (eds.) 1995.
20.The nature of disease in plants - Scheffer, R.P.
21.Principles of Plant Pathology -Tarr, S.A.J .

Bot C32: Plant Physiology and Biochemistry: (Theory 40 marks; 2.5credits; 40 lecture hours)

Section A (PHOTOSYNTHESIS AND RESPIRATION)

Genes and polypeptide components of photosynthetic complexes; Bioenergetics of light reaction, Generation of proton gradient and ATP synthesis; Water to Water Cycle; CO_2 concentrating mechanism in plants; Regulation of C_2, C_3, C_4 and CAM cycles.

Metabolic regulation of glycolysis, acetyl CoA synthesis and citric acid cycle; Mitochondrial electron transport complexes – structure, function; Mechanism of ATP synthesis; Gluconeogenesis; Glyoxylate cycle.

Section B (TRANSPORT MECHANISM OF WATER, IONS AND MACROMOLECULES)

Mechanisms of uptake and transport of water, ions, solutes and macromolecules from soil to plants, Ion transporter - types, structure and function; Mechanisms of loading and unloading of photo assimilates.

Section C (DEVELOPMENTAL PHYSIOLOGY)

Concept of hormones as chemical messengers, Biosynthesis and mechanisms of action of hormones, synthetic regulatory compounds and their uses.

Concept on sensory photobiology and reproductive physiology - Structure, function and action of phytochromes, cryptochromes and phototropins; stomatal movement; Regulation of flowering by light temperature and hormones.

Physiology of senescence and aging - Senescence promoters, whole plant senescence and organ senescence, hormonal and environmental control of senescence, programmed cell death in life cycle of plants.

Types of dormancy, seed viability, dormancy enforcement and termination, biochemical and molecular basis of dormancy, hormonal regulation of dormancy and germination, circadian clock and germination control.

Section D (BIOMOLECULES)

Carbohydrates: Simple and conjugated sugars, nomenclature; structure; stereochemistry – Fischer projection, Haworth perspective, boat and chair conformation; mutarotation; glycoside formation; Derivative sugar; glycoproteins and proteoglycans –.

Protein : Hierarchy of protein structure, motifs and domains, torsion angle and Ramachandran plot, Forces stabilizing protein structure, fibrous proteins (keratins and collagen), globular protein; Protein folding: Leventhal paradox, different models and concept of chaperones;

Lipid: simple and conjugated lipid, different neutral & polar classes, nomenclature of different fatty acids, lipidomics concept.

Nucleic acid (DNA, RNA) : non Watson-Crick pairing, Sugar puckering and base stacking; torsion angle, Supercoiling; Denaturation kinetics of DNA, Cot curves.

Section E (ENZYMOLOGY AND METABOLISM)

Enzyme activity and specificity, Constitutive and Induced enzymes; Active site, Activation energy, Reaction rate, Mechanism of action, Kinetics: rate order of reactions; Derivation of MichaelisMenten equation – single substrate; MichaelisMenten plot and Lineweaver Burke plot; Enzyme inhibition: Reversible, irreversible with one example in each case.

Nitrogen metabolism: Structure and function of nitrogenase, Mechanism of nodule formation; Nitrate assimilation in plants.

Lipid metabolism: Biosynthesis and oxidation of fatty acids, regulation of FAS, Phospholipid synthesis and sterol synthesis, LOX for biotic and abiotic stress.

Reactive oxygen species – formation, role and scavenging.

PRACTICALS

1. Assay of catalase, peroxidase and ascorbic acid oxidase activity; determination of Km value of Urease.
2. Complexometric assay of Calcium and Magnesium
3. Colorimetric estimation of IAA.
4. Isolation of chloroplast and assay of Hill activity
5. Tetrazolium test of seed viability
6. Estimation of total phenolic content from seeds.
7. Colorimetric estimation of amino groups by Ninhydrin reaction.

8. Extraction of proteins and phosphoproteins from plant tissues and qualitative gel analysis by SDS PAGE and pro Q diamond staining.

SUGGESTED READINGS

1. Physiology by Teiz & Zeiger, Physiology, Biochemistry & Molecular biology by Buchanon et al. , Book by Cleon W. Ross and Frank B. Salisbury Physiology.
2. Biochemistry by Voet and Voet.; Principles of Biochemistry by Lehninger, Cox & Nelson Biochemistry by Lubert Stryer, Biochemistry by Herper, Biochemistry by Lippincott.
3. Biochemical calculation by Segel (Cambridge).
4. Practical Biochemistry by Rodney Boyers.

Optional Paper I (any 1 of the following)

1. **O-I-A: Applied Virology**
2. **O-I-B: Molecular and Applied Phycology**
3. **O-I-C: Molecular and Applied Mycology**
4. **O-I -D: Molecular Plant Physiology**
5. **O- I -E: Advanced Cell Biology**
6. **O- I -F: Advanced Paleobotany and Palynology**
7. **O- I -G: Advanced Phytochemistry and Pharmacognosy**
8. **O- I-H: Taxonomy and Biosystematics**

O-I-A*: Applied Virology*

1. Introduction to Virus Like Particles (VLPs) production strategies and applications.
2. Baculovirus protein expression system, application and importance.
3. Virus as vectors: gene therapy to gene silencing
4. Conventional vaccines -killed and attenuated, modern vaccines— designing and production strategies for recombinant proteins, subunits, DNA vaccines, peptides, vaccine delivery and adjuvants,
5. Interferons, designing and screening for antivirals, mechanisms of action, antiviral libraries, antiretrovirals-mechanism of action and drug resistance.

SUGGESTED READINGS

1. Antiviral Agents, Vaccines, and Immunotherapies. Stephen K. Tyring. 2004. Publisher: Marcel Dekker.
2. Antiviral Drug Discovery for Emerging Diseases and Bioterrorism Threats. Paul F. Torrence (Editor). July 2005. Publisher: Wiley, John & Sons, Incorporated.
3. Chimeric Virus -like Particles as Vaccines. Wolfram H. Gerlich (Editor), Detlev H. Krueger (Editor), Rainer Ulrich (Editor). November 1996 Publisher: Karger, S. Inc.
4. Vaccines. Stanley A. Plotkin, Walter A. Orenstein. September 2003. Publisher: Elsevier Health Sciences.
5. Retroviruses. Coffin JM, Hughes SH, Varmus HE, editors. Cold Spring Harbor (NY): Cold Spring Harbor Laboratory Press; 1997. (Available on NCBI)
6. Baculovirus Molecular Biology [Internet]. 3rd edition.Rohrmann GF. Bethesda (MD): National Center for Biotechnology Information (US); 2013. (Available on NCBI)
7. New Vaccine Development Establishing Priorities: Volume II: Diseases of Importance in Developing Countries. Institute of Medicine (US) Committee on Issues and Priorities for New Vaccine Development. Washington (DC): National Academies Press (US); 1986. (Available on NCBI)

O-I-B*: Molecular and Applied Phycology*

1. Molecular Evolution and taxonomy of Cyanobacteria and Green algae
2. Molecular Biology of Cyanelle :Molecular genetics, Protein transport, phylogenetic analysis
3. Algal Biodiversity of Indian subcontinent
4. Cyanobacteria and Algae in carbon mitigation process and bio-fuel production
5. Algal Biorefinary

Suggested Reading

1. **Algae: Nutrition, Pollution control and energy sources.** Editor: Kristian N. Hagen

Publishers: Nova Science publishers, New York.2009

2. **Cyanoprokaryota: Oscillatoriales** (Süßwasserflora Von Mitteleuropa: Oscillatoriales *Süsswasserflora von Mitteleuropa*) Authors: Adolf Pascher, Jiří Komárek, Konstantinos Anagnostidis, Burkhard Büdel, Hanuš Ettl, Lothar Krienitz, Georg Gärtner, Michael Schagerl. Publishers: G. Fischer, 2005

3. **Algae Energy:** Algae as a New Source of Biodiesel Author: Ayhan Demirbas, Muhammet Fatih Demirbas Publishers: springer

O-I-C*: Molecular and Applied Mycology*

1. Bar coding as a tool for molecular identification of fungi.
2. Transformation and gene manipulation in filamentous fungi; protoplast technology; linear plasmid-structure and function.
3. Endophytic fungi and its application; Degradation of biological and chemical waste by fungi.
4. Mycoses; mycotoxins; Fungi as a source of next generation medicine.
5. Commercial applications of fungi.

O-II- D*: Molecular Plant Physiology*

1. **Plant nutritional physiology**: Molecular regulation of intercellular and intracellular uptake and transport of nutrients. Structure and function of ATPase/pump. Signaling mechanism of nutrient transport with special reference to iron and phosphorus uptake. Regulation of nutrient homeostasis by target mimicry.

2. **Signal transduction in plant growth, morphogenesis and reproductive physiology**: Receptors and G-proteins, phospholipid signaling, calcium-calmodulin cascade, diversity in protein kinases and phosphatases. Role of cyclic nucleotides, miRNAs, circular RNAs and long-non coding RNAs in plant growth, morphogenesis and flowering.

3. **Molecular aspect of biological nitrogen fixation (BNF) in plants**: Organization, function and regulation of *nif* and *nod* genes. Carbon and nitrogen (C/N) balance signaling in plants under elevated CO2 condition. Application of BNF for crop improvement.

4. **Plant environment interaction and adaptive physiology**: Signal perception and transduction in plants during different environmental changes (water, temperature, elevated CO_2 and salt). Adaptive features of plants against environmental challenges. Molecular regulation and crosstalk among different signaling pathways to mitigate environmental challenges.

5. **Analytical approaches and molecular techniques**: Analysis of gene expression at RNA and protein level in plants during different physiological phenomena and stress responses, Global expression profiling by NGS and comparative proteomics analysis. Protein sequencing methods, detection of post translation modification of proteins. Detection of molecules using northern blot, western blot, immunoprecipitation, and immunofluorescence microscopy.

O-I -E*: Advanced Cell Biology*

1. Cell death- apoptosis, autophagy, necrosis and programmed cell death
2. Cell signalling- signalling molecules, receptors (GPCR,PTRK, JAK/STAT), second messenger and pathways
3. DNA repair and recombination: Direct reversal of DNA damage, excision repair, translesion repair, recombination repair.
4. Cancer biology

Suggested Readings:

1. The biophysical Chemistry of nucleic acids and proteins-Creighton
2. The physical and chemical basis of molecular biology-Creighton
3. Principles of Biochemistry-Nelson et al
4. Lewin's Cell- Plopper, George (edtd)
5. Principles of Mol. Biology-Tropp, Burton
6. Cell Biology-Pollard
7. The Cell: a molecular approach-Cooper
8. Molecular Biology-Clarke, David
9. Molecular Biology-Weaver

O-I -F*: Advanced Paleobotany and Palynology*

1. **Paleofloristics**: Deccan intertrappean, Siwalik and Karewa flora.
2. **Past climate/environment reconstruction**: Quantitative palaeoenvironmental reconstructions using different approaches: NLR, CLAMP, Co-Existence approach, Indicator species approach, Assemblage approach, and Multivariate transfer function approach , stable isotopes ($\delta^{13}C$, $\delta^{18}O$) , pCO_2 concentration; palynomorphsin study of near shore environments, sea level fluctuation, deposition of kerogen, paleo- thermometry, bathymetry, salinity and temperature; and DNA (eDNA/ PalEnDNA) in past environment research, basics of the biome reconstructions (PFT concept).

3. **Fossil evidence of physiological and developmental mechanisms**-: evolution of plants using the

C_4 and CAM photosynthetic pathway: the first grasses, polar auxin flow; expansion of C4 grasses since the Miocene and probable causes: examples

4. **Brief concept of mass extinction**: evidence in the geological record: plants versus animals; floral change-over across the Cretaceous – Tertiary boundary.

5. **Past Biotic interactions**: Interaction among different groups of plants, Plant –animal interaction and their co-evolution in the fossil record.

6. **Archaeobotany and palaeoethnobotany**: origin and development of agriculture in India, near East and Europe; study of plant economy (cereals, pulses, fruits and drug plants) from Palaeolithic to Historic age; archaeopalynology in analysis of prehistoric vegetation and human/animal diet.

7. **Plant proxies in past catastrophic studies**: detection of cyclones and tsunamis in the geological past (Palaeotempestology); past fire and environmental change; charcoal as information source in reconstructing fire history.

8. **Modern techniques in paleobiological research**: pollen DNA Bar coding, Raman spectroscopy, Fluorescence microscopy, XRD, EDX.

O- I -G*: Advanced Phytochemistry and Pharmacognosy*

1. Secondary metabolism; role of compartmentation and metabolite trafficking; Biosynthetic pathways for secondary metabolism; Biosynthesis of fatty acids and polyketides, phenols, flavonoids, tannins, lignans and lignins, alkaloids, terpenoids, steroids; turnover and degradation of secondary metabolism.
2. Classification, Phytochemical sources in plant kingdom, phytoconstituents and biological activities of secondary metabolites (Phenols and phenolic glycosides, sterols, steroidal alkaloids, stanols, miscellaneous isoprenoids, saponins, alkaloids, volatile oils, lipids and carbohydrates).
3. Enzymes (Proteolytic enzyme), proteins (RIP, Lectins), Amino acids as drugs, vaccines, toxins and toxoids, antitoxins, immune globulins, antisera, pharmacological activities of plant drugs (tumour inhibitors, hypoglycaemic, anti-hepatotoxic, antiviral antiprotozoal, immunomodulators, anti-oxidants, phytoestrogens and enzyme inhibitors).
4. Antibiotics and their chemical nature, mode and mechanism of actions and bases of toxicity of antibiotics derived from amino acid metabolism, acetate metabolism and carbohydrate metabolism.
5. Methods for phytochemical analysis, tissue culture and biotechnology for the discovery and production of phyto – molecules; immunoassay; metabolomics: terms and definitions, different metabolomic technologies, merits and demerits, data acquisitions and applications; Ethnopharmacology: importance in drug developments

O- I -H*: Taxonomy and Biosystematics*

1. Plant taxonomy through ages in India: Major contributions of W. Roxburgh, N. Wallich, J.D. Hooker, C. B. Clarke, G. King and K.P. Biswas. Brief knowledge of Botanical Survey of India (B.S.I), Central National Herbarium (CAL): role in systematic study in India. Acharya Jagadish Chandra Bose Indian Botanic Garden (AJCBIBG) & National Botanical Research Institute (NBRI): activities in relation to taxonomic studies and conservation. Taxonomic Literature: Categories, brief concept with examples.

2. Floristic regions of the world (Takhtajan, 1987); Floristic Composition of India: description and composition of Himalayan, Peninsular and Desert vegetation. Biodiversity Act, Role of National Biodiversity Authority (NBA) in biodiversity management; CBD and environmental protocols.

3. Latest changes, addition and alteration in International Code of (Botanical) Nomenclature (ICN); Valid Publication: provision of new taxa (Genus); Nomenclature of Hybrid Plants; Nomenclature of Cultivated Plants (ICNCP).

4. Evolutionary concepts: monophyly, paraphyly, polyphyly, plesiomorphy, apomorphy, anagenesis, stasigenesis, cladogenesis, homology, analogy, homoplasy, parallelism and convergence, synapomorphy and symplesiomorphy.

5. Modern trends in Taxonomy: Nodal Anatomy: structure, types, evolution and applications. Palynotaxonomy: pollen structure, types and evolution of pollen grains, applications. Serology, Ultrastructures.

Fourth Semester

Bot C 41: Plant Anatomy and Developmental Biology: Theory (40 marks; 2.5 credits; 40 lecture hours)

Plant Anatomy: (20 marks, 20 lectures)

I.Differentiation of primary and secondary plant bodies: Origin and development of sclereids, fibres and their control of differentiation; vascular cambium, factors influencing cambial activity; Periderm structure and development; nature and development of cell wall of sieve elements; nature and function of p-protein.

II.Plant anatomy in systematics, ecology and evolution: Phylogeny of xylem and phloem elements; wood anatomy, nodal anatomy, mineral inclusion in systematics and evolution; leaf and wood anatomy in ecological perspective; anatomical response to pollutants.

III.Physiological plant anatomy: Structure and function of cuticle and epicuticular waxes**;** anatomical response to mineral deficiency; response of plants to wounding and invasion by microorganisms; leaf structure in C_3 and C_4 plants; xylem structure and water movement.

IV.Reproductive plant anatomy: Floral vasculature; development of pollen grains; structure of floral nectaries and seed coat.

V.Applied plant anatomy: Application of anatomical studies in climatology, genetics and plant breeding, biomedical research and forensic science.

Plant Developmental Biology: (20 marks,20 lectures)

I.Basic concepts of developmental biology: Development involves major overlapping processes; Stem cell developmental potency; cellular plasticity in plants; determination and differentiation , mechanism of cellular determination; morphogenetic gradients, cell fate and cell lineages; positional information, pattern formation (apical-basal and radial); morphogenesis. Model plants for developmental studies: *Physcomitrella patens*, *Arabidopsis thaliana*, *Zea mays*, *Antirrhinum majus* .

II.Fertilization and early development in plants: Gametophyte development and fertilization, post-fertilization changes, formative cell divisions as principal determinants in plant morphogenesis; axis and pattern formation in *Arabidopsis*, organization of shoot and root apical meristem and cell niche; Formation of lateral roots; leaf development and phyllotaxy; Approaches to study genes involved in plant development in *Arabidopsis* and maize. Genes controlling development: MADS-box genes, KNOX genes; major gene regulatory networks involved.

III.Reproductive biology: Development of flower: Vegetative to reproductive evocation, floral meristems and floral development; floral homeotic mutations in *Arabidopsis*, *Antirrhinum* and *Petunia*, 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, mechanisms of male sterility, pollen embryogenesis. Pollen-pistil interaction: pollen germination, double fertilization, self-compatibility mechanisms.

PRACTICALS

Plant Anatomy

1. Cell types- trichomes, sclerides, tracheids, vessels 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, trilacular, 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, succulent, halophytic and hydromorphic leaves.

8. Histology of seed coats: *Gossypium*, *Citrus, Phaseolus*, *Phoenix*/ *Musa*.

Plant Developmental Biology

1. Study of the stages of pollen and ovule development.

2. Pollen *in vitro* germination methods: Sitting drop culture, suspension culture, surface culture.

3. Correlation between fertility (stainability), viability (TTC and FDA staining) and germinability (*in vitro*) of pollen grains

4. Use of DNA fluorochromes to localize nuclei during pollen and ovule development.

5. Dissection of embryo and endosperm: Study of post-fertilization stages.

6. Histological characterization of SAM and RAM development.

7. Demonstration of vegetative to floral phase transition using PCR.

SUGGESTED READINGS

Plant Anatomy

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 (4^{th} 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 and II) - Cutter, E.G.

Plant Developmental Biology

1. Molecular Genetics of Plant Development, Howell SP (1998) – Cambridge University Press
2. Developmental Biology of Flowering Plants,V Raghavan (2000) - Springer
3. Developmental Genetics and Plant Evolution, Quentin C.B. Cronk, Richard M. Bateman, Julie A. Hawkins (2002) - CRC Press
4. Flower Development: Methods and Protocols, JL Reichmann and F Wellmer (2014)- Humana Press

Bot C 42: Plant Biotechnology: Theory (40 marks; 2.5 credits; 40 lecture hours)

1. Over view of Plant Biotechnology: Introduction and applications of plant biotechnology across the plant kingdom

2. Basic concepts of plant cell, tissue and organ cultures: Pathways for *in vitro* morphogenesis: Organogenesis and somatic embryogenesis; Structural and developmental ontogeny; Physiological, biochemical and molecular aspects of somatic embryogenesis; Concept of gametic embryogenesis, microspore and anther culture-importance of developmental stage of microspores and other factors for haploid production. Protoplast isolation, culture and regeneration with example.
Somaclonal and gametoclonal variations---causes and genetic basis. Cryopreservation and germplasm conservation *in vitro*.

3.Applications of plant cell ,tissue and organ cultures : Micropropagation, methods and stages; clonal/ genetic fidelity testing ; use of bioreactors in micropropagation; Examples of commercially propagated species.
Zygotic embryo and endosperm culture: applications with examples ; Synthetic seeds-methods of delivery systems.
Somatic cell hybridization: protoplast fusion,chemical fusogen and electric fusion; screening of hybrids; Cybrids.
Production of natural products by cell suspension cultures , shoot and root organ cultures in batch cultures and in bioreactors with examples.

Strategies and Methods of genetic manipulation in plants: Vectors used to introduce foreign DNA into plant cells. Binary cloning vector, disarmed Ti plasmid, cointegrate cloning vector, arrangement of genes in the vector, Role of markers and reporter genes in plant transformation; detection of transgene copy number, position and features. Molecular mechanism of T DNA transfer, Genetic elements and engineering of Ti and Ri plasmids, Direct gene transfer methods: particle bombardment, electroporation, PEG-mediated and floral-dip; Chloroplast transformation : principles and advantages; marker-free transgenics and novel strategies; genome editing, transgene stability and transgene silencing; case studies of transgenic traits in plants. Strategies to avoid gene silencing and improve gene expression in transgenic plants.

Applications of plant transgenic technology : Transgenic crops for resistance against biotic and abiotic stresses; Engineering crops for male sterility; modification of flower color, flowering, fruit ripening and senescence; RNAi mediated crop improvement; Plant metabolic engineering : case study of phenyl propanoid pathway and other examples of manipulating secondary metabolism; GM crops for nutritional quality and quantity; Molecular pharming; Global status and biosafety of transgenic plants; GM crops and ethical issues.

Practicals:

1. Organization of a tissue culture laboratory; Equipment and supplies; Basic techniques in aseptic plant tissue culture.
2. Different types of basal medium;medium components; Preparation of MS, B5 and SH medium. Sterilization of medium and equipments.
3. Surface sterilization of seed, bulb/ rhizome and culture in different types of basal medium.
4. Study effects of phytohormones (2,4-D/NAA with and without KN/BA) and basal medium(MS/B5/SH) on callus induction from explants excised from aseptically germinated seedlings and bulbs.
5. Study of de novo direct organogenesis / somatic embryogenesis (monocot and dicot)
6. Study of callus mediated organogenesis/somatic embryogenesis (*Nicotiana tabaccum* / *Daucus carota*)
7. Study of stages of micropropagation using shoot tip/ nodal buds (*Withania somnifera*)
8. Preparation of competent cells and *Agrobacterium* transformation.
9. *Agrobacterium tumefaciens (*disarmed strain) mediated transformation in *Nicotiana tabaccum*.
10. *Agrobacterium rhizogenes* (wild type strain A4) mediated transformation in *Withania somnifera*.
11. Visit to a commercial Tissue Culture Facility in West Bengal.

Book List

1. Plant propagation by Tissue Culture Volume 1 George, Edwin F., Hall**,** Michael A., De Klerk, Geert-Jan (Eds.) ,(Springer 2008)

2. Plant tissue Culture: Theory and Practice by SS Bhojwani and MK Razdan . El;sevier

3. Plant Cell Tissue and Organ Culture :Fundamental methods by OL Gamborg and GC Phillips . Naropsa.

4. Biotechnology and Plant Breeding, 1st Edition (2014), by Borém & Fritsche-Neto (Elsevier)

5. Plant Biotechnology and Agriculture by Arie Altman and PM Hasegawa (Elsevier 2012)

Bot C 43: Ecology Theory (20 marks; 1.5 credits; 20 lecture hours)

1. Ecology: Definition, branches, importance.
2. The environment: Physical, biotic, and abiotic.
3. Habitat and Niche: Concept, types, resource partitioning.
4. Population ecology: Characteristics of a population; population growth curves; life history strategies (r and k selection).
5. Community ecology: Nature of communities; community structure; edges and ecotones.
6. Ecosystem: Structure and function; energy flow and mineral cycling (CNP); forest grassland and aquatic ecosystems.
7. Major Biome of the world.
8. Environmental pollution and its effect on plants.
9. Greenhouse effect and Global warming; Ozone depletion.

SUGGESTED READINGS:

1) Odum, E. P. 1971. Fundamentals of Ecology. W.B Sounders Co., Philadelphia.
2) Odum, E. P. 1997. Ecology: A Bridge Between Science and Society. Sinauer Associates.
3) Chapman, J. L. & Reiss, M. J. 1999. Ecology Principles and Applications. Cambridge University Press, U.K.
4) Sharma, P. D. 2009. Ecology and Environment. Rastogi publicatios, Meerut.
5) Ambasht, R. S. 1990. A Text Book of Plant Ecology. Students' Friends & Co. Varanasi.
6) Dhaliwal, G. S., Sngha, G. S. and Ralhan, P. K. 1998. Fundamentals of Environmental Science. Kalyani Publishers.
7) Kaushik, A. and Kaushik, C. P. 2014. Perspective in environmental studies. New Age International
(8) Ltd. Publishers, New Delhi.

Optional Papers II(any 1 of the following)

1. **O-II-A: Microbial Biotechnology**
2. **O-II-B: Plant protection**
3. **O-II-C: Green Nanotechnology**
4. **O-II-D: Plant Molecular genetics**
5. **O-II-E: Plant Molecular Biology**
6. **O-II-F Molecular stress biology**

7. **O-II-G: Immunology**
8. **O-II-H: Instrumentation and Biostatistics**

O-II-A *Microbial Biotechnology*:

1. Introduction to microbial biotechnology: multidisciplinary nature of microbial biotechnology, history of development
2. Bioprocessing: bioprocess stages and units of operation, microorganisms used in biotechnology: sources, screening for productive strains and strain improvement, media formulation, and process optimization.
3. Fermenter and fermentation systems: Fermenter: types, components, and operation. Submerged and solid state fermentation; open and closed system of fermentation.
4. Downstream processing: removal of solids, filtration, centrifugation, foam separation, precipitation, cell disruptions, liquid-liquid extraction, chromatography, membrane processes. Drying and crystallization. Product certification and bioprocess economics.
5. Application of microbial biotechnology: in biopharmaceuticals (human insulin, recombinant proteins, enzymes, DNA vaccine, taxol production), green chemistry (PLA, PHA production); agriculture (thuricide production); food (nutraceuticals, SCP); and environment (biosensors, bioremediation).

SUGGESTED READINGS:

1. Microbial Biotechnology by A. N. Glazer and H. Nikaido
2. Modern Industrial Microbiology and Biotechnology: N. Okafor
3. Industrial Microbiology: An Introduction by M. J. Waites, N. L. Morgan, J. S. Rockey, and G. Higton.
4. Industrial Microbiology by M. J waites, N. L. Morgan and J.S. Rocky
5. Industrial Microbiology by L. E. Casida Jr.
6. Principles of Fermentation Technology by P. F. Stanbury, A. Whitaker and S .J. Hall.
7. Comprehensive Biotechnology by Moo-Young

O-II-B: Plant protection

1. Methods to prove Koch's postulates with biotroph and necrotroph pathogens; Preservation of plant pathogens and disease specimens; serological and molecular techniques for detection of plant pathogens.
2. Chemical protection and chemotherapy, nature, properties and mode of action of antifungal, antibacterial and antiviral chemicals; Health and environmental hazards, residual effects and safety measures.
3. Trends and future possibilities of biological control; Biotechnology in biological control; Mass production of quality biocontrol agents- techniques, formulations, economics, field release/application and evaluation.
4. Plant immune system; Microbial patterns and plant pattern recognition; PAMP-triggered immunity (PTI); Effector-triggered immunity (ETI).
5. Dynamism of IPM under changing cropping systems and climate; Prevention and Management of Pesticide Resistance.

O-II-C: Green Nanotechnology

1. An overview; Green manufacturing technology for different method, metal oxide, metaloid and non metal nanoparticles.
2. Physico-chemical methods for characterization of nanoparticles.
3. Application of nanoparticles in agriculture.
4. Nanotechnology in health care.
5. Toxicological effects of nanoparticles.

O-II-D: Plant Molecular genetics

1. **Evolution of plant genome architecture**: Evolution and synteny of plant genomes; gene and genome duplication in evolution; Genomic views on hybridization, heterosis, domestication, and speciation.

2. **Gene expression in plants**: Key aspects in regulation of gene expression; Transcriptional and post-transcriptional silencing of genes in plants

3. **Genetic variations and their biological consequences**: Analysis and utilization of genetic variation; Genetic control and manipulation of breeding systems including male sterility and apomixes

4. **Genetic resources in plants**: Characterization and utilization; Cytogenetics and its role in evolution and improvement of major cereal crops.

5. **Molecular Breeding**: Phenomics; Marker Assisted Selection, QTL analysis, Genome-Wide Association Studies in plants; Chromosome engineering; Gene pyramiding for multi-trait incorporation

Suggested Readings:

1. Principles of Plant Genetics and Breeding (2010) George Acquaah, Wiley-Blackwell Publishers

2. Series Developments in Plant Genetics and Breeding, Elsevier publishers

3. Plant Genetic Resources And Climate Change (2014) Jackson et al, CABI Publishing

O-II-E: Plant Molecular Biology

1. Structure and expression of nuclear genes, regulatory signals in plant genes, post translational modification and direction of proteins to different cellular compartments, transit peptides and genetic specification of protein transport.

2. The plastome and chloroplast biogenesis, chloroplast genetics and extent of plastid autonomy, chloroplast ribosomes and protein synthesis, Effect of light on synthesis of chloroplast proteins, Transcription and processing of chloroplast RNA,

3. Regulation of differential gene expression during plant development, seed development and germination.

4. Biochemical and gene regulatory networks, Fractionation of plant tissue for biochemical analysis, Plant Protein-Protein Interaction Network and Interactome, protein interaction at the systems biology age, major approaches for interactome mapping, protein-protein interaction network as applied to specific plant biology questions

5. Comparative and functional genomics Principles of comparative genomics, Transcriptomics: Promoter Case Study, Scaling up analysis. Network case study

O- II -F*: Molecular stress biology*

1. Abiotic and biotic stress inducible genes and transcription factors

2. Molecular control of ROS production and anti-oxidant processes

3. Signal transduction pathways: salicylic acid mediated signal transduction pathway, Jasmonic acid/Ethylene mediated pathway, ABA-dependent and ABA independent pathways

4. Molecular cross talk between the different signalling pathways, the defence genes involved and how they are regulated.

5. Role of surface structures and receptors in detecting stresses.

Suggested Books:

5. Abiotic stress adaptation in plants : physiological, molecular & genomic foundation by Sokori, Bohnert&Govindjee
6. Improving crop resistance to abiotic stress by Tuteja
7. Plant Stress and Biotechnology by Devarajan
8. Oxidative stress in plants by Dirk Inze&Mondago
9. Plant Stress Physiology by Shabala& Sergey
10. Genes involved in plant defense by T. Boller& F. Meins
11. Genes and Environmental Stress by Burdon, Roy H
12. Molecular strategies of pathogens and host plants by Suresh Patil

O- I I-G: *Immunology*

1. Cells and molecules involved in innate and adaptive immunity, antigens, antigenicity and immunogenicity, B and T cell epitopes. Structure and function of antibody molecules. generation of antibody diversity, monoclonal antibodies, antibody engineering, antigen-antibody interactions.

2. MHC molecules, antigen processing and presentation, activation and differentiation of B and T cells, B Cell Receptor (BCR) and T Cell Receptor (TCR). Humoral and cell-mediated immune responses, primary and secondary immune modulation, the complement system, Toll-like receptors, cell-mediated effector functions.
3. Inflammation, hypersensitivity and autoimmunity, Immune response during bacterial (tuberculosis), parasitic (malaria) and viral (HIV) infections, congenital and acquired immune deficiencies, vaccines.

4. Cancer: Genetic rearrangements in progenitor cells, oncogenes, tumor suppressor genes, cancer and the cell cycle, virus-induced cancer, metastasis, interaction of cancer cells with normal cells, apoptosis, therapeutic interventions of uncontrolled cell growth.

5. Techniques: Flow cytometry and immunofluorescence microscopy, detection of molecules in living cells, *in situ* localization by techniques such as FISH and GISH. Detection of molecules using ELISA, RIA, immunoprecipitation.

SUGGESTED READINGS

1. Cellular and molecular immunology- Abul K Abbas, Andrew H Lichtman,Shiv pillai,9th edition ,Elsevier.

2.Essentials of Clinical immunology- Helen Chapel, Mansel Haeney,Siraj Misbah, Neil Snowden, 6th edition, Blackwell

3. Practical immunology - Frank C.Hay, Olwyn M.R. westwood,5th edition, Blackwell

4. Basic immunology - Arun Ingale ,New central Book agency(P) Ltd

5. Immunology and Immunotechnology- Ashim K Chakravarty, Oxford

O-II-H: Instrumentation and Biostatistics

1. Principles of optical, phase contrast, fluorescence and electron microscopy, spectrophotometry, UV and VIS, fluorimetry; AAS & ICP-OES/MS; Radioisotopic; Electrophoresis-general principles and application, gel electrophoresis 1D & 2D, isoelectric focusing; Chromatographic techniques - paper, thin layer, column chromatography, GC and HPLC; GCMS, LCMS ESI-MS. Centrifugation - principles of sedimentation, differential centrifugation, density gradient centrifugation and ultracentrifugation. Microarray and DNA chips.

2. Biochmical calculations based on metabolic processes; Calculations based on principles of the Instruments used in applied biology; Mathematical expression of Thermodynamic principles and redox potential.

3. Frequency distribution, mean, mode and median. Standard, normal, binomial and Poisson's

distribution, Sampling methods and standard errors, Measures of central tendency and dispersal; probability distributions (Binomial, Poisson and normal);Correlation and regression: Partial and multiple, tests of significance, t, chi- square, ANOVA, Design of experiments: Principles of Randomized block design, Completely randomized block design, Latin square design, Split-plot designs; Basic concept on bivariate and Multivariate data set. Use of soft ware packages like SPSS, SAS, R etc. for the above tests and designs of experiments for analysis.

Appendix-1

The students will have to choose one optional paper each in semester III and IV from the given list of optional papers. There is no limit on number of seats for optional papers.

The students will have to choose one course under CBCS from each of the following two groups. No student is allowed to choose the course offered by his/her parent department. Each course is of 50 marks and carries 4 credits.

GROUP-A

OA1. Neurobiology: Function & Dysfunction (SN Pradhan Centre for Neuroscience)
OA2. Human Genetics: Concepts and Paradigms (Dept. of Genetics)
OA3. Fundamentals of Biochemistry (Dept. of Biochemistry)
OA4. Biotechniques and Instrumentations (Dept. of Biotechnology)

GROUP-B

OB1. Concepts in Zoological Science (Dept. of Zoology)
OB2. Introduction to Marine Environment (Dept. of Marine Science)
OB3. Perspectives of Environmental Science (Dept. of Environmental Science)
OB4. Fundamentals of Plant Science (Dept. of Botany)
OB5. Fundamentals of Bacteriology (Dept. of Microbiology)

OA1. Neurobiology: Function & Dysfunction (SN Pradhan Centre for Neuroscience)

1. Brain Anatomy **8 Classes**

Different Lobes/ Cortex
Brain Organisation – CNS, PNS, ANS
Structure of Cerebellum and Basal Ganglia
Histology of Brain Sections (Coronal/sagittal) – Normal vs. Diseased
Neuro-developmental Biology (Briefly)
Blood Brain Barrier

2. Cell Biology **12 Classes**

Neurons and Glial Cells
Detection of different neuronal cells (by IHC/ICC)
Neuronal Transmission

i. Electrical Impulse – Action Potential, Excitatory and Inhibitory Postsynaptic Potentials (EPSP and IPSP)
ii. Chemical Impulse
iii. Synapse
iv. Neurotransmitters and their metabolism
v. Different Pathways (Dopaminergic, Adrenergic, Seretonergic etc.)
vi. Examples of malfunctions of pathways

Neuronal study in Cell/Organ

a. Isolation and culturing of primary neurons and means of manipulation
b. Culturing and methods of differentiation of cultured neuronal cells
c. Organotypic brain cultures

3. Sensation and Sensory Processing **4 Classes**

i. The Somatic Sensory System: Touch and Proprioception
ii. Pain
iii. Vision – The Eye and Central Visual Pathways
iv. The Auditory System
v. Olfactory System
vi. Gustatory System

4. Neuropathology **16 Classes**

Clinical, Cellular and Molecular Mechanisms of the Neurological Diseases:
Alzheimer's Disease, Parkinson's Disease, Huntington Disease, Dystonia, Wilson Disease, Epilepsy, Autism, Multiple Sclerosis, Amyotrophic Lateral Sclerosis (ALS), Attention Deficit Hyperactivity Disorder (ADHD), Schizophrenia, Depression, Dementia, Cerebro-vascular Disease (Stroke)
Techniques and tools applicable in neuroscience: MRI, PET, Fluorescence microscopy, FACS, Electron Microscopy, Patch Clamp, etc., Database sequence information and mutation information on specific neurodegenerative diseases

5. Behavioral Testing using Animal Models **10 Classes**

C. elegans, Fruit fly, Zebra Fish, Mouse
Testing motor functions – Rotarod Test, Force Swimming Test, Beam Walking Test, Grip Strength Test
Testing Cognitive Functions – Learning and memory related test (Any-arm Maze, Water Maze etc.)

OA2. Human Genetics: Concepts and Paradigms (Dept. of Genetics)

Traits of interest:
Inheritance pattern of Mendelian and complex trait: pigmentation, intelligence and creativity as models of complex trait; Microbiota shaping human traits [7].

Clinical Genetics and Genetic disorders:
a) Concept of mutation and polymorphism
b) Single gene vs complex disorder: Cystic Fibrosis, Beta-thalassemia, ADHD, Haemophilia as models
c) Gene-environment interplay in diseases: cancer as model
d) Genetic variations and susceptibility of horizontal disease: Malaria as a case study [15].

Population Genetics and Evolution:
a) Concepts of allele frequency, genotype frequency, HW equilibrium and genetic drift
b) Human migration and 'Out of Africa' hypothesis and evolution of *Homo sapiens* [5].

Immunogenetics and Network Ecology:
Evolution of genes involved in immune response to parasites; Genetics of diseases resistance [3].

Pharmacogenetics:
Concept of personalized medicine [2].

Tools in human genetic research:
a) PCR-sequencing based screening of disease genes; Microarray analysis
b) Gene therapy, gene editing and gene replacement therapy
c) Study of database in relation to human disorders: OMIM as a model [7].

Genetics and Society:
a) Genetic counseling and risk assessment; Carrier detection
b) IVF and stem cell genetics
c) Forensic studies and paternity testing; Cord blood banking, New born screening in genetic disorders [4].

Community Genetics and legal issues:
Ethics in genetic research; Case studies [2].
Genetic models of human diseases:
Disease Models in *Drosophila melanogaster* and the role of the fly in therapeutic drug discovery; Humanized mice; Canine model of eye disorders [2].
Epigenetics: Methylation and histone modification in causation of disorders; Inheritance of fear as a case study [3].

OA3. Fundamentals of Biochemistry (Dept. of Biochemistry)

1. **pH and Buffers:** Bronsted-Lowry Concept of Acids and Bases, Buffers: Henderson-Hasselbalch equation, Biological buffer systems: The phosphate buffer system, The bicarbonate buffer system, The protein buffer system, The amino acid buffer system, The hemoglobin buffer system **(Three Lectures:** 1 hour each)

2. **Biomolecules:Carbohydrates**: Importance, Nomenclature, Classification, Asymmetry, Optical Isomerism, Mutarotation, General structure of monosaccharide, disaccharide, oligosaccharides, polysaccharides (Lactose, Maltose, Cellobiose, Isomaltose, Trehalose, Starch, Glycogen, Cellulose, Pectin, Chitin, Heparin.
   Proteins: Importance, Amino Acids: Structure, Distribution in Proteins, Location in proteins, Physical properties, Electrochemical properties, Classification, Nonprotein Amino Acids, Peptide bonds, Chemical Bonds involved in Protein structure, Protein Configuration: Primary Structure, Secondary Structure, Tertiary Structure, Quaternary Structure, Physical Properties of Proteins: Shape and Size, Molecular weight, Colloidal nature, Denaturation, Amphoteric nature, Solubility, Optical Activity, Chemical Properties of Protein: Hydrolysis, Reaction involving COOH group, NH2 group, R group, SH group.
   Lipids: Importance, Definition, Alcohols and Fatty Acids, Biological roles of lipids, Classification: Simple Lipids and Compound Lipids, Properties of Fats and oils: Solubility, Melting Point, Insulation, Emulsification, Surface Tension, Chemical Properties: Reactions involving COOH group, Hydrolysis, Saponification, Rancidity, Hydrogenation, Halogenation, Oxidation, Oxidative Rancidity, Reactions involving OH group, Dehydration.
   Nucleic Acids: Nucleosides, Nucleotides, DNA, Internucleotide linkages, Base composition, Evolution of Watson-Crick model, Double helical structure, Denaturation and renaturation, Molecular weight, Length, Shape and Size, Variants of Double helical DNA, DNAs with unusual structures, Single stranded DNA, RNA. Differences with DNA, Ribosomal RNA, Transfer RNA, Messenger RNA, Heterogeneous nuclear RNA. **(Twenty Lectures**: 1 hour each)

3. **Enzymes**: Importance, Nomenclature and Classification, Isoenzymes, Multienzyme system. Biological roles of enzymes. Chemical nature of enzyme, Characteristics of enzymes, Specificity of enzyme action, Thermostability, Reversibility of a reaction, pH sensitivity, MichaelisMenten Hypothesis, MichaelisMenten equation, Lineweaver-Burk equation, Significance of Km and Vmax values, Active site, Enzyme reaction rates, Modifiers of Enzyme activity, Enzyme Inhibitors (Competitive, Noncompetitive, Uncompetitive), Allosteric enzymes. **(Six Lectures**: 1 hour each)

4. **Nutrition:** Energy turnover, Assessment of nutrient transport and fate, Biochemical effects of neutraceuticals. **(Four Lectures:** 1 hour each)
5. **Bioenergetics and Metabolism:** Definition of metabolism, Catabolic pathways, Anabolic pathways, Carbohydrate metabolism, Amino acid metabolism, Lipid metabolism, Nucleic acid metabolism. Regulation of metabolic pathways, Bioenergetics. **(Ten Lectures:** 1 hour each**)**

6. **Analytical Biochemistry:** Principles and application: equipments, sample preparation, Homogenization, Differential centrifugation, Chromatography, Spectrophotometry, Electrophoresis, Ultracentrifugation.
   (Five Lectures: 1 hour each)

OA4. Biotechniques and Instrumentations (Dept. of Biotechnology)

1. **Molecular Biology and Recombinant DNA methods:**
   Isolation and purification of RNA , DNA (genomic and plasmid) and proteins, different separation methods. Analysis of RNA, DNA and proteins by one and two dimensional gel electrophoresis, Isoelectric focusing gels. Molecular cloning of DNA or RNA fragments in bacterial and eukaryotic systems. Expression of recombinant proteins using bacterial, animal and plant vectors. Isolation of specific nucleic acid sequences Generation of genomic and cDNA libraries in plasmid, phage, cosmid, BAC and YAC vectors. In vitro mutagenesis and deletion techniques, gene knock out in bacterial and eukaryotic organisms. Protein sequencing methods, detection of post translation modification of proteins.

2. **Spectroscopic Methods:**
   Molecular analysis using UV/visible, fluorescence, circular dichroism, NMR and ESR spectroscopy Molecular structure determination using X-ray diffraction and NMR, Molecular analysis using light scattering, and surface plasma resonance methods.

3. **Mass spectroscopy and Proteomics:**
   Different types of mass spectrometry and applications in biology.

4. **Modern Genomics Techniques:**
   DNA sequencing methods, strategies for genome sequencing. Methods for analysis of gene expression at RNA and protein level, large scale expression, western blot, such as micro array based techniques Isolation, separation and analysis of carbohydrate and lipid molecules RFLP, RAPD and AFLP techniques.
   Gene mapping methods : Linkage maps, tetrad analysis, mapping with molecular markers, mapping by using somatic cell hybrids, development of mapping population in plants. Pedigree analysis, lod score for linkage testing. QTL mapping.

OB1. Concepts in Zoological Science (Dept. of Zoology)

1. Outline of animal classification

1.1 Linnaean Hierarchy and species concept
1.2 Phylogenetic reconstruction, characters and character states, cladistic and phenetic methods
1.3 Molecular taxonomy and evolutionary theories

2. Ecological principles and Biodiversity

2.1 Population and community ecology revisited: basis for conservation
2.2 Conceptual framework of biological diversity including threats and management options
2.3 Biodiversityindicators: Taxon based indicators, Surrogatespecies and global pattern of diversity endemism and megadiversity centers
2.3 Global pattern of biological diversity endemism and megadiversitycentres
2.4 Wild life resources of India: conservation framework and status of threatened taxa

3.Evolutionary Biology

3.1 Methods of studying natural selection and adaptation; Models of selection
3.2 Gene flow (Hardy Weinberg equilibrium), genetic drift and NeutralTheoryofEvolution
3.3 Molecular clock of evolution

4. Principlesof DevelopmentalBiology

4.1Determinationanddifferentiation;morphogeneticgradients;cellfateandcell lineages
4.2 Productionofgametes,prerequisitesoffertilization
4.3 Zygote formation, cleavage, blastula formation, embryonic fields,
4.4 Gastrulation and formation of germ layers in animals; embryogenesis

5.MetamorphosisandOrganogenesisinmodelanimalsystems

5.1 Axes, compartmentformationandpatternformationin*Drosophila*.
5.2 Vulvaformationin*Caenorhabditiselegan*
5.3 OrganizerformationandMesodermspecification in *Xenopus*
5.4 Development of heart and circulatory systems in vertebrate
5.5 Development and maturation of the immune system
5.6 Limb development and regeneration in vertebrates

6. Animal Physiology

6.1 Size and scaling of organisms
6.2 Physiological adjustments to extreme environmental conditions;
6.3 Thermal and sensory physiology; chemical communications

7. Animal Behaviour

6.5 Animalbehaviour study: proximate and ultimate causes
6.6 Sociobiology of social insects and vertebrates: theory and empirical studies
6.7 Optimal foraging theory and parent offspring conflict

OB2. Introduction to Marine Environment (Dept. of Marine Science)

Earth system & hydrosphere. Hydrological cycle. Global ocean basin and their dimension. Physical characteristics of the ocean & zonation of the marine environment.
Estuary classification and its characteristics
Physical properties of seawater and their distribution in the global ocean.
Current, waves and tides in the ocean.
Composition and stoichiometry of seawater. Major, minor and trace elements
Marine pollution and its impact on biota with special reference to Heavy metals.
Dissolved gases and carbonate system in the seawater.
Air-sea interactions.
Primary and secondary production in the ocean.
Distribution of life in the marine environment and classification of marine organisms. Phytoplankton, zooplankton, nekton and fisheries oceanography. Mangroves and its adjacent Biota .

OB3. Perspectives of Environmental Science (Dept. of Environmental Science)

1. **Understanding the environment**
   - 1.1. Multidisciplinary approach of environment
   - 1.2. Rise of environmentalism
   - 1.3. Environmental ethics
   - 1.4. Concepts of sustainability
2. **Environmental systems**
   - 2.1. Concept of atmosphere, lithosphere, hydrosphere and biosphere
   - 2.2. Natural Resources
   - 2.3. Carbon footprint and low carbon economy
   - 2.4. Biogeochemical cycles
   - 2.5. Scale of meteorology
3. **Ecology and Biodiversity**
   - 3.1. The order of the natural world
   - 3.2. Ecosystem energetics
   - 3.3. Population dynamics; Concept of community, niche and community development
   - 3.4. Biomes, biogeography and landscape ecology
   - 3.5. Behavioural ecology and sociobiology
   - 3.6. Biodiversity: extinction, conservation and restoration
4. **Disaster Management**
   - 4.1. Types of disasters
   - 4.2. Case studies of natural and anthropogenic disasters
   - 4.3. Disaster prediction, prevention
   - 4.4. Pre and post disaster management
5. **Environmental vulnerability**
   - 5.1. Air pollution: source, impacts and remedial measures
   - 5.2. Water pollution: source, impacts and remedial measures
   - 5.3. Soil pollution: source, impacts and remedial measures
   - 5.4. Waste: solid, biomedical, electronic and radioactive wastes
   - 5.5. Climate change mitigation and adaptation
6. **Environmental Health**
   - 6.1. Disease ecology with special reference to vector and water borne diseases
   - 6.2. Genotoxicity and epigenetic approach
   - 6.3. Occupational toxicology and health
   - 6.4. Xenobiotics and endocrine disruption
7. **Prioritizing environmental concerns**
   - 7.1. Global and National initiatives
   - 7.2. Recent Environmental Concerns and Debates
   - 7.3. Environmental Regulations: Acts and Laws
   - 7.4. Environmental Impact Assessment
   - 7.5. Ecomark and Ecolabelling
8. **Modern tools for addressing environmental challenges**
   - 8.1. Bio remediation
   - 8.2. Analytical tools for solving environmental problems
   - 8.3. Environmental applications of remote sensing and GIS
   - 8.4. Environmental informatics and modelling

OB4. Fundamentals of Plant Science (Dept. of Botany)

1. **Introduction to plant kingdom** ;Classification and Phylogeny of different plant groups (Algae, Bryophyta, Pteridophyta and higher plants).
2. **Plant Systematics**:Taxonomy and systematics; taxonomic hierarchy, categories and ranks, species concept; phenetic and phylogenetic classification systems, Angiosperm Phylogeny Group (APG); plant nomenclature; biosystematics: objectives, steps, categories.
3. **Phytogeography:** General principles; phytogeographic regions of world; phytogeographic regions of India; Vegetation of Eastern & Western Himalayas and Sunderban vegetation. Endemism; Indian endemic flora; exotics & aliens.
4. **Plant Ecology and Environment** :Components, population, community, biome; aquatic Ecosystem, wetlands classification with examples and their Characteristics; environmental laws and environmental education programmes : WWF, IUCN, MAB, Biosphere Reserve; environmental protocols; remote sensing technique and Geographical Information System (GIS).
5. **Palaeobotany & Palynology**:Preservation, Nomenclature, Dating and reconstruction of plant fossils; plant life through ages; application of plant fossil studies.Spore/pollen morphology; basic concepts of neo and palaeopalynology; application of palynomorph studies.
6. Plant pathogen interaction.
7. **Basic aspects of Plant Biotechnology**:Plant Tissue culture and its application. De-differentiation; Cyto-differentiation; Plant regeneration; Organogenesis; Embryogenesis; Micropropagation (introductory); Protoplast culture and application; Haploid culture; Triploid culture; Genetic transformation.
8. Phytoremediation:
   Definition; Concept of excluders and accumulators; Mechanisms of phytoremediation, limitations and concerns.
9. **GM Crops**: Basic principle, Types of transgenic events, Molecular characterisation of transgenic plants, Bio-safety analysis, Field application: Pros and Cons.

Suggested Readings:

1. Ecology: A Bridge between Science & Society. By EP Odum. Sinauer Associates, Inc. USA, 1997.
2. Asthana DK & Asthana M 2001. Environment: problems & solutions. S. Chand & Company Ltd., New Delhi.
3. Kormondy, EJ 2012. Concepts of Ecology. PHI Learning Pvt. Ltd., New Delhi.
4. Krishnamurthy, KV 2003. An Advanced text book on Biodiversity: Principles and Practice. Oxford &IBH Publishing Co. Pvt. Ltd., New Delhi.
5. Takhtajan AL 1986. The Floristic Regions of The World. University of California Press, Berkeley.
6. Good R 1964. The Geography of the Flowering Plants. John Wiley & Sons, Inc., New York.
7. Plant Tissue Culture: Theory and Practice: By SS Bhojwani and MK Razdan, Elsevier, 1996.
8. Plant Cell and Tissue Culture: By S Narayanaswamy, Tata McGraw-Hill Publishing Co Ltd, 1994.
9. Palaeobotany and the evolution of plants. 2nd Edition. Stewart WN and Rothwell GN. Cambridge University Press, 1993.
10. Handbook of Palynology. Erdtman G. Munksgaard, Copenhagen, 1969.
11. Phytoremediation, management of environmental contaminants. Eds. Ansari, Gill, Gill, Lanza. Newman.
12. Phytoremediation in India. By MNV Prasad.

Suggested Readings:

13. Ecology: A Bridge between Science & Society. By EP Odum. Sinauer Associates, Inc. USA, 1997.
14. Asthana DK &Asthana M 2001. Environment: problems & solutions. S. Chand & Company Ltd., New Delhi.
15. Kormondy, EJ 2012. Concepts of Ecology. PHI Learning Pvt. Ltd., New Delhi.
16. Krishnamurthy, KV 2003. An Advanced text book on Biodiversity: Principles and Practice. Oxford &IBH Publishing Co. Pvt. Ltd., New Delhi.
17. Takhtajan AL 1986. The Floristic Regions of The World. University of California Press, Berkeley.
18. Good R 1964. The Geography of the Flowering Plants. John Wiley & Sons, Inc., New York.
19. Plant Tissue Culture: Theory and Practice: By SS Bhojwani and MK Razdan, Elsevier, 1996.
20. Plant Cell and Tissue Culture: By S Narayanaswamy, Tata McGraw-Hill Publishing Co Ltd, 1994.
21. Palaeobotany and the evolution of plants. 2nd Edition. Stewart WN and Rothwell GN. Cambridge University Press, 1993.
22. Handbook of Palynology. Erdtman G. Munksgaard, Copenhagen, 1969.
23. Phytoremediation, management of environmental contaminants. Eds. Ansari, Gill, Gill, Lanza. Newman.
24. Phytoremediation in India. By MNV Prasad.

OB5. Fundamentals of Bacteriology (Dept. of Microbiology)

1) The discovery of microorganisms, the conflict over spontaneous generation, Koch's postulates, an overview of prokaryotic cell structure, cell wall, cell membrane, nucleoid, plasmids, endospore, comparison of prokaryotic and eukaryotic cells. **(15 lectures)**
2) Microbial nutrition, growth and control: Common nutrient requirements, nutritional types of organisms, culture media, isolation of pure culture, continuous cultures of microorganism; control of microorganism by physical and chemical agents, basics of water bacteriology, influence of environmental factors on microbial growth in natural environments. **(15 lectures)**
3) Identification of microbe and microbial community, comparison of ribosomal RNA sequences – Pairwise alignment: local and global alignment, Multiple sequence alignment, construction of phylogenetic tree. **(15 lectures)**