

**COURSE STRUCTURE OF M. Sc. Botany Syllabus
TO BE IMPLEMENTED FROM July 2018 (Semester I & II)
AND FROM July 2019 (Semester III & IV)**

Course No. Title of course	Credits allotted (80C)
Semester - I	
	(20 C)
BO1.1 Taxonomy -I (Algae, Fungi, Bryophytes)	4C
BO1.2 Plant Ecology	3C (Optional)
BO1.3 Genetics and Plant Breeding	3C
BO1.4 Practicals on BO1.1	5C
BO1.5 Practicals on BO1.2	2C (Optional)
BO1.6 Practicals on BO1.3	3C
Semester - II	
	(21 C)
BO2.1 Taxonomy- II (Pteridophytes and Gymnosperms)	3C
BO2.2 Cell Biology	3C
BO2.3 Molecular Biology	4C
BO2.4 Plant Physiology& Biochemistry	3C
BO2.5 Practicals on BO2.1	2C
BO2.6 Practicals on BO2.2 and BO2.3	4C
BO2.7 Practicals on BO 2.4	2C
Semester - III	
	(21 C)
BO3.1 Taxonomy –III (Angiosperms)	3C
BO3.2 Plant Development	3C
BO3.3 Tools and Techniques in Botany	3C (Optional)
BO 3.4 Special Paper/s-I (Any one of the following)	3C (Optional)
BO3.5 Practicals on BO3.1 and BO3.2	3C
BO3.6 Practicals on BO3.3	3C (Optional)
BO 3.7 Practicals on special Paper/s -I	3C
Semester - IV	
	(18 C)
BO 4.1 Biostatistics and bioinformatics	2C (Optional)
BO 4.2 Special paper/s-II	3C (Optional)
BO 4.3 Practicals on BO 4.1	2C (Optional)
BO 4.4 Practicals on Special paper/s-II	3C
BO 4.5 Project	8C
BO 3.5 & BO 4.2 Special paper I & II will consist of the following papers: (any one)	
BO3.5a & 4.2a Algology	3C
BO3.5b & 4.2b Advanced Mycology	3C
BO3.5c & 4.2c Angiosperms Systematics	3C
BO3.5d & 4.2d Plant Ecology	3C
BO3.5e & 4.2e Plant Physiology	3C
BO3.5f & 4.2f Pharmacognosy	3C
BO3.5g & 4.2g Advanced Plant Genetics and Breeding	3C
BO3.5h & 4.2h Plant Biotechnology	3C

BO 1.1 - Taxonomy (Algae, Fungi, Bryophytes): 4C

Credits-1.5: Algae	23L
1. Plant Systematics: Taxonomy vs Systematics, Principles and Methods of Taxonomy: Concept of species and hierarchical taxa, Biological nomenclature (International code of Botanical Nomenclature), Classical and quantitative methods of taxonomy.	2L
2. Algae and their position in “Domains and Kingdoms” system, Trends in classification of algae.	2L
3. Cyanophyta: Ultrastructure; Strategy of cell division; Thallus organization, Heterocyst.	2L
4. Brief introduction, structural and reproductive features of Chrysophyta, Xanthophyta, Bacillariophyta, Dinophyta.	4L
5. Chlorophyta – structure and evolution of thallus, Unicellular eukaryotes (endosymbiotic theory), Morphogenesis in <i>Acetabularia</i> , reproduction and life histories with reference to orders of green algae.	5L
6. Charophyta and Euglenophyta: structure and reproduction and interrelationship	2L
7. Phaeophyta: general account of morphology, anatomy, reproduction and life histories.	3L
8. Rhodophyta: classification, thallus structure, reproduction, reproductive strategies and Life histories.	3L
Credits - 1.5: Fungi	22L
1. Taxonomy of fungi: Characters of fungi used of classification, various systems of classification of fungi.	2L
2. Chromista – Its present status in classification; general characters, classification up to orders. Lichen: types, morphology and reproduction.	4L
3. Fossil fungi: Occurrence and their significance.	1L
4. An outline of latest classification system proposed by Ainsworth or Alexopoulos	3L
2. Myxomycotina: structure, life cycle patterns of major classes	1L
3. Mastigomycotina: structure, life cycle patterns of major classes.	2L
4. Zygomycotina: structure, thallus organization, evolution of sexual reproductive structures.	2L
5. Ascomycotina: thallus organization, centrum development, different types of ascocarps	3L
6. Basidiomycotina: tissue differentiation, development of basidia and basidiospore	2L
7. Deuteromycotina: types of conidial ontogeny and fruit body organization	2L
Credit -1: Bryophytes	15L
1. Introduction, characteristic features and diversity of Bryophytes, Medicinal, Ecological and economic importance of Bryophytes.	2L
2. Systems of classification of Bryophytes.	1L
3. Distribution, morphological, anatomical, reproductive studies along with comparative account of sporophyte and gametophyte, interrelationships and evolutionary trends of the following orders: (development of sex organs is not included).	
(a) Sphaerocarpaceae	1L
(b) Calobryales, Takakiales	1L
(c) Marchantiales	1L
(d) Jungermanniales	2L

(e) Anthocerotales	1L
(f) Sphagnales	1L
(g) Andraeales	1L
(h) Polytrichales	1L
(i) Buxbaumiales	1L
(j) Funariales	1L
4.Fossil bryophytes	1L

References- Algae:

1. Brodie, J. and Lewis, J. (2007). (Ed.) Unravelling the algae: the past, present and future of algal systematics. CRC press, New York, pp. 335.
2. Bellinger, E. G. and Sigeo, D. C. (2010). Freshwater algae: Identification and use as bioindicators. Wiley-Blackwell, UK, pp. 271.
3. Cole, K. M. and Sheath, R. G. (1990). *Biology of the red algae*. Cambridge University Press. USA, Pp. 503.
4. Desikachary, T.V. (1959). *Cyanophyta*. ICAR, New Delhi.
5. Graham, L. E. and Wilcox, L. W. (2000). *Algae*. Prentice-Hall, Inc. pp. 640.
6. Krishnamurthy, V. (2000). Algae of India & neighbouring countries I. Chlorophycota, Oxford & IBH, New Delhi.
7. Lee, R. E. (2008). *Phycology*. Cambridge University Press, pp. 547.
8. Misra, J. N. (1966). *Phaeophyceae in India*. ICAR, New Delhi.
9. Prescott, G. W. (1969). *The algae: A review*. Nelson, London.
10. Smith, G. M. (1950). The fresh water Algae of the United States, Mc-graw Hill, Newyork.
11. Srinivasan, K. S. (1969) *Phycologia India*. Vol I & Vol II B.S.I. Calcutta.

References – Fungi:

1. Alexopolus, C. J., Minms, C. W. and Blackwell, M. (1999). (4th edn) *Introductory Mycology*. Wiley, New york. Alford, R. A..
2. Deacon, J. W. (2006). *Fungal biology*. (4th Ed.) Blackwell publishing, ISBN. 1405130660.
3. Kendrick, B. (1994). *The fifth kingdom* (paperback), North America, New York, Publisher: 3rd edition, ISBN- 10: 1585100226.
4. Kirk et al., (2001). Dictionary of the fungi, 9th edition, published Wallingford : CABI, ISBN: 085199377X.
5. Mehrotra, R. S. and Aneja, K.R. (1990). *An introduction to mycology*. New age publishers, ISBN 8122400892.
6. Miguel U., Richard, H. and Samuel, A. (2000). Illustrated dictionary of the Mycology, Elvira Aguirre Acosta, Publisher: St. Paul, Minn: APS press, ISBN 0890542570.
7. Webster, J. and Rpland W. (2007). *Introduction to fungi*. (3rd Ed.), Cambridge University Press, 978-0-521-80739-5.

Reference- Bryophytes:

1. Cavers, F. (1976). *The inter relationships of the bryophyte*. S.R. Technic, Ashok Rajpath, Patna.
2. Chopra, R. N. and Kumar, P. K. (1988). *Biology of bryophytes*. John Wiley&Sons, New York, NY.
3. Kashyap, S. R. (1932). *Liverworts of the Western Himalayas and the Panjab plain* (illustrated): Part 2 The Chronica Boanica New Delhi.
4. Kashyap, S. R. (1929). *Liverworts Of The Western Himalayas And The Panjab Plain Part 1* Chronica Botanica New Delhi.
5. Parihar, N. S. (1980). *Bryophytes: An introduction to Embryophyta Vol I*, Bryophya central Book Depot.
6. Prem puri (1981). *Bryophytes: Morphology, Growth and Differentiation*, Atma ram and Sons, New delhi.
7. Udar, R. (1975). *Bryology in India*: Chronica Botanica Co., [c], New Delhi.
8. Udar, R. (1970). *Introduction to bryophyta* Shashidhar Malaviya Prakashan Lucknow
9. Watson, E. V. (1971). *Structure and life of bryophytes 3rd*, Hutchinson University Library London.

BO 1.2 Plant Ecology (3C)

Credit 1	15L
A. Concept and scope of Ecology	
1. Inter disciplinary nature of ecology and relevance to mankind	2L
2. Autecology and synecology	1L
3. Taxonomy as base for ecology	1L
B. Population ecology	
1. Characteristics of population: Distribution and size, factors affecting population size	2L
2. Ecological limits and size of the population	2L
3. Life history strategies, r and K selection, CSR triangle	2L
4. Concept of metapopulation, types and dynamics in metapopulation	2L
5. Extinction events, population viability analysis	3L
Credit 2	15L
A. Community Ecology	
1. Community structure and species diversity: alpha, beta and gamma diversity	2L
2. Ecotone and edge effect	2L
3. Niche, evolution and coevolution	2L
4. Control processes: homeostasis and homeorhesis	2L
B. Community interactions	
1. Plant-plant interaction, Concept of allelopathy, parasitism, dimorphism	3L
2. Species interaction: Mutualism, commensalism, competition, predation, herbivory	2L
3. Community analysis methods	2L
Credit 3	15L
A. Ecosystem ecology	
1. Development of ecosystem: Succession	1L
2. Organization of ecosystem: Biotic and abiotic components	1L
3. Ecosystem types: Natural and artificial	2L
4. Perturbation in ecosystems: Natural and anthropogenic	2L
5. Resistance and resilience in ecosystem	2L
B. Applied Ecology	
1. Sources of pollution (air, water and soil)	2L
2. Pollution monitoring: Physicochemical and biological analysis	2L
3. Environmental impact assessment (EIA) methodology	2L
4. Carbon test plants and carbon sequestration	1L

References

1. Begon, M., Townsend, C. R. and Harper, J. L. (2005). *Ecology: From individuals to Ecosystems* 4th edition, Wiley-Blackwell.
2. Odum, E. P. (2007) *Fundamentals of Ecology*, 5th edition, Thomson books.
3. Coleman, D.C., Crossley, D. A. and Handrix, P. F (2004) *Fundamentals of Soil Ecology*, 2nd edition, Elsevier academic press.
4. Ambhast, R. S. (1998) *A Text Book of Plant Ecology*, 9th edition, Friend and Co.
5. Canter L (1996) *Environmental Impact Assessment*, 2nd Edition, McGraw Hill Publishing Company.
6. Coller, B. D., Cox, G.W. and Miller, P. C. (1973). *Dynamic Ecology*, Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
7. De, A. K. (1994) *Environmental Chemistry*, Wiley Eastern publication.
8. Gurevitch, J., Scheiner, S. M. and Fox, G. A. (2006) *The ecology of plants*, Sinauer Associates.
9. Hynes, H. B. N. (1978) *Biology of polluted water*, 1st edition, Liverpool University Press.
10. Kershaw, K. A. (1978) *Quantitative and Dynamic Plant Ecology*, 2nd edition, Edward Arnold publication.
11. Kumar, H. D. (1981) *Modern concepts of ecology*, (8th edition), Vikas publication.
12. Barbour, M.G., Pits, W.D. and Burk, J. H. (1967) *Terrestrial Plant Ecology*, Addison-Wesley Publisher.
13. Crawley, M., Crawley, J., Crawley, M. (1997) *Plant ecology*, 2nd edition, Wiley-Blackwell.
14. Mishra, R. (1968) *The Ecology Work Book*, Oxford and IBH public. Co., Kolkata.
15. Mukherjee, B. (2000) *Environmental management: Basic and applied aspects of management of ecological environmental system*, 1st edition, Vikas Publication House.
16. Mukherjee, B. (1996) *Environmental Biology*, 1st edition, Tata Mcgraw Hill.
17. Yadav, P. R., and Mishra, S. R. (2004) *Environmental biology*, Discovery publication, New Delhi.

BO 1.3 Genetics and Plant Breeding (3C)

Credit- 1

1. Extensions of Mendelian principles:Codominance, Incomplete dominance, pleiotropy, genomic imprinting, penetrance, expressivity and phenocopy, sex linkage, sex limited and sex influenced characters **3L**
2. Inheritance of complex traits -introduction to complex traits, Polygenic inheritance. Heritability & its measurement **3L**
3. Karyotype analysis:Method, karyotype evolution, applications **1L**
4. Structural alterations of chromosomes:Inversion, translocation, complex translocation heterozygotes, Robertsonian translocations and their genetic implications **3L**
5. Population genetics:Allele frequencies and genotype frequencies, random mating and Hardy-Weinberg principle, Implications of Hardy-Weinberg principle, rate of change in gene frequency through natural selection, mutation, migration and random genetic drift. **5L**

Credit- 2

1. Microbial genetics: mutant phenotypes, Methods of genetic transfers in bacteria: transformation, conjugation and transduction, mapping of bacterial genome by interrupted mating. **3L**
2. Phage genetics: Phage mutants, Lytic and lysogenic cycles in phages, genetic recombination in phages, mapping the bacteriophage genome, Fine structure analysis of *rII* gene in T4 bacteriophage. **4L**
3. Linkage and mapping in eukaryotes: Linkage and crossing over, Recombination: homologous and non-homologous, Linkage maps, lod score for linkage testing, mapping by 3 point test cross, mapping by tetrad analysis in Yeast and *Neurospora*. **8L**

Credit- 3

1. Breeding objectives, Plant Genetic resources:Centers of origin, Importance of genetic diversity in crop improvement and its erosion. **2L**
2. Breeding methods in self, cross pollinated and clonally propagated crops: Self-pollinated crops: Mass selection, Pureline selection, Pedigree selection, Bulk method, Backcross method **3L**
3. Cross pollinated crops: Mass selection, Progeny selection, Recurrent selection **3L**
4. Clonally propagated crops: Clonal selection, Hybridization **2L**
5. Breeding for heterosis **1L**
6. Mutation breeding: Types, Mutagens: Physical and chemical mutagens, Mutant types, Role of mutation in breeding. **2L**
7. Role of polyploidy in plant breeding **2L**

References:

1. Atherly, A.G., Girton, J.R. and McDonald, J. F. (1999) The science of genetics. Saunders College Pub. Fort Worth USA.
2. Burnham, C.R.(1962) Discussions in cytogenetics. Burgess Pub. Co., Minnesota.
3. Hartl, D.L., Jones E.W.(2001). Genetics: Principle and analysis (4th edn) Jones and Barlett Pub., USA.
4. Khush, G S (1973) Cytogenetics of Aneuploids. Academic press New York, London.
5. Lewin, B. Genes VIII. Oxford, University press. New York, USA.
6. Russel, P.J. 1998. Genetics (5th edn). The Benjamin/ Cummins Pub. Co., Inc. USA.
7. Snustad, D.P. and Simmons, M.J. 2000. Principles of genetics (4th edn). John Wiley and Sons, Inc., USA.
8. David Freifelder, Microbial Genetics
9. Strickberger, M.W: Genetics (4th edn). Mcmillan Publishing company, New York.
10. Griffiths, A.J.F and Gilbert, W.M (2nd edn). Modern genetic analysis. W.H. Freeman and Company, New york.
11. Singh, B.D.(2005). Plant breeding: principles and methods. 7th edn.
12. Allard, R.W.(1960), principles of plant breeding. John Wiley and sons, Inc., New York.
13. Chopra, V.L. (2000) Plant breeding: Theory and practice 2nd edn. Oxford & IBH Pub., Co., Ltd. New Delhi.
14. Jain, H.K. and Kharwal, M.C.(2003) Plant breeding: Mendelian to molecular Approaches. Navrosa Publishing House Pvt. Ltd., New Delhi.
15. Mandal, A.K. Ganguli, P.K., Banergee, S.P. 1991. Advances in Plant breeding. Vol 1 and 2, CBS Pub. & distributors.
16. Sharma, J.R. 1994. Principles and practices of plant breeding. Tata Mcgraw Hill. Pub. Co. Ltd. New Delhi.
17. Simmonds, N.W.1979 Principles of crop improvement. Longman, London and New York.

BO 1.4 - Practicals based on BO 1.1 (5C)

Practicals on Algae (Any 8 practicals)

1. Handling of compound microscope and methods to study algae (Use computational Facility attached with microscope for observations) 2P
2. Morphological observations, documentation (description and illustrations) and classification with reasons of taxa belonging to:
 - a. Chlorophyta 3P
 - b. Charophyta 1P
 - c. Phaeophyta 1P
 - d. Rhodophyta 1P
 - e. Cyanophyta 1P
 - f. Minor groups 1P
3. Use of monographs 1P

Practicals on Fungi (Any 8 practicals)

1. Study of the representative genera belonging to Myxomycotina, Mastigomycotina, Zygomycotina, Ascomycotina, Basidiomycotina and Deuteromycotina with respect to observations made based on tissue differentiation, accessory organs, asexual and sexual structures, and fruiting body: Ascocarp/Basidiocarp.
 - Subdivision Myxomycotina: Any five forms 1P
 - Subdivision Mastigomycotina: Any five forms 1P
 - Subdivision Zygomycotina: Any two forms 1P
 - Subdivision Ascomycotina: Any ten forms 1P
 - Subdivision Basidiomycotina: Any ten forms 1P
 - Subdivision Deuteromycotina: Any four forms 1P
 - Lichen: Any three forms 1P
- Preparation of PDA medium and isolation and culture of plant pathogenic fungi 2P
- Study the antimicrobial activity against of *Trichoderma* against fungi. 2P

Practicals on Bryophytes (Any 4 practicals)

- Morphological, anatomical, and reproductive studies of the following members:
1. Marchantiales: *Astrella*, *Plagiochasma*, *Targionia* and *Cyathodium*. 1P
 2. Metzgerineae: *Fossombronia*, *Pallavicinia* 1P
 3. Metzgerineae: *Riccardia* and *Metzaria* 1P
 4. Jungermannie: *Porella*, *Frullania* 1P
 5. Anthocerotales: *Folioceros*, *Phaeoceros*, *Notothylus* 1P
 6. Musci: *Sphagnum*, *Polytrichum*, *Pogonatum*, *Bryum*, *Fissidens* (**any three**)

BO 1.5 Practicals based on BO 1.2 (2C)

Any 8 practicals

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| 1. Finding minimum size of sampling unit for studying specific plant community | 1P |
| 2. Determination of frequency, density, abundance and IVI of the plant community | 1P |
| 3. Determination of species richness, similarity and diversity indices in different plant Communities | 1P |
| 4. Estimation of DO and free CO ₂ | 2P |
| 5. Determination of Palmer's algal index | 1P |
| 6. Study of morphological and anatomical characteristics of plants under pollution stress | 2P |
| 7. Allelopathic analysis of the plants | 2P |

BO 1.6 Practicals based on BO 1.3 (3C)

Any 12 practicals

1. Preparation of stains, Fixatives, preservatives and pretreatments to plant material **1P**
2. Karyotype analysis, preparation of somatic C- metaphase chromosomes of appropriate material using camera lucida drawing and Karyotype analysis in *Allium/ Aloe*. **2P**
3. Study of meiotic configuration In maize/ *Allium*, *Rhoeo/ Aloe*, *Tradescantia* (prophase I, chiasma analysis). **3P**
4. Study of chromosomal aberrations in irradiated plant material **1P**
5. Study of Polygenic inheritance. **1P**
6. Problems of Mendelian inheritance and estimation of gene frequencies and heterozygotic frequencies, population genetics and Linkage. **1P**
7. Neurospora tetrad aanalysis. **1P**
8. Handling of *Drosophilla* for study of mono, dihybrid, and sex linked inheritance **1P**
9. Linear differentiation of chromosomes through banding techniques such as C-Banding, G-Banding and Q-Banding. **2P**
10. Penetrance and expressivity of PTC testing ability in humans and tongue rollers/ non rollers **1P**
11. Floral Biology, study of Pollen Viability, germination in vitro and staining of any two major crops. **1P**
12. Study of monohybrid and dihybrid crosses and interactions. **1P**
13. Study of quality traits in rice, cotton/wheat/soybean/Brassica. **1P**
15. Use of Colchicine for induction of polyploidy in appropriate plant material. **1P**

BO 2.1 Systematics II (Pteridophytes, Gymnosperms): 3C

Credit 1: Pteridophytes

1. Introduction, diversity and importance of pteridophytes 1L
2. Recent systems of classification 1L
3. Telome concept, Soral evolution in Filicales 2L
4. Gametophyte evolution, Heterospory and seed habit, Stellar evolution 1L
5. Study of Fossil groups-
6. Psilopsida salient features of Psilophytes 1L
7. External and internal morphology of *Rhynia* and Lycopsidea salient features of Lepidodendrales. 1L
8. External and internal morphology of *Calamites*, *Annularia*, *Calamostactys*. 1L
9. Pteridosperms salient features of pteridosperms *Lyginopteris*, *Oldhamia*, *Lagenostoma* 2L
10. Comparative account of distribution, morphology, anatomy, gametophyte, sporophyte and interrelationship of following orders– Psilotales, Lycopodiales, Isoetales, Equisetales, Ophioglossales, Maratiales, Osmundales 5L

Credit 2: Pteridophytes and Gymnosperms

1. Alternation of generations of Pteridophytes, Apogamy, Apospory 1L
2. Comparative account of distribution, morphology, anatomy, gametophyte, sporophyte and interrelationship of following orders–Filicales, Marsileaales, Salviniiales 3L
3. Fossil history, geographical distribution, characteristic features, affinities and distinct features with Pteridophytes and Angiosperms 3L
4. Classification systems, economic importance of Gymnosperms 2L
5. Affinities and distinct features of progymnosperms, Pteridospermsles, Cycadeoidales, Cycadales, Caytoniales, Glossopteridales, Pentoxylales, Ginkgoales 4L
6. Comparative account of morphology, anatomy, sporogenesis, gametogenesis, embryology, and interrelationship Cycadales and Ginkgoales 2L

Credit 3: Gymnosperms

1. Introduction to Gymnosperms- Characters, diversity, importance and affinity with Angiosperms and Pteridophytes 3L
2. Comparative account of morphology, anatomy, sporogenesis, gametogenesis, embryology, and interrelationship of Cordiatales and Voltziales 1L
3. Coniferales 4L
4. Taxales 1L
5. Gnetales, Ephedrales and Welwitschiales 3L
6. Seed development in Gymnosperms 2L
7. Economic importance of Gymnosperms 1L

References:

1. Agashe SN (1995) Paleobotany, Oxford and IBH Publ. Co.Pvt. Ltd., New Delhi.
2. Anold AC (2005 Repr.) An Introduction to Paleobotany, Agrobios (India), Jodhpur.
3. Bhatnagar Sp and Motia A (1996) Gymnosperms. New Age International, New Delhi.
4. Biswas C and Johri BM (1997) Gymnosperms. Narso. Pub., New delhi.
5. Chamberlain CJ (1986) Structure and Evolution. CBS Punlishers, New Delhi
6. Eames EJ (1983) Morphology of Vascular Plants. Standard University Press.
7. Johari M, Sneh Lata and Kavita Tyagi (2012) A textbook of Gymnosperm.Dominant Publishers and Distributors, New delhi
8. Rashid A (1999) An introduction to Pteridophyta. Vikas Publishing house Pvt.Ltd. New Delhi.
9. Sharma OP (1990) textbook of Pteridophyta. Mac Millan India Ltd. Delhi.
10. Singh VP (2006) Gymnosperms (Naked seed plants): Structure and development, Sarup and sons, New Delhi.
11. Smith GM (1955) Cryptogamic Botany Vol. II Mc Grew Hill.
12. Sporne KR (1986) The morphology of Pteridophytes. Hutchinson University Press. London.
13. Stewart WN and Rothwell GW (2005) Paleobotany and the Evolution of plants, 2nd Edn. Cambridge University Press.
14. Sundara Rajan S. (1999) Introduction to Pteridophyta. New Age International Publishers, New Delhi.
15. Surange KR (1966) Indian fossil Pteridophytes. Council of Scientific and Industrial research.
16. Parihar NS (1976) Biology and morphology of the Pteridophytes. Central Book Depot.

BO 2.2 Cell Biology (3C)

Credit 1: Cell organelles–functional aspects	15L
1. Cell wall – biogenesis, ultra structure and function. Growth - primary and Secondary Wall	2L
2. Cell membranes - Molecular organization, Fluid mosaic model, membrane protein diffusion, properties of membranes, transport across membranes - facilitated diffusion, carrier & channel proteins, transporters, active transport, transport of ions and solutes	2L
3. Plasmodesmata – Structure and role in movement of molecules, virus transport	1L
4. Vacuoles – Tonoplast membrane biogenesis, transporters, role as storage organelle, transport across vacuolar membrane	1L
5. Endoplasmic reticulum- Role in synthesis and transport of Secretory proteins	2L
6. Golgi complex – Role in sorting, storage and secretion,	1L
7. Lysosomes , Glyoxysomes and Peroxisomes- structure and functions	1L
8. Cytoskeleton – Composition and organization of microtubules, microfilaments. Treadmilling, role in cell division, signalling and intracellular traffic.	2L
9. Nucleus – Structure, organization and regulation of nuclear pore complex. Transport across nuclear membrane.	1L
10. Ribosomes – Structure, assembly and dissociation of subunits, function.	1L
11. Biogenesis of chloroplasts and mitochondria	1L
Credit 2: Signal transduction	15L
1. Signal transduction: Types of receptors, G-proteins and G-protein coupled receptors	4L
2. Phospholipid signalling, Ca ²⁺ -calmodulin cascade, diversity in protein kinases and phosphatases, secondary messengers, regulation of signalling pathways	5L
3. Specific signalling mechanisms with suitable examples – biotic and abiotic stress, ABA induced stomatal closure	4L
4. Nuclear-organelle signaling during plastid development	2L
Credit 3: Cell cycle, aging and cell death	15L
1. Cell Cycle – Phases of Cell Cycle, functional importance of each phase, Molecular events during cell cycle, Check points, Cyclins and protein kinases, MPF (Maturation Promoting Factor), Regulation of cell cycle. Methods to study Cell cycle – labelled mitotic curve, flow cytometry, use of mutants.	10L
2. Senescence, programmed cell death- molecular aspects, regulation of cell death, PCD in response to stress	2L
3. Apoptosis- Role of different genes, cell organelles during apoptosis, genetic control of apoptosis.	3L

Reference Books:

1. Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K. and Watson, J. D. 1989. *Molecular biology of the Cell* (2nd edition). Garland Pub. Inc., New York.
2. Karp, G. 1999. *Cells and Molecular Biology: Concepts & Experiments*. John Wiley and Sons, Inc., USA.
3. Lodish S, Baltimore B, Berk, C and Lawrence K, 1995, *Molecular Cell Biology*, 3rd edn, Scientific American Books, N.Y
4. De Robertis and De Robertis, 1988, *Cell and Molecular Biology*, 8thedn, Info-Med, Hongkong
5. Buchanan, Grissem and Jones, 2000, *Biochemistry and Molecular Biology of Plants*, American Soc. Plant Biologists, Waldorf
6. Lewin, B. 2000. *GENE VII*. OxfordUniversityPress, New York, USA
7. Cooper G M and Hausman R E, 2007, *The Cell: Molecular Approach* 4thEdn, Sinauer Associates, USA

BO 2.3 - Molecular Biology (4C)

Credit 1: DNA	15L
1. DNA structure – types of base pairing, unusual structures, topology	2L
2. Melting and reassociation of DNA, Cot curves and kinetic complexity of DNA. Organization of genomes (from whole genome sequences), repetitive and unique sequences, C value paradox, gene duplication and divergence. Number of genes, exons. Rot curves and gene expression	3L
4. Packaging of genomes in viruses, bacteria, organelles and nuclei. Structure of chromatin, nucleosome positioning. Histone modifications. Chromosome organization, centromeres, telomeres, specialized chromosomes	3L
5. Initiation, elongation and termination of DNA replication, molecular machinery of DNA replication in prokaryotes and eukaryotes.	3L
5. DNA damage and repair.	2L
6. Molecular mechanism of recombination and transposition	2L
Credit 2: RNA	15L
1. RNA structure – modified bases, pairing, secondary structure	2L
2. Transcription units, RNA polymerases, initiation, elongation and termination of transcription in prokaryotes and eukaryotes, proof reading	5L
3. RNA processing – Processing of tRNA, rRNA and mRNA. mRNA localisation	5L
4. Non-coding RNAs, ribozymes and riboswitches	3L
Credit 3: Proteins	15L
1. Protein synthesis – tRNA charging, ribosomal organisation. Initiation, elongation and termination of protein synthesis in prokaryotes and eukaryotes. Antibiotics used in inhibition of protein synthesis. Proof reading	5L
3. Post-translational processing of proteins, protein modifications. Chaperones and protein folding.	3L
3. Proteases. Ubiquitination and degradation of proteins by proteasomes.	2L
4. Targeting of organelle and secretory proteins. Localisation of membrane proteins.	3L
5. Seed-storage proteins and their genes in cereals and legumes.	2L
Credit 4: Regulation of gene expression	15L
1. Regulation of transcription - Operons, repressors and inducers, positive and negative control, regulation of lytic and lysogenic cycles in phages.	4L
2. Transcription factors in eukaryotes, response elements. Post-transcriptional regulation.	4L
3. Regulation of gene expression at higher levels of genome organization, chromatin remodeling, locus control regions, enhancers and insulators	4L
4. Regulation of protein synthesis, post-translational regulation, regulation of protein function	3L

Reference books:

1. Genes IX– Benjamin Lewin, Jones and Bartlett, 2008
2. Genes X– Benjamin Lewin, Jones and Bartlett, 2011
3. Molecular Biology of the Cell – Alberts, B, Bray, D, Raff, M, Roberts, K and Watson JD, Garland Publishers, 1999
4. Principles of Biochemistry – Lehninger, W.H. Freeman and Company, 2005

BO 2.4 Plant Physiology & Biochemistry (3C)

Credit 1	15L
1. Structure and properties of water: Biological significance. Ionization of water, pH, buffers	1L
2. Bioenergetics: Free energy, changes in free energy during chemical reactions, entropy and enthalpy, high energy compounds, synthesis of ATP, activation energy	1L
3. Enzymology: Classification and properties of enzymes, Isoenzymes, coenzymes and cofactors, coupled reactions, units of enzyme activity. Enzymekinetiks–substrate concentration and rate; Competitive and noncompetitive inhibitors. Covalent and allosteric regulation	3L
4. Building blocks of biological macromolecules: Biosynthesis and metabolism of amino acids, carbohydrates, fatty acids and lipids, purine and pyrimidine bases	3L
5. Mineral nutrition of plants: Cation-anion exchange capacity of soil, types of ion transporters, passive and active transport, primary and secondary active transport, Role of membrane potential in ion transport, high and low affinity transporters.	4L
6. Nitrogen: Uptake, assimilation and remobilization of nitrogen in plants, Biological nitrogen fixation by free living and symbiotic organisms, mechanism of nitrogen fixation.	4L
7. Phloem structure and function: Source and sink relationship, translocation of photoassimilates through phloem, phloem loading and unloading, composition of phloem sap.	4L
Credit 2	15L
1. Water uptake, transport and transpiration, Stomatal physiology, mechanism and regulation of guard cell	2L
2. Photosynthesis – Photosynthetic pigments, organization of photosynthetic electron transport system in thylakoid membranes. Charge separation and electron transport, fluorescence and photochemistry, oxygen evolution, NAPD reduction, photophosphorylation.	4L
3. Reduction of carbon dioxide - RuBPCase and Calvin cycle, photorespiration. CO ₂	
4. concentrating mechanisms in C ₄ and CAM plants.	4L
5. Respiration – Glycolysis, citric acid cycle, pentose phosphate pathway. Organization of mitochondrial electron transport system, ATP synthesis. Respiratory control, Anaerobic respiration	5L
Credit 3	15L
1. Plant growth hormones – Structure, biosynthesis and metabolism of auxins, cytokinins, gibberellins, abscisic acid and ethylene. Physiological role of hormones	8L
2. Photoperiodism and vernalization. Tropic and nastic movements in plants	3L
3. Secondary metabolites: Terpenoids, phenolics, alkaloids. Major secondary metabolite synthesis pathways in plants. Role of secondary metabolites	4L

Reference books:

1. Berg J.M., Tymoczko J.L., Stryer L. (2002) Biochemistry. 5th Ed. Wlt. Freeman and Company, New York.
2. Buchanan B.B., Gruissem W., Jones R.L. (2000) Biochemistry and Molecular Biology of Plants. IK International, Mumbai.
3. Davis P. J. (Eds.).(2004) Plant Hormones. Kluwer Academic Publishers, Dordrecht, Netherlands.
4. Goodwin T.W., Mercer E.I. (1998) Introduction to Biochemistry. CBS Publishers, New Delhi.
4. Heldt H. W. (2004) Plant Biochemistry. Academic Press, California.
5. Lawlor D.W. (2001) Photosynthesis in C3 and C4 Pathway.3rd Ed. Viva. New Delhi.
6. Nelson David and Cox Michael. (2007) Lehninger Principles of Biochemistry.W.H.Freeman and Company. New York.
7. Lincoln Taiz and Eduardo Zeiger (2010) Plant Physiology, 5th edition. Sinauer Associates, Inc. Publishers. Sunder land, USA.

BO 2.5 Practical's on BO2.1 (2C)

Pteridophytes (Any 4 Practicals)

Morphological and/or anatomical and/or reproductive studies of the following members with the help of live material/or herbarium specimens and/or museum specimens and/or permanent slides of the following orders: (any 8 orders)

4P

1. Psilotales: *Psilotum*, *Tmesipteris*
2. Lycopodiales: *Lycopodium*
3. Selaginellales: *Selaginella*
4. Isoetales: *Isoetes*
5. *Equisetales: Equisetum*
6. Ophioglossales: *Ophioglossum*, *Botrychium*, *Helminthostachys*, *Marattiales*, *Angiopteris*
7. Osmundales: *Osmunda*
8. Filicales: *Anemia*, *Lygodium*, *Gleichenia*, *Ceratium*, *Goniopteris*, *Phymotodes*, *Pteris*, *Acrostichum*, *Blechnum*, *Platyserum*, *Pteridium*, *Pleopeltis*, *Cheilanthes*, *Ceratopteris*, *Athyrium*, *Adiantum*.
9. Salviniiales: *Salvinia*, *Azolla*
10. Marsileales: *Marsilea*

Study of available fossil of Pteridophytes

1P

Field visit for the study of Pteridophytes biology.

1P

Gymnosperm (Any 4 Practicals)

1. Double staining technique and permanent slide preparation
2. Study of available fossils- At least 10 specimen
3. Morphological and/or anatomical and/or reproductive studies of the following members with the help of live material/or herbarium specimens and/or museum specimens and/or permanent slides of the following orders: (any 4 orders)
4. Field visit for the study of Gymnosperms biology.
5. Methods of turpentine and oleo resin extraction from the pine tree (Demonstration with the help of samples)

1P

1P

4P

i) Cycadales- *Cycas*, *Zamia*, *Ceratozamia*, *Encephalartos*

ii) *Coniferales*

iii) *Taxales*

iv) *Ginkgoales*

v) *Gnetales*

1P

1P

BO 2.6 practicals based on BO 2.2 & BO 2.3 (4C)

Cell Biology (Any 8 Practicals)

1. Differential centrifugation for isolation of cell fractions – Nuclear fraction **1P**
2. Isolation of chloroplasts to study: **2P**
 - a. Hill reaction to measure intactness,
 - b. measurement of size of chloroplasts using micrometry and chlorophyll estimation
3. Isolation of mitochondria and **2P**
 - a. Estimation of succinic dehydrogenase activity
 - b. Microscopic observations using MitoTracker Green FM/ MitoTracker Red 580/ Janus green B
4. Isolation of lysosomal fraction and estimation of acid phosphatase activity **1P**
5. Study of electron micrographs of cell organelles **1P**
6. Study of cell cycle using BrdU (demonstration) **1P**
7. Isolation of protoplasts and viability staining to determine % viability. **1P**
8. Study of metaphase nucleus: Localization of euchromatin and heterochromatin **1P**
9. Cytochemical studies of special cell types- guard cells, senescent cells, bundle sheath cells, meristematic cells, laticiferous cells, glandular cells, pollen grains **2P**
10. Study of induced cell senescence in leaf discs **1P**
11. Study of programmed cell death in plants **1P**
12. Ouchterlony immunodiffusion technique for testing specificity of antigens and Antibodies **1P**
13. To study plasmodesmatal connections in plant cells **1P**
14. Determination of permeability of living cells to acids and bases **1P**

Molecular Biology (Any 8 Practicals)

1. Isolation of plasmid DNA and quantification **2P**
2. Electrophoretic separation of plasmid isoforms **1P**
3. Restriction digestion of plasmid DNA, electrophoresis and molecular weight determination of DNA fragments. **2P**
4. Isolation of plant genomic DNA and quantification **2P**
5. Effect of temperature and alkali on absorbance of DNA – hyperchromicity **1P**
6. Separation of seed-storage proteins from leguminous seed and quantitation of each fraction
7. SDS-PAGE separation of seed storage proteins from legumes. Determination of molecular sizes of the globulin subunits. **3P**

BO 2.7 Practicals based on BO 2.4 (2C)

Any 08 Practicals

1. Estimation of soluble proteins in germinating and non-germinating seeds by Lowry/Bradford's method **2P**
2. Estimation of total amino acids in germinating and non-germinating seeds **1P**
3. Estimation of ascorbic acid in ripe and unripe fruits **1P**
4. Bioassay of Cytokinin concentration using test system of greening of cotyledons **2P**
5. Studies on induction of amylase activity by GA₃ in germinating cereal grains **2P**
6. Measurement of respiration and photosynthetic rates using oxygen electrode (demonstration) **1P**
7. Measurement of CO₂ uptake using IRGA (Demonstration) **1P**
8. Assay of Nitrate reductase activity **2P**
9. Assay of PEPcase activity in a C₃ and C₄ plants **2P**
10. Assay of invertase activity **1P**
11. Effect of substrate concentration and pH on enzyme activity. **2P**
12. Separation and measurement of flavonoids using chromatography **2P**
13. Separation and measurement of Anthocyanins from flowers of different stage of maturation. **1P**

BO 3.1 - Taxonomy of Angiosperms (3C)

Credit -1	15L
1. Aims, principles and practices in taxonomy. Botanical Nomenclature: Brief history, Scientific names, ICN, Principles, typification, Principle of priority, effective and Valid publication, rank of taxa.	4L
2. Tools of taxonomy: Floras, monographs, revisions, websites. Herbarium and Botanical gardens, their role in teaching, research and conservation, important herbaria and botanic gardens of the World. Botanical Survey of India.	3L
3. Floristics: Need and significance. History of botanical exploration in India and Recent works with special emphasis on Maharashtra. Botanical Survey of India.	3L
4. Morphological features used in identification. Artificial dichotomous keys	3L
5. Importance and need for classification Biodiversity, types, importance and methods of conservation. Hierarchical classification. Criteria used for classification: phases of plant classification.	2L
Credit -2	15L
1. Overview on pre- and post-Darwinian systems of classification.	1L
2. Artificial systems of classification - Herbalists, Theophrastus, Linnaeus	1L
3. Natural system of classification - Bentham and Hooker	1L
4. Phylogenetic systems of classification - Cronquist, Takhtajan	2L
5. APG system of classification, contributors, APweb	3L
6. Origin and evolution of agriculture: Introduction, food crops, centers of plant domestication of major crops, crop dispersal and distribution.	2L
7. Plant domestication: Introduction, Evolution of farming, Plant domestication, origin of crops, Changes during domestication, genetic regulation of domestication syndromes, evolution of weeds, genetic diversity and domestication. Centers and threats to diversity.	3L
8. Crop plants and their wild relatives: Cereal grains, legumes, starch plants, fruits, vegetables, fibers, cordage, medicinal plants, poisonous plants.	2L
Credit - 3	15L
Major clades in APG-IV: characteristic features, interrelationships, classification (APG-IV) and economic importance of families of angiosperms in following clades: ANAGRADE: Amborellaceae, Nymphaeaceae, Hydatellaceae; MAGNOLIIDS: Magnoliaceae.	4L
MONOCOTS: Araceae; COMMELINOIDS: Arecaceae;	4L
PROBABLE SISTER OF EUDICOTS: Ceratophyllaceae;	
EUDICOTS: Ranunculaceae;	
CORE EUDICOTS: Amaranthaceae;	
EUROSIDS-I: Leguminosae;	
EUROSID-II: Malvaceae;	
ASTERIDS: Santalaceae;	
EUASTERIDS-I: Apocynaceae,	
EUASTERID-II: Asteraceae.	7L

Reference Books:

1. Briggs, David. 2009. Plant microevolution and Conservation in Human-influenced Ecosystems. Cambridge University Press.
2. Cooke, T. 1903-1908. The Flora of Presidency of Bombay, Vol. I-III.
3. Cronquist, A. 1981. An Integrated System of Classification of Flowering Plants. Columbia University Press, New York.
4. Cronquist, A. 1988. The Evolution and Classification of Flowering Plants (2nd ed.) Allen Press, U.S.A.
5. Hickey, M. and King, C. 2000. The Cambridge Illustrated Glossary of Botanical Terms. Cambridge University Press, UK.
6. Hutchinson, J. 1959. Families of Flowering plants. Clarendon Press, Oxford.
7. Jain S.K. and Rao R.R. 1976. Handbook of Field and Herbarium Methods, Today and Tomorrow Publishers, New Delhi.
8. Jones, S. B. and Luchinger A.E. 1986. Plant Systematics 2nd edn, McGraw Hill Book Co.
9. Judd Walter S., Campbell, C. S., Kellogg, E. A., Stevens, P.F. and M. J. Donoghue. 2008. Plant Systematics- A Phylogenetic Approach. Sinauer Associates, INC, Publishers. Sunderland, Massachusetts, USA.
10. Kubitzki, K. 1977. Flowering Plants Evolution and Classification of Higher Categories. Plant Systematics – Evolution Supplement I.
11. Kuijt J. 1969. The biology of parasitic flowering plants. California University Press.
12. Lawrence, G. H. M. 1951. Taxonomy of Vascular Plants. Oxford and IBH Publ. Co. Pvt. Ltd. New Delhi.
13. Mabberly, T. J. 2009. The Plant Book 2nd edn Cambridge University Press, Cambridge.
14. Manilal, K. S. and M. S. Muktesh Kumar [ed.] 1998. A Handbook of Taxonomic Training. DST, New Delhi.
15. Naik, V. N. 1984. Taxonomy of Angiosperms. Tata McGraw-Hill, New Delhi.
16. Nair, P.K.K. 1966. Pollen morphology of Angiosperms. Periodical Expert Book Agency, New Delhi.
17. Paech, K. and M.V. Tracey. 1956. Modern Methods of Plant Analysis. Vol-I & II. Springer-Verlag.
18. Quicke, Donald L. J. 1993. Principles and Techniques of Contemporary Taxonomy. Blakie Academic & Professional, London.
19. Radford A.E. 1986. Fundamentals of Plant Systematics, Harper and Row N Y.
20. Sharma A.K. and A. Sharma. 1980. Chromosome Technique: Theory and Practices (3rd ed.) Butterworths, London.
21. Shivanna, K.R. and N.S. Rangaswamy. 1992. Pollen Biology- A Laboratory Manual. Springer-Verlag.
22. Simpson, M.G. 2010. Plant Systematics. Elsevier, Amsterdam.
23. Singh, Gurcharan. 2010. Plant Systematics: An Integrated approach.. 3rd edition. Science Publishers Inc., New Hampshire, USA.
24. Singh, Gurcharan. 2012. Plant Systematics: Theory and Practice. Completely revised and enlarged 3rd edition. Oxford & IBH, New Delhi.
25. Sivarajan, V.V. 1984. Introduction to Principles of Plant Taxonomy, Oxford and IBH, New Delhi.
26. Smith, P. M. 1976. The Chemotaxonomy of Plants, Edward Arnold Pub. Ltd.

27. Sporne, K. R. 1974. Morphology of Angiosperms, Hutchinson University Library, London.
28. Stace, C. A. 1989. Plant Taxonomy and Biosystematics. Edward Arnold, London.
29. Stewart, W. N. and Rothwell, G. W. 2005. Paleobotany and the Evolution of Plants, 2nd edn, Cambridge University Press.
30. Stuessy, Tod F. 2009. Plant Taxonomy: The Systematic Evaluation of Comparative Data, second edition. Columbia University Press.
31. Takhtajan, A. 1969. Flowering plants-Origin and Dispersal. Oliver and Boyd, Edinburg.
32. Taylor, D.V. and L.J. Hickey 1997. Flowering Plants: Origin, Evolution and Phylogeny. CBS Publishers & Distributers, New Delhi.

BO 3.2 – Plant Development (3C)

Credit 1 – Vegetative development	15L
1. Processes basic to plant development	2L
a. Competence, determination, commitment, specification, induction, differentiation, dedifferentiation and redifferentiation.	
b. Morphogenetic gradients, cell fate and cell lineages.	
c. Polarity and symmetry.	
d. Juvenility and transition to adult phase.	
2. Vegetative development –	
a. Meristem types and activities of meristems. Organization of shoot and root apical meristems. Regulation of meristem size, lateral organ initiation from root and shoot meristems.	2L
b. Leaf development, plastochron, phyllotaxy, development of trichomes and stomata.	2L
c. Vascular elements – differentiation of xylem, phloem.	1L
d. Secondary growth – cambium, gross structure of wood.	1L
e. Secretory tissues – Nectaries, laticifers, resin ducts.	1L
f. Molecular genetics of root, shoot and leaf development.	5L
g. Transition from vegetative to reproductive phase – induction, morphological and histochemical changes in shoot apex, floral meristems.	1L
Credit 2 – Reproductive development	15L
1. Transition to flowering and flower development: Molecular Basis-ABC & ABCE Model.	3L
2. Development of stamen, anther, sporogenous tissue, tapetum, microsporogenesis, types of pollen tetrads, pollen and male gametophyte.	2L
3. Development of carpel, placenta, ovule, integuments, sporogenous tissue, megaspore, female gametophyte.	2L
4. Molecular basis of male and female gametophyte development.	2L
5. Interaction between pollen & pistil, pollen tube guidance, self-incompatibility, Double fertilization and triple fusion, role of synergids, endosperm development and imprinting.	3L
6. Fruit development, structure of seed, germination, and germination mutants.	1L
7. Stages of embryogenesis, structure and organization of embryo, suspensor, Embryogenesis mutants, establishment of body plan.	2L
Credit 3 - Intrinsic and extrinsic factors regulating plant development	15L
1. Light mediated regulation	
a. Photoreceptors- phytochromes, cryptochromes, phototropins.	2L
b. Signal transduction leading to photo morphogenesis and photoperiodic responses.	3L
c. Circadian rhythms	2L
2. Hormonal regulation.	
a. Perception, signaling and regulation of gene expression by hormones, hormone receptors, mutants in hormone signaling, transcription factors	

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| involved in hormone signaling. | 4L |
| b. Role of hormones in germination, growth and flowering. Cross-talk between hormone signaling pathways | 3L |
| 3. Regulation of development by metabolites (sugars, nitrogen status) | 1L |

References:-

1. The Arabidopsis Book. (www.arabidopsisbook.org)
2. Bhojwani S. S., Dantu P. K. and Bhatnagar S. P. (2014). The Embryology of Angiosperms. (6th Edition) Vikas Pub. House. Paperback edition.
3. Bhojwani S.S. and Soh W.Y. (2001). Current Trends in Embryology of Angiosperms, Kluwer Academic Publishers.
4. Buchanan B. B., Gruissem W. and Jones R. L. (2015) Biochemistry and Molecular Biology of Plants. Second Edition. Wiley Blackwell.
5. Burgess J. (1985) An Introduction to Plant Cell Development. Cambridge University Press.
6. Davies P. J. (Editor) (2004) Plant Hormones. Biosynthesis, Signal Transduction, Action Springer Publications.
7. Fahn A. (1990) Plant Anatomy (4th Edition) Pergamon Press, London, New York.
8. Gilbert S. F. (2013). Developmental Biology (10th Edition). Sinauer Associates, Inc., Massachusetts, USA.
9. Graham C.F. and Wareing P.F. (1984). Developmental Control in Animals and Plants. Blackwell Scientific Publications, UK.
10. Johri B. M. and Srivastava P. S. (2001). Reproductive Biology of Plants. Narosa Publishing House, New Delhi.
11. Jones R., Ougham H., Thomas H. and Waaland S. (2013) The Molecular Life of Plants. Wiley Blackwell.
12. Krishnamurthy K.V. (1988) Methods in Plant Histochemistry. S. Viswanathan Printers & Publishers.
13. Lyndon R.F. (1990) Plant Development The Cellular Basis. (Topics in Plant Physiology, Vol. 3) Springer Publications.
14. Leyser O. and Day S. (2009) Mechanisms in Plant Development. Wiley Blackwell.
15. Raghavan V. (2000) Developmental Biology of Flowering Plants. Springer Verlag.
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18. Wareing P. F. and Philips I. D. J. (1981) Growth and Differentiation in plants. Pergamon Press
19. Wolpert L., Tickle C. and Arias A. M. (2015) Principles of Development. (5th Edition) Oxford University Press.

BO 3.3: Tools and Techniques in Botany (3C)

Credit 1 **15L**

1. Microtomy: Principle of tissue fixation for microtomy, types of microtome, serial sectioning and staining. **3L**
2. Radioactive techniques: Isotopes and their half-life and biological half life, Specific activity of radioisotopes, making radioisotope solutions, detection and measurement of radioactivity - radiation counters, liquid scintillation counters, autoradiography. **4L**
3. Electrochemical techniques: Construction and working of equipments for measurement of electrical conductivity, pH meter. **2L**
4. Measurement of water potential and osmolarity: Osmolarity equation, Osmolarity and osmotic pressure measurement, types of osmometers. Construction and working of osmometers. **2L**
5. Gas exchange measurements: Types, Construction and working of Infra- red gas analyzer, O₂ electrode. **2L**
6. Centrifugation techniques: High speed centrifuges, rotors, ultracentrifugation, density gradient centrifugation. **2L**

Credit 2

1. Spectroscopic techniques: UV-visible and IR spectrophotometry, spectrofluorimetry, NMR and ESR spectroscopy, circular dichroism, atomic absorption and mass spectrometry, MALDI-TOF. **8L**
2. Microscopy and microscopic techniques: Light, phase contrast, fluorescence, electron, confocal microscopy, micrometry. **7L**

Credit 3

1. Chromatographic techniques: Paper, thin layer and column chromatography, gel filtration, ion exchange and affinity chromatography, high pressure liquid chromatography, gas chromatography. **5L**
2. Immunological techniques: Immune response. Antibodies and their specificity, antigen-antibody interactions, immunodiffusion and immunoelectrophoresis techniques, immunoassays, Western blotting **5L**
3. Electrophoretic techniques: Supports, electroendosmosis, electrophoresis under native and denaturing conditions, 2-D electrophoresis, staining, activity staining. **5L**

References:

1. David L. Nelson, Michael M. Cox Lehninger (2013) Principles of Biochemistry; W. H. Freeman 6th edition edition.
2. David M Freifelder (1983) Physical Biochemistry: Applications to Biochemistry and Molecular Biology (Life Sciences/Biochemistry), W. H. Freeman; 2nd Revised edition.
3. Jeremy M. Berg, John L. Tymoczko, Lubert Stryer Biochemistry, W. H. Freeman (2011) 7th edition edition.
4. Keith Wilson, John Walker, (2010) "Practical Biochemistry Principles and Techniques" Cambridge University Press

5. S. M. Khasim, (2002) "Botanical Microtechnique: Principles and Practice". Capital Publishing Company.
6. Thomas J. Kindt, Barbara A. Osborne and Richard Goldsby(2006) "Kuby Immunology" W. H. Freeman; 6th edition
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8. Jerom Mertz, (2009) "Introduction to Optical Microscopy" Roberts & Company Publishers; 1st edition
9. Jill Clark, (2015) "Gel Electrophoresis: Basic Concepts and Principles" Callisto Reference; 2nd edition

BO 3.4a: Algology - I (3C)

Credit 1	15L
1. Tools in algal systematics, Problems in the identification of algal species	1L
2. Blue-green algae: Botanical and Bacteriological approaches, Komárek's contribution, traditional and modern (biochemical, molecular) trends used in classification.	4L
3. Green algae: Morphological concept, ultrastructural concept-flagella; chloroplast, pyrenoid, eye spot, mitosis and cytokinesis, major green algal lineages	5L
4. Charophyte evolution and origin of land plants	2L
5. Brown algae: Ultrastructure, environmental factors in the life histories, Phlorotannins and physodes, modern trends in classification	3L
Credit 2	15L
1. Brief overview of modern criteria in the taxonomy and phylogeny of Xanthophyceae, Eustigmatophyceae, Bacillariophyceae, Dinophyceae and Euglenophyceae	5L
2. Red algae: Development of primary and secondary pit connections, ultrastructure of pit plugs, sites of meiosis, structural and molecular evidences for red algal relationships	3L
3. Phytoplankton ecology: Introduction, Classification based on size and habitats, Physical and chemical environments, Sampling methods, Primary productivity, Nutrient uptake models (Michaelis - Menten and Monod, Droop models)	6L
4. Databases and On-line information resources for the study of algae	1L
Credit 3	15L
1. Algae in extreme environments, Survival mechanisms in extremophilic algae	3L
2. Algal adaptation to nutrients (Carbon, Nitrogen and Phosphate)	2L
3. Cyanobacterial symbioses with fungi forming lichen, and other plants (Bryophytes, <i>Azolla</i> , Cycads and <i>Gunnera</i>), Cellular responses in host-symbionts, Nitrogen-fixation in cyanobacteria.	3L
4. Algae in marine environment: Physico-chemical properties, Intertidal seaweeds, zonation patterns and factors affecting distribution of intertidal seaweeds	3L
5. Remote sensing strategy for the study of algal monitoring, Carbon sequestration by algae, Algae as bioindicators, Bioluminescent algae	4L

References

1. Bellinger, E. G. and Sigeo, D. C. (2015). Freshwater algae: Identification, enumeration and use as bioindicators. Wiley Blackwell, pp. 275.
2. Bhattacharya, D. (ed.) (1997). Origins of algae and their plastids, Plant systematics and evolution supplement 11. Springer-Verlag Wien, pp. 287.
3. Brodie, J. and Lewis, J. (2007). Unravelling the algae: the past, present, and future of algal systematics. CRC Press, Boca Raton, pp. 376.
4. Graham, L. E. and Wilcox, L. W. (2000). Algae. Prentice Hall, Inc., NJ, pp. 640.
5. Hoek, C. Van Den, Mann, D. G. and Jahns, H. M. (2009). Algae: An introduction to Phycology. Cambridge University Press, New Delhi, pp. 623.

6. Lee, R. E. (2008). *Phycology*. Cambridge University Press, Cambridge, pp. 547.
7. Lobban, C. S. and Harrison, P. J. (1997). *Seaweed ecology and physiology*. Cambridge University Press, Cambridge, pp. 366.
8. Pal, R. and Choudhury, A. K. (2014). *An introduction to phytoplanktons: Diversity and ecology*. Springer, India, pp. 167.
9. Pawlowski, K. (ed.) (2009). *Prokaryotic symbionts in plants –Microbiology Monographs, Volume 8*. Springer-Verlag Berlin Heidelberg, pp. 306.
10. Pereira, L. and Neto, J. M. (eds.) (2015). *Marine algae: Biodiversity, Taxonomy, Environmental Assessment, and Biotechnology*. CRC Press Boca Raton, pp. 390.
11. Round, F. E. (1984). *The Ecology of Algae*. Cambridge University Press, pp. 653.

BO 3.4b: Advanced Mycology - I (3C)

Credit: 1-Fungal systematics	15L
1. Systematic, origin, evolution and phylogeny of fungi: Natural and molecular method of fungal systematics.	3L
2. Overview of A higher – level phylogenetic classification of fungi (Kirk 2008 and Hibbett et al., 2007)	1L
3. Fungal systematics: Kingdom- Fungi Phylum: Chytridiomycota, Class: Chytridiomycetes, Class: Monoblepharidomycetes Order: Monoblepharidales	4L
4. Phylum: Blastocladiomycota Class: Blastocladiomycetes,	2L
5. Phylum: Neocallimastigomycota Class: Neocallimastigomycetes,	2L
6. Phylum: Glomeromycota Class: Glomeromycetes,	3L
 Credit: 2- Fungal systematics	15L
1. Fungal systematic: Kingdom fungi: Phylum: Microsporidia	1L
2. Sub-Phylum: Mucoromycotina,	2L
3. Sub-phylum: Entomophthoromycotina,	1L
4. Sub-Phylum: Zoopagomycotina	2L
5. Sub-Phylum: Kickxellomycotina	2L
6. Fungal systematic: Kingdom fungi: Subkingdom - Dikarya: Ascomycota- Subphylum: Taphrinomycotina, Saccharomycotina, Pezizomycotina.	7L
 Credit: 3- Fungi in Bioremediation	15L
1. Nutritional modes of fungi-saprotrophs, biotrophs and necrotrophs; role of fungi in ecosystem.	5L
2. Biodegradation of waste – Solid and liquid waste management through fungi.	5L
3. Application of fungi in biodegradation.	5L

BO 3.4c: Angiosperms Systematics - I (3C)

Credit 1	15L
1. Definitions and concepts, importance of taxonomy, Alpha and Omega taxonomy, taxonomy as synthetic discipline. Charles Darwin, Neo-Darwinism. The evolutionary theory by Darwin and Wallace. Overview of Post Darwinian Classifications	2L
2. Apomorphies of Angiosperms: Flower, Stamens, Reduced male and female gametophyte, Carpel, double Integuments, Endosperm formation, Sieve tube members, Vessels etc.	5L
3. Taxonomic Hierarchy: Ranks of taxa; major categories: division, class, order, family; minor categories: genus, species and intraspecific categories.	3L
4. Systematics: overview. sources of data for systematics: Morphology, Anatomy, Embryology, Palynology, Biochemistry, Micromorphology, Karyology, protein and DNA sequences	5L
Credit 2	15L
1. Species concepts. Causes of variations in population.	2L
2. Plant speciation, Isolation mechanisms.	3L
3. Plant geography, ecology and systematics: Patterns of geographic distribution, Disjunction and Vicariance, Biogeography, Endemism, Hotspots, Centres of diversity, Ecological differentiation, Alien plants, Phenotypic plasticity.	4L
4. Species diversity: Species Richness, Species Abundance. Spatial Patterns of Species Diversity.	6L
Credit 3	15L
1. Morphological variations, systematic position, interrelationships, phylogeny and economic importance of following families: ANAGRADE- Hydatellaceae; MAGNOLIIDS- Lauraceae, Piperaceae, Aristolochiaceae; MONOCOTS- Hydrocharitaceae, Potamogetonaceae; COMMELINIDS- Commelinaceae, Typhaceae, Eriocaulaceae, Zingiberaceae, Costaceae, Musaceae. EUDICOTS- Menispermaceae, Ranunculaceae, Nelumbonaceae; CORE EUDICOTS- Nyctaginaceae, Portulacaceae, Polygonaceae, Loranthaceae, Santalaceae; ROSIDS- Vitaceae, Zygophyllaceae, Oxalidaceae, Euphorbiaceae, Phyllanthaceae, Rhizophoraceae, Passifloraceae, Polygalaceae.	

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BO 3.4d: Plant Ecology - I (3C)

Credit 1: Behavioural Ecology	15L
1. Mimicry in plants, types and mechanisms of mimicry	3L
2. Invasive species, epiphytic and parasitic nature of plants	3L
3. Saprophytic plants, mechanism of saprophytic nutrition	3L
4. Plant-insect-predator interaction: Plants responses to oviposition, attraction of predators	3L
5. Chemical ecology of Plant-animal interaction	3L
Credit 2: Natural resources and management	15L
1. Types of natural resource: Forest, minerals, water, soil, energy etc.	2L
2. Forest resources: Types of vegetation and floristic composition	2L
3. Types of forest w. r. t. climatic and edaphic factors	1L
4. Role of forest: productive, protective, regulatory, economic and social, Aesthetic	2L
5. Deforestation: Causes and impacts, forest policy:	2L
6. Water Resources: Types of water resources, surface, ground water and marine water	2L
7. Assessment of water quality:	1L
8. River ecosystems and conflicts	1L
9. Intertidal ecology: Mangrove	1L
10. Watershed: planning and management	1L
Credit 3: Conservation Biology	15L
1. <i>In situ</i> and <i>ex situ</i> conservation strategies, Sacred groves: Aims and objectives	3L
2. IUCN Categories	2L
3. Phytogeography and Endemism	2L
4. Environmental legislation in India	2L
5. Various conventions and their protection and conservation: Reviews of various national and international obligations in the environmental protection such as CITIES, RAMSAR, Montreal, Basal, CBD etc.	4L
6. Kyoto protocol, CDM, Carbon sequestration	2L

BO 3.4e: Plant Physiology - I (3C)

Credit 1: Water relations, mineral nutrition and crop physiology	15L
1. Forces involved in water uptake and transpiration, stomatal physiology, hydraulic conductance, regulation of Aquaporins.	2L
2. Energizing transporters, role of ATPases and PPases, role of chelators in mineral uptake and transport. Low and high affinity transporters. Mechanism of uptake and transport of Potassium, Calcium, Magnesium, Iron, Zinc, Copper, Sulphur. Hydroponic media and applications.	5L
3. Evolution of biological nitrogen fixation, regulation of nitrogen fixation.	2L
4. Crop growth - Relative growth rate, Leaf area index and net assimilation rate	2L
5. Allocation of resources to storage organs, fruits and seeds (endosperm, cotyledons) Source –sink relations. Harvest Index	2L
6. Factors affecting phenology and yield	1L
7. Water use efficiency and nitrogen use efficiency of crop plants.	1L
Credit 2: Photosynthesis	15L
1. Chlorophyll fluorescence kinetics and determination of PSI, PSII efficiency. Photosynthesis measurements. Light saturation curves, CO ₂ response curves and CO ₂ compensation point. Canopy photosynthesis, Carbon sequestration by plants	4L
2. Photoinhibition and protection mechanisms. Water-water cycle, photorespiration	3L
3. Evolution and diversity of photosynthetic systems. Bacterial photosynthesis, Algal photosynthesis	3L
4. Regulation of photosynthesis in response to changing climate conditions.	2L
5. Partitioning of photosynthetic assimilates, long distance transport, phloem loading and unloading and its regulation, feedback regulation of photosynthesis.	3L
Credit 3: Respiration, Growth and Photophysiology	15L
1. Comparative account of energy release efficiency of Glycolysis, TCA cycle and PPP. Alternative pathways in plants, alternate oxidase, regulation of different pathways, GABA shunt	3L
3. Mitochondrial electron transport system, inhibitors and uncouplers, diverse electron transport systems in plant mitochondria, Oxidative phosphorylation, respiratory control and measurements	4L
4. Interdependence of mitochondria and chloroplasts. Protective effects of mitochondrial respiration on photosynthesis	3L
5. Growth and maintenance respiration. Role of respiration in plant carbon balance	2L
6. Seed germination and dormancy, Measurement of growth,	2L
8. Photophysiology of Blue light responses	1L

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2. Buchanan B.B., Gruissem W., Jones R.L. (2000) Biochemistry and Molecular Biology of Plants. IK International, Mumbai.
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4. Davis P. J. (Eds.).(2004) Plant Hormones.Kluwer Academic Publishers, Dordrecht, Netherlands.
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6. Heldt H. W. (2004) Plant Biochemistry. Academic Press, California.
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9. Lincolin Taiz and Eduardo Zeiger (2010) Plant Physiology, Fifth edition. Sinauer Associates, Inc. Publishers. Sunder land, USA.

Periodicals and Journals

1. Trends
2. Annual Review of Plant Biology.
3. Plant Cell.
4. Plant Physiology
5. Journal of Plant Physiology.
6. Physiologia Plantarum.
7. Physiology and Molecular Biology of Plants

BO 3.4f: Pharmacognosy – I (3C)

Credit 1: Evaluation of Drugs, Processing and Marketing	15L
a. Evaluation of Drugs: Concept, considerations, parameters and methods of quality control for medicinal plant materials as per various pharmacopoeia and other guidelines.	} 3L
b. Preparation of monograph of crude drug.	
c. Comparative study of IP, European Pharmacopoeia, BP / Ayurvedic Pharmacopoeia of India.	2L
d. Pharmacognostic studies of some drugs: w.r.t. geographical distribution, cultivation, post-harvest technology, collection, macroscopic and microscopic characters, commercial products if any, chemical constituents, chemical tests, therapeutic uses, commercial varieties, adulterants and substitutes.	7L
Root Drugs: <i>Aconitum napellus</i> Linn., <i>Gentiana lutea</i> Linn., <i>Withania somnifera</i> (L.) Dunal	
Rhizome Drugs: <i>Rauwolfia serpentina</i> Benth., <i>Acorus calamus</i> Linn.	
Stem Drugs: <i>Ephedra</i> sp., <i>Quassia amara</i> Linn.	
Bark Drugs: <i>Cinchona</i> sp., <i>Saraca asoka</i> (Roxb.) De Wild.	
Leaf Drugs: <i>Ocimum sanctum</i> Linn., <i>Adhatoda vasica</i> Nees., Senna	
Flower Drugs: <i>Woodfordia floribunda</i> Salisb., <i>Eugenia caryophyllata</i> Thumb.	
Fruit Drug: <i>Tamarindus indica</i> Linn., <i>Corriandrum sativum</i> Linn.	
Seed Drugs: <i>Strychnos nux-vomica</i> Linn., <i>Plantago ovata</i> Forskal)	
e. Herbal fingerprint profile of single and multi-component herbal drugs.	} 3L
f. Stability testing of natural products. Examples of use of these techniques for plant products.	
Credit 2: Natural Products Chemistry	15L
a. Major secondary metabolism pathways in plants.	2L
b. Brief outline of occurrence, distribution and synthesis of phenolics, alkaloids, terpenoids, coumarins, flavonoids, glycosides, volatile oils, tannins and resins.	6L
c. Methods of extraction, isolation, purification, identification and estimation of above types of metabolites. Case studies	5L
d. Regulation of secondary metabolite pathways and compartmentation of these in plants.	} 2L
e. High Throughput Screening (HTS).	
Credit 3: Applied Pharmacognosy	15L
a. Ethnobotany: Concept, relevance and classification. Methods and techniques used in ethnobotany. Ethnopharmacology and its applications.	3L
b. Regulatory requirements for new drugs: Markers constituents- Definition, importance in crude drug standardization. Examples of Biomarkers.	4L

- c. Standardization, quality, efficacy and safety requirements & assessment procedures for herbal medicines as per USFDA. 3L
- d. Nutraceuticals and Cosmeceuticals: General introduction, Classification and their formulations, Botanical sources, properties and uses. 3L

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8. European Pharmacopoeia. 9th Edition. (2017). 3 Volume Set.
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10. Farooqi A. A. and Sreeramu B.S. (2004) Cultivation of Medicinal and Aromatic Crops. Revised Edition. Universities Press (India) Pvt. Ltd.
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22. Ramawat K. G. and Goyal Shaily (2009) *Comprehensive Biotechnology*. 1st Edition. S. Chand Publishing.
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26. Sensen C. W. (Editor) (2002) *Essentials of Genomics and Bioinformatics*, Wiley-VCH, Germany.
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BO 3.4g: Advanced Plant Genetics and Breeding - I (3C)

Credit 1: Cytogenetics	15L
1. Chromosome markers, banding, genetic maps, cytogenetic maps and physical maps, GISH and FISH analysis.	3L
2. Aneuploids (Nullisomics, monosomics, trisomics, tetrasomics). Mapping methods with aneuploids, alien addition / substitution lines.	2L
3. Apomixis: Genetics of apomictic systems & its application.	2L
4. Distant hybridization in plant breeding: Barriers for the production of distant hybrids, Technique, sterility in distant hybrids and its application in crop improvements.	2L
5. Heterosis and its exploitation: Concept of heterosis, inbreeding depression. Estimation of heterosis,	2L
6. Hybrid varieties: Development and evaluation of inbreeds, production of hybrid seeds, merits, demerits and achievements through hybrid varieties.	4L
Credit 2: Breeding for Quality traits	15L
1. Breeding for resistance to Abiotic stresses – Drought stresses, Salinity, mineral deficiency and mineral toxicity, Heat and cold resistance	4L
2. Biotic stresses – Disease resistance, Insect resistance	2L
3. Breeding for quality improvement - Protein and oil through conventional and biotechnological approach.	3L
4. Use of haploids, euploids, aneuploids, auto and allopolyploids in breeding, synthesis of new crop species.	3L
5. Role of induced mutations in plant breeding.	2L
6. Application of field designs for setting hybridization experiments	1L
Credit 3: Molecular markers and its applications	15L
1. Molecular markers: Different types of molecular markers, Diversity assessment using molecular markers, Genome analysis, Gene Mapping with molecular markers, Map based cloning, QTL identification and mapping.	8L
2. Marker assisted selection (MAS): Mapping populations, MAS in Gene pyramiding and backcross breeding.	3L
3. Use of MAS for QTL identification and disease resistance.	4L

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BO 3.4h Plant Biotechnology – I (3C)

Credit 1: Recombinant DNA technology and gene cloning	15L
1. Introduction to recombinant DNA technology	1L
2. Enzymes used in genetic engineering- Restriction endonucleases, other endonucleases, exonucleases, ligases, polymerases, kinases and phosphatases, DNA methylases, topoisomerases.	4L
3. Use of vectors in cloning- Plasmids, phages, cosmids, phagemids, BACs and YACs, Gateway system of cloning	6L
4. Polymerase chain reaction- Principles and uses in gene cloning	4L
Credit 2: Gene libraries, screening of recombinants and sequencing	15L
1. Genomic and cDNA libraries – choice of vectors, construction	4L
2. Screening of libraries and isolation of specific genes- Nucleic acid hybridization using specific nucleotide probes, antibodies, PCR amplification using gene specific primers.	5L
3. DNA sequencing methods, sequencing strategies for large regions of DNA contig maps	2L
4. High throughput and next generation sequencing methods.	4L
Credit 3: Genetic transformation of plants	15L
1. Agrobacterium: Ti and Ri plasmids, transfer of DNA into host by <i>Agrobacterium</i> , mechanism of integration of DNA into plant genomes	4L
2. Vectors for plant transformation: Agrobacterium-based vectors, improved <i>Agrobacterium</i> based vectors, virus-based vectors for transient expression, vectors for chloroplast transformation vectors for marker-free selection	5L
3. Transformation techniques: Agrobacterium-mediated, direct DNA transfer. Factors affecting transformation. <i>In planta</i> transformation	3L
4. Screening and analysis of transformants in subsequent generations – copy number, heterozygosity, stable expression, silencing	3L

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2. Principles of gene manipulation. Primrose SB, Twyman RM and Old RW, 6th Edition, Blackwell Science, Oxford, 2001
3. Differentially expressed gene in plants. Hansen and Harper, Taylor and Francis Ltd. London, 1997.
4. Engineering plants for commercial products and applications. Eds. Collins GB and Shepherd RJ, NY Acad. Of Science Publishers 1996
5. DNA markers. Eds. Caetano-Anolles and Gresshoff, Wiley-VCH Publishers, NY, 1998
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Relevant review articles from journals

1. Plant molecular biology
2. BMC

BO 3.5: Practicals on BO 3.1 and 3.2 (3C)

Practicals on BO 3.1 – Taxonomy of Angiosperms (any 6 practicals)

1. Studies on the following Classes as per Bentham and Hooker's system of classification using any 3 type specimens and preparation of artificial keys for identification of any two unknown specimen: **6P**

Dicotyledonae

- a. Polypetalae: Thalamiflorae, Disciflorae, Calyciflorae
- b. Gamopetalae: Inferae, Heteromerae, bicarpellatae
- c. Monochlamydae: Curvembryae, Multiovulateaquaticae, Multiovulate terrestris, Microembryae, Daphniales, Achlamydosporae, Unisexuales, Ordinesanomali.

Monocotyledonae

- a. Microspermae
- b. Epigynae
- c. Coronariae
- d. Calycinae
- e. Nudiflorae
- f. Apocarrae
- g. Glumaceae

2. Comparative study of morphological and structural adaptations of hydrophytes, mesophytes, xerophytes, halophytes **1P**
3. Ex-situ conservation methods of biodiversity – through seed, vegetative and micro-propagation methods. (Any one plant species per technique) **2P**

Practicals on BO 3.2 – Plant Development (Any 6 Practicals)

1. Isolation of vegetative and reproductive apical meristems. **1P**
2. Tracing the course of stomatal development and observations on stomatal types. **1P**
3. Anatomical studies on secondary growth (wood). **1P**
4. Origin and development of epidermal structures (trichomes, glands and lenticels) and Study of secretory structures (nectaries and laticifers). **1P**
5. Histochemical comparison between vegetative SA and reproductively induced SA. **1P**
6. Observations on: **4P**
- a. Microsporogenesis and development of male gametophyte (pollen).
 - b. Megasporogenesis and development of female gametophyte.
7. Observations on types of endosperm, dissection and isolation of endosperm. **1P**
8. Observations on stages of embryo development, dissection and isolation of developing embryo (3 stages). **1P**
9. *In vitro* germination of spore/ pollen. Correlation between fertility (stainability), viability (TTC and FDA staining) and germinability (*in vitro*) of pollen **1P**

BO 3.6: Practicals based on BO 3.3 (3C)

Any 12 Practicals

1. Principle and working of Conductivity meter and pH meter. Conductivity measurement of different solutions. Determination of pKa and buffering capacity of acetate buffer. **3P**
2. Absorption spectra of BSA / DNA and determination of absorption maxima, molar extinction coefficient. **2P**
3. Separation of Plant Pigments by Thin Layer Chromatography / Column Chromatography **3P**
4. Native PAGE and activity staining. **3P**
5. Ouchterlony immunodiffusion technique for testing specificity of antigens and antibodies. **2P**
6. Separation of protein Gel filtration/ affinity / ion exchange chromatography **2P**
7. Microtomy – fixation, dehydration, serial sectioning and staining of plant tissues **3P**
8. Demonstration of Spectrofluorimetry **1P**
9. Demonstration of HPLC and GC-MS techniques and quantification. **2P**

BO 3.7a: Practicals based on BO 3.4a (3C)

Any 12 Practicals

- | | |
|-------------------------------------------------------------------------------------------|-----------|
| 1. Collection, characterization and identification of algae from diverse habitats | 3P |
| 2. Morphometric studies on algae | 1P |
| 3. Estimation of phytoplankton primary productivity | 2P |
| 4. Documenting algal biofilm development on an artificial substratum/habitats | 2P |
| 5. Study of SEM/TEM photographs of algae published in standard publications | 1P |
| 6. Karyological studies in algae | 1P |
| 7. Demonstration for using algal databases and other on-line resources | 1P |
| 8. DNA extraction and amplification by using 18/16s rRNA in microalgae | 3P |
| 9. Data mining and construction of phylogenetic tree based on housekeeping genes in algae | 2P |
| 10. Heavy metal/salt tolerance by microalgae | 2P |
| 11. Effect of nitrogen/phosphorus concentrations on the growth of microalgae | 2P |
| 12. Effect of light intensities on the growth of microalgae | 2P |
| 13. Study of desiccation stress tolerance in algae | 2P |

BO 3.7b: Practicals based on BO 3.4b (3C)

Any 12 Practicals

1. Study of the representative genera belonging to subkingdom-Dikarya-Ascomycota and Division-Mucoromycotina, observations made based on tissue differentiation, accessory organs, asexual and sexual structures and fruiting body: Ascocarp. **4P**
2. Study the morphological and anatomical features of Lichen thallii **2P**
3. Preparation of PDA, sterilization, pouring, inoculation and culturing of fungi. **2P**
4. Isolation and culture of fungi from rhizosphere. **2P**
5. Slide culture technique for *in vivo* study of fungi. **2P**
6. DNA isolation from fungi for molecular identification. **4P**

BO 3.7c: Practicals based on BO 3.4c (3C)

Any 12 Practicals

1. Study of the representative genera belonging to subkingdom-Dikarya-Ascomycota and Division-Mucoromycotina, observations made based on tissue differentiation, accessory organs, asexual and sexual structures, and fruiting body: Ascocarp. **4P**
2. Study the morphological and anatomical features of Lichen thallii **2P**
3. Preparation of PDA, sterilization, pouring, inoculation and culturing of fungi. **2P**
4. Isolation and culture of fungi from rhizosphere. **2P**
5. Slide culture technique for *in vivo* study of fungi. **2P**
6. DNA isolation from fungi for molecular identification. **4P**

BO 3.7d: Practicals based on BO 3.4d (3C)

12 Practicals

- | | |
|-----------------------------------------------------------------------------|-----------|
| 1. Vegetation assessment through remote sensing | 2P |
| 2. Studying effect of pollutants on plant growth | 2P |
| 3. Estimation of lipids from different petro crops | 2P |
| 4. Studying antifungal activity of plants against the crop pathogenic fungi | 2P |
| 5. Studying pesticide degradation by bacteria | 2P |
| 6. Studying carbon sequestration in plants | 2P |

BO 3.7e: Practicals based on BO 3.4e (3C)

Any 12 practicals

1. Study of photosynthesis, transpiration and stomatal physiology under abiotic stress using IRGA **2P**
3. Measurement of chlorophyll fluorescence and calculating Fv/Fm ratios. **2P**
4. Determining respiration flux through cytochrome c and AOX pathway using oxygen electrode **2P**
5. Determining Rubisco in C3 and C4 plants **1P**
6. Determining PEPcase activities in C4 and CAM plants **1P**
7. Comparison of alteration in growth rate, days to flowering, in any one crop plant subjected to altered photoperiod / excess nitrogen fertilizer / water deficiency. **3P**
8. Estimation of neutral and acid invertase activity during grain filling in any crop sp. **3P**
9. Studies on effect of mineral deficiency on plant growth. **2P**
10. Measurement of mineral composition in plants and hydroponic media by AAS. **2P**

BO 3.7f: Practicals based on BO 3.4f (3C)

(Any 12 practicals)

- | | |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1. Identification of drug with the help macroscopic & microscopic evaluation techniques, percentage extractives and fluorescence analysis of drugs | 1P |
| 2. Histochemical studies of drugs and determination of ash values of drugs. | 1P |
| 3. Chemotaxonomic studies of drugs belonging to Meliaceae, Rutaceae and Simarubiaceae | 1P |
| 4. Estimation of alkaloids from suitable medicinal plants. | 1P |
| 5. Estimation of glycosides from suitable medicinal plants. | 1P |
| 6. Extraction of essential oils from suitable medicinal plants. | 1P |
| 7. Thin layer chromatography and identification of phytoconstituents using standard compounds | 2P |
| 8. Paper chromatography and identification of phytoconstituents using standard compounds | 1P |
| 9. Characterization of the phytopharmaceuticals by HPLC / HPTLC | 2P |
| 10. Profiling of plant extracts using HPTLC as a marker for identification | 2P |

BO 3.7g: Practicals based on BO 3.4g (3C)

Any 12 Practicals

- | | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 1. Analysis of induced aberration (Maize) | 3P |
| 2. Meiotic behaviour of auto and allopolyploid. | 2P |
| 3. Analysis of chiasma frequency. | 2P |
| 4. Karyotype analysis through slide preparation. | 3P |
| 5. Handling data on polygenic traits for analysis of variance and covariance, partitioning of variance components, heterosis. | 2P |
| 6. Analysis of interspecific hybrids | 3P |
| 7. Chromosome banding. | 3P |
| 8. Detection of alien chromatin in interspecific hybrids using <i>in situ</i> hybridization. | 4P |
| 9. Study of genomic behaviour in interspecific hybrids by meiotic analysis. | 2P |
| 10. Biochemical analysis of segregating population or mutant for protein and oil quality. | 3P |
| 11. Analyzing data for quantitative traits (Partitioning of genotypic and environmental components, heritability, prediction of combining ability, heterosis and inbreeding) | 2P |
| 12. Testing segregating population / mutant against biotic or abiotic stress. | 2P |
| 13. Use of ISSR/RAPD markers for assessing genetic diversity in genetic resources. | 4P |
| 14. Floral biology studies, selfing and crossing in selected crops e.g. <i>Capsicum</i> , maize, soybean/cotton/Bajra/rice | 3P |
| 15. Studies on induced mutations – chlorophyll/biochemical/morphological/tolerance | 2P |
| 16. Study of segregating populations. | 1P |
| 17. Study of induced tetraploids | 3P |
| 18. Crossing plants for heterosis and study of hybrids | 2P |
| 19. Anther / microspore culture in suitable plant material | 2P |
| 20. Plant genetic transformation and confirmation of transgenic | 3P |
| 21. Handling of data on heritability and genetic advance/diallele crosses | 2P |

BO 3.7h: Practicals based on BO3.5h (3C)

Any 12 practicals

1. Construction of recombinant plasmid using REs, PCR based methods **3P**
2. Transformation of *E.coli* with recombinant plasmid, selection of transformants by Selectable markers / blue- white screening. **3P**
3. Transformation of *A. tumefaciens* with binary vector using freeze thaw method and selection for transformants. **3P**
4. Transformation of plant tissues using *Agrobacterium tumefaciens* based vectors. **3P**
5. Detection of transformants using GUS/GFP/gene specific PCR **4P**
6. Transformation of plant tissues using *Agrobacterium rhizogenes*. **4P**
7. Basic Linux commands for handling Next generation sequencing data **1P**
8. Next generation sequencing file formats, quality control and removal of low quality reads. **1P**

BO 4.1: Biostatistics and Bioinformatics (2C)

Credit 1 - Statistics 1	15L
1. Descriptive statistics - Populations and samples, graphical presentation of data frequency distribution, central tendency and dispersion - mean, median, variance standard deviation	1L
2. Sampling distributions, standard error of mean	1L
3. Normal distribution, standardised normal distribution (z), attributes of normal distributions, Student's t distribution Estimation, Confidence interval	1L
4. Hypothesis testing, type I and type II errors	2L
5. Binomial and Poisson distribution	2L
6. Non-parametric tests	2L
7. Experimental designs- completely randomised, randomised block and factorial experimental designs, Analysis of variance.	3L
8. Correlation and regression, linear and non-linear regression,	2L
9. Chi-square test for goodness of fit and independence	1L
Credit 2 – Basic Bioinformatics	15L
1. Introduction to databases and retrieving information from databases: Databases	1L
2. Molecular tools in protein and nucleotide sequence analysis; origin of new genes and proteins.	1L
3. Sequence similarities. Pairwise comparison of DNA and protein sequences, dynamic programming algorithms, FASTA and BLAST.	2L
4. Multiple sequence alignments, progressive methods, iterative methods, localized alignments	1L
5. Determining phylogenetic relationships using DNA and protein sequences	3L
6. Protein structures, Ramachandran plot, protein folding,	2L
7. Structure function relationship, conformational energy calculations,	2L
8. Protein structure predictions, secondary and tertiary,	2L
9. Protein structure classification- SCOP, CATH,	1L

References:

1. Statistical Methods – Snedecor G.W. and Cochran W.G. Affiliated East-West Press Pvt. Ltd. 1989
2. Statistical methods in Agriculture and Experimental Biology – Mead, R. and Curnow, R.N. Chapman and Hall, 1983
3. Practical statistics and experimental design for plant and crop science – Clewer, A.G. and Scarisbrick, A.H., John Wiley, New York, 2001
4. Bioinformatics - Westhead, DR, Parish JH and Twyman, RM, BIOS Scientific Publishers Ltd., Oxford, 2003
5. Bioinformatics – Sequence and genome analysis. D.W. Mount, CBS Publishers, New Delhi, 2003
6. Bioinformatics and Molecular Evolution – Higgs PG and Attwood TK, Blackwell Publishing, Oxford, UK, 2005
7. Bioinformatics A Practical Guide to the Analysis of Genes and Proteins- Baxevanis A. D., Francis Ouellette B. F. John Wiley & sons Inc., 2001

BO 4.2a: Algology- II (3C)

Credit 1	15L
1. Cultivation of microalgae: Sampling methods, nutrient media, Isolation techniques, Role of physical and chemical factors on cultures, Scaling up, Growth kinetics and measurements, Harvesting and drying of algal biomass, Synchronous and continuous cultures	6L
2. Photobioreactors (Closed system) for mass production of microalgae: Principle considerations and designing, tubular and flat-plate reactors, merits and demerits	3L
3. Mariculture of seaweeds: Necessity and principles of mariculture, commercial cultivation of economically important seaweeds (<i>Porphyra</i> , <i>Gracilaria</i> , <i>Kappaphycus</i> , <i>Laminaria</i>)	4L
4. <i>In-vitro</i> studies of economically important seaweeds, genetic improvement	2L
Credit 2	15L
1. Secondary metabolites from microalgae as chemical defense and their biosynthesis: Terpenoids, Polyketoids, Shikimates, Inducibility of defense metabolites against herbivores in microalgae, <i>Microcystis-Daphnia</i> interaction: a case study	7L
2. Eutrophication: Causes, Chemical and biological responses of eutrophication, Production of toxic metabolites from bloom forming algae and their consequences on aquatic environments and trophic level	3L
3. Applications of macroalgae: Seaweeds as food; Source and structure of seaweed polysaccharides (Agar, Alginate, Carrageenan), Seaweed liquid fertilizer	5L
Credit 3	15L
1. Grazers on benthic seaweeds: Classification of seaweed grazers, Digestive adaptations in grazers, Grazers impact on seaweeds and seaweed communities, Seaweed defenses against grazing	3L
2. Phycoremediation by High Rate Algal Ponds (HRAPs), Algae as food and functional food	2L
3. Biodiesel and hydrogen production from microalgae, genetic improvement	3L
4. Algal nanoparticles, their synthesis and applications, Diatomite, Biofertilizer, value added products (Pigments, Vitamins, fatty acids, enzymes) from microalgae	4L
5. Conservation strategies for algae: Introduction, Role of genetic resource centres and culture collections, methodological strategies employed to conserve algae	3L

References:

1. Amsler, C. D. (ed.) (2008). *Algal chemical ecology*. Springer-Verlag Berlin Heidelberg, pp. 313.
2. Andersen, R. A. (ed.) (2005). *Algal culturing techniques*. Elsevier Academic Press, pp. 578.
3. Becker, E. W. (1994). *Microalgae: biotechnology and microbiology*. Cambridge University Press, pp. 293.
4. Day, J. G. (1999). Conservation strategies for algae. In Benson, E. E. (ed.) *Plant conservation biotechnology*. Taylor & Francis, pp. 111-124.
5. Lobban, C. S. and Harrison, P. J. (1997). *Seaweed ecology and physiology*. Cambridge University Press, pp. 366.
6. Posten, C. and Walter, C. (eds.) (2012). *Microalgal biotechnology: potential and production*. Walter de Gruyter GmbH, Berlin/Boston, pp. 266.
7. Singh, R. P. and Reddy, C. R. K. (2014). Seaweed-microbial interactions: key functions of seaweed-associated bacteria. *FEMS Microbiol. Ecol.*, 88: 213-220.
8. Singh, B., Baudh, K. and Bux, F. (eds.) (2015). *Algae and environmental sustainability*. Springer, India, pp. 181.
9. Thajuddin, N. and Dhanasekaran, D. (eds.) (2016). *Algae-organisms for imminent biotechnology*. InTech, pp. 330.
10. Tiwari, B. K. and Troy, D. J. (eds.) (2015). *Seaweed sustainability: food and non-food applications*. Elsevier Inc., pp. 470.
11. Venkataraman, G. S. (1969). *The cultivation of algae*. ICAR, New Delhi, pp. 319.

BO 4.2b: Advanced Mycology- II (3C)

Credit: 1-Fungal systematics	15L
1. A higher – level phylogenetic classification of fungi (Kirk 2008 and Hibbett et al., 2007)-Fungal systematics: Kingdom fungi: Subkingdom Basidiomycota: Subphylum: Pucciniomycotina; Ustilaginomycotina; Agaricomycotina.	10L
2. Kingdom:Chromista; Phylum: Hyphochytriomycota, Labyrinthulomycota, Oomycota	3L
3. Kingdom: Protozoa; Phylum: Mycetozoa	2L
Credit:2-Fungi as food and food processing	15L
1. Fungi as food, Mushrooms and other edible fungi, fungi in food web, cell and mycelium as human food, fermented products, nutraceuticals	5L
2. Application of fungi in food and beverages Industry, Industrially important fungal enzymes.	5L
3. Fungi and food spoilage.	5L
Credit:3-Medicinal fungi	15L
1. Utilization of fungi for production of metabolites: primary and secondary, Fungal secondary metabolite.	3L
2. Therapeutic proteins from fungi, fungal immunomodulatory proteins.	3L
3. Endophytic fungi and their role in therapeutics	3L
4. Antibiotics from fungi, Product of pharmaceutical importance of fungi, pharmacological importance of <i>Cordyceps</i> .	3L
5. Lichens as sources of secondary metabolites, pathway of secondary metabolites in lichen and their applications.	3L

BO 4.2c: Angiosperms Systematics – II (3C)

Credit1	15L
1. Taxonomic literature: Floras, manuals, monographs and revisions, periodicals, glossaries, dictionaries, cultivated and economic plants, location of type specimens and protologues, websites.	4L
2. Botanical keys: Single access-bracketed and indented keys, multi-access keys, edge-punched and body-punched (polyclave) keys; computerized keys, their merits and demerits.	3L
3. Biosystematics: Aims, concepts of species, methods in biosystematic studies, biosystematic categories- ecotype, ecospecies, cenospecies, comparium, ecotypic variations and taxonomy, scope and limitations.	3L
4. Origin of angiosperms, cradle of angiosperms, species pump hypothesis, abominable mystery, Continental drift and evolution of angiosperms, fossil angiosperms.	5L
Credit2	15L
1. Evolutionary trends in vessels, sieve elements, leaf, carpel, male and female gametophytes, seed.	2L
2. Floral Biology: Evolution of flower, co-evolution of flowering plant and insects, sex distribution in flowers and plants, types of pollinations; chasmogamy and cleistogamy.	3L
3. DNA based markers- DNA polymorphism studies using hybridization-based techniques and PCR based techniques- RAPD, AFLP, SSR polymorphisms, microsatellite-primed PCR, Sequence-based polymorphism.	4L
4. Determining genetic relatedness using DNA based markers- Clustering and Dendrogram construction using Distance based methods, UPGMA, Neighbour joining. Character based methods- Maximum likelihood, maximum parsimony, Bayesian analysis and Whole Genome Sequencing.	3L
5. Applications of molecular markers in diversity studies, DNA fingerprinting, Population structure, Phylogenetic relationships, Taxonomic disputes.	3L
Credit3	15L
1. Morphological variations, systematic position, interrelationships, phylogeny and economic importance of following families: ROSIDS-Rhamnaceae, Moraceae, Urticaceae, Cucurbitaceae, Begoniaceae, Casuarinaceae, Lythraceae, Onagraceae, Myrtaceae, Melastomataceae, Rutaceae, Meliaceae, Sapotaceae, Lecythidaceae, Solanaceae; ASTERIDS- Convolvulaceae, Boraginaceae, Rubiaceae, Apocynaceae, Oleaceae, Scrophulariaceae, Bignoniaceae, Lentibulariaceae, Verbenaceae, Lamiaceae.	15L

Reference Books:

1. Agashe, S.N. 1995. Paleobotany, Oxford and IBH Publ. Co. Pvt. Ltd, New Delhi.
2. Bhojwani, S.S. and Bhatnagar, S.P. 1984. Embryology of Angiosperms. Vikas Publ. House, New Dehli.
3. Briggs, David. 2009. Plant microevolution and Conservation in Human-influenced Ecosystems. Cambridge University Press.
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5. Cronquist, A. 1981. An Integrated System of Classification of Flowering Plants. Columbia University Press, New York.
6. Cronquist, A. 1988. The Evolution and Classification of Flowering Plants (2nded.) Allen Press, U.S.A.
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9. Erdtman, G. 1966. Pollen Morphology and Plant Taxonomy of Angiosperms (An introduction to Palynology I), Hafner Pub.Co. London.
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12. Hutchinson, J. 1959. Families of Flowering plants. Clarendon Press, Oxford.
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14. Johri, B. M. 1984. Comparative embryology of Angiosperms. Ind. Nat. Sc. Acad. New Delhi.
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16. Judd Walter S., Campbell, C. S., Kellogg, E. A., Stevens, P.F. and M. J. Donoghue. 2008. Plant Systematics- A Phylogenetic Approach. Sinauer Associates, INC, Publishers. Sunderland, Massachusetts, USA.
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18. Kuijt J. 1969. The biology of parasitic flowering plants. California University Press.
19. Lawrence, G. H. M. 1951. Taxonomy of Vascular Plants. Oxford and IBH Publ. Co. Pvt. Ltd. New Delhi.
20. Mabberly, T. J. 1997. The Plant Book 2nd edn Cambridge University Press, Cambridge.
21. Maheshwari, P. 1985. An Introduction to Embryology of Angiosperms. Tata McGraw Hill, New Delhi.
22. Manilal, K. S. and M. S. Muktesh Kumar [ed.] 1998. A Handbook of Taxonomic Training. DST, New Delhi.
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24. Nair, P.K.K. 1966. Pollen morphology of Angiosperms. Periodical Expert Book Agency, New Delhi.
25. Paech, K. and M.V. Tracey. 1956. Modern Methods of Plant Analysis. Vol-I & II. Springer-Verlag.

26. Quicke, Donald L. J. 1993. Principles and Techniques of Contemporary Taxonomy. Blakie Academic & Professional, London.
27. Radford A.E. 1986. Fundamentals of Plant Systematics, Harper and Row N Y.
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29. Shivanna, K.R. and N.S. Rangaswamy. 1992. Pollen Biology- A Laboratory Manual. Springer-Verlag.
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38. Taylor, D.V. and L.J. Hickey 1997. Flowering Plants: Origin, Evolution and Phylogeny. CBS Publishers & Distributers, New Delhi.

BO 4.2d: Plant Ecology - II (3C)

Credit 1 Communication in plants and microbes	15L
1. Plant-plant communication: Rhizosphere signalling	3L
2. Nitrogen fixing microbes and legumes interaction	2L
3. Tri-trophic interaction: Plant volatiles and their ecology, indirect defense, Pollinator attractants	3L
4. Growth-defense tradeoffs	3L
5. Analysis of plant communities through qualitative and quantitative characters Quadrat and transect and remote sensing methods, Statistical tools and softwares	4L
Credit 2 Bioremediation mechanisms	15L
1. Decontamination practices: chemical, physical and biological	3L
2. Microbial systems: Aerobic and anaerobic degradation of the wastes	3L
3. Solid waste management practices, composting and biogas production	3L
4. Mechanisms of phytoremediation: Phytoextraction, Phytostabilization, Phytoaccumulation and Phytovolatilization	3L
5. Heavy metal stress and its management	3L
Credit 3: Sustainable Development	15L
1. Environmental policies; International, national and local	3L
2. Sustainable agricultural practices: Use of bio fertilizers and biopesticides, Concept of organic farming	3L
3. Sustainability of wetlands	3L
4. Management of water resources for irrigation and drinking	3L
5. Urban planning and sustainable cities	3L

BO 4.2e: Plant Physiology – II (3C)

Credit 1: <i>In vitro</i> culture and genetic transformation of plants	15L
1. <i>In vitro</i> responses of plant cells, tissue and organs- effect of nutrient medium constituents, growth regulators and environmental factors.	3L
2. Physiological and genetic basis of somaclonal variation and their applications	1L
3. Protoplast culture, somatic hybridization and cybridization, production of haploids	2L
4. Secondary metabolite production in cultured plant cells and tissues	2L
5. Genetic transformation of plants - transfer of foreign DNA into host plant tissues Using Agrobacterium based vectors, mechanism of integration of DNA into plant genomes.	3L
6. Factors affecting transformation, Screening and analysis of transformants.	2L
7. Direct DNA transfer to plants – Electroporation, biolistic transfer	2L
Credit 2: Responses of plants to drought, Temperature and salinity stress	15L
1. Drought stress – effects on growth and metabolism in plants. Acclimation responses to drought stress at physiological and molecular level, stress signaling. Adaptive responses to drought stress, drought escape, tolerance.	4L
2. Salinity stress – osmotic and ionic effects on growth and metabolism. Mechanisms for removal of sodium from cells - SOS pathway, NHX transporters. Improvement of salinity tolerance in plants	4L
3. Stress due to extreme temperatures – effects on growth and metabolism. Adaptive responses of plants to low and high temperature stress	2L
4. Hormone signaling, Types of hormone receptors, signaling and gene expression with auxin, cytokinin, gibberellic acid, polyamines, ethylene, abscisic acid, brassinosteroid.	5L
Credit 3. Chemical signaling in plant interactions	15L
1. Symbiotic interactions of plants with rhizobia and mycorrhiza. Signaling mechanisms leading to successful symbiosis. Nitrogen and phosphorus availability.	4L
2. Chemical signaling during interactions of plants and pathogens, physiological interactions leading to expression of resistance or susceptibility.	4L
3. Chemical signaling in plant interactions of plants and herbivores, pollinators	4L
4. Allelopathy, mechanism of action of allelochemicals in allelopathy.	3L

References

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1. Buchanan B.B., Gruissem W., Jones R.L. (2000) Biochemistry and Molecular Biology of Plants. IK International, Mumbai.
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6. Lawlor D.W. (2001) Photosynthesis.3rd Ed. Viva. New Delhi.
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8. Lincoln Taiz and Eduardo Zeiger (2010) Plant Physiology, Fifth edition. Sinauer Associates, Inc. Publishers. Sunder land, USA.

Periodicals and Journals

1. Trends in Plant Sciences
2. Annual Review of Plant Biology
3. Plant Cell
4. Plant Physiology
5. Journal of Plant Physiology
6. Physiologia Plantarum
7. Physiology and Molecular Biology of Plants

BO 4.2 f: Pharmacognosy - II (3C)

Credit I: Conservation of medicinal plants and study of secondary metabolism	
<i>in vitro</i>	15L
a. <i>Ex-situ</i> conservation methods: Micropropagation of medicinal plants w. r. t. Culture media, explants, incubation conditions, stages of micropropagation, acclimatization and field trials	2L
b. Organized growth in cultures : using preexisting meristems, organogenesis and embryogenesis	2L
c. Types of culture systems used for secondary metabolite production	2L
d. Screening and selection of high secondary metabolite producing cell lines	1L
e. Manipulations of secondary metabolite production in cultures	5L
I. Manipulation of culture media.	
II. Immobilization of cells.	
III. Elicitation using biotic and abiotic elicitors.	
IV. Biotransformation.	
V. Precursors	
f. Scaling up and use of Bioreactors:	3L
I. Strategies used for mass cultivation for hyper-production of secondary metabolites	
II. Types of bioreactors	
Credit II: Screening and evaluation of phytochemicals	15L
a. Brief information about various chemical and biological activities of plant drugs reported in literature	2L
b. Study of pharmacological screening methods of the following categories of drugs: Antimicrobial, antioxidants, anticancer, hypolipidemic, diuretics, cardiovascular, hepatoprotective, antidiabetic, immunomodulatory and antimalarial w. r. t. mechanism of action and property of drug being used.	6L
c. Import and export of medicinal plants / crude drugs. Criteria potential for exports - Plants, crude drugs, crude extracts, products etc. Export agencies	3L
d. Intellectual property right and Patents in relation to Pharmacognosy	4L

Credit III: Engineering of secondary metabolite pathways and molecular pharming	15L
1. Tools for metabolism engineering	4L
a. Agrobacterium mediated transformation	
b. Direct DNA transfer	
c. Plant based vectors	
d. Cloning desired genes	
2. Modifications of plant secondary metabolism by genetic engineering: case studies	1L
3. Genetic engineering of enzymes diverting amino acids into secondary metabolites	2L
4. Transcriptional regulators to modify secondary metabolites	1L
5. Modulation of plant function and plant pathogens by antibody expression	1L
6. Altering biosynthetic pathways using antisense technology, Modifying existing pathways by introduction of genes coding for biosynthetic enzymes from other organisms	2L
7. Genetic engineering for production of biopharmaceuticals – vaccines, antibodies	1L
8. Strategy to identify possible drug target molecules, parameters and strategies for drug discovery using bioinformatics.	2L
9. Bioinformatics tools for analysis of metabolic pathways	1L

References :-

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BO 4.2 g: Advanced Plant Genetics and Breeding-II (3C)

Credit 1: Molecular methods and Sequencing strategies for genome analysis 15L

1. Dividing the genome - fragmentations with restriction enzymes, separation of large DNA fragments, isolation of chromosomes by Cell sorting Chromosomal micro dissection - vectors for cloning DNA - Yeast artificial chromosomes (YAC), P1 derived and bacterial artificial chromosomes (BAC), choice of vectors. **5L**
2. Strategies for genome mapping - restriction enzyme fingerprinting, Marker sequences - sequence tag sites (STS) and sequence tag connectors, expressed sequence tags, simple sequence length polymorphism and single nucleotide polymorphism, hybridization and PCR based other polymorphic markers, their characterization and generation. **5L**
3. Basic DNA sequencing, principles of automated DNA sequencing. High throughput screening, Sequencing strategies - sequencing short stages, sequence of genes, genome sequencing, closing sequence gaps and completing sequence assembly. Sequencing by hybridization and development of microarray and variations in it. **5L**

Credit 2: Functional Genomics 15L

1. Introduction to Functional Genomics, Relationship of Genotype and Phenotype, Functional Genomics Using Reverse Genetics and Forward Genetics **1L**
2. Approaches to expression profiling: Northern hybridization, DDRT-PCR, cDNA-AFLP, SSH, SAGE, Microarray, NGS. **7L**
3. Reverse Genetic Tools for Investigating Gene Function: Gene Silencing by RNA interference (RNAi), VIGS **2L**
4. Insertional mutagenesis: T-DNA and transposon mediated mutagenesis, TILLING **3L**
5. Genome editing for targeted improvement of plants: Engineered meganucleases (EMNs), zinc finger nucleases (ZFNs), transcription activator-like effector nuclease (TALENs) and CRISPR/Cas9 **2L**

Credit 3: Gene transfer and genetically modified plants 15L

1. Gene transfer approaches: Direct DNA transfer methods and Agrobacterium-mediated transformation: Ti Plasmid and mechanism of T-DNA transfer and integration into plant genome. **3L**
2. Agrobacterium based vectors: Binary vectors, super-binary vectors, Gateway vectors for function analysis. **3L**
3. Development of transgenic crop plants for biotic and abiotic stress tolerance (salinity & drought), improvement of nutrition quality. **5L**
4. Regulations regarding GMOs– Potential problems with GMOs, efforts to prevent these problems, gene containment, safer selectable markers and strategies to remove antibiotic resistance markers from transformed plants. Regulatory bodies in government **4L**

References:

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9. Strickberger, M.W: Genetics (4th edn). Mcmillan Publishing Company, New York.
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11. Primerose S. B. & Twyman R. M. (7th Edition) Principles of Gene Manipulation & Genomics. Blackwell Pub. Co. USA

BO 4.2h: Plant Biotechnology - II (3C)

Credit 1- Tools for understanding gene expression and interactions **15L**

1. Techniques used to study gene expression at transcription level:
Northern hybridization, reverse northern hybridization, differential screening and Subtractive hybridization, differential display of mRNA, ESTs, SAGE, cDNA-AFLP, DNA microarrays **4L**
2. Studies on alterations in gene expression: Site-directed mutagenesis, Insertional mutagenesis, knock out mutants, targeting induced local lesions in genomes (TILLING), plant genome editing using CRISPR-CAS system **5L**
3. Gene silencing - Gene inhibition at RNA level - antisense, co-suppression, miRNAs and siRNAs. Silencing mechanisms **4L**
4. Protein-DNA and protein-protein interactions–Chromatin immunoprecipitation assays, gel mobility shift assays, yeast 2-hybrid system, GST-pull down etc. **2L**

Credit 2: Molecular markers and their applications **15L**

1. Molecular markers: Different types of molecular markers, Hybridization and PCR based techniques – RAPD, AFLP, SSR polymorphism, microsatellite-primed PCR, sequence-based polymorphism, single nucleotide polymorphism (SNP) **5L**
2. Applications of molecular markers: Diversity studies, DNA fingerprinting, population structure studies, phylogenetic relationships, distance based, maximum likelihood, maximum parsimony methods **5L**
3. Genetic maps using molecular markers, map based cloning, mapping populations **2L**
4. QTL analysis and marker assisted selection **3L**

Credit 3 Transgenic Plants: Applications **15L**

1. Target genes for improving:
 - a. Resistance against pathogens and pests – Case studies **4L**
 - b. Abiotic stress tolerance – Case studies **4L**
2. Genetic engineering for production of food, biopharmaceuticals and other useful products–vaccines, antibodies, growth factors etc. Case studies **5L**
4. Regulations regarding GMOs– Potential problems with GMOs, efforts to prevent these problems, gene containment, excision of antibiotic resistance markers from transformed plants. Regulatory bodies in government **2L**

References:

1. Recombinant DNA – Principles and Methodologies. Greene JJ and Rao VS, Marcel Dekker, New York, 1998.
2. Principles of gene manipulation. Primrose SB, Twyman RM and Old RW, 6th Edition, Blackwell Science, Oxford, 2001
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4. Engineering plants for commercial products and applications. Eds. Collins GB and Shepherd RJ, NY Acad. Of Science Publishers 1996
5. DNA markers. Eds. Caetano-Anolles and Gresshoff, Wiley-VCH Publishers, NY, 1998
6. Introduction to Bioinformatics. Attwood, T.K., Parry-Smith, DJ, Addison Wesley Longman,

Harlow, Essex, 1999

7. Bioinformatics. Westhead, DR, Parish JH and Twyman, RM, BIOS Scientific Publishers Ltd., Oxford, 2003

8. Bioinformatics – Sequence and genome analysis. D.W. Mount, CBS Publishers, NewDelhi, 2003

9. Collins GB and Shepherd RJ Eds., 1996, Engineering plants for commercial products and application. , NY Acad. Of Science Publishers

10. Senson CW Edt, 2002, Essentials of Genomics and Bioinformatics, Wiley-VCH Publishers, NY,

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14. Buchanan BB, Grussem Wand Jones RL ,2000 , Biochemistry and molecular biology of plants , IK International Pvt Ltd. New Delhi

15. Verapoorte R and Alferman HW Eds ,2002 Metabolic engineering of plant secondary metabolites. Kluwar Academic Publ., Netherlands

Relevant review articles from journals

BO 4.3: Practicals on BO 4.1 (2C)

Biostatistics (Any 4 Practicals)

1. Data, graphical presentation of data – frequency distribution, Sample means and standard deviations, confidence intervals **1P**
2. Hypothesis testing-comparison of means **1P**
3. Analysis of variance **1P**
4. Correlation and regression **1P**
5. Binomial distribution **1P**
6. Non-parametric test **1P**

Bioinformatics (Any 4 Practicals)

1. Databases and database searching **1P**
2. Pairwise comparison of DNA and protein sequences - BLAST **1P**
3. Multiple sequence alignments, progressive methods, CLUSTAL **1P**
4. Determining phylogenetic relationships using DNA and protein sequences **1P**
5. Visualizing protein 3D structure **1P**
6. Prediction of 3D structure of proteins using homology modeling **1P**
7. Assessment of homology modeled protein structure **1P**

BO 4.4a: Practicals based on BO 4.2a - II (3C)

Any 12 Practicals

- | | |
|-------------------------------------------------------------------------------|-----------|
| 1. Preparation of nutrient media for algal culture | 1P |
| 2. Collection, isolation, purification and maintenance of microalgae | 4P |
| 3. Qualitative and quantitative analysis of algal lipids | 2P |
| 4. Study of algal biodiesel properties | 1P |
| 5. Biphasic culturing of N ₂ -fixing soil algae | 1P |
| 6. Immobilization of microalgae | 1P |
| 7. Extraction of agar-agar/alginates from seaweeds | 2P |
| 8. Preparation of seaweed liquid fertilizer and its effect on seedling growth | 2P |
| 9. Enrichment of algal cultures | 1P |
| 10. Determination of carotenoids/phycobiliproteins in microalgae | 1P |
| 11. Measurement of photosynthesis in algae | 1P |
| 12. Determination of microalgal cell counts using Haemocytometer | 1P |
| 13. Algal growth measurements and growth curve studies | 2P |
| 14. Lyophilization of microalgae and testing for its viability | 2P |
| 15. Study of algae-herbivore interaction | 2P |
| 16. Study of bloom causing algae | 2P |

BO 4.4b: Practicals based on BO 4.2b – II (3C)

Any 12 Practicals

1. Study of the representative genera belonging to subkingdom-Dikarya-Basidiomycota observations made based on tissue differentiation, accessory organs, asexual and sexual structures, and fruiting body: Basidiocarp. **4P**
2. Determination of AM fungal diversity and abundance **2P**
3. Isolation of endophytic fungi and study of antimicrobial activity. **4P**
4. Detection of various secondary compound from lichen thallus **2P**
5. Study the antimicrobial activity of *Trichoderma* against plant pathogenic fungi. **2P**
6. Isolation and culture of aquatic fungi by baiting method. **2P**
7. Sensitivity of fungicides on fungal cultures **2P**
8. Production and estimation of Penicillin from *Penicillium* **2P**

BO4.4c: Practicals on BO 4.2c - II (3C)

Any 12 Practicals

- | | |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1. Exercises on nomenclature problems. | 1P |
| 2. Describing new taxon. | 1P |
| 3. Studies on anatomy of different types of wood. | 2P |
| 4. Use of molecular markers to determine genetic relatedness between species | |
| a. ISSR / RAPD markers – DNA isolation, PCR amplification, scoring polymorphism | 2P |
| b. Construction of dendrograms using MEGA or other appropriate software (data provided) | 2P |
| c. Genic markers and their use in distinguishing species (using data available in NCBI database) | 2P |
| 5. Descriptions, Sketching, classification and identification of families (At least 20 plants species belonging to locally available families of flowering plants) | 4P |
| 6. Field trips to places for study and observation of vegetation types. (including any one plant diversity hotspots / National Parks/ Wildlife Sanctuary) | -- |

BO 4.4d: Practicals on BO 4.2d - II (3C)

Any 12 practicals

- | | |
|---------------------------------------------------------------|-----------|
| 1. Analysis of air by measuring temperature, humidity and SPM | 2P |
| 2. Analysis of texture and water holding capacity of soil | 2P |
| 3. Studying plant adaptations to light, temperature and water | 2P |
| 4. Studying effect of pollutants on plant reproduction | 2P |
| 5. Studying activity of fungal decomposition enzymes | 2P |
| 6. Determination of BOD and COD of polluted water | 2P |
| 7. Studying phytoremediation in hyperaccumulator plants | 2P |
| 8. Visit to the site of ecological restoration | 2P |

BO 4.4e: Practical based on BO 4.2e –II (3C)

Any 12 practicals

1. Studies on depletion of mineral elements from media and accumulation in in vitro cultured plant tissues using Atomic absorption spectrometry **3P**
2. Studies on effect of growth regulators on in vitro responses of plant tissues **3P**
3. Genetic transformation of tobacco using *Agrobacterium tumefaciens* based vector and screening for transformants **3P**
4. Studies on superoxide dismutase, catalase and peroxidase activity in response to drought stress / xenobiotic stress / pathogen application **3P**
5. Studies on proline accumulation in plants exposed to salinity stress. **1P**
6. In situ localization of superoxide and hydrogen peroxide in pathogen tolerant and susceptible genotypes in response to pathogen application **2P**
7. Estimation of change in MeJA levels in plants infected with pathogen/ infested with herbivore using Gas chromatography. **2P**

BO 4.4f: - Practicals based on BO 4.2f - II (3C)

Any 12 Practicals

- | | |
|-----------------------------------------------------------------------------------------|-----------|
| 1. Micropropagation of a plant through multiplication of pre-existing meristems | 3P |
| 2. Micropropagation of a plant through organogenesis | 4P |
| 3. Detection and estimation of alkaloids in callus of suitable medicinal plants | 2P |
| 4. Study of growth and secondary metabolite production in cell suspension cultures | 3P |
| 5. Elicitation of plant cells for secondary metabolites | 2P |
| 6. Screening for biological activities Antimicrobial screening of Herbal drugs/ Extract | 2P |
| 7. Antifungal screening of Herbal drugs/Extracts | 2P |
| 8. Anticancer activity by MTT assay | 2P |
| 9. Antioxidant activity of herbal drugs/extracts | 1P |

BO 4.4g: Practicals based on BO 4.2g –II (3C)

Any 12 Practicals

- | | |
|-----------------------------------------------------------------------------------------------------------------|-----------|
| 1. Isolation of plant genomic DNA, determination of concentration and purity | 1P |
| 2. Isolation of plasmid DNA | 1P |
| 3. Cloning of DNA in plasmid and selection of clones | 4P |
| 4. Amplification of plant DNA by using PCR and detection of polymorphism | 2P |
| 5. Restriction of genomic DNA, preparation of southern blots, testing homology at species and/or Varietal level | 2P |
| 6. Detection of alien chromatin in interspecific hybrids using in situ hybridization | 4P |
| 7. Study of genomic behaviour in interspecific hybrids by meiotic analysis | 2P |
| 8. Handling of data for diversity analysis | 2P |
| 9. Practical on Bioinformatics (sequence comparison) | 3P |

BO4.4h: Practicals based on BO 4.2h –II (3C)

Any 12 practicals

- | | |
|----------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1. DIG – labeling of DNA fragment for use as probe in Southern hybridization | 3P |
| 2. Restriction and electrophoresis of plant genomic DNA, Southern blotting and Southern hybridization | 3P |
| 3. RNA isolation from plant tissues and electrophoresis of RNA | 2P |
| 4. RT-PCR and comparing gene expression in two treatments | 2P |
| 5. Use of PCR-based molecular markers- AFLP, SSR markers for scoring polymorphism. Construction of phylogenetic trees using given data | 2P |
| 6. Making linkage maps from given data using mapmaking software. QTL analysis using given data | 1P |
| 7. Separation and detection of specific proteins using Western blotting | 3P |
| 8. De novo RNA-Seq assembly and analysis using Trinity and EdgeR | 3P |
| 9. Genome/reference-based RNA-Seq analysis using Tuxedo package | 3P |

BO 4.5: Project based on Specialization courses (8C)