Detailed M.Sc. Syllabus
In Botany
University of Calcutta
2022

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:

Semester	Duration
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 80 (eighty), 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.

4. Semester wise distribution of courses:

Semester	Type of 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 CBCC	2 1 2	130 20 100	20
4th Semester	Core Courses Optional Course Dissertation Social Outreach Program	3 1 1 1	160 20 40 10	20
Total			**1000**	**80**

5. 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)

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

Marks	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	****

7. Award of Grades:

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

8. 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 Score
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.

9. 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)
4.50-4.99	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	Fail (F)	Fail

10. 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.

11. 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.

12. 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.

13. 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.

14. 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.

15. 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.

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

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

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

19. 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			
		Marks (Theory+Practical)	Credits
Bot C 11	Phycology	40+25	5
Bot C 12	Archegoniatae	40+25	5
Bot C 13	Mycology	40+25	5
Bot C 14	Cell Biology	40+25	5
	Total	**160+100=260**	**20**
2nd Semester			
		Marks (Theory+Practical)	Credits
Bot C 21	Phytochemistry and Pharmacognosy	40+25	5
Bot C 22	Palaeobotany and Palynology	40+25	5
Bot C 23	Plant Systematics and Biodiversity	40+25	5
Bot C 24	Genetics and Genomics	40+25	5
	Total	**160+100=260**	**20**
3rd Semester			
		Marks (Theory+Practical)	Credits
Bot C 31	Microbiology	40+25	5
Bot C 32	Plant Physiology and Biochemistry	40+25	5
Bot OP-1	Optional Paper 1	20	2
O A	Choice based credit course (CBCS 1)	50	4
O B	Choice based credit course (CBCS 2)	50	4
	Total	**200+50=250**	**20**
4th Semester			
		Marks (Theory+Practical)	Credits
Bot C 41	Plant Biotechnology	40+25	5
Bot C 42	Plant Disease Biology	40+25	5
Bot S 43	Anatomy and Ecology	30	2
Bot OP-2	Optional Paper 2	20	2
BOT D	Dissertation	40	5
BOT OT	Social Outreach Programme	10	1
	Total	**180+50=230**	**20**
	Grand Total	**1000**	**80**

Optional Papers (any 1 of the following)

1	Bot OP-1-A	Applied Virology
2	Bot OP-1-B	Applied Mycology
3	Bot OP-1-C	Molecular Stress Biology
4	Bot OP-1-D	Molecular Plant Physiology
5	Bot OP-1-E	Genetics of Plant Development
6	Bot OP-1-F	Bioinformatics
7	Bot OP-1-G	Advanced Phytochemistry and Pharmacognosy
8	Bot OP-1-H	Advanced Palaeobotany and Palynology

Optional Papers (any 1 of the following)

1	Bot OP-2-A	Microbial Biotechnology
2	Bot OP-2-B	Applied Phycology
3	Bot OP-2-C	Plant Molecular genetics and Evolution
4	Bot OP-2-D	Organic Crop Production Technology
5	Bot OP-2-E	Immunology
6	Bot OP-2-F	Plant Molecular Biology
7	Bot OP-2-G	Analytical Techniques
8	Bot OP-2-H	Taxonomy and Biosystematics

C – Core course; OP – Optional course; S – Supportive course; D- Dissertation; OT- Outreach Prog

1st semester

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

Section – A

Classification, Phylogeny and Evolution: Algal classification: Classical system and modern polyphasic approach; Biome classification and algal phylogeny (Whittaker 5 kingdom classification,1962). Symbiosis theory of evolution: Primary, Secondary and tertiary endosymbiosis; Horizontal gene transfer and evolution of algal chloroplast; Evidences of endosymbiotic events and prokaryotic ancestry of plastids

Section – B

General overview of major algal divisions: Cyanoacteria – Protoplasmic structure, cellwall, Heterocyst-ultrastructure and biochemistry, 'nif' gene regulation. Glaucophyta- Diagnostic characters, Phylogenetic significance. Rhodophyta- Cellular ultrastructure; Rhodoplast, pit connection; calcification, iridescence, defense mechanisms, Mucilage from Red algae.Dinophyta – Cell structure; Heterotrophic nutrition,Redtide, Toxins. Chlorophyta- Cell division pattern, Ultrastructure of flagella, Classification and phylogeny.Bacillariophyta- Cell divisions ,Frustule development and ultrastructure: role of SDV and Frustulene protein; motility

Section – C

Algal Ecology: Biodiversity and conservation of Algae: Algae of different habitat, importance of conservation, *in-situ* and *ex-situ* conservation. Algal bloom formation and its control.Wet land ecology: Algal assemblages in wetlands;Role of Algae in wetlands; Conceptual models of Wetlands. Phytoplankton ecology: types of phytoplankton; Community pattern analysis: Species diversity, Species richness, Species evenness. Phytoplankton dynamics: Physical factors (light, heat), Chemical environment (carbon, nitrogen, phosphorus); Red field ratio; Phytoplankton nutrient uptake model (Monod's model and Droop's Cell quota model). Seaweed productivity of Indian coast

Section – D

Algal biotechnology: Algae in human welfare – Nutraceuticals, Pharmaceuticals; Biofertilizers; Biofuels; CO_2 Sequestration (CCM in Algae); Pollution control. Metabolic engineering of algae: Biohydrogen production and carotenoids synthesis; *Chlamydomonasreinhardtii* as model organism; Evolutionary engineering, GM Algae.Mass production of algae: Culture techniques ,photobioreactor and open raceway pond, Downstream processing, Mariculture techniques of seaweeds.

Practicals (25 marks; 2.5 credits, 40 Lecture hours)

1. Algal Diversity study: (Freshwater) Cyanobacteria, Chlorophyta, Euglenophyta, Bacillariophyta
2. Identification of seaweeds from different divisions- Chlorophyta, Phaeophyta, Rhodophyta
3. GeneralPrinciplesofculturingalgaeinlaboratoryandgrowthcurvedetermination
4. Demonstration of mass cultivation in pho to bioreactor
5. Collection of local flora and submission as voucher specimens (atleast10vouchers)

SUGGESTEDREADINGS:

1. Phycology (4thEd.) R.L. Lee, CambridgeUniversityPress,2008.
2. Algae-An introduction to Phycology- CVandenHoek, DG Mann, HMJanes, Cambridge UniversityPress,1995.
3. Hand Book of Microalgal culture.Ed by A.Richmond. Blackwell Publishing House,2003
4. Algae-Anatomy,Biochemistry and biotechnology-.Barsanti&P.Gualtieri.Taylor&Francis,2006.
5. Molecular Biology of Cyanobacteria-DABryant.KluwerAcademicPublisher,1995.
6. Photosynthesis in Algae-W.D.Larkman,E.Douglass &JARaven,KluwerAcademicPublishers.
7. AlgalEcology- Fresh Water Benthic Ecosystems. Ed by R. J Stevenson, MLBothwell, R.L. Lowe,Academic Press,1996.
8. Ecology of Cyanobateria-Their diversity in time and space- B AWhittan, MPotts. KluwerAcademicPublishers.
9. Origin of algae and their plastids. Ed. D Bhattacharya, Springer Wien, NewYork
10. The Biology of Blue Green Algae-NCCarr & B A Whitton, Berkley: University of CaliforniaPress,1973
11. An Introduction to Phytoplanktond :Diversityand Ecology. R.Pal and A.Choudhury,Springer

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

Group-A: General overview, Phylogeny and Evolution

1. Concept of Archegoniatae**;** Evolutionary implications in Land Plants; Phylogeny and Evolution (Bryophytes, Pteridophytes and Gymnosperms).
2. Comparative morphology: Leaf, root, axillary branching; stelar evolution; transition from 2D to 3D apical growth.
3. Life Strategies: Evolution of sexual growth and breeding systems.

Group-B: Bryophyte

1. Classification as proposed by Crandall-Stotler et al. (2009) & Goffinet et al. (2008).
2. Cytogenetics: Polyploidy, sex chromosomes; Metabolic chemistry.

3. Bryophyte ecology and ecosystem dynamics; Physiological ecology; Biochemical and molecular mechanism of desiccation tolerance in bryophytes; as a bio-indicator; Succession dynamicity.

Group-C: Pteridophyte

1. Classification of Extant ferns (Smith et al. 2006).
2. Diversity and distribution of Pteridophytes; Insect-Fern interaction.
3. Cytogenetics: Sexuality; Polyploidy, apogamy, apospory, apomixis and hybridisation; genetic variability in fern population; Biochemistry and molecular biology of spore germination.

Group-D: Gymnosperm

1. Recent classification as proposed by Kramer & Green (1990), Bhatnagar & Moitra (1996).
2. Chemosystematics; Pollination mechanism, Embryogeny, Karyology, Conservation.
3. Forest biotechnology; Gymnosperm as food supplements, ornamentals, pharmaceutics, toxic principles; Biotic interaction with algae, fungi & insects.

PRACTICAL:

Bryophytes

1. Workout on structural modifications in Marchantiales, Jungermanniales, Anthocerotales, Isobryales, Hypnobryales, Funariales & Dicranales (*depending on availability of the specimen*).
2. Workout on different types of peristome structure for classification of mosses.

Pteridophytes

1. Study on the morphology of vegetative and reproductive structures in (*depending on availability of the specimen*).
   Gleicheniales, Schizaeales, Salviniales, Cyatheales, Polypodiales
2. External morphological features from the following-
   Isoetales, Psilotales, Ophioglossales, Marattiales, Schizaeales, Polypodiales

Gymnosperms

1. Study on external morphology of the genera from the following orders:
   Cycadales, Ginkgoales, Coniferales, Taxales, Gnetales
2. Study of general habit, external morphology and anatomy of leaf, stem and reproductive structures, pollen grains, wood anatomy of the following:
   Cycadales, Ginkgoales, Coniferales, Taxales, Gnetales

Suggested Readings (*Bryophyte*)

1. Vanderpoorten, A. & Goffinet, B. (2009). *Introduction to Bryophytes*. Cambridge University Press, United Kingdom.
2. Shaw, A. J. & Goffinet, B. (Eds.). (2000). *Bryophyte Biology*. Cambridge University Press,United Kingdom.
3. Smith, A. (Ed.). (2012). *Bryophyte ecology*. Springer Science & Business Media, Berlin, Germany.
4. Glime, J. M. (2007). *Bryophyte Ecology. Volume 1. Physiological Ecology*. Ebook sponsored by Michigan Technological University and the International Association of Bryologists. re. bryoecol. mtu. edu/. Acessoem, 20, Houghton, Michigan.
5. Bates, J. W. & Farmer, A. M. (1992). *Bryophytes and lichens in a changing environment.* Clarendon Press, Oxford, London.
6. Gangulee, H. C. (1985). *Handbook of Indian Mosses*. New Delhi, Bombay, Kolkata, New York: Amerind Pubs. Co. Pvt. Ltd
7. Chopra, R. N. (2005). *Biology of Bryophytes*, eds R.N. Chopra and P.K. Kumra, New Age International, New Delhi, India.

Suggested Readings (*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. San Francisco.
3. Kubitzki K. (1976). *The families and Genera of Vascular plants: Vol. I Pteridophytes.* Vikas Publishing House, Noida, Uttar Pradesh, India.
4. Rashid A. (1976). *An Introduction to Pteridophytes*. Vikas Publishing House. Noida, Uttar Pradesh, India.
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 Research, Lucknow, India.
7. Louis J.D. (1977). *Evolutionary patterns and processes in ferns:* Advances in Botanical Research.Scott. Studies in Fossil Botany. Haffner publications.,Clawson, Michigan.
8. Smith, G.M. (1976). *Cryptogamic Botany Vol. II.* Tata McGraw Hill, Publishing Co. Ltd. New Delhi, India.
9. Stewart W.N. & Rothwell G.W. (2005). *Paleobotany and the Evolution of Plants*, (2nd Edn.) Cambridge University Press, United Kingdom.
10. Sharma O.P. (2006). *Text book of Pteridophyta*. Macmillan India Ltd., New Delhi, India.
11. Ranker T.A. & Haufler C.H. (2008). *Biology and Evolution of Ferns and Lycophytes.* Cambridge University Press, United Kingdom.
12. Eames E.J. (1983). *Morphology of vascular Plants.* Standard University Press.

Suggested Readings (*Gymnosperm*)

1. The morphology of Gymnosperms. K.R. Sporne
2. Morphology of Gymnosperms. John M. Coulter and Charles J. Chamberlain. 1917. University Chicago Press, Chicago.
3. Gymnosperms. S.P. Bhatnagar and Alok Moitra, 1996. New Age International Limited.
4. The Gymnosperms. C. Biswas and B. M. Johri
5. Morphology and Evolution of Vascular Plants. Ernest M. Gifford, Adriance S. Foster (1989) W.H. Freeman & Co., New York
6. The families and Genera of Vascular Plants. K.U. Kramer, P.S. Green (Edited by Kubizki)

7. Diversity of Seed Plants and their Systematics. Dr. Nupur Bhowmik
8. Moonlight pollination in the gymnosperm Ephedra (Gnetales). Biology Letters. 11: 20140993.http://dx.doi.org/10.1098/rsbl.2014.0993. Catarina Rydin and Kristina Bolinder.
9. Mycorrhizal Fungal–Plant–Insect Interactions: The Importance of a Community Approach. Environmental Entomology. 38(1): 93Ð102 (2009). Catherine Gehring and Alison Bennett.
10. GREEN PLANTS: Their origin and Diversity - by Peter R. Bell & Alan R. Hemsley (2000) Cambridge University Press.
11. AN INTRODUCTION TO GYMNOSPERMS, CYCAS AND CYCADALES - by Divya Darshan Pant (2002) Birbal Sahni Institute of Palaeobotany, Lucknow, India.
12. GYMNOSPERMS: STRUCTURE AND EVOLUTION - by C. J. Chamberlain (1935), Chicago Univ. Press, Chicago.
13. STUDIES IN GYMNOSPERMOUS PLANTS. CYCAS - by D. D. Pant & B. Mehera (1962), Central Book Depot, Allahabad.
14. LIVING INDIAN GYMNOSPERMS. Pt. I (Cycadales, Ginkgoales and Coniferales) - by M.B. Raizada and K.C. Sahni (1960) Ind. For. Rec. (N.S.) Bot. 5: 73-150.

Bot C13: Mycology Theory (40 marks; 2.5 credits, 40 Lecture hours)

Group-A

Fungal systematics and physiology: Classification of fungi (after Ainsworth 1973); Fungal DNA Barcoding – a tool for molecular identification; Evolution of fungi within the groups; Physiology of spore dormancy, activation and germination; Nutrient sensing (Glucose & other nutrients) and uptake; Growth of Fungi; Environmental factors influencing growth and sporulation.

Group-B

Fungal Biochemistry: Chitin, Trehalose and glycogen synthesis in fungi; Physiological Significance of Glycogen Storage; Central metabolic pathway in yeast; Fungal secondary metabolites (Polyketides, Terpenes, Indole alkaloids, Non-ribosomal peptides); Heat shock protein in filamentous fungi.

Group-C

Fungal cytology and genetics: Signal transduction pathways during hyphal morphogenesis and growth; Mitotic cell cycle control in filamentous fungi, modulation of nuclear transport during cell cycle; Genetics of asexual sporulation; Mating-Type switching in Yeasts; Sex hormones in fungi; Non-sexual variations; Retroposon and retrotransposon in fungi; Extra-chromosomal inheritance in fungi; Transformation and gene manipulation in filamentous fungi.

Group-D

Applied mycology: Food and beverages from fungi (fungi to enhance food value, food coloring, wine, beer and spirit, functional food and nutraceuticals); Mushrooms: a resource for new generation medicines; Mycoses (Types, diagnosis and treatments); Mycoremediation and mycofumigation; Commodities from fungi (cosmetics, preservatives, textile dye and organic acids); Myconanotechnology.

Practical (25 marks; 2.5 credits, 40 Lecture hours)

1. Introduction to basic Mycological Techniques and Laboratory Safety; Methods of sterilization,media preparation and culturing.
2. Isolation and identification of phosphate solubilizing fungi.
3. Isolation and identification of arbuscularmycorrhizalfungi.
4. Morphological and reproductive structure of some macro- and micro-fungi.
5. Hyphal types from poroid fungi.
6. Fungal tissue- culture; Preparation of spawn and cultivation of *Pleurotus*.
7. Citric acid and ethanol production.
8. Nuclear staining in fungi.
9. Identification of specimens from field trip.

Suggested Reading

1. Cellular and Molecular Biology of Filamentous Fungi. Katherine A. Borkovich and Daniel J. Ebbole.
2. Modern Mycology. J. W. Deacon
3. Introduction to Fungi. John Webster and Roland W. S. Weber
4. Introduction to Mycology. C. J. Alexopoulos, C. W. Mims and M. Blackwell.
5. Fungi Nutrition & Physiology. Michael O. Garraway and Robert C. Evans.
6. Physiology of Fungi. Lilian E. Hawker
7. The Mycota; Vol: VII: Systematics and Evolution (Part A). K. Esser and P. A. Lemke.
8. The Mycota; Vol: III: Biochemistry and Molecular Biology. K. Esser and P. A. Lemke.

Bot C 14: Cell Biology Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section-A

Microscopy and different techniques: Microscopy-Principles of Light microscopy; Phase contrast microscopy; Fluorescence microscopy, Confocal microscopy; Electron microscopy (EM)- Scanning Electron Microscopy (SEM); Transmission Electron Microscopy (TEM) and Scanning Transmission Electron Microscopy (STEM); Immunosorbant Electron Microscopy; FRET microscopy. Different fixation and staining techniques for EM, image processing methods

in microscopy. Separation: -Different process of Sub-cellular fractionation and visualization. Differential and density gradient centrifugation, Magnetic separation.

Protein Sorting and Vesicular Transport: Chaperon and protein folding, protein cleavage,glycosylation, attachment of lipids. Endocytosis &Phagocytosis.Components of the Endomembrane System, RER - Protein Synthesis & Targeting; Glycosylation & Quality Control.Golgi - Glycosylation & COP-Mediated Vesicular Transport; TGN Sorting, Lysosomes & Receptor-Mediated Endocytosis. Posttranslational uptake of proteins by Peroxisomes, Mitochondria and Chloroplasts.

Section-B

Cell and cell organelles: Cell wall- building blocks, architecture, macromolecules involved, biosynthesis and assembly Plasma membrane-structure (physical structure of the bilayer,components) and function, pumps, channels and transporters. Chloroplast, mitochondria, golgi bodies (structures only). Cytoskeleton- different types (actin, intermediate filaments, microtubules),structures, components and assembly, associated proteins, motors- structures and function. Nucleus -chromosome territories, topological associated domains, lamina associated domains, structural and functionalorganization of chromatin,histonemodification,eu and hetero chromatin, X chromosome inactivation, Centromere and telomere structure, nucleolus,
Nuclear transport

Section-C

Cell cycle, cell death and communication: Cell cycle- different phases,regulation and checkpoints to control cell division and exit, Cell death-brief idea about apoptosis, autophagy and necrosis, role of relevant proteins. Cell-cell interaction- different types of junctions (tight junction, adhesion junction and gap junctions), structure and function ;junctional proteins-types, structure and role in junction. Cell signalling- type of receptors, different signaling molecules, transduction pathways and examples (only GPCR and Ca mediated pathway)

Section-D

DNA replication, repair and recombination: Basic concepts of prokaryotic and eukaryotic replication, unit of replication, important enzymes involved, replication origin, replication fork, fidelity of replication, extrachromosomal replicons, DNA damage & repair pathways, homologus and site specific recombination.

RNA synthesis & processing:Basic concept of transcription in prokaryotes & eukaryotes, RNA polymerase, transcription factors and machinery, formation ofinitiation complex, transcription activator and repressor, eukaryotic m RNA processing (5' capping & 3' polyadenylation); Post transcriptional processing (splicing, RNA Editing, RNA transport and regulation, RNA stability).

Protein synthesis and processing: Basic concept of prokaryotic and eukaryotic translation, ormation of initiation complex, initiation factors and their regulation, elongation and elongation factors, termination, RNA surveillance pathways, Translation inhibitors, Post translational

modification (N-acetylation, lipidation, N-myristoylation, S-palmitoylation, S- prenylation, glycosylation, nitrosylation, methylation, protyelysis)

Control of gene expression at transcription and translation level: Role of chromatin in gene expression and gene silencing.

Practical (25 marks; 2.5 credits, 40 Lecture hours)

1. Isolation of plant genomic DNA, purity estimation by UV spectroscopy, and visualization by agarose gel electrophoresis.
2. Determination of antigen concentration by sandwich ELISA method.
3. Staining of mitochondria by Janus Green B
4. Estimation of lipid peroxidation
5. Estimation of protein by Lowry method and standard curve preparation.
6. Isolation of protein from plant samples and electrophoresis by SDS-PAGE.

Suggested Books:

1) The World of the Cell- Becker WM et al., - Benjamin Cummings
2) Cells- Benjamin Lewin, Lynne Cassimeris, Vishwanath R. Lingappa, George PiopperJonesand 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. BianchiPublished by John Wiley & Sons 3rdedition
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

2nd semester

Bot C21: Phytochemistry and Pharmacognosy Theory (40 marks; 2.5 credits, 40 Lecture hours)

Group-A

Introduction to Phytochemistry Pharmacognosy and Biomedicine: Introduction: Phytochemistry, Pharmacognosy and biomedical applications. Drug: Definition, Physicochemical properties of drugs – Solubility, Hydro lipophilicity, Hydrogen bonds, Surface binding, Polar surface area; Drug likeness – definition, Lipinski's rule of five, Pfizer's 3/75 rule, ADMET (Absorption, Distribution, Metabolism, Excretion and Toxicity). Drug Discovery Cycle**:** Basics of drug discovery phase and drug development phase (preclinical research, clinical research, FDA review and FDA Post-Market Safety Monitoring). Naturally derived drugs: Drug Discovery from Natural Resources: Advantages and Disadvantages; Toxicity and Regulations: Herbals vs Conventional drugs; Toxicity studies as per OECD guidelines; Druggability of Isolated Phytochemical Compounds; Plant-derived medicines (Vincristine and Vinblastine, Taxol, Camptothecin, Podophyllotoxin)

Group-B

Origin of Secondary Metabolites, Biosynthetic Pathways & Phytochemical Analysis: Biosynthetic Pathways for the origin secondary metabolites: Acetate pathway (fatty acids and polyketides), Mevalonate and Deoxy-xylulose phosphate pathway (terpenoids and steroids), Shikimate pathway (phenols, amino acids, lignans, lignins etc.): a brief account. Secondary metabolism; role of compartmentation and metabolite trafficking.General methods of extraction (maceration, percolation, SCF extraction, distillation, hydro distillation, soxhlet, aqueous alcoholic extraction, counter current extraction, sonication, phytonic process etc.) separation, isolation, purification and characterisation of bioactive compounds from plant extracts using different chromatographic techniques (basic principles and applications of planer and column chromatography, PC, TLC, HPTLC, HPLC, GC, GLC, LC).Quality control of plant drugs: Classical and modern approaches, chemoprofiling.Chemical races- a general introduction.Phytochemicals as anti-nutrients

Group-C

Phytochemical Structure and Functions: Functional foods and neutraceuticals, Classification of Nutraceuticals, Source, name of marker compounds and their chemical nature, medicinal uses and health benefits of following used as Neutraceuticals / Functional foods. Phytochemicals as Neutraceuticals: Occurrence and Characteristic features (Chemical nature, uses in pharmacy, medicinal, health benefits etc.) of the following:-

Carbohydrates: Polyols, starch, cellulose derivatives, gums and mucilage's

Glycosides: nomenclature, classification, biosynthesis

Alkaloids: definition, properties, classification, alkaloidal drugs: tropane alkaloids (Hyoscyamine and atropine, scopolamine, cocaine) quinoline (Cinchona alkaloids) and

isoquinoline alkaloids (Berberine), terpenoidindole alkaloids (Ergot alkaloids, Cathranthus alkaloids, strychnine and brucine), Purine alkaloids (Tea, coffee), benzylisoquinoline alkaloids (Opium alkaloids), steroidal alkaloids (Holarrhena alkaloids), indole alkaloids (Physostigmine)

Phenolic compounds: Classification, biological activities and drugs – Senna, Aloe, Hypericum, Capsicum

Steroidal compounds: Different types, biological activity, general pharmaceutical importance

Vitamins: general account

Carotenoids: chemistry, types, uses, apocarotenoids

Resins: chemistry, different types, biological activities

Lipids: Essential and non-essential fatty acids, nomenclature, fats – saturated, unsaturated and trans-fats, fixed oils and waxes

Volatile oils: composition, drugs – Clove, Mentha, Eucalyptus, Foeniculum, Cinnamomum, Citronella

Group-D

Bioprospecting: Definition, Role in drug discovery, Biopiracy, Ethnobotanical approach for plant screening. Biological activity guided fractionation for compound isolation with special emphasis to Cancer and Diabetes. Brief idea about compound identification through spectroscopic techniques (UV, IR, MS, ESIMS, ^{1}H NMR and ^{13}C NMR).

Patents: Indian and international patent laws, proposed amendments as applicable to herbal/natural products and process; Geographical indication, Copyright, Patentable subject maters, novelty, non-obviousness, utility, enablement and best mode.

Guidelines: Pharmacovigilance of Drugs of Natural Origin; WHO and AYUSH guidelines for safety monitoring of natural medicine, Spontaneous reporting schemes for bio-drug adverse reactions; Bio drug-drug and bio drug-food interactions with suitable examples

Practicals: (25 marks; 2.5 credits, 40 Lecture hours)

1. Preparation of extracts of organised crude drugs / herbs by successive solvent extraction method for subjecting them to phytochemical screening
2. Detection of phytoconstituents such as alkaloids, phenols, tannins, flavonoids, anthraquinones, cardenolides, different pigments (anthocyanins, betacyanins and carotenoids), steroidsand others
3. Microscopic study of starch grains from different plant sources
4. Chemical tests for unorganised drugs: starches,gums, resins etc.
5. Extraction of bioactive compounds from plant drugs
6. Detection of different classes of phytoconstituents using chromatographic techniques**.**
7. TLC profiling of crude extract
8. Extraction and isolation of caffeine from tea leaves

SUGGESTED READINGS:

1. Paul M. Dewick, 2009. 3rd Edition, Medicinal Natural Products: A biosynthetic Approach, John Wiley & Sons Ltd.
2. Bruneton J., 1999. Pharmacognosy, Phytochemistry, Medicinal Plants, Intercept Ltd., Paris
3. Evans W.C., 2009, 16th Edition, Trease and Evans. Pharmacognosy, W.B. Saunders
4. Textbook of Pharmacognosy and Phytochemistry. Biren Shah & A.K. Seth.ELSEVIER, 2010
5. Cereal Grain-based Functional Foods Carbohydrate and Phytochemical Components. Edited by Trust Betaand Mary Ellen Camire. Royal Society of Chemistry, 2018.
6. Textbook of Pharmacognosy. Dr. Mohammed Ali. CBS PUBLISHERS & DISTRIBUTORS. Reprint 2005.
7. Phenolic compound Biochemistry. Wilfred Vermerris& Ralph Nicholson. 2006. Springer.
8. Harbourne, J.B., 1998. Phytochemical Methods, Chapman and Hall.
9. Kolkate C.K., 1991. Practical Pharmacognosy, VallabhPrakashan, Delhi
10. Samuelsson G., 1999. Drugs of natural origin: A textbook of Pharmacognosy, Apotekarsocieteten, Swedish Pharmaceutical Society, Swedish Pharmaceutical Press, Stockholm, Sweden.
11. Tyler V. E., L. R. Brady and J. E. Robbers, 1988. Pharmacognocy, Indian Edition, K.M. Varghese
12. Vickery M.L. and B. Vickery, 1981. Secondary Plant Metabolism, The MacMillan Press Ltd.
13. Wallis T. 1967. Textbook of Pharmacognosy, J & A Churchill, London.
14. Wagner H., S. Bladt and E.M. Zgainiski (Translated by A.Scott) 1984, Plant Drug Analysis. Springer-Verlag
15. Molecular Biology and Biotechnology: A Comprehensive Desk Reference Ed. Robert A. Meyers. 1995
16. CHROMATOGRAPHY AND ITS APPLICATIONS. Edited by SasikumarDhanarasu. Published by InTech, 2012
17. Principles and Practice of Chromatography. Chrom-Ed Book Series. Raymond P. W. Scott
18. Phytochemistry- Pharmacognosy, Nanomedicine and Contemporary issues. Edited by ChukwuebukaEgbuna, Shashank Kumar, Jonathan ChinenyeIfemeje, JayaVikasKurhekar. Apple Academic Press.

Bot C22: Palaeobotany and Palynology Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section-A

Brief knowledge of earth system: Types of rocks with special reference to sedimentary rocks; taphonomy;geo-chronology: dating the pages of earth's history; principles of Uniformitarianism and Superposition; stratigraphy and its branches with special reference to

biostratigraphy; brief concepts of continental drift and plate tectonics; evolutionary theories and plant fossil records

Section-B

Origin and evolution of early life forms and terrestrialization of plants: The prebiotic environments; origin of life: theory and biology; earlier records of life on earth; geological records and ecological significance of algae (blue-green algae, diatoms and dinoflagellates), fungi (endomycorrhiza and epiphyllous fungi), bryophytes and early ferns; Environmental adaptations for terrestrialization; evolution of land plants: evidences, earliest trees in fossil records

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; Origin and evolution of angiosperms: fossil evidences; nature and distribution of earliest angiosperms; reasons for late arrival; phylogeny of angiosperms; Morphology and diversity of pre-pollen/pollen/non-pollen palynomorphs(eg. phytoliths)

Section-D

Applied palaeobotany and palynology: Fundamentals of palaeofloristics, palaeogeography, palaeoecology and palaeoclimatology; ancient DNA and other fossil biomolecules, stable isotopes, tree rings and their application in evolutionary and palaeoclimate research; fossil fuels: origin, depositional environment; role of palynomorphs(pollen and non-pollen) in fossil fuel exploration, palaeovegetation and palaeoclimate reconstructions(with special reference to Bengal Basin peat and lower Gondwana coal).

Practical(25 marks; 2.5 credits, 40 Lecture hours)

1. Types of rocks, study of fossil types and modes of preservations
2. Techniques for studying plant fossils: thin section method (demonstration and study of prepared slides); peel technique method (demonstration and study of prepared peel sections); preparation of leaf cuticles (demonstration) for study of micromorphological parameters and epiphyllous fungi
3. Systematic study of fossil plants through ages
4. Acetolysis method (demonstration); study of morphology of modern spores and pollen grains; pollen analysis of honey
5. Study of macerated samples of peat, lignite and coal. Qualitative and quantitative (using tally mark) study of spores/pollen grains and preparation of histograms and pollen

diagrams, inference on floristic composition, environment of deposition and stratigraphic age of sediments

Suggested Readings;

1. Bhattacharyya, K., Majumdar, M.R., Bhattacharyya, S.G. 2011. A textbook of Palynology. New central Book Agency (P) Ltd. p.352
2. Brasier, M.D. 2013. Microfossils. George Allen and Unwin, London. 2nd Edition. p.193
3. Cleal, C. J., Thomas, B.A. 1999. Plant Fossils. The History of Land vegetation. Woodbridge Boydell Press, Woodbridge, VA. p.128
4. Kumar R. 2011. Fundamentals of Historical Geology and Stratigraphy of India. New Age International Publishers. P.254
5. Jones, T.P., Rowe, N.P. 1999. Fossil Plants and Spores: modern techniques. The Geological Society, London. p. 396
6. Moore, P.D., Webb, J.A., Collinson, M.E. 1991. Pollen Analysis. 2nd Edition. Oxford (Blackwell Scientific Publications). p.216
7. Surange, K.R., Lakhanpal, R.N., Bharadwaj, D.C. 1974. Aspects and Appraisal of Indian Palaeobotany. BirbalSahni Institute of Palaeobotany, Lucknow. p.674
8. Taylor, T.N., Taylor, E.L., Krings, M. 2009. Palaeobotany-The Biology and Evolution of Fossils Plants. Elsevier. p. 1230
9. Willis, K. J., McElwain, J.C. 2002. The Evolution of Plants. Oxford University Press, New York. p. 378
10. Cleal, C.J. Thomas, B.A. 2019. Introduction to plant fossils
11. Krings, Michael et al.,2018.Transformative palaeobotany

Bot C23: Plant Systematics and Biodiversity Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section-A

Classification, cladistics and angiosperm diversity: Components of major systems of classification: Cronquist (1981), Takhtajan's System (2009), Thorne (2007); Basis of APG Classification, APG IV (2016), emphasis on major clades; Concepts of palaeoherbs and eu-dicots (tricolpates). Cladistics: Components methodology and implications; Angiosperm diversity: General characteristics, phylogeny and evolutionary trends in Magnollidae, Asteridae, Alismatidae, and Liliidae (sensuCronquist, 1981).

Section-B

International Code of (Botanical) Nomenclature (ICN): Principles, latest changes, typification: methods with emphasis on lectotypification, neotypification and epitypification;

priority of names; effective and valid publications: new provisions; Names of new taxa (species); new combinations; names at new rank; replacement of names, rejection of names; Proposed BioCode and PhyloCode.

Section-C

Tools of Taxonomy, Species and Biosystematics: Data sources in Taxonomy: Embryology, Anatomy and ultrastructure; Molecular taxonomy–DNA barcoding; Tools of Taxonomy: Application of GIS and GNSS (Remote Sensing) in Botany. Species concept; Biosystematics: Objectives, steps, categories, relevance with classical taxonomy; Numerical Taxonomy: Principles and applications

Section-D

Biodiversity, Conservation and ITK: Concept, levels, components, importance of biodiversity, hotspots and hottest hotspots, megadiversitycenters of world, loss of biodiversity; IUCN threat categories: methods of assessment; strategies of in situ and ex situ conservation; CITES and TRAFFIC; Red Data Book; Ethnobotany and Traditional Knowledge: Concept, history, importance of ethnobotany, and development of Ethnobotany in India.

Practicals: (25 marks; 2.5 credits, 40 Lecture hours)

1. Workout of plant specimens and description of vegetative and reproductive characters from representative families.
2. Training in identification of specimens described in classes using relevant literature and herbaria.
3. Study of various taxa of a genus, determining key characters and preparation of keys at species and genus level.
4. Basic techniques of molecular systematics including DNA extraction, amplification, gel electrophoresis. Exercise on analyzing molecular sequence data using various computer software.
5. 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 20 herbarium specimens of common plants.
6. Ecological sampling of an area by using quadrat method and data analysis.
7. Determination of minimum size of a quadrat by species-area curve method.

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 C24: Genetics and GenomicsTheory (40 marks; 2.5 credits, 40 Lecture hours)

Section A

BASIC CONCEPTS IN GENETICS AND GENETIC ANALYSES: Discoveries in Classical and Molecular Genetics; Structural and functional elements of chromosomes; Allelic types and interactions; Gene-environment interactions; Penetrance and Expressivity; Genome Imprinting; Phenocopy; Pleiotropy; Continuous and Discontinuous Variations; Genetics of Sex determination; Extra-chromosomal inheritance; Overview of Genetic Analysis, complementation test for alleles, Epistasis analysis, genetic analysis of pathways; mapping using somatic cell hybrids, development of mapping population in plants; Pedigree analysis, LOD score for linkage testing, karyotypes, genetic disorders.

Section B

QUANTITATIVE AND EVOLUTIONARY GENETICS: Statistical Analysis of polygenic inheritance; measurement of heritability and partitioning of variance; quantitative inheritance in plants; Population Genetics: concepts and rate of change in gene frequency through natural selection; genetic equilibrium; 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; DNA typing of plants; Inbreeding and genetic consequences of self-pollination in plants; Evolutionary Genetics: evolutionary forces that change allelic

frequencies; Neutral evolution, molecular divergence and molecular clock concept; origin of new genes and proteins; gene duplication and divergence.

Section C

GENOME ORGANIZATION AND ANALYSIS: Types of genomes; Physical and genetic features of eukaryotic nuclear genomes, Gene Density, Repetitive DNA, C-value paradox, genome size and chromosome number in phylogenetic analysis. Regulation of gene expression. Sequencing of genomes: DNA sequencing methods, Next generation sequencing; Shotgun and Contigapproach,Generation of genomic and cDNA libraries, Genome Mapping; RFLP, RAPD and AFLP techniques, DNA fingerprinting, Restriction map, FISH, Methods for sequence alignment and genome annotation, synteny, positional cloning and QTL mapping.Recombination: Homologous and non-homologous recombinations; mechanisms and genetic control. Mutagenesis: transposon mutagenesis: structure and function of transposable elements, molecular features of Ac/Ds transposable elements

Section D

FUNCTIONAL GENOMICS: Approaches to analyze differential expression of genes - ESTs, SAGE, microarrays and their applications. Concept of forward and reverse genetics, Gene tagging, gene trapping, knockout and knockdown in eukaryotic organisms.*In vitro* mutagenesis and deletion techniques. Overview of over-expression of proteins in heterologous systems: *E. coli* and yeast. Proteome analysis-two dimensional - isolation and sequence analysis of individual protein spots by mass spectroscopy.Protein sequencing methods, Identification of post-translational modifications, protein-protein interactions and targeted quantification of proteins,Gel free methods of proteome analysis (label as well as label free), Comparative proteomics, interactomics, protein chips, arrays and proteogenomics, BLAST searches and multiple sequence alignment, Reconstruction methods used in molecular phylogeny.

Practicals: ***(25 marks; 2.5 credits, 40 Lecture hours)***

1. Preparation of stains and staining techniques for chromosome analysis.
2. Karyotype analysis in diploids and polyploids.
3. Chromosome pairing in diploids and polyploids.
4. Study of genetic variation using random and gene-specific molecular markers: molecular phylogeny reconstruction
5. Restriction mapping.
6. Differential expression of a gene by semiquantitative RT PCR
7. Overexpression of protein in bacterial system
8. Bioinformatic 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

3rd semester

Bot C31: Microbiology: Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section A (GENERAL MICROBIOLOGY)

Microbial taxonomy: Bacterial classification: analysis of phenetic, genetic and phylogenetic characteristics; polyphasic approaches to bacterial taxonomy. Salient features of major bacterial groupsArchaea, Actinomycetes

Methods in microbiology: Isolation of pure cultures,Types of culture media, maintenance and preservation of bacterial cultures.

Growth and differentiation: Measurement of growth, growth kinetics, batch, fed batch, continuous and synchronous growth.Physico-chemical factors influencing bacterial growth. Basic design of a typical fermenter.Types of bioreactors.

Differentiation: Sporogenesis-physiobiochemicaland genetic aspects, Caulobacterdifferentiation. Bacterial cell wall ultra-structure and synthesis.

Section B (MICROBIAL GENETICS)

Bacterial Genetics: Conjugation: molecular mechanism of gene transfer and regulation. Conjugationmapping, Plasmids: types, function and application. Transformation: Natural transformation and competence;molecular mechanism of transformation. Transduction: Generalized and specialized transduction.

Gene regulation: Positive and negative gene regulation and attenuation, *lac*, *gal*, *trp*, and *ara*operons and theirapplications. geneticswitches.Quorum sensing.

CRISPR-CAS evolutionary significance in bacterial innate immunity, mode of action and application.

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

Section C (APPLIED MICROBIOLOGY)

Microbes and r-DNA Technology: Cloning and expression of recombinant proteins, peptides and vaccines in bacterial system.Purification of recombinant proteins.

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

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

Environmental microbiology: Distribution and implications of microbes in air and water, waste watertreatment; Microbial production of pesticides and biofertilizers; degradation of xenobiotics Bioremediation of heavymetals.

Section D (VIROLOGY)

General Virology: Virus classification.Cultivation of viruses, methods for detection and quantification.Satellite virus, viroid, prions.

Bacteriophages genome organization. Genetic analysis of phages – complementation and recombination tests with phages.General account of T4, T7 and lambda phages. Lysogenic phages: genome organization and its regulation.Phage therapy and typing.

Human Virus: HIV, SARS, HCV, Influenzagenome organization, structure and replication.

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

Practicals *(25 marks; 2.5 credits, 40 Lecture hours)*

1. Analysis of soil or water microbiota, characterization of selected pure culture isolates by staining and physio-biochemical features (extraceullar enzymes: amylase, cellulose, protease, antibiotic).
2. Antibiotic sensitivity assay disc diffusion method.
3. Enrichment and isolation of nitrogen fixing bacteria from soil and their characterization.
4. Microbiological analysis of milk by MBRT assay
5. Determination of bacterial growth and growth kinetics under batch cultivation (turbidimetric method).
6. Plasmid isolation and gel electrophoresis.
7. Bacterial transformation: Competent cell preparation, transformation, screening of transformed isolates usingblue white screening.
8. Gene Expression analysis by IPTG induction under Lac operon.
9. Bacteriophage titration, purification and quantification.
10. Industry visit (Milk, pharmaceutical, distillery etc).

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, N S SubbaRao and YR Dommergues.

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

Section-A

Plant metabolism and enzymology: Bioenergetics of light reaction, regulation of C_2, C_3, C_4 and CAM cycles, photoprotective mechanism; regulation of carbohydrate metabolism; coupled reaction; group transfer; genes and polypeptide components of photosynthetic complexes; mitochondrial electron transport complexes – structure, function; mechanism and regulation of ATP synthesis in plastid and mitochondria; motors and pumps, alternate oxidase, regulation of gluconeogenesis and glyoxylate cycle, regulation of fatty acids biosynthesis and oxidation; Nitrogen metabolism: underlying mechanism of nodule formation; regulation of nitrate assimilation and amino acid biosynthesis; Enzyme activity and specificity, active site, activation energy, Reaction rate, Mechanism of action, Kinetics: rate order of reactions; Derivation of MichaelisMenten equation – single substrate; MichaelisMenten plot and Lineweaver Burk plot; Types of enzyme inhibition.;

Section-B

Sensory Photobiology: Structure, light mediated activation and mechanism of action of phytochromes, cryptochromes and phototropins; regulation of skotomorphogenesis and photomorphogenesis, shade avoidance responses, signalling mechanism of phototropism, mechanism of stomatal and choloroplast movement; regulation of phase changes and induction of flowering; hormone and light signalling in flowering; induction, evocation and development of flowering; circadian clock mechanism, coincidence model of flowering; prevention mechanism of premature flowering; homeodomain and ABCE model; epigenetic changes during autonomous pathway and vernalization

Section-C

Plant growth regulators and signal transduction: Biosynthesis, storage, transport and breakdown and signalling mechanisms of hormones (IAA,GA, cytokinin, ethylene, ABA, jasmonic acid, salicylic acid, brassinosteroids), hormone mediated plant growth regulation through signalling system, mutant analysis to understand hormone action, Acid growth hypothesis and starch statolith concept of IAA, GA and ABA mediated hormonal regulation of dormancy and germination, hormonal and environmental control of plant senescence,

Section-D

Chemistry of primary metabolites: Structure of Carbohydrate: stereochemistry – Fischer projection, Haworth perspective, boat and chair conformation; mutarotation; glycoside formation; inverted sugar, derivative sugar; Conformation of proteins: motifs and domains, torsion angle and Ramachandran plot, Forces stabilizing protein structure, fibrous proteins (keratins and collagen), globular protein; Protein folding: Leventhal paradox; protein purification

techniques, Hoogstein base pairing of nucleic acids, Sugar puckering and base stacking; torsion angle and supercoiling of nucleic acid

Practicals (25 marks; 2.5 credits, 40 Lecture hours)

1. Effect of different modulators on urease activity; determination of Km value of Urease.
2. Determination of Chlorophyll-a, Chlorphyll b and total chlorophyll content from different plant species
3. Determination of hill activity from plants growing under altered light conditions.
4. Analysis of seed viability through dehydrogenase assay
5. Determination of relative water content and spectrophotometric analysis of proline content from plant samples after exposure to osmotic stress for different time periods.
6. Determination of nitrate reductase activity from plants
7. Isolation of chloroplast proteins from plants and identification of phosphoprotein through Pro-Q Diamond staining.
8. Demonstration of western blot to identify protein of interest from total protein.

SUGGESTED READINGS:

1. Taiz&Zeiger, Plant Physiology and Development, 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 LubertStryer, Biochemistry by Herper, Biochemistry by Lippincott.
3. Biochemical calculation by Segel (Cambridge).
4. Practical Biochemistry by Rodney Boyers.

Optional Papers (any 1 of the following)

1	Bot OP-1-A	Applied Virology
2	Bot OP-1-B	Applied Mycology
3	Bot OP-1-C	Molecular Stress Biology
4	Bot OP-1-D	Molecular Plant Physiology
5	Bot OP-1-E	Genetics of Plant Development
6	Bot OP-1-F	Bioinformatics
7	Bot OP-1-G	Advanced Phytochemistry and Pharmacognosy
8	Bot OP-1-H	Advanced Palaeobotany and Palynology

Bot OP-1-A: Applied Virology Theory (20 marks; 2 credits, 15 Lecture hours)

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. Antiviral stratagies for Direct Acting Antivirals (DAA)
5. Conventional vaccines -killed and attenuated, modern vaccines— designing and production strategies for recombinant proteins, subunits, DNA vaccines, peptides, vaccine delivery and adjuvants,
6. 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)

Bot OP-1-B: Applied Mycology -in food industryTheory (20 marks; 2 credits, 15 Lecture hours)

1. **Commercial utilization of edible fruiting fungi:** Commercial cultivation of some edible and medicinal mushrooms; Utilization of spent substrates; Functional food and dietary supplements from mushrooms; Fortification of edible mushrooms.

2. **Fungal metabolites in food processing:** Organic acids, amino acids, nucleotides and related substances, vitamins and nutritional supplements, polysaccharides, lipid substances.

3. **Fungal enzymes in food processing:** In baking, fruit and juice processing, brewing and wine making, dairy, starch processing and sucrose refining industry.

4. **Fermented foods with kojimolds:** Sake, Shochu, Vinegar, fermented soybean foods in East and Southeast Asia; Mixed culture dough inocula for food and beverage fermentation.

Bot OP-1-C: Molecular Stress BiologyTheory (20 marks; 2 credits, 15 Lecture hours)

1. Abiotic and biotic stress inducible genes and transcription factors: Types and structure of transcription factors involved with plant defense, Ethylene-responsive-element-binding factors (ERF), stress signalling via ERFs, Basic-domain leucine-zipper (bZIP) and role in defence briefly, WRKY proteins, GCC box–containing stress response genes.

2. Signal transduction pathways: Salicylates (History, Synthesis: ICS and PAL mediated pathways, Role of SA in NPR1 monomerization, Role of SA in defense gene regulation), Jasmonate (History, synthesis, Role of JA, JA derivatives, JA signalling with reference to COI1, JAZ, NINJA, TPL), Ethylene: (Synthesis, role in plant defense) and Abscisic acid (ABA dependent and ABA independent pathways, steps of ABA synthesis in plastid and cytosol, Regulation of ABA, ABA catabolism in plants)

3. Molecular control of ROS production and anti-oxidant processes: Hypersensitive response and role of Reactive Oxygen Species (ROS) in plant defence, Mechanisms of ROS production in response to pathogens, sites of production of ROS, ROS scavenging systems, functions of ROS after infection.

4. Role of surface structures and receptors in detecting stresses, plant to plant communication: Pattern recognition receptors, PTI and ETI, Trichomes in plant disease development and plant defense, Stomata as entry points of pathogens, defense regulation in guard cells, SA mediated Stomatal regulation, communication between plants during stress.

5. Modern technologies for improvement of stress tolerance in crop plants: Transgenic approach, defense related micro-RNA, use of transposable elements for stress tolerance.

Suggested readings

1. An Overview of Plant Defenses against Pathogens and Herbivores.By Freeman, B.C. and G.A. Beattie. 2008. The Plant Health Instructor. The American Phytopathological Society.

2. Mycology and Phytopathology. P.D. Sharma. First Edition. Rastogi Publications.

3. Plant Pathology. George N. Agrios.Academic Press.

4. Mehrotra, R. S. 2011. Plant Pathology. Tata McGraw-Hill Publishing Company Limited, New Delhi.

5. Latest reseach publications related to the topics.

Bot OP-1-D : Molecular Plant Physiology ***Theory (20 marks; 2 credits, 15 Lecture hours)***

1. **Plant Nutrition Physiology:** Nutrient uptake, types of transport: intracellular, intercellular, mobile and immobile nutrient elements, iron uptake mechanism: type I and type II, Short distance transport, long distance transport with special reference to iron, intracellular iron transport, different group of iron transporters, signalling mechanism of iron uptake, phosphate uptake and transport: phosphate deficiency signalling response in plants with reference to transporter regulation (PHO2 and miRNA399 mediated signalling).

   Signal transduction: Receptors and receptor kinase, Different groups of receptor kinase, MAP kinase signalling pathway, G protein signalling, Calcium signalling, Calcium-calmodulin pathway, Phospholipid- calcium signalling (IP3, DAG signalling), Different types of Phosphates, MicroRNA biogenesis, MicroRNA mode of action, Function of long non coding RNAs in plant development (Apollo, ENOD40, LDMAR regulation)

2. **Molecular aspect of pollination and fertilization in plants**: Different phases of sperm cells delivery, Regulation of compatibility between pollen and stigma,Ca^{2+}signalling in pollen tube growth, function of ROP1-GTPase in pollen tube growth, role of synergids in fertilization, Molecular mechanism of GSI and SSI.
3. **Plant environment interaction and adaptive physiology**: Plant response against water, temperature and salinity stress, adaptive features of plants against environmental challenges, hormonal crosstalk and osmotic stress regulation, cell wall expansion mechanism under osmotic stress, expansin protein and function, role of lectins in developing climate resilient crops

Suggested Readings:

1. Plant Physiology and Development, Taiz&Zeiger (Sixth edition)
2. Biochemistry & Molecular biology of plants by Buchanan, Gruissem and Russell
3. Plant Physiology, Cleon W. Ross and Frank B. Salisbury

Bot OP-1-E: Genetics of Plant Development Theory (20 marks; 2 credits, 15 Lecture hours)

I. Basic concepts of plant developmental biology: Stem cell developmental potency; cellular plasticity in plants; Formative cell divisions as principal determinants in plant morphogenesis; Programmed cell death and plant development; Axis and pattern formation in *Arabidopsis* and maize; Approaches to study genes involved in plant development in model plants

II.Genes controlling morphogenesis in plants: Major gene families involved in plant development; Morphogenetic cascades in plant life cycle; Homeotic genes and mutants in plant development; MADS-box genes; KNOX genes; Major gene regulatory networks involved. Genetic regulation of gametophyte development, fertilization and post-fertilization changes; Phylogenetics of major gene families involved in plant development

III. Genetics of floral structure diversity and evolution: Genetic regulation offloral meristems and flower development in maize, rice, lily, orchid, *Arabidopsis, Antirrhinum* and *Petunia*; Genetics of anther and ovule development; Gender expression in monoecious and dioecious plants; Genetic and genomic aspects of floral diversity evolution.

IV. Epigenetics and RNA mediated control of plant development: Epigenetic regulation of key plant developmental pathways; Epigenetic resetting during gametogenesis; Genome imprinting; small/microRNA control over developmental phase transitions; long non coding RNA and plant development

Suggested Readings

1. Plant Epigenetics Eds. Rajewskyet. al. Springer
2. Developmental Biology of Flowering Plants, Raghavan (2000) - Springer
3. Developmental Genetics and Plant Evolution, Quentin C.B. Cronk, Richard M. Bateman, Julie A. Hawkins (2002) - CRC Press

Bot OP-1-F: Bioinformatics Theory (20 marks; 2 credits, 15 Lecture hours)

1. **Basics of informatics:-** Basics of bioinformatics and computational biology; Emergence and aims of bioinformatics; Research areas associated with bioinformatics:- a)Genomics b) Proteomics c) Computer-aided drug designing (CADD) d) Biological database e) Biological data mining f) Microarray informatics g) Molecular phylogenetics h) System biology i) Argo-informatics
2. **Databases in bioinformatics:-** Introduction to database; Database contents; Biological databases:- a) Nucleic acid sequence databases (NCBI, EMBL) b) Specialized genome database (GISAID) c) Protein sequence database (The Swiss Institute for Bioinformatics and The Protein Information Resource (PIR) and associated databases) (UniProt) d) Structure database (RCSB PDB, PDBsum); Sequence formats (FASTA)
3. **Sequence alignment and phylogenetic study:-** Introduction to sequence and alignment; Local alignment and global alignment; Pairwise alignment:- a) Basic Local Alignment Search Tool (BLAST) b) FASTA c)Comparison of FASTA and BLAST; Multiple sequence

alignment (Clustal W) and applications; Molecular Evolution and Molecular Phylogenetics; Phylogenetic trees

4. **Structural bioinformatics:-** Properties of amino acids and peptide bonds; Protein stability and folding (Ramachandran plot); Protein Structure Database(Protein Data Bank); Protein Structural Visualization (RasMol, PyMOL, DDS); Homology modeling (SwissMODEL)
5. **Computational drug discovery and designing:-** Drug discovery and development; Bioinformatics in drug discovery and development (*In silico* drug designing); High Throughput Screening; Virtual screening; Quantitive Structure-Activity Relationship; The lead compound; Natural products; Drugs- principles of drug development; ADME properties; Improving on the lead compound; Drug target identification and validation; Active sites; Grid boxes; Molecular docking; Tools and molecular docking programs (AutoDock, Patchdock); Molecular dynamics- setting and running a molecular dynamics; Molecular dynamics using simple models; Trajectory analysis, CHARMM, Monte Carlo simulation; Applications of drug design

Suggested books:

1. Essential bioinformatics- Jin Xiong
2. Introduction to bioinformatics- Arthur M. Lesk
3. Bioinformatics sequence and genome analysis- David W. Mount
4. Structural bioinformatics- Philip E. Bourne
5. Molecular modelling- Andrew R. Leach
6. Molecular Modelling for Beginners- Alan Hinchliffe
7. Bioinformatics And Functional Genomics- Jonathan Pevsner
8. Instant Notes in Bioinformatics- David R. Westhead
9. Essentials of Bioinformatics- Noor Ahmad Shaik
10. Understanding Bioinformatics- MarketaZvelebil& Jeremy O. Baum

Bot OP-2-G: Advanced Phytochemistry and Pharmacognosy Theory (20 marks; 2 credits, 15 Lecture hours)

1. **Secondary metabolism and biological activities of secondary metabolites**: Turnover and degradation of secondary metabolism, phenols and phenolic glycosides, sterols, steroidal alkaloids, stanols, miscellaneous isoprenoids, saponins etc.

2. **Enzymes, proteins, amino acids as drugs**: proteolytic enzymes, RIPs, Lectins etc.Antibiotics derived from amino acid metabolism, acetate metabolism and carbohydrate metabolism

3. **Pharmacological activities of plant drugs**: tumour inhibitors, hypoglycaemic, anti-hepatotoxic, anti-viral, anti-protozoal, immunomodulators, anti-oxidants, phytoestrogens and enzyme inhibitors

4. **Methods for phytochemical analysis**: tissue culture and biotechnology for the discovery and production of phyto-molecules, biologics

5. **Metabolomics:** terms and definition, different metabolomics technologies, merits and demerits, data acquisition and application.

Bot OP-1-H: Advanced Palaeobotany and Palynology Theory (20 marks; 2 credits, 15 Lecture hours)

1. **Palaeofloristics of Indian subcontinent:** Brief knowledge of Deccan intertrappean, Siwalik and Karewa floras
2. **Some methods and approaches of past depositional environment/climate reconstructions:**Nearest living relative (NLR) method,Climate Leaf Analysis Multivariate Program (CLAMP), Co-existence approach (Co-A), stable isotopes ($\delta\ ^{13}C$, $\delta\ ^{18}O$) and pCO_2 conc.
3. **Fossil evidence of physiological, developmental mechanisms and biotic interactions:** evolution of C4 and CAM photosynthetic pathways in plants; Miocene expansion of C4 grasses and probable causes; evolution of grasses and grazers; polar auxin flow;Plant-animal interaction and their co-evolution in the fossil record
4. **Brief concept of past extreme events:** Mass extinctions through geological time; floral change-over across the Palaeocene-Eocene thermal maxima (PETM) and Cretaceous-Tertiary boundary; Detection of tropical cyclones and tsunamis in the geological past (Palaeotempestology); past fire and environmental change; charcoal as information source in reconstructing fire history
5. **Archaeobotany and palaeoethnobotany:** Origin and development of agriculture in India; study of ancient plant economy (cereals, pulses, fruits and drugs plants) from Palaeolithic to Historic age of India; archaeopalynology in analysis of prehistoric vegetation and human/animal diet

Suggested Readings:

1. Cleal, C. J., Thomas, B.A. 1999. Plant Fossils. The History of Land vegetation. Woodbridge Boydell Press, Woodbridge, VA.
2. Krings, Michael et al.,2018.Transformative palaeobotany
3. Levin, H. L. 1981. Contemporary Physical geology.
4. Scott, A. C., et al., 2014. Fire on Earth: An Introduction. Willey Blackwell Publ.

5. Senger, R. 1999. Encylopedia of Palaeontology. Fitzroy Dearborn Publ.
6. Taylor, T.N., Taylor, E.L., Krings, M. 2009. Palaeobotany-The Biology and Evolution of Fossils Plants. Elsevier.
7. Willis, K. J., McElwain, J.C. 2002. The Evolution of Plants. Oxford University Press, New York.
8. Traverse, A. 1988. Palaeopalynology

O A : Choice based credit course (CBCS 1): Botany
BOT-1: Biology and applications of non-flowering plants
(50 marks; 4 credits, 50 Lecture hours)

1. Origin and phylogeny of cyanobacteria and algae; Basic characteristics of major algal groups; Algal biotechnology.
2. Fungi: overview; Mycoses (Types, diagnosis and management); Nutritional and medicinal prospects of macrofungi.
3. Bryophytes: overview; Bryophytes as indicator plant; Physcomitrella patens genetic and physiological model in plant research.
4. Pteridophytes: General account; Diversity and Distribution; Fundamental and applied.
5. Plant diseases an overview; Causal agents and diseases under broad categories (viruses, bacteria, fungi, etc.); Management strategies (Conventional to modern methods); Diagnosis of plant diseases; Biotechnology based easy transition to low cost organic crop production.

O B : Choice based credit course (CBCS 2): Botany
BOT-2: Biology and applications of flowering plants
(50 marks; 4 credits, 50 Lecture hours)

1. Plant morphology; Nomenclature, Classification and Botanical Code; Biodiversity and CBD, ITK; Importance of herbarium in plant research; Species concept; Biosystematics.

2. Carbon assimilation in plants: general view; Effects of temperature, CO2 on carbon metabolism and plant productivity; Adaptive features of plants against environmental challenges like salinity and drought.

3. Fossilization process, types of fossils, modes of preservation; geological time scale, plant life through age (outline), dating methods; importance of plant fossil study.

4. Introduction and scope of phytochemistry; Primary vs secondary metabolism; Different groups of pharmacologically active metabolites; Biosynthetic pathways : a brief account.

5. Therapeutic uses of medicinal plants; Drug Discovery from Natural Resources; Advantages and Disadvantages; Druggability of Isolated Phytochemical Compounds; Selection of Candidate Plant Species for Screening; Biological Activity Guided Fractionation for Compound Isolation; Bio-prospecting of plants.

6. Phytoremediation: Definition; Concept of excluders and accumulators; Mechanisms of phytoremediation; Limitations and concerns.

7. Plant tissue culture and its application; De-differentiation, Cyto-differentiation, plant regeneration organogenesis, embryogenesis, micropropagation and protoplast culture. Agrobacterium mediated plant transformation and its application in GM crops.

4th semester

Bot C 41: Plant Biotechnology: Theory (40 marks; 2.5 credits; 40 lecture hours)

Section-A

Basic concepts of plant regeneration: Major overlapping processes in development; Developmental potency; cellular plasticity in plants; determination and differentiation, mechanism of cellular determination; morphogenetic gradients, cell fate and cell lineages; positional information; Pathways of *in vitro* morphogenesis: Structural and developmental ontogeny, Physiological, biochemical and molecular aspects of *in vitro* organogenesis, gametic and somatic embryogenesis; Important considerations of haploid production; Protoplast culture and regeneration with examples; Somaclonal and gametoclonal variations: causes and genetic basis; Model plants for developmental studies: *Physcomitrella patens, Arabidopsis thaliana, Zea mays, Antirrhinum majus.*

Section-B

Applications of plant cell, tissue and organ cultures: Micropropagation: methods and stages, clonal/ genetic fidelity testing, Examples of commercially propagated species; Tissue culture for tree improvement; Zygotic embryo and endosperm culture: applications with examples; Synthetic seeds; Excised unorganized and organ cultures: establishment and applications; Production of natural products by cell suspension cultures; Micropropagation, shoot and root organ cultures in batch cultures and in bioreactors with examples. Problems in commercial exploitation plant *in vitro* cultures; Cryopreservation and germplasm conservation *in vitro*.

Section-C

Principles and methods of genetic transformation: Introduction; Direct gene transfer methods: particle bombardment, electroporation, protoplast transformation PEG-mediated and floral-dip; Marker and reporter genes; Mechanism of Agrobacterium mediated transformation, binary vectors; Chloroplast transformation: principles and advantages; Detection of transgene, identification of integration site, determination of copy number, inheritance of transgene. Genetic elements and engineering of Ti and Ri plasmids, hairy root cultures, strategies used for enhanced production of secondary metabolites, Biotransformations using plant cell cultures

Section-D

Applications of genetic transformation: Case studies on use of transgenic technology for basic studies and crop/plant improvement; phenotypic, genetic and molecular analysis of transgenic plants; factors influencing transgene expression levels; transgene stability, transgene silencing; marker-free transgenics; genome editing for crop improvement; Zinc finger nuclease, TALEN, CRISPR technology, selection and application. environmental, social and legal issues. Transgenic crops for improved yield and nutritional quality: Engineering crops for male sterility, modification of flower colour, flowering, fruit ripening and senescence. RNAi mediated crop improvement, GM plants with enhanced resistance against biotic and abiotic stresses.

Practicals (25 marks; 2.5 credits, 40 Lecture hours)

1. Organization of a tissue culture laboratory, basic techniques establishment of aseptic plant tissue culture
2. Surface sterilization of seed, bulb and establishment of *in vitro* cultures in different types of basal medium
3. Study effects of phytohormones (2,4-D/NAA, KN/BA) and basal medium (MS/B5) medium on *in vitro* morphogenesis from different explants (*Nicotianatabacum/ Daucuscarota*)
4. Study of stages of micropropagation using shoot tip/nodal buds
5. Study of callus and cell suspension cultures; induction of somatic embryogenesis
6. Preparation of constructs and competent cells for *Agrobacterium* transformation
7. Protoplast transformation
8. *Agrobacterium tumefaciens*and *Agrobacterium rhizogenes*mediated transformation in *Nicotianatabacum*and *Oryza sativa*

Suggested reading:

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. Elsevier.
3. Plant Cell Tissue and Organ Culture: Fundamental methods by OL Gamborg and GC Phillips Naropsa.
4. Principles of Gene Manipulation by Primrose and Twyman. Wiley-Blackwell publishers.

Bot C 42: Plant Disease Biology Theory (40 marks; 2.5 credits, 40 Lecture hours)

Section-A

Basic concepts in plant disease biology, plant-abiotic factor interaction and disorders of plants: A brief concept of diseases and disorders of plants; Disorders in crop plants, abiotic factors leading to disorders: salinity (soil salinity, excessive fertilizer use, acid rain), drought, water-logging, temperature extremes (scalds, frost injury), micronutrient deficiency, pollutants (toxic gases, heavy metals, particulate matters, chemical pesticides and herbicides), light (excessive light, shade, UV damage), symptoms of disorders associated with abiotic factors, host factors associated with environmental susceptibility. Concept on structural and biochemical plant defense against abiotic stresses, over view of plant defense signalling, innate immunity in plants, hypersensitive reactions, role of Reactive Oxygen Species during abiotic stress.

Section B

Biology of plant diseases: Classification of plant diseases. Diseases caused by biotrophic, necrotrophic and hemibiotrophic pathogens, localized and systemic acquired resistance. Symptomology of important plant viral diseases, transmission, virus vector relationship, replication and movement of plant viruses. Plant pathogenic bacteria, symptomology of important plant bacterial diseases of dicots and monotocot crops, crown gall disease, bacterial blights. Diseases caused by protists, symptomatology, mode of dissemination, difference from fungal pathogens. Diseases caused by nematodes, symptoms, interaction of nematodes with trap fungi as biocontrol agents. Insect herbivory, major groups of crop insects, mining, boring and sucking insects, insect vectors for plant viruses and other plant pathogens. Fungal diseases in plants, penetration and post penetration stages, signalling in appressorial development, propagules of phytopathogenic fungi including spores and sclerotia, calcium signalling during host-pathogen interaction.

Section C

Epidemiology of plant diseases, endemic diseases and diseases forecasting: General information, terms and definitions in diseases epidemiology, history of plant epidemics. Elements of epidemics, disease triangle, disease tetrahedron, Factors affecting the elements of epidemic. Measurement of plant disease in field: disease severity, disease incidence, disease index, types and patterns of epidemics, disease progress curves, disease gradient curves. Disease forecasting, study of local weather parameters, analysis of air bourne pathogen propagules, computer simulation. Epidemiology of selected endemic diseases of India with reference to local conditions: fungal blight of rice (*Rhizoctonia solani*), Wheat blast (*Magnaporthe oryzae* Triticum), Mungbean yellow mosaic disease, *Alternaria* blight of mustard, Anthracnose of chilli (*Colletotrichum sp*), Black mould of onion (*Aspergillus niger*), Root knot of brinjal by nematodes (*Meloidogyne spp*), Red rust of tea (*Cephaleuros virescens*).

Section D

Prevention, Diagnosis and Control of plant diseases : Agricultural practices and remedial measures for prevention of disease, plant quarantine, tolerant crop varieties against abiotic and biotic stresses, crop rotation, mixed cultivation, use of barrier plantation. Integrated disease management: basic principles and importance. Molecular basis of plant adaptation during environmental stresses. Diagnosis of plant diseases– from field diagnosis to molecular diagnosis, Detection of latent diseases, immuno-detection of plant diseases. Chemical pesticides, modes of application, tolerance to chemical pesticides. Biopesticides: types of biopesticides, advantages and disadvantages of use of biopesticides. Conventional methods of generating disease tolerant plants though plant breeding and its limitations. Control of plant diseases through transgenic approaches, Isolation and molecular cloning of disease resistance genes, promoters and reporters

used for improved tolerance. Use of enzyme inhibitor genes for insect resistance. Insect and pathogen resistant crops, advantages and disadvantages. Post-harvest protection of grains, vegetables and fruits.

Plant Disease Biology Practical (25 marks)

1. Isolation of pathogens from diseased plant samples
2. Study of symptoms of selected diseases of dicots and monocots.
3. Histopathology of diseased plants compared with healthy control plants
4. Identification and culture of common fungal phytopathogens
5. Molecular diagnosis of fungal diseases
6. Detection of latent viral infection in plants
7. Study of selected insects important for plant herbivory
8. Estimation of pathogenesis-related enzyme from diseased plant samples
9. Estimation of super-oxide dismutase
10. Localization of ROS due to abiotic stresses
11. Cell types and cell inclusions - trichomes, sclereides, tracheids, vessels, phytoliths, cystolith, crystals, glandular hairs, oil glands, salt glands, resin canals and laticifers.
12. Nodal anatomy-unilacunar, trilacunar, multilacunar.
13. Wood anatomy from TS, TLS, RLS of woody plants.

Suggested reading:

1. Plant Pathology. George N. Agrios.Academic Press
2. Singh R.S. 1982. Plant Pathogens – The Fungi.Oxford& IBH, New Delhi.
3. Alexopoulos C.J, Mims C.W & Blackwell M.2000.Introductory Mycology. 5th Ed. John Wiley & Sons, New York.
4. Mehrotra R.S &Arneja K.R. 1990. An Introductory Mycology. Wiley Eastern, New Delhi.
5. Sarbhoy A.K. 2000. Text book of Mycology. ICAR, New Delhi.
6. Webster J. 1980. Introduction to Fungi. 2nd Ed. Cambridge Univ. Press, Cambridge, New York.

Bot S 43: Plant Anatomy and Ecology Theory (30 marks; 2 credits, 30 Lecture hours)

Group-A

Primary and secondary tissues: Origin and development of sclereids, fibres and their control of differentiation; vascular cambium, factors influencing cambial activity; nodal anatomy: types, relevance in plant systematics and evolutionary aspects; secretary systems: salt glands and

nectarines; floral vasculature; wood and leaf anatomy and their ecological perspectives; application of anatomy in climatology; leaf and wood anatomical features in ecological conditions; anatomical response to pollutants.

Developmental anatomy: Pattern formation (apical, basal and radial); morphogenesis; organization of shoot, root and apical meristem; floral meristem and flower development.

Group-B

Community and Population ecology: Community ecology: Nature of communities, community structure and attributes, species interactions, levels and measurements, climax concept; Habitat and Niche: Concept, types, resource partitioning, character displacement; Population ecology: Characteristics of a population, growth curves, population regulation; life history strategies (*r* and *K* selection), concept of metapopulation.

Ecosystem ecology: Ecosystem: Nature and function, energy flow and mineral cycling (CNSP); forests, grassland and aquatic ecosystems; Major Biomes of the world; Environmental pollution and its effect on plants, environmental policies and regulations; Global warming: Greenhouse effect and ozone depletion.

Suggested readings

1. Comparative Plant Anatomy: Carlquist, S. (1961)
2. An Introduction to Plant Anatomy: Eames, AJ and McDaniels, LH (1947)
3. Anatomy of Seed Plants: Easu, 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: Beck, CB (2010)
7. Integrative Plant Anatomy: Dickison, WC (2000)
8. Plant Anatomy: Mauseth, JD (1988)
9. Plant Anatomy (Part I and II): Cutter, EG
10. Plant Anatomy: A Concept-Based Approach to the Structure of Seed Plants: Crang, Richard(2018)
11. Plant Anatomy and Morphology: Structure, Function and Development : Luke Fitzerald(2020)
12. Plant Anatomy, Morphology and Physiology: Koelling, Clive(2016)
13. Odum, E.P. (1971). *Fundamentals of Ecology.* W.B Sounders Co., Philadelphia.
14. Chapman, J.L. & Reiss, M.J. (1999). *Ecology Principles and Applications*. Cambridge University Press, U.K.
15. Sharma, P.D. (2009). *Ecology and Environment.*Rastogi publicatios, Meerut.
16. Smith, T.M. & Smith, R.L. (2015). Elements of Ecology, (9th eds), Pearson Education, India.

Optional Papers (any 1 of the following)

1	Bot OP-2-A	Microbial Biotechnology
2	Bot OP-2-B	Applied Phycology
3	Bot OP-2-C	Plant Molecular genetics and Evolution
4	Bot OP-2-D	Organic Crop Production Technology
5y	Bot OP-2-E	Immunology
6	Bot OP-2-F	Plant Molecular Biology
7	Bot OP-2-G	Analytical Techniques
8	Bot OP-2-H	Taxonomy and Biosystematics

Bot OP-2-A: Microbial Biotechnology Theory (20 marks; 2 credits, 15 Lecture hours)

1. Introduction to microbial biotechnology: multidisciplinary nature of microbial biotechnology

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); 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

Bot OP-2-B: Applied PhycologyTheory (20 marks; 2 credits, 15 Lecture hours)

1. Bioactive compounds from Algae
2. Use of Cyanobacteria and Algae as novel food products and fertilizers
3. Microalgae in Aquaculture
4. Algae for Biofuel production
5. Phyconanotechnology
6. Phycoremediation and CO_2 sequestration by algae
7. Algal Biorefinary
8. Algal resources of India

Suggested readings

1. Algae: nutrition, pollution control and energy sources. Hagen, K.N. NOVA
2. Plant Biology and Biotechnology: Bahadur, B., VenkatRajam, M., Sahijram, L., Krishnamurthy, K. (eds), Springer .
3. Algal Biorefinery : An Integrated Approach. Das, D. (eds) Springer.
4. Seaweeds of India by Bhavnath Jha;CRK Reddy; Mukund C.Thakur; M. Umamaheswararao.Springer

Bot OP-2-C: Plant Molecular genetics and EvolutionTheory (20 marks; 2 credits, 15 Lecture hours)

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. **Utilization of Genetic resources in plants**: Role of cytogenetics in evolution and improvement of major cereal crops; Phenomics; Marker Assisted Selection, QTL analysis, Genome-Wide Association Studies in plants; Gene pyramiding for multi-trait incorporation; Chromosome engineering

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

Bot OP-2-D: Organic Crop Production TechnologyTheory (20 marks; 2 credits, 15 Lecture hours)

1. Introduction to organic crop production; Guidelines of organically food produce; Principles of organic agricultural practice. Plant propagation, criteria for seed evaluation, characterization and multiplication. Importance of traditional varieties; seed conservation.
2. Criteria for crop selection during organic conversion; crop rotation; Intercropping; Cover crops; Designing of cropping system; Mulching and its Importance; Water management in organic crop production system.
3. Nutrient management in organic crop production: Compost, Vermicompost, Green manures, Liquid fertilizers, organic growth promoters; microbial fertilizers, mineral fertilizers – mass production technology.
4. Pest and weed management: Prevention practices; Monitoring; Induction of innate immunity in plants, Promoting and managing natural enemies; Mechanical control strategies; Natural pesticides; Biological control; Mass production of technology for biocontrol agents.

Bot OP-2-E: Immunology Theory (20 marks; 2 credits, 15 Lecture hours)

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 its application in biomedical sciences, detection of molecules in living cells, *in situ* localization by techniques such as FISH and GISH. Detection of molecules using ELISA, RIA, immunoprecipitation.

Suggested Books:

1. Kuby Immunologyby Jenni Punt, Sharon Stranford, Patricia Jones, Judith A Owen.
2. Roitt's Essential Immunology.
3. Fundamental Immunology by William E Paul

Bot OP-2-F: Plant Molecular Biology Theory (20 marks; 2 credits, 15 Lecture hours)

1. The physical and chemical basis of molecular biology: Thermodynamics for molecular biology, Non covalent interactions between atoms and molecules, Absorption and emission of light by biomolecules, interaction between biomolecules
2. Nucleotides and aminoacids biosynthesis in plants, labelling and detection of nucleic acids and proteins in plants (both *in vitro* and *in vivo*). Structure and expression of nuclear, chloroplast and mitocondrial genes in plants, regulatory signals in plant genes and their detection
3. Organellar compartmentalization of protein synthesis, protein synthesis in plastids, protein modification and targeting, protein engineering, degradation and their detection in plants
4. Molecular regulation of plant development, transition from vegetative to reproductive development, molecular basis of flower development , molecular basis of self- incompatibility, molecular basis of seed development and germination

Suggested readings

1. Molecular Biology of the Cell, Alberts B et al., - Garland
2. Molecular Cell Biology, Lodish H et al., - Freeman
3. Cell and Molecular Biology, De Robertis and De Robertis – Lippincott and Wilkins
4. Advanced Molecular Biology, Richard Twyman - Garland Science
5. Recombinant DNA: Genes and Genomes, A Short Course – Watson JD et al.-Macmillan
6. Molecular Biotechnology: Principles and Applications of Recombinant DNA, Glick BR et al.-
7. Biochemistry and molecular biology of plants Buchanan, Gruissem and Russell
8. Molecular biology and biotechnology edited by Walker and Raply
9. Molecular biology: principles of genome function Craig Nancy et al.
10. The physical and chemical basis of molecular biology T.E.Creighton

Bot OP-2-G: Analytical TechniquesTheory (20 marks; 2 credits, 15 Lecture hours)

Spectrophotometry: Properties of Electromagnetic radiations; Beer Lambert's Law, Extinction Coefficient, Principle and applications of UV-Visible light Spectroscopy, Atomic absorption and Flame emission spectroscopic techniques, Mass spectrometry: X-ray diffraction; X-ray crystallography; Principle & biological applications of IR & NMR.

Detection of biomolecules interaction: Protein-protein interaction by yeast two hybrid assay, bimolecular fluorescence complementation, FRET, Co-immunoprecipitation, pull down assay, DNA-protein interaction by yeast one hybrid assay, ChIP, EMSA, DNAasefootprinting, Molecular Beacon, RNA protein interaction and aptamers

Radiolabeling techniques: Detection and measurement of different types of radioisotopes used in biology, incorporation of radioisotopes in biological tissues and cells, autoradiography, safety guidelines

Bioinformatics techniques: Primer designing, analysis of primer efficiency, Distance and similarity matrix,, construction of phylogenetic tree, protein structure prediction by homology modelling, threading, de-novo method, structure refinement, energy minimization and validation by Ramachandran plot analysis.

Suggested Readings:

1. Molecular Biotechnology by Primrose
2. Molecular Cell Biology, Lodish H et al., - Freeman
3. Cell and Molecular Biology, De Robertis and De Robertis – Lippincott and Wilkins
4. Recombinant DNA: Genes and Genomes, A Short Course – Watson JD et al.-Macmillan
5. Molecular Biotechnology: Principles and Applications of Recombinant DNA, Glick BR et al.-
6. Analytical techniques in Biochemistry and molecular biology by RajanKatoch

Bot OP-2-H: Taxonomy and Biosystematics Theory (20 marks; 2 credits, 15 Lecture hours)

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; Role of field studies in plant systematic; Centers of taxonomic and floristic studies in India; 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. International Code of (Botanical) Nomenclature (ICN): Provisions at generic and suprageneric ranks. Nomenclature of Hybrid Plants; Nomenclature of Cultivated Plants (ICNCP).

4. Modern trend and Evolutionary taxonomy: Nodal Anatomy: structure, types, evolution and applications. Palynotaxonomy: pollen structure, types and evolution of pollen grains, implications in plant systematics. Concepts of primitive and advanced characters, anagenesis, stasigenesis, cladogenesis, homology, analogy, homoplasy, parallelism and convergence, synapomorphy and symplesiomorphy.

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.