Programme: M. Sc. (Botany)
Course Code: BOC-121
Title of the Course: Algae, Bryophytes, Pteridophytes and Gymnosperms.
Number of Credits: 3
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Botany.	
Objective:	To study general characteristics, classification, trends in classification, phylogeny and inter-relationships of Algae, Bryophyta, Pteridophyta and Gymnosperms.	
Content:	**1. Algae:** General introduction to algae: Classification of Algae; Recent trends in the classification of Algae; General account of morphology, anatomy, reproduction, life histories, classification, phylogeny and inter-relationship, ecological and economic importance of the following groups: Chlorophyta, Charophyta, Chrysophyta, Cryptophyta, Pyrrhophyta, Phaeophyta and Rhodophyta **2. Bryophyta:** Introduction to Bryophyta: General characteristics, classification; Distribution, morphological, anatomical , reproductive studies and comparative account of sporophytes and gametophytes and interrelationships of the following groups: **Hepaticae:** Sphaerocarpales, Calobryales, Takkakiales, Marchantiales, Jungermanniales, **Anthoceotae**: Anthocerotales; **Musci:** Spagnales, Andaeales, Polytrichales, Buxbaumiales Funariales including their fossil relatives **3. Pteridophyta:** General characters and classification of Pteridophytes; Comparative account of Psilophyta. Lycophyta, Eqisetophyta and Flicophyta; Aposory and Apogamy, Heterospory, Soral Evolution, Fossil Pteridophytes **4. Gymnosperms:** General characters and Classification of Gymnosperms; Comparative account of Morphology, anatomy, phylogeny and interrelationships of Pro-Gymnospermopsida, Gymnospermopsida, Gnetopsida and Fossil Gymnosperms.	**9 hours** **9 hours** **9 hours** **9 hours**
Pedagogy:	Lectures/ Tutorials/Assignments/Self-Study	
References/Readings	**1. Agashe, S. N.** (1995). Paleobotany, Oxford and IBH Publ. Co. Pvt. Ltd, New Delhi. **2. Arnold, A. C.** (2005). An Introduction to Paleobotany, Agrobios (India), Jodhpur. **3. Bhatnagar S. P. and Moitra A.** (1996). Gymnosperms. New Age International, New Delhi. **4. Biswas C. and Johri B. M.** (1997). Gymnosperms.	

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5. Bold H.C. and Wynne M. J. (1985). Introduction to the algae; Structure and reproduction. Prentice Hall, Englewood cliffs, New Jersey.
6. Cavers, F. (1976). The inter relationships of the bryophyte. S.R. Technic, **Ashok Rajpath**, Patna.
7. Chapman V.J. and Chapman D.J. (1975). The algae, 2nd Edition, Mac. Millan Publ. Inc. New York.
8. Chopra, R. N., and Kumar P. K. (1988). Biology of Bryophytes. John Wiley and Sons, New York, NY.
9. Desikachary, T.V. (1959). Cyanophyta ICAR, New Delhi
10. Hoek, C. van den, Mann, D. G. and Jahns, H. M. (1995). Algae: An introduction to Phycology, Cambridge University Press, UK.
11. Kashyap, Shiv Ram (1929). Liverworts Of The Western Himalayas And The Punjab Plain Part 1 Chronica Botanica, New Delhi.
12. Kashyap, Shiv Ram, (1932). Liverworts of the western Himalayas and the panjab plain (illustrated): Part 2. The Chronica Botanica New Delhi.
13. Parihar, N.S. (1976). Biology and morphology of the Pteidophytes. Central Book Depot.
14. Parihar, N. S. (1980). Bryophytes: An introduction to Embryophyta Vol I Bryophyta. Central Book Depot.
15. Prem Puri (1981). Bryophytes: Morphology, Growth and Differentiation, Atmaram and Sons, New Delhi.
16. Prescott G. W. (1969). The algae: A review. Nelson, London.
17. Rashid, A. (1999). An Introduction to Pteridophyta, Vikas Publishing House Pvt. Ltd., New Delhi.
17. Ramanujan, C.K.G. (1970). Indian Gymnosperms in time and space. Today & Tomorrow's Printers & Publishers.
18. Round, F.E. (1981). The Ecology of Algae, Cambridge University Press, Cambridge.
19. Sharma, O.P. (1990). Textbook of Pteridophyta. Macmillan India Ltd., Delhi.
20. Singh, V. P. (2006). Gymnosperms (Naked seed plants): Structure and Development, Sarup and Sons, New Delhi.
21. Sporne, K.R. (1965), Morphology of Gymnosperms Hutchinson University Library.
22. Sporne, K.R. (1986). The morphology of Pteridophytes. Hutchinson University Press, London,

	23. Smith, G. M. (1995). The fresh water Algae of the United States, Mc-Graw Hill, New York. **24. Srinivasan, K. S**. (1969). Phycologia India. Vol I & Vol II B.S.I., Calcutta. **25. Surange, K.R.** (1966). Indian fossil Pteridophytes Council of Scientific and Industrial research. New Delhi. **26. Sundara Rajan, S.** (1999). Introduction to Pteridophyta. New Age International Publishers, New Delhi. **27. Trainor, F.R.** (1978). Introductory Phycology, Wiley & Sons. New York. **28. Udar, Ram ,** (1975). Bryology in India: Chronica Botanica, New Delhi. **29. Udar, Ram,** (1970). Introduction Bryophyta Shashidhar Malaviya Prakashan, Lucknow. **30. Vashishta B.R.** (1988). Algae. S. Chand & Co., New Delhi. **31. Waston E. V**. (1971). Structure and life of Bryophytes 3rd Hutchinson University Library, London.	
Learning Outcomes	1. Students will have clear idea of the characteristics of the important plant groups taught in this paper. 2. Concepts in the evolution of plants will be clear to students.	

Programme: M. Sc. (Botany)
Course Code: BOC-122
Title of the Course: Lab in Algae, Bryophytes, Pteridophytes and Gymnosperms.
Number of Credits: 1
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Botany.	
Objective:	To introduce and expose the students to skills required in field and lab based on theory.	

Content:	**1.** Study of vegetative and reproductive features of important algal groups with the available representatives; Chlorophyta, Charophyta, Euglenophyta, Chrysophyta, Cryprtophyta, Pyrrhophyta, Phaeophyta, and Rhodophyta. **2.** Study of vegetative and reproductive features of important bryophytes groups with the available representatives - Hepaticae, Anthocerotae and Musci. **3.** Study of vegetative and reproductive features of important Pteridophyta groups with the available representatives: Psilotales Lycopodiales, Selaginallales Isoetales, Equisetales, Ophioglossales, Marattiales, Osmundales, Filicales, Marsileales and Salviniales **4.** Vegetative and reproductive reproductive features of Gymnospermopsida and Gnetopsida with available representatives.	**8 hours** **6 hours** **6 hours** **4 hours**
Pedagogy:	Conducting Practicals mostly with freshly collected and herbarium specimens, field visits, demonstrations, small projects, *etc.*	
References/Readings	**1. Biswas C. and Johri B. M.** (1997). Gymnosperms. Narosa Publishers, NewDelhi. **2. Bold H.C. and Wynne M. J.** (1985). Introduction to the algae; Structure and reproduction. Prentice Hall, Englewood cliffs, New Jersey. **3. Desikachary, T.V.** (1959). Cyanophyta ICAR, New Delhi. **4. Parihar, N.S.** (1976). Biology and morphology of the Pteidophytes Central Book Depot. **5. Parihar, N. S.** (1980). Bryophytes: An introduction to Embryophyta Vol I Bryophyta central Book Depot. **6. Prem Puri** (1981). Bryophytes: Morphology, Growth and Differentiation, Atmaram and Sons, New Delhi. **7. Prescott G. W**. (1969). The algae: A review. Nelson, London. **8**. **Rashid, A.** (1999). An Introduction to Pteridophyta, Vikas Publishing House Pvt. Ltd. New Delhi. **9. Ramanujan, C.K.G.** (1970). Indian Gymnosperms in time and space. Today & Tomorrow's Printers & Publishers. **10. Sporne, K.R.** (1986). The morphology of Pteridophytes. Hutchinson University Press. London **11. Smith, G. M.** (1995). The fresh water Algae of the United States, Mc-Graw Hill, New york. **12. Srinivasan, K. S**. (1969). Phycologia India. Vol I &	

	Vol II B.S.I. Calcutta. **13. Vashishta B.R.** (1988). Algae. S. Chand & Co., New Delhi. **14. Waston E. V**. (1971). Structure and life of Bryophytes 3rd Hutchinson University Library London.	
Learning Outcomes	1. Able to understand technical description of plants and construct and use keys for identification. morphological, anatomical and reproductive characteristics of the respective plant groups. 2. Able to understand the concepts of the plant evolution. 3. Overall they will have better understanding in area of plant diversity and will be able to carry out research work in this field.	

Programme: M. Sc. (Botany)
Course Code: BOC-123
Title of the Course: Plant Microbiology and Pathology.
Number of Credits: 3
Effective from AY: 2018-19

Prerequisites for the course:	Knowledge of basic microbiology-bacteria, viruses, fungi and plant pathogens at UG level.	
Objective:	The aim of the course is, for students of botany, to understand the diversity and biology of fungi; microbial world, plant diseases and fundamental concepts needed to manage crop diseases. The paper covers mycology, microbiology and principles of plant pathology, with particular emphasis on identification of diseases and disease causative agents. Major scope is on understanding the fungi, microbiology, plant protection, and cultural, chemical and biological control of diseases. In the plant pathology component, the course will also deal with host-pathogen physiology, genetics, taxonomy of disease causing organisms, chemistry of fungicidal actions, etc. The students will understand fungi, microbes, the nature of plant diseases and their control practices	

Content:	**1.General Introduction:** Plant microbe interactions in health and diseases and the changing picture due to climate change	**1hour**
	2. Plant Virology: Origin of viruses, introduction to molecular virology, Virology on Internet - viral databases and their use for understanding viral phylogeny, Viral genomics and proteomics; Viral nucleic acids, enzymes and proteins; classification and nomenclature of Viruses with special stress on plant viruses; modern techniques to study the viruses; Morphology, chemical composition, ultrastructure, replication; The virus cryptogram; Transmission of Plant Viruses.	**4 hours**
	3.Plant Bacterial Interactions and Mycoplasma: Evolutionary aspects of plant microbe interaction; Species of bacteria associated with plants in health and disease; bacterial endophytes; phylloplane and rhizhosphere microbiology; role of bacteria in biogeochemical cycling; Present picture of phylogeny and systematics of bacteria; techniques used to study plant-microbe interactions; Agriculturally beneficial bacteria; Economic importance in relation to biological N-fixation and production of antibiotics and enzymes, importance of Actinobacteria and actinorrhiza. Present knowledge of biology and role of Mycoplasma and L-forms.	**4 hours**
	4. Mycological Dimensions of Plants: Plants and fungi interaction through the window of evolution; present knowledge of fungal biodiversity, phylogeny and classification; fungal plant ecology and fungal endophytes; general biology, forms, structure and functions of Fungi; physiological aspects and nutritional modes of fungi; fungal genetics at classical and molecular level; the fungal holomorph; asexual and sexual reproduction; Structural, functional and ecological specialization of fungal mycelia and spores; Modern fungal systematics, Morphology and molecular-based taxonomy; fungi in tropical habitats in relation to the plants.	**4 hours**
	5. Study of different groups of fungi with suitable native examples: Slime moulds, Chytridiomycota; Ooomycota; Glomeromycota; Zygomycota; Ascomycota and Basidiomycota; Straminopile fungi.	**11 hours**
	6. Economic and biotechnological dimension of fungi: Study of economic importance of fungi; Endo- and ecto-mycorrhizae; Orchid mycorrhizae; Edible and	**12 hours**

	poisonous mushrooms; Wood decay by fungi; Lichens; Yeasts; Fungal cultures; Fungal bioprospecting; Secondary metabolites; Industrial significance; Fungi in food processing, production of enzymes, alcohols, antibiotics; use of fungi for green chemistry and nanobiotechnological applications. 7. **Tropical Plant Pathology:** Diseases of plants in the tropics and their systematic studies using modern techniques. A brief history of plant pathology in India. Symptomatology in fungal, bacterial, viral and mycoplasma diseases of plants; Obligate and facultative pathogens. Classification of plant diseases; methods in the study of plant diseases; Koch postulates; Principles of infection and spread of disease; Sources of inoculum; Physiology of host-pathogen interaction; Role of enzymes and toxins in pathogenesis; Molecular basis of plant diseases; Susceptibility and resistance; Epidemiology, disease cycle, disease forecasting; Control of crop diseases by cultural, physical, chemical and biological methods; Crop rotation; Plant quarantine; Resistant varieties; Algal diseases. Diseases of cereals, pulses, vegetables, oil-seed crops, fruit plants, and plantation crops; Viruses, mycoplasma, protozoan and nematode diseases; Etiology, epidemiology and management of major diseases of paddy (blast, brown leaf-spot, sheath blight, bacterial leaf blight and tungro Virus), jowar (smut by *Sphacelotheca sorghi* and *S. cruenta*), sugarcane (red rot, smut, grassy shoot disease), groundnut (tikka), cotton (wilt), coconut (leaf blight, wilt, yellowing), banana (leaf spot, bunchytop), mango (powdery mildew, sooty mould). Post-harvest and market pathology.	
Pedagogy:	Lectures/ Tutorials/Assignments/Seminars/Moodle Based Work/Videos/Self-Study	
References/Readings	1. **Atlas, M. and Bartha, R.** (2000). Microbial Ecology, Longmann, New York. 2. **Black, J. G.** (1999). Microbiology–Principles and Explorations, Prentice Hall, London. 3. **Brock, T. D.** (1996). Biology of microorganisms Prentice Hall, London. 4. **Casida, L. E.** (1997). Industrial microbiology. New Age Publishers, New Delhi. 5. **Dubey, R. C. and Maheswari, D. K.** (2010). A Text book of Microbiology, S. Chand & Company, New Delhi.	

6. **Gerald Karp** (2008). Cell and Molecular biology-concepts and experiments. John Wiley & Sons, New York.
7. **Kumar, H. D. and Swati Kumar** (1999). Modern concepts of Microbiology, Vikas Publishing House, New Delhi.
8. **Harvey L., Arnold B., Zipursky S. L., Matsudaira P., Baltimore D. and Darnell, J.** (2008). Molecular Cell Biology 6th ed. W. H. Freeman & Co. New York.
9. **Pelezar, M.J., Chan, E.C.S and Kreig, N.R.**(1993).Microbiology-concepts and Applications. McGraw Hill, Inc. New York.
10. **Powar, C.B. and Daginawala, H.F.**(1982).General Microbiology Vol.II.Himalaya Publishers,Bombay.
11. **Rao, A.S.**(2001).Introduction to Microbiology. Prentice Hall of India, New Delhi.
12. **Ainsworth, G.C., Sparrow, F. K. and Sussman, A. S.** (1973). The Fungi. Academic Press, New York.
13. **Alexopoulose, C.J., Mims, C.W., Blackwell, M.** (1996).Introductory Mycology. John Wiley & Sons, New York.
14. **Bessy, E.A.** (1979).Morphology and Taxonomy of Fungi.Vikas Publishing House, New Delhi.
15. **Burnett, J.H.** (1968).Fundamentals of Mycology.Edward Arnold Ltd. London.
16. **Chopra, G.L.** (1998). A text book of Fungi. S.Nagin & Co. Meerut.
17. **Dube, H.C.** (1996). An Introduction to Fungi.Vikas Publish.House, New Delhi.
18. **ElizabethMoore-Landeeker** (1996).Fundamentals of Fungi.Prentice Hall, New Jersey.
19. **Hale, M.E.** (1983).Biology of Lichens. Edward Arnold,London.
20. **Hudson, H. J.** (1986). Fungal Biology. Edward Arnold, London.
21. **Mehrothra, R.S. and Aneja, K.R.** (1990).An Introduction to Mycology. Wiley Eastern Ltd. New Delhi.
22. **Sharma, O.P.** (2007).Text book of Fungi. Tata McGraw Hill, Publishing Co. Ltd. New Delhi.
23. **Sharma, P.D.** (2004).The Fungi for University students.Rastogi Publications, Meerut.
24. **Srivastava, J.P.** (1998).Introduction to Fungi. Central Book Depot, Allahabad.
25. **Sumbali,G.** (2005).The Fungi.Narosa Publishing House, New Delhi.

	26. **Agrios, G.N.** (1997).Plant Pathology. Academic Press, New Delhi. 27. **Bilgrami, K.S. and Dube, H. C.** (1990).A text book of Modern Plant Pathology. Vikas Publishing House, New Delhi. 28. **Butler, E.J. and Jones, S. G.** (1949).PlantPathology. Mc Millan,London. 29. **Chatterjee, P.B.** (1997).Plant Protection Techniques.Bharati Bhavan, Patna. 30. **Chattopadhayay, S.B.** (1991).Principles and Procedures of Plant Protection. Oxford &IBH, New Delhi. 31. **Manners, J.G.** (1982).Principles of Plant Pathology.Cambridge University Press, London. 32. **Marshall,H.**(1999). Diseases of Plants.Anmol Publications Pvt. Ltd. New Delhi. 33. **Mehrotra, R.S.** (2000). Plant Pathology. Tata McGraw Hill,Publishing Co.Ltd. New Delhi. 34. **Mundkur, B.B.** (1982). Text Book of Plant Diseases. Macmillan India Ltd., New Delhi. 35. **Pathak, V. N., Khatri, N. K. and Pathak,M.** (1996).Fundamentals of Plant Pathology. Agrobotanical Publishers (India), Bikaner. 36. **Rangaswamy, G. and Mahadevan, A.** (2002). Diseases of Crop Plants in India. Prentice Hall of India, New Delhi. 37. **Sharma, P.D.** (2005).Plant Pathology.Narosa Publishing House, New Delhi. 38. **Singh, R.S.** (2000). Introduction to the Principles of Plant Pathology. Oxford IBH, New Delhi	
Learning Outcomes	1. Be able to identify microbial habitats and plant disease symptoms. 2. Be able to work in a field laboratory for mycological studies. 3. Gain better understanding of tropical microbial biodiversity and their ecological roles. 4. Have better prospects as plant pathologist in various farms.	

Programme: M. Sc. (Botany)
Course Code: BOC-124
Title of the Course: Lab in Plant Microbiology and Pathology
Number of Credits: 1 (Total sessions 24 hours)
Effective from AY: 2018-19

Prerequisites for the course:	Basic knowledge of microbial habitats in a tropical setup and general idea of diseases affecting crops.	
Objective:	To impart requisite field and lab skills in plant microbiology and pathology with emphasis on tropical strains and local needs in agriculture and economy dealing with economically important microbes.	
Content:	**1**. Microbial ecology in relation to the plants-Introduction to field techniques to studyplant-microbe interactions. **2**. Isolation and maintenance of pure cultures using common microbiological media. **3.** Phylloplane microflora- visualization and isolation. **4**. Rhizosphere microflora- visualization and isolation. **5.** Use of Microscopy in studying microbes in detail - preparation of unstained and stainedspecimens of eubacteria, actinobacteria. **6.** Preparation of unstained and stained specimens of yeasts, fungi. **7.** Examination of gram character of bacteria. **8.**Photomicrography and digital image analysis of representative pure cultures andinterpretation of results. **9.** SEM study of plant viruses using electron dense stains. **10.**Studying Phylogeny of plant viruses using bioinformatics tools. **11.** Study of root nodulation, symbiosome, Nitrogen fixing *Rhizobium*, leghemoglobin and Quorum Sensing in bacterial population. **12**.Methods of isolation and culturing of fungi: colony characters; microscopic observations;morphology of hyphae and spores. **13.** Study of reproductive structures of different genera of fungi. **14.** Study of fungal physiology in pure colonies – characterization of fungal colonies. **15.** Microfluidics in mycology- fabrication and application of microfluidics devices to fungalcultures for real time visualization of fungal metabolic activities. **16.** Introduction to mycological databases and mycosystematics on Internet. **17.** Introduction to Mycobioinformatics- tools and techniques (exercise to construct fungalphylogenetic	**Except 25-27 All 2 hour sessions**

	tree to be given). **18.** Observation of different fungal substrates using sterile moist chamber incubation (*e.g.*herbivore dung; decomposing leaf-litter). **19.**Observations on ecological succession of fungi; Terrestrial, marine and freshwater fungi. **20**. Particle-plating technique for isolation of litter fungi. **21**. Technique for isolation of fungal endophytes. **22.** Isolation and serial dilution techniques (*e.g.* soil, dung and leaf litter). **23.** Collection of infected specimens in the field and observation of symptoms. **24.** Hand sections and tease mounts from infected plant specimens. **25.** Study of as many as possible viral, bacterial and fungal diseases of crop plants (cereal,vegetable, fruit, and plantations) from surrounding habitats in Goa. **26.** Submission of 10 dried herbarium specimens of infected plant materials [fungal (4) +bacterial (3) + viral (3)] collected from nearby habitats. **27.** A mini field project to study crop diseases from field and market specimens.	
Pedagogy:	Field visits and lab exercises/sample collections/use of electronic, digital and visual keys, herbarium production/videos/moodle guided exercises/mini projects/demonstration.	
References/Readings	1. **Sharma, P.D.** (2004).The Fungi for University students.Rastogi Publications, Meerut. 2. **Srivastava, J.P.** (1998).Introduction to Fungi. Central Book Depot, Allahabad. 3. **Sumbali, G.** (2005).The Fungi.Narosa Publishing House, New Delhi. 4. **Agrios, G.N.** (1997).Plant Pathology. Academic Press, New Delhi. 5. **Bilgrami, K.S. and Dube, H. C.** (1990).A text book of Modern Plant Pathology. Vikas Publishing House, New Delhi. 6. **Butler, E.J. and Jones, S. G.** (1949).PlantPathology. Mc Millan,London. 7. **Chatterjee, P.B.** (1997).Plant Protection Techniques.Bharati Bhavan, Patna. 8. **Chattopadhayay, S.B.** (1991).Principles and Procedures of Plant Protection. Oxford &IBH, New Delhi.	
Learning Outcomes	1.Ability to work as a field microbiologist to sample various habitats and asplant pathologist being able to	

	identify disease symptoms 2.Being able to identify common micro and macrofungi from diverse natural habitats 3.Being able to prepare herbarium of diseased plants 4.Being able to isolate and manage microbial cultures 5.Being able to do photomicrography and image analysis of cultures 6.Being able to apply techniques learnt in appropriate projects involving economically important microbes	

Programme: M. Sc. (Botany)
Course Code: BOC-125
Title of the Course: Systematics of Angiosperms.
Number of Credits: 3
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied Plant Taxonomy at undergraduate level. They should be good in basics of classification and nomenclature of angiosperms.	
Objective:	Taxonomy is fundamental to the rest of the studies in biology and at the same time it takes inputs from other branches. The ultimate aim of taxonomy is to understand the evolution at work. Angiosperms being the dominant as well as most evolved plant group, the sources of characters for taxonomy are also varied. It is also being practiced at various levels, from morphology to phylogenomics. This course aims to give comprehensive understanding in angiosperm taxonomy as well as its practice and applications.	
Content:	1. **Plant taxonomy**: Scope and importance; taxonomy as a synthetic discipline; principles and goals; applications - IUCN Red List, Conservation priorities. 2. **Floras, Revisions and Monographs:** Floras, Revisions and Monographs as basis of taxonomy; components, design and methods of floristics and revisionary/ monographic studies; role of herbaria, botanic gardens and literature in taxonomic studies; important literature resources. 3. **Nomenclature:** Purpose, Principles, and overall knowledge of International Code of Nomenclature for algae, fungi, and plants (ICN) and Articles pertaining to typification, publication, priority, author citation and their application. 4. **Cladistics:** Introduction – advantages and problems; classical taxonomy as base for molecular systematics; systematics and phylogenetics classifications – use and utility. The choice of molecules in systematics – Nucleic acids, proteins and amino acids. Molecular evolution – neutral theory, molecular clock.	**4 Hours** **6 Hours** **7 Hours** **9 Hours**

	Cladistics (Phylogeny) – concepts, parsimony, cladograms and trees; characters: apomorphic and plesiomorphic characters, homologous vs analogous; character states, binary and multistate characters, characters transformations; morphometric vs molecular characters. Trees - monophly, polyphyly and paraphyly; rooted and unrooted. Sequences – finding homologous sequences and alignment; local vs global alignment; pairwaise and multiple sequence alignment. Tree construction – algorithmic (UPGMA and Neighbour Joining) and tree-searching (Parsimony, Maximum Liklihood and Bayesian). Phylogenomics as the modern trend in plant taxonomy. 5. **Phylogeny and Classification of Angiosperms:** Fossil angiosperms and their ecology. APG IV system of classification of angiosperms; characteristics and phylogeny of clades: Orders – Amborellales, Nymphaeales, Austrobaileyales, Chloranthales; Clades (Magnoliids), (Monocots (Commelenids)), Order Ceratophyllales, (eudicots ((superrosids(Rosids (malvids, fabids))) (Superasterids (asterids (campanulids, lamids))))).	**10 Hours**
Pedagogy:	Lectures/ Tutorials/Assignments/Self-Study	
References/Readings	1) **APG IV,** 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV, *Botanical Journal of the Linnean Society*, Volume 181, Issue 1, 1 May 2016, Pages 1–20, https://doi.org/10.1111/boj.12385 2) **Barry G. Hall,** 2011. Phylogenetic Trees Made Easy: A How-To Manual. Fourth Edition.Sinauer Associates, Inc., Publishers, Sunderland, USA (Now Oxford University Press). 3) **Benson, L.D.** 1962. Plant Taxonomy: Methods and Principles. Ronald Press, New York. 4) **Cronquist, A.** 1981. An Integrated System of Classification of Flowering Plants. Columbia University Press, New York. 5) **Davis, P.H. and V.M. Heywood.** 1963. Principles of Angiosperm Taxonomy. Oliver & Boyd, Edinburgh. 6) **Douglas Soltis, Pamela Soltis, Peter Endress, Mark Chase, Steven Manchester, Walter Judd, Lucas Majure, and Evgeny Mavrodiev,** 2017. Phylogeny and Evolution of Angiosperms (Revised and Updated edition). University of Chicago Press: 1427 E. 60th Street Chicago, IL 60637 USA. 7) **Ian J. Kitching, Peter L. Forey, Christopher J. Humphries and David M. Williams,** 1998. Cladistics: The Theory and Practice of Parsimony analysis (2nd Ed.). The Oxford University Press. 8) **Jain, S.K. and R.R. Rao.** 1977. A handbook of Field and	

Herbarium methods. Today and Tomorrow Printers and Publishers, New Delhi.
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10) **Jones, S.B. and A.E. Luchsinger.** 1987. Plant Systematics (2nd Ed.) McGrawHill Book Company. New York.
11) **Lawrence, G.H.M.** 1951. Taxonomy of Vascular. Plants. Oxford & IBH Publishing Co.
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13) **Michael George Simpson,** 2010. Plant systematic (2nd Edition). Academic Press.
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16) **Stevens, P. F.** (2001 onwards). Angiosperm Phylogeny Website. Version 14, July 2017 [and more or less continuously updated since]. http://www.mobot.org/MOBOT/research/APweb/
17) **Quicke, D.L.J.** 1993. Principles and Techniques of Contemporary Taxonomy. Blackie Academic & Professional (An imprint of Chapman & Hall.).
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19) **Robert W. Scotland and Toby Pennington,** 2000. Homology and systematics: coding characters for phylogenetic analysis.Systematics Association.
20) **Salemi, M. and A.-M. Vandamme,** 2003.The Phylogenetic Handbook. A Practical Approach to DNA and Protein Phylogeny.Cambridge University Press.
21) **Singh, G.** 2010. Plant systematics: an integrated approach (Third Edition). CRC Press.
22) **Sivarajan, V.V.** 1991. (2nd ed.). Introduction to the Principles of Plant Taxonomy (Ed. N S K Robson). Oxford & IBH publishing Co. Pvt. Ltd.
23) **Stace, C.A.** 1989 (2^{nd} ed.). Plant Taxonomy and Biosystematics. Edward Arnold.
24) **Stuessy, Tod F.,** 2009. Plant taxonomy: the systematic evaluation of comparative data (2nd ed.). New York: Columbia University Press.

	25) **Walter S. Judd, Christopher S. Campbell, Elizabeth A. Kellogg, Peter F. Stevens, Michael J. Donoghue,** 2015. Plant Systematics: A Phylogenetic Approach, Fourth Edition.Sinauer Associates, Inc., Publishers, Sunderland, USA (Now Oxford University Press).	
Learning Outcomes	1. Able to relate plant taxonomy to various other branches including conservation. 2. Should be in a position to understand and use Floras, Revisions and Monographs. 3. Should be able to apply nomenclatural rules. 4. Able to understand and interpret the phylogenetic trees. 5. Know the latest phylogenetic classification of angiosperms, relationships among major clades and their evolution.	

Programme: M. Sc. (Botany)
Course Code: BOC-126
Title of the Course: Lab in Systematics of Angiosperms
Number of Credits: 1
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied or have the practical knowledge of Plant morphological terms.	
Objective:	To learn plant taxonomy through dissection of flowers, use of Floras and field study and develop skills to handle plant identification and floristic work independently and at the same time able to handle molecular data for interpreting phylogeny.	
Content:	1. Writing of technical descriptions. 2. Construction of keys. 3. Identification of local species using Floras, keys and campus field trips. 4. Identification of 25 families using diagnostic characters; diagnostic characters to be illustrated. 5. Construction of phylogentic tree based on gene sequences available at NCBI database (each student may be given different gene sequences/taxa).	**2 hours** **2 hours** **4 hours** **12 hours** **4 hours**
Pedagogy:	Through actual dissection of floral parts/ Field trip /Practice	

References/ Readings	1) **Barry G. Hall.** 2007. Phylogenetic Trees Made Easy: A How-To Manual, Third Edition. Sinauer Associates, Inc., Publishers, Sunderland, USA. 2) **Jain, S.K. and R.R. Rao.** 1977. A handbook of Field and Herbarium methods. Today and Tomorrow Printers and Publishers, New Delhi. 3) **Lawrence, G.H.M.** 1951. Taxonomy of Vascular. Plants. Oxford & IBH Publishing Co. 4) **Singh, G.** 2009. Plant systematics: an integrated approach. Science Pub Inc. 5) **Utteridge, T. and G. Bramley.** 2014. Tropical Plant Families Identification Handbook. Kew Publishing. 6) **Walter S. Judd, Christopher S. Campbell, Elizabeth A. Kellogg, Peter F. Stevens and Michael J.Donoghue.** 2007. Plant Systematics: A Phylogenetic Approach, Third Edition.Sinauer Associates, Inc., Publishers, Sunderland, USA.	
Learning Outcomes	1. Able to write technical description of plants and construct and use keys for identification. 2. Able to identify common plant families based on the morphological features. 3. Able to recognise common plants. 4. Able to construct phylogenetic tree based on molecular sequences.	

Programme: M. Sc. (Botany)
Course Code: BOC-221
Title of the Course: Internal Morphology and Developmental Biology of Angiosperms.
Number of Credits: 3
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Botany. It is assumed that students have a basic knowledge of anatomy and developmental biology of higher plants.	
Objective:	The paper provides deeper understanding of various anatomical structures and their functions, several embryological processes including pollen pistil interaction, applied aspects of embryology, various palynological methods to understand pollen biology and pollen biotechnology of flowering plants.	
Content:	**Internal Morphology** **1. Meristems:** Shoot and root apical and intercalary meristems; their ultra-structure and histochemistry;	**3 hours**

	cytological and molecular analysis of the shoot apical meristem; autonomy of the meristem and vascular tissue differentiation in the shoot apex.	
	2. Vascular cambium vs cork cambium, factors controlling their activity; lenticels; abscission; wound healing.	**2 hours**
	3. Ontogeny, phylogeny, evolution, ultra-structure and function of primary and secondary xylem; wood anatomy; bio-deterioration of wood and its prevention.	**3 hours**
	4. Ontogeny, phylogeny, evolution, ultra-structure and function of primary and secondary phloem.	**2 hours**
	5. Structural variability in leaves including leaf structures of C_3 and C_4 sub-types, CAM plants; leaf histogenesis; leaf meristems; evolution of leaf forms, heteroblasty. Origin, development and ultra-structure of trichomes and stomata.	**3 hours**
	6. Nodal anatomy: Nodal types, phylogenetic and evolutionary considerations.	**1 hour**
	9. Anatomy of monocotyledonous and dicotyledonous seeds and fruits - their ontogeny structure and functions.	**2 hours**
	<u>Embryology</u>	**2 hours**
	1. Microsporogenesis and formation of the male gametophyte: Anther differentiation, pollen development and maturation, gene expression during pollen development, male sterility and pollen abortion, male gametogenesis.	**2 hours**
	2. Megasporogenesis and formation of embryo sac: Ovule differentiation and development, megasporogenesis, organization of embryo sac, types of embryo sac, gene function during megagametogenesis.	**3 hours**
	3. Pollen pistil interaction and fertilization: Pollen-stigma interaction and pollen tube guidance, pollen recognition by stigma, self-incompatibility, structural, biochemical and molecular aspects of gametophytic and sporophytic self incompatibility. Double fertilization, *in vitro* fertilization.	**3 hours**
	4. Endosperm and embryogenesis: Endosperm, embryo, nutrition and growth of embryo. Gene action during embryogenesis, storage compounds in endosperm and embryo, storage protein gene expression in transgenic systems; apomixis and polyembryony; applied aspects of embryology.	**3 hours**
	<u>Palynology</u>	
	1. Pollen Biology: Pollen morphological characters, Pollen wall features, pollen development and evolution of pollen types, palynology and taxonomy.	**2 hours** **2 hours**

	2. Aeropalynology: Methods of aerospora survey and analysis; pollen allergy and pollen calendars. **3. Mellittopalynology:** Honey bee and pollen loads; role of apiaries in crop production. **4. Palaeopalynology:** Study of fossil pollens and spores and their significance in paleobotany and coal and oil explorations. **5.** Pollen biotechnology for crop production and improvement.	**2 hours** **1 hour**
Pedagogy:	Lectures/ Tutorials/Assignments/Seminars/Self-Study	
References/Readings	1.**Shivanna, K. R. and Rangaswamy N. S.** 1992. Pollen Biology - A Laboratory Manual, Narosa Publishing House, New Delhi. 2. **Batygina T. B.** 2009. Embryology of Flowering Plants Terminology and Concepts, Volume 3, Reproductive Systems, Science Publishers, USA. 3. **Raghavan V.** 2000. Developmental Biology of Flowering Plants, Springer-Verlag, New York. 4. **Bhojwani S. S. and Bhatnagar S. P.** 1992. The Embryology of Angiosperms, Vikas Publishing House Pvt. Ltd., New Delhi. 5. **Johri B.M.** 1984. Comparative Embryology of Angiosperms, Ind. Nat. Sci. Acad., New Delhi. 6. **Maheshwari P.** 1985. An Introduction to Embryology of Angiosperms, Tata McGraw Hill, New Delhi. 7. **Fahn. A.** 1990. Plant Anatomy, 4th Edition, Pergamon press, New York, Oxford. 8. **Esau K.** 1985. Plant anatomy, 2nd Edition, Wiley Eastern Limited, New Delhi. 9. **Metcalf C. R. and Chalk L.** 1950. Anatomy of Dicots Vol. I & II, London Press, Oxford. 10. **Romberger J. A., Hejnowicz Z. and Hill J. F.** 1993. Plant Structure: Function and Development, Springer-Verlag. 11. **Nair P.K.K.** Essentials of Palynology, Asha Publishing House, New York. 12. **Shivanna, K. R. and Sawhney V. K.** 1997. Pollen Biotechnology for Crop Production and Improvement, Cambridge University press. U.K. 13. **Lyndon R. F.** 1990. Plant Development, the Cellular Basis. Cambridge University Press, UK. 14. **Hesse M. and Ehrendorfer F.** 1990. Morphology, Development and Systematic Relevance of Pollen and Spores, Springer-Verlag, New York.	

	15. **Kashinath Bhattacharya, M. R. Majumdar and S. G. Bhattacharya.** 2006. A text Book of Palynology, New Central Book Agency (P) Ltd., Kolkata, India.	
Learning Outcomes	1. Being able to apply the knowledge of anatomy, structure and functions to all flowering plants. 2. Being able to apply the embryological processes and applied aspects of embryology in various situations. 3. Being able to apply the knowledge of pollen biology and biotechnology and methods and techniques learnt to various situations and applications.	

Programme: M. Sc. (Botany)
Course Code: BOC-222
Title of the Course: Lab in Internal Morphology and Developmental Biology of Angiosperms
Number of Credits: 1 (24 hours)
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Botany (6 or 3 Units). It is assumed that students have a basic knowledge of anatomy and developmental biology of higher plants.	
Objective:	To learn plant anatomy, embryology and palynology through sectioning and staining of various vegetative and reproductive parts of plants. Development of skills such as isolation of embryo and endosperm from early stages of seed development. Also to study various ornamentation patterns in pollen grains from flowers and honey samples.	
Content:	1. Comparative anatomy of monocotyledon and dicotyledon root, stem and leaf. 2. Anatomical basis of identification C_3 & C_4 sub types in grasses. 3. Phytoliths of grasses and their potential use in identification. 4. Anatomy of lenticels and periderm in plants. 5. Anatomy of monocotyledonous and dicotyledonous seeds. 6. Study of different types of stomata and trichomes. 7. Maceration of wood to study xylem components. 8. Study of microsporangium and microsporogenesis. 9. Study of megasporangium and embryo sac development. 10. Study of types of endosperm and its modifications. 11. Study of development of embryo in dicot and monocot. 12. Study of different ornamentation patterns in pollen	**2 hours** **2 hours** **2 hours** **2 hours** **2 hours** **2 hours** **4 hours** **2 hours** **2 hours** **2 hours** **2 hours** **4 hours**

	grains by acetolysis. 13. Analysis of honey samples to identify uni-floral or multi-floral honey.	**4 hours**
Pedagogy:	Hands on Practical.	
References/Readings	1. **Shivanna, K. R. and Rangaswamy N. S.** 1992. Pollen Biology - A Laboratory Manual, Narosa Publishing House, New Delhi. 2. **Batygina T. B.** 2009. Embryology of Flowering Plants Terminology and Concepts, Volume 3, Reproductive Systems, Science Publishers, USA. 3. **Raghavan V.** 2000. Developmental Biology of Flowering Plants, Springer-Verlag, New York. 4. **Bhojwani S. S. and Bhatnagar S. P.** 1992. The Embryology of Angiosperms, Vikas Publishing House Pvt. Ltd., New Delhi. 5. **Johri B.M.** 1984. Comparative Embryology of Angiosperms, Ind. Nat. Sci. Acad., New Delhi. 6. **Maheshwari P.** 1985. An Introduction to Embryology of Angiosperms, Tata McGraw Hill, New Delhi. 7. **Fahn. A.** 1990. Plant Anatomy, 4th Edition, Pergamon press, New York, Oxford. 8. **Esau K.** 1985. Plant anatomy, 2nd Edition, Wiley Eastern Limited, New Delhi. 9. **Metcalf C. R. and Chalk L.** 1950. Anatomy of Dicots Vol. I & II, London Press, Oxford. 10. **Romberger J. A., Hejnowicz Z. and Hill J. F.** 1993. Plant Structure: Function and Development, Springer-Verlag. 11. **Nair P.K.K.** Essentials of Palynology, Asha Publishing House, New York. 12. **Shivanna, K. R. and Sawhney V. K.** 1997. Pollen Biotechnology for Crop Production and Improvement, Cambridge University press. U.K. 13. **Lyndon R. F.** 1990. Plant Development, the Cellular Basis. Cambridge University Press, UK. 14. **Hesse M. and Ehrendorfer F.** 1990. Morphology, Development and Systematic Relevance of Pollen and Spores, Springer-Verlag, New York. 15. **Kashinath Bhattacharya, M. R. Majumdar and S. G. Bhattacharya.** 2006. A text Book of Palynology, New Central Book Agency (P) Ltd., Kolkata, India.	
Learning Outcomes	1. Being able to apply the knowledge of anatomy, structure and functions to all flowering plants.	

	2. Being able to apply the embryological techniques and methods to various plant species and situations. 3. Being able to apply the knowledge of pollen biology and methods and techniques to various plant species. 4. Environmental biomonitoring of pollen allergens.	

Programme: M.Sc. Botany
Course Code: BOC-225
Title of the Course: Plant Physiology
No. of Credits: 3
Effective from AY: 2018-19

Prerequisite for course	Knowledge of the subject at UG level.	
Objective	This course teaches processes of plant water relationship, mineral nutrition and assimilation (nitrogen, sulphur and other inorganic nutrients), photosynthesis with emphasis on mechanism of abiotic stresses at physiological and molecular level with reference to crop productivity. The Course also teaches Plant growth and development due to light and phytohormones with emphasizes on cellular and molecular mechanism of signal transduction and physiological response.	
Content	The physico-chemical organisation of the plant cell and cell organelles; structure and composition of plasma membrane fluid mosaic lipo-protein model, membrane, Water relation of plants, unique physico chemical properties of water; bulk movement of water and substances across the membrane, aquaporins, stomatal regulation of transpiration, anti transpirants.	**4 hours**
	Inorganic nutrition, macro and micro nutrients, deficiency symptoms, hydroponic studies; mineral absorption and translocation and assimilation; Nernst equation and Donnan's equilibrium.	**2 hours**
	Nitrogen metabolism: Nitrogen nutrition, organic nitrogen, nitrogen fixation in legumes, nitrate and ammonia assimilation: Sulfur metabolism and amino acid synthesis. Inter relationship between photosynthesis, respiration and nitrogen metabolism.	**3 hours**
	Photosynthesis: Importance of photosynthesis, Photosynthesis and environment. Light reaction: Radiant energy, photosynthetic apparatus, pigments and their biosynthesis; light harvesting complex; characteristics of two photosystems, photosynthetic electron transport, water oxidation and its molecular mechanism, photophosphorylation, pseudocyclic electron transport (Mehler reaction).	**5 hours**

	Dark reaction: Carbon dioxide fixation in C3, C4 and CAM plants regulation of PCR cycle; photorespiration and its regulation, environmental factors affecting photosynthesis.	**3 hours**
	Respiration: Aerobic and anaerobic respiration; cyanide independent respiration; cytochrome system; carbohydrate and lipid metabolism; high energy compounds and factors affecting respiration. ROS generation, effect and metabolism	**6 hours**
	Enzymes: Structure and classification; mechanism of action; Michaelis-Menten equation; Lineweaver-Burk plot; enzyme regulation; allosteric enzymes, isozymes, co-enzymes and vitamins.	**2 hours**
	Growth and development: Phytochromes and light control, regulatory mechanism; role of phytochrome in phototropism; physiology of flowering and fruiting.	**2 hours**
	Phytohormones: Auxin; cytokinin; Gibberellins; ethylene; ABA. polyamines; brassinosteroids, jasmonate, their synthesis, distribution; and physiological effects. Molecular mechanism of action.	**5 hours**
	Stress Physiology: Abiotic stresses (drought, salt and metal), morphological and cellular adaptation; molecular mechanism of stress tolerance and protection.	**4 hours**
	Seed dormancy and germination, senescence, circadian rhythms in plants (exogenous factors and molecular mechanism).	
Pedagogy	Lecture through PPT/E-learning/Assignments/Seminars/LSM Moodle	
Reading/reference	1. **Nair, L. N.** (2007). Topics in Mycology and Pathology, New Central Book agency, Kolkata. 2. **Taiz L. and Zeiger E. Plant Physiology. Panima, New Delhi** Henry R.J. Plant Molecular Biology. Chapman and Hall, Panima, New Delhi. 3. **Anderson et al. Molecular Genetics of Photosynthesis, IRL Press, New Delhi**. Hipkins, M.F and Baker N.R. Photosynthesis: Energy transduction a practical approach, IRL Press. 4. **Hopkins, W.G. Introduction to Plant Physiology, Wiley, New York**. Luttuge U. Physiological Ecology of Tropical plants. Springer. 5. **Mengel K**. Principles of Plant Nutrition, Panima. 6. **Salisbury F.B.** Plant Physiology. 7. **Thomson Tesar M.B.** Physiological basis of crop growth and development, Panima. 8. **Wills R.** Post harvest: An introduction to the physiology and handling of fruit. Nobel P.S. Physiological and environmental Plant Physiology. Allied Press.	

9. **Buchanan B.B., Gruissen W. and Jones R.L.** Biochemistry and Molecular Biology of Plants, ASPP.
10. **Finkelstein A.** Water movement through lipid bilayers, pores and plasma membranes: Theory and reality. Wiley, New York.
11. **Friedman M.H.** Principle and models of biological transport. Springer-Verlag. Stein W.D. Transport and diffusion across cell membrane. Academic press.
12. **Jarvis P.G. and Mansfield T.A.** Stomatal Physiology, Cambridge. Kramer P.J. and Boyer J.S. Water relations of plants and soils. Academic Press. San Diego. Zimmermann M.H. Xylem structure and ascent of sap. Springer.
13. **Lauchli A. and Bieleski** Inorganic plant Nutrition. Springer Brady N.C. The nature and properties of soils. Macmillan.
14. **Epstein E.** Mineral nutrition of plants: Principles and perspectives. Wiley, New York.
15. **Marschner H.** Mineral nutrition of higher plants.
16. **Mengel K. and Kirkby E.A.** principles of plant nutrition. Worblaufen-Bern, Switzerland.
17. **Luttuge U and Higinbotham N.** Transport in plants. Springer-Verlag, Germany Small J. pH and Plants, an introduction to beginners. Nostrand, New York.
18. **Hall D.O and Rao K.K. Photosynthesis Edwards-Arnold**,
19. Coombs J., Hall D.O., Long, S.P. and Scurlock J.M.O. Techniques in bioproductivity and Photosynthesis. Pergamon, Oxford.
20. **Blankenship R.E.** Molecular Mechanism of photosynthesis Blackwell Science, Oxford.
21. **Edwards G.E. and Walker D.** C3-C4 mechanisms and cellular and environmental regulation of photosy nthesis. Univ. California Press.
22. **Pollock C.J., Farrar J.F. and Gordon, A.J.** Carbon partitioning within and between organisms. BIOS Scientific, Oxford.
23. **Davies D.** The Biochemistry of Plants Academic Press.
24. **Dennis D.T., Turnip D.H., Lefebvre, D.D. and Layzell D.B.** Plant Metabolism. Longman, Singapore.
25. **Douce R.** Mitochondria in higher plants: Structure, function and Biogenesis. Academic Press.
26. **Douce R and Day D.A.** Higher plant cell respiration. Springer, Berlin.
27. **Nicholls D.G. and Ferguson S. J.** Bioenergetics. Academic Press.
28. **Dixon R.O.D. and Wheeler C.T.** Nitrogen fixation in plants. Chapman and Hall, New York.
29. **Wray J. L. and Kinghorn J.R.** Molecular and genetic aspects of nitrate assimilation. Oxford Science, Oxford.

	30. **Mann** Secondary Plant Metabolites. 31. **Karban R. and Baldwin I.T.** Induced response to herbivory. Uni. Chicago press. Galston A. Life processes of Plants. Sci. Am. Library, New York. 32. **Kendrick R.E. and Frankland B.** Phytochrome and Plant Growth. Edward-Arnold, London. 33. **Smith H.** Phytochrome and photomorphogenesis: An introduction to the photocontrol of plant development. McGraw Hill London. 34. **Senger H.** Blue light effects in biological systems. Springer, Berlin. 35. **Davies P.J.** Plant Hormone and their role in plant growth development. Kluwer, Dordrecht, Netherland. 36. **Bopp M.** Plant Growth substances. Springer, Berlin. 37. **Moore T.D.** Plant Growth regulators. Kluwer, Dordrecht. The Netherland. Cherry J.H. Environmental Stress in plants. Springer, Berlin. 38. **Mussel H. and Staples R.C.** Stress physiology in crop plants. Wiley New York. 39. **Levitt J.** Response of plants to environmental stresses. Academic press, New York.
Learning outcome	Students will be able to demonstrate a depth of knowledge of physiological processes together with a better understanding of interaction and regulation of growth, metabolism and development and influence of environment on plant and further will be able to communicate scientific ideas in both written and oral forms to diverse audiences.

Programme: M.Sc. Botany
Course Code: BOC-226
Title of the Course: Lab in Plant Physiology
No. of Credits:1
Effective from AY: 2018-19

Prerequisite for course	Knowledge of the subject at UG level to be able to prepare various types solution, set pH, and handle basic laboratory tools and techniques. Preferably taken paper BOO 121 and 122	
Objective	This course is designed primarily to relate the learning of concepts in classroom to demonstrate experimental foundation of underline concepts/principles mainly on aspects of biological molecules, photosynthesis, respiration, transport, growth, growth substances and the stress physiological aspects of crop yield.	
Content	1. Verification of law of diffusion and osmosis	**2 hours**
	2. Determination of water potential and osmotic potential	**2 hours**

	and RWC in plant tissue.	
	3. Analysis of plant tissue for: Water, organic and inorganic content; Determination of a few macronutrients by Flame photometer, and micronutrient by AAS.	**4 hours**
	4. Quantitative estimation of protein.	**2 hours**
	5. Determination of ascorbic acid content of tissue.	**2 hours**
	6. Separation of protein by PAGE.	**2 hours**
	7. Pigments extraction, separation, identification and quantification.	**2 hours**
	8. Photo-oxidation of plant pigments.	**2 hours**
	9. Determination of oxidative damage in tissue using TBARS method	**2 hours**
	10. Enzyme activity with respect to temperature or pH or substrate concentration.	**4hours**
	11. Isolation of intact organelles: chloroplasts and mitochondria.	**2 hours**
	12. Assay of photosynthetic electron transport activity from isolated chloroplast using oxygraph.	**2 hours**
	13. Assay of respiratory electron transport activity from isolated mitochondria using oxygraph.	**2 hours**
	14. Non-invasive measurements of photosynthesis (chlorophyll fluorometer).	**2 hours**
	15. Assay of nitrate/nitrite reductase activity in leaves/algae.	**2 hours**
	16. Estimation of Proline under stress and normal conditions.	**2 hours**
Pedogogy	Wet laboratory exercises	
Reading/reference	1. **D.T. Plummer,** An introduction to practical Biochemistry. Tata McGraw Hill publishing company Limited. New Delhi. 2. **J.B. Harborne,** Phytochemical Methods. Chapmann and Hall. London.	
Learning outcome	The understanding of the rationale behind the practical procedures and ability to interpret the observations will enhance the student's ability to modify/design their own procedures if necessary as they advance to higher levels. They will develop ability to apply the knowledge of plants symptoms/observation to their underline physiological causes.	

Programme: M. Sc. (Botany)
Course Code: BOC-321
Title of the Course: Plant Molecular Biology
Number of Credits: 3
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Botany. It is assumed that students have a basic knowledge of biochemistry and molecular biology.	
Objective:	The paper deals with various molecular biological processes of DNA replication, transcription and translation. Molecular biology of recombination, synthesis and processing of various RNA molecules are discussed. Further the paper provides deeper understanding of regulation of gene expression in various organisms.	
Content:	**1. Introduction to Molecular Genetics and Genomics:** History of DNA molecule & discoveries till date. Physical nature of DNA: DNA is the genetic material, Chemical nature of DNA: Structure of nucleotides, Bonding, double helix and other helices. Factors affecting DNA structure. Organization of DNA. How Genes function at Molecular level - Replication, Transcription & Translation.	**5 hours**
	2. Molecular Biology of DNA Replication: Enzymes involved in replication, DNA replication is semi-conservative, Meselson-Stahl expt., Multiple Origins & bi-directional DNA replication in Eukaryotes, Replication of Virus & Theta replication of Circular DNA molecules, Rolling Circle replication, Plasmid DNA using a Rolling Circle, Unwinding, Stabilization & Stress relief, initiation by a Primosome complex, Chain elongation & Proofreading, discontinuous replication of the lagging strand, Terminator sequencing of DNA.	**6 hours**
	3. Molecular Biology of Recombination: Molecular mechanisms of Recombination, Gene conversion, Mismatch repair, the Holliday model of recombination, Single strand break & repair model.	**3 hours**
	4. Transcription: Enzymes in transcription; Basic features of transcription, Initiation elongation and termination, promotors and enhancers; prokaryotic and eukaryotic transcription.	**5 hours**
	5. Regulation of Gene Expression: Regulation of gene expression in prokaryotes and Eukaryotes. Transcriptional Control I, expression of lac operon, Transcriptional Control II, Attenuation, Antitermination, Methylation, Yeast GAL regulatory pathway, alteration of gene expression by DNA sequence rearrangements in	**6 hours**

	Salmonella and *Trypanosoma*. **6. RNA Molecules and RNA Processing:** Gene structure, Structure & Processing of messenger RNA, transfer RNA, ribosomal RNA, small interfering RNAs & micro RNAs, regulation through RNA processing & decay, alternative splicing, mRNA stability, co-suppression through RNA turnover, RNA interference (RNAi). **7. The Genetic Code and Translation:** Molecular relation between Genotype & Phenotype, The Genetic Code, Factors involved in initiation, elongations and termination of translation, Post translational processing and modification, Transport of protein across the membrane.	**5 hours** **6 hours**
Pedagogy:	Lectures/ Tutorials/Assignments/Seminars/Self-Study	
References/Readings	1. **Burton E. Tropp.** 2012. Molecular Biology. Fourth Edition. Jones and Bartlett India Pvt. Ltd, New Delhi. 2. **David Freifelder.** 1990. Molecular Biology. Second Edition. Narosa Publishing House, New Delhi. 3. **James D. Watson, Tania A. Baker, Stephen P. Bell, Alexander Gann, Michael Levine and Richard Losick.** 2008. Molecular Biology of Gene. Sixth Edition. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York.U.S.A. 4. **Primrose, S. B. and R. M. Twyman.** 2009. Principles of Gene Manipulation and Genomics. Seventh Edition. Blackwell Publishing, U.S.A. 5. **Brown T. A.** 2007. Genomes. Third Edition. Garland Science Publishing, New York. U.S.A. 6. **Benjamin Lewin.** 2008. GENES IX. Jones and Bartlett Publishers, London, UK. 7. **Mary A. Schuler and Raymond E. Zielinski.** 2005. Methods in Plant Molecular Biology. Academic Press, USA. 8. **R. J. Henry.** 2005. Practical Applications of Plant Molecular Biology. Chapman & Hall, London, UK. 9. **Shaw, C. H.** 1988. Plant Molecular Biology, Practical Approach. IRL Press, Oxford, Washington DC. 10. **Grierson D and S. Covey.** 1984. Plant Molecular Biology. Panima Educational Agency, New Delhi. 11. **Gloria Coruzzi.** 1994. Plant Molecular Biology - Genetic Analysis of Plant Development and Metabolism. Springer-Verlag, New York, London. 12. **Tewari, K. K. and G. S. Singhal.** 1997. Plant Molecular Biology and Biotechnology. Narosa Publishing House, New Delhi.	
Learning Outcomes	1. Being able to apply the knowledge of various molecular	

	biological processes of DNA replication, transcription and translation to various other organisms. 2. Molecular biology of recombination, synthesis and processing of various RNA molecules could be employed in various situations and applications. 3. Being able to apply the regulation of gene expression to various other organisms.	

Programme: M.Sc. Botany
Course Code: BOC-323 Title of the Course: Plant Genetic Engineering
No. of Credits Three (3)
Effective from AY: 2018-19

Prerequisite for course	Knowledge of the subject at UG level.	
Objective	This course is designed to understand basic principles, tools, techniques and recent advances in plant genetic engineering. Students will be exposed to restriction enzymes, vectors (plasmids, phasemids, *etc*), joining and construction of genome and cDNA library and its screening for desired gene, transformation, etc. Student will also be exposed to site directed mutation techniques and other modern techniques such as sequencing, PCR, RT-PCR, RNAi *etc.* to study gene amplification and their expression. This paper also discusses other application of genetic engineering such as genetic marking and Molecular taxonomy.	
Content	Introductory lecture on application of genetic engineering in the field of Plant science with regard to Agriculture, environment and medical field and study of plant taxonomy.	**2 hours**
	Restriction and modification of DNA: Basic principle of genetic engineering; restriction enzyme, cutting and joining the DNA; Vectors: plasmids, fine structure of vector gene desirability traits; construction of plasmid, purification of plasmids, various types of plasmids, Bacteriophage and cosmid, single and double standard vectors and their growth cycle and regulation; various cloning strategies, Genome library and cDNA library, selection strategies for desired transformants, Genetic system provided by *E. Coli* and its host.	**8 hours**
	Agrobacterium-mediated gene transfer: Biology and molecular basis of Agrobacterium mediated plant transformation and its application. Other direct gene transfer methods. Conventional Plant Breeding vs Genetic Engineering.	**4 hours**
	Site directed mutagenesis: DNA sequencing, various strategies for carrying out site directed mutagenesis.	**3 hours**
	Structure, function and regulation of genome: General organization and replication, transcription and translation of , mitochondrial and chloroplast genome; Genetic interactions in nucleus, chloroplast and	**6 hours**

	mitochondria (retrograde signaling/plastid factors); Genetic codes in organelles;	
	Gene silencing, editing, sequencing, amplification expression in plants: Post transcriptional and transcriptional gene silencing (RNAi, Antisense), Gene editing and its application (CRISPER-CAS9), mutants of gene silencing, RNA virus in plants, virus induced gene silencing, Dideoxy and other methods of sequencing, PCR, RT-PCR and microarrays.	**6 hours**
	Application of plant genetic engineering: Genetic engineering of plants for various desired characters (herbicide resistance, insect resistance, virus and abiotic stress resistance; to improvement of crop yield and quality; rice genome project, other sequenced genomes, (With relation to matter discussed above)	**5 hours**
	Genetic Engineering and public Concerns: Ethical & Environmental concerns on Genetic Engineering of plants. Genetically Engineered Foods, Safety of Genetically Engineered Foods, Labeling, Future Foods and Regulatory Challenges, 'Pharm' Factories of the Future. Field testing of transgenic plants; Bio-safety issues in Indian contest; Indian rules, regulation and procedures for handling transgenic plants.	**2 hours**
Pedagogy	Lectures/E-learning/Assignments/Seminar/Moodle/Group discussion	
Reading/ reference	1. **David Freifelder.** 1987. Molecular Biology. Second Edition. Narosa Publishing House, New Delhi. 2. **R. W. Old and S. B. Primerose.** Principles of Gene Manipulation. An Introduction to Genetic Engineering. 3. **Benjamin Lewin**. 1999. GENES VII. Oxford University Press. 4. **O'Brien, L. and R. J. Henry.** Transgenic cereals, American Association of Cereal Chemists, St. Paul, Minnesota, USA. 5. **Shaw, C. H.** 1988. Plant Molecular Biology-Practical Approach. IRL Press, Oxford, Washington DC. 6. **Grierson D and S. Covey.** 1984. Plant Molecular Biology. Panima Educational Agency, New Delhi. 7. **Gloria Coruzzi** 1994. Plant Molecular Biology-Genetic Analysis of Plant Development and Metabolism. Springer-Verlag, New York, London. 8. **Tewari, K. K. and G. S. Singhal.**1997. Plant Molecular Biology and Biotechnology. Narosa Publishing House, New Delhi. 9. Books referred for BOC-321 Plant Molecular Biology should also be read.	
Learning outcome	After completing this course student should be able to understand basic principles of plant genetic engineering in order to develop and validate transgenic plants.	

Programme: M. Sc. (Botany)
Course Code: BOC-324
Title of the Course: Lab in Plant Molecular Biology and Genetic Engineering
Number of Credits: 2 (48 hours)
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Botany. It is assumed that students have a basic knowledge of biochemistry, molecular biology and instrumental techniques at UG level.	
Objective:	To learn and understand various methods, techniques and hands on experiments with techniques concerning study of plant molecular biology and genetic engineering. This course is designed to introduce students to both the principles and the applications of molecular recombinant DNA technology to plants and microbial organisms. It describes the use of genetically engineered products to solve agriculture and environmental problems for human welfare.	
Content:	1. Preparation of media and other requirements, sterilized glassware etc.	2 hours
	2. Isolation and purification of genomic DNA from plant materials.	2 hours
	3. Isolation and purification of RNA from plants.	2 hours
	4. Culture of plasmid and maintenance of culture.	2 hours
	5. Isolation of plasmid DNA.	2 hours
	6. Quantitative estimation of genomic DNA and RNA using spectrophotometer.	2 hours
	7. Agarose gel electrophoresis of genomic DNA and RNA and detection using gel documentation system.	2 hours
	8. Digestions of DNA by restriction enzymes and size fractionation of fragments.	2 hours
	9. Ligation of digested fragments.	2 hours
	10. Primer designing.	2 hours
	11. cDNA formation using reverse transcriptase.	4 hours
	12. RT-PCR quantitation of selected gene(s) using SYBRG.	4 hours
	13. Use of software for quantitation of gene and compare the expression level.	2 hours
	14. Southern Blotting/Northern Blotting/Western Blotting (any one)	2 hours
	15. Creating a transformant using commercial construct.	4 hours
	16. 16 or 18s rRNA analysis.	4 hours
	17. Leaf disc transformation using Agrobacterium, establishment of transgenic plants and GUS staining of GFP viewing.	4 hours
	18. Amplification of genomic DNA using ISSR/ RAPD random primers in PCR and agarose gel electrophoresis and detect the banding patterns under gel documentation system and analysis of bands to understand genetic variation in plants.	4 hours

	Any 15 experiments will be conducted depending on availability of material/equipments etc.	
Pedagogy:	Hands on practicals.	
References/ Readings:	1. Burton E. Tropp. 2012. Molecular Biology. Fourth Edition. Jones and Bartlett India Pvt. Ltd, New Delhi. 2. David Freifelder. 1990. Molecular Biology. Second Edition. Narosa Publishing House, New Delhi. 3. James D. Watson, Tania A. Baker, Stephen P. Bell, Alexander Gann, Michael Levine and Richard Losick. 2008. Molecular Biology of Gene. Sixth M.Sc Syllabus - 2018 Core 29 Edition. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York.U.S.A. 4. Primrose, S. B. and R. M. Twyman. 2009. Principles of Gene Manipulation and Genomics. Seventh Edition. Blackwell Publishing, U.S.A. 5. Brown T. A. 2007. Genomes. Third Edition. Garland Science Publishing, New York. U.S.A. 6. Benjamin Lewin. 2008. GENES IX. Jones and Bartlett Publishers, London, UK. 7. Mary A. Schuler and Raymond E. Zielinski. 2005. Methods in Plant Molecular Biology. Academic Press, USA. 8. R. J. Henry. 2005. Practical Applications of Plant Molecular Biology. Chapman & Hall, London, UK. 9. Shaw, C. H. 1988. Plant Molecular Biology, Practical Approach. IRL Press, Oxford, Washington DC. 10. Grierson D and S. Covey. 1984. Plant Molecular Biology. Panima Educational Agency, New Delhi. 11. Gloria Coruzzi. 1994. Plant Molecular Biology - Genetic Analysis of Plant Development and Metabolism. Springer-Verlag, New York, London. 12. Tewari, K. K. and G. S. Singhal. 1997. Plant Molecular Biology and Biotechnology. Narosa Publishing House, New Delhi. 13. C. Neal Stewart Jr. Plant Biotech and genetics: Principle, techniques and applications. Wikley jones and Sons, Canada 14. J.H. Dodds. Plant Genetic Engineering. Cambridge University Press. 15. Isil Aksan Kurnaz. Techniques in Genetic Engineering. CRC Press	
Learning Outcomes:	After completing this course student should be able to recognize the foundations of modern biotechnology and explain the principles that form the basis for recombinant DNA technology and be able to carry out R & D work or work in quality control laboratory on molecular biology and recombinant DNA technologies such as vector construction, cloning and gene expression etc.	

Programme: M. Sc. (Botany)
Course Code: BOC - 421
Title of the Course: Cytogenetics and Plant Breeding.
Number of Credits: 3
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Botany. It is assumed that students have a basic knowledge of Genetics and Plant Breeding.	
Objective:	The paper provides the students with detailed concepts of cytogenetic and Plant breeding.	
Content:	**1. Cell division and Cell cycle**: In prokaryotes and Eukaryotes; Eukaryotic chromosome replication; Regulation of Mitotic Phase (M Phase); Mitosis and Meiosis, their significance; Bacterial and Viral genomes. **2. Morphology of eukaryotic chromosomes:** Chromosome number, size and general morphology; Karyotype; Chromosomes banding patterns; Specialized chromosomes; B chromosomes; Chromosome movement; Prokaryotic nucleoids; Fluorochromes. **3. Molecular organization of Eukaryotic chromosomes:** Chemical composition, chromosome structure; Organization of chromatin fibres; Molecular structure of Centromere and telomere. **4. Organellar chromosomes:** Basis of extra nuclear inheritance; Plastid inheritance, Mitochondrial inheritance; Organellar DNA – Chloroplast DNA (cpDNA), Mitochondrial DNA (mtDNA), Replication of cpDNA and mtDNA. **5. Plasmids, IS elements, transposons and Retroelements:** Plasmids, Insertion sequence or IS elements; Transposons and controlling elements (in prokaryotes and Eukaryotes - copia, FB, P and I in Drosophila; Ty in yeast; AC-DC and Spm in corn; Retroelement (viral and non viral); Mechanism of transposition, uses of transposons. **6. Molecular mechanisms to mutation and DNA repair**: Types of mutations; Molecular basis of mutations; mutagens, mechanism of DNA repair. **7. Introduction to Plant Breeding:** Objectives and achievements; Pattern of evolution in crop plants; Plant introduction - Purpose of plant introduction; some	**5 hours** **4 hours** **3 hours** **3 hours** **3 hours** **3 hours** **4 hours** **5 hours**

	important achievements of plant introduction; Domestication and acclimatization. **8. Heterosis and inbreeding depression:** Inbreeding depression; Effects of inbreeding; Degrees of inbreeding depression; Homozygous and Heterozygous balance; Heterosis in cross and self-pollinated plants; Genetic basis of heterosis and inbreeding depression; Dominance hypothesis; Over-dominance hypothesis; Physiological basis of heterosis; Commercial applications. **9. Distance hybridization and *in-vitro* techniques in plant breeding:** Distant hybrids and barriers in the production of distant hybrids, Application in crop improvement; embryo, Meristem, anther and pollen culture, achievements. **10. Genetics and crossing techniques of economically important crop plants:** Wheat, Rice, Maize and Cotton.	**3 hours** **3 hours**
Pedagogy:	Lectures/Assignments/Tutorials/Self study.	
References/Readings	**1. Strickberger, M. W.** (1985). Genetics. 3rd Edition. MacMillan Pub. Co., Philadelphia. **2. Gupta, P. K.** (2000). Cytology, Genetics and Evolution. 6th Edition. Rastogi Publications, Meerut. **3. Lewin, B.** (2008) Genes IX. Oxford Univ. Press, New York. **4. Darlington, C. D.** (1965) Cytology, Churchill. London. **5. De Robertis, E.D.P. and E.M.F. De Robertis** (1987) Cell and Molecular Biology. 8th Edition. B. I. Waverly, New Delhi. **6. Watson, J. D. et al.,** (2009) Molecular Biology of the Gene. 6th Edition. Benjamin Cummings, New York. **7. Broda, P. W.** (1979) Plasmids. Freeman. Oxford. **8. Swaminathan, M. S., P. K. Gupta and U. Sinha** (1983) Cytogenetics of crop plants. MacMillan India Pvt. Ltd., New Delhi. **9. Swanson, C. P. and P. L. Webster** (1989) The Cell. 7th Edition Prentice-Hall of India Pvt. Ltd. New Delhi. **10. Sinha, U and S. Sinha** (1989) Cytogenetics, Plant Breeding and Evolution. Vikas Publishing House Pvt. Ltd. New Delhi. **11. Allard, R. W.** (1999) Priniciples of Plant Breeding. 2nd Edition. John Wiley, New York. **12. Singh, B. D.** (2003) Plant Breeding – Principles and Methods. Kalyani Publishers, New Delhi. **13. Sharma, J. R.** (1994) Principles and Practice of Plant Breeding. Tata Mc Graw-Hill Publishing Co. Ltd., New	

	Delhi. **14. Poehlman, J. M. and D. Borthakur** (1969) Breeding Asian Field Crops. Oxford and IBH Publishing Co. New Delhi.	
Learning Outcomes	1. The candidates can work in Research institutes like ICAR. 2. The candidates can start their own entrepreneurship in Tissue culture and breeding. 3. The candidates can work in Tissue culture laboratories.	

Programme: M. Sc. (Botany)
Course Code: BOC - 422 **Title of the Course:** Lab in Cytogenetics and Plant Breeding.
Number of Credits: 1 (24 hours)
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Botany with basic knowledge of Genetics and Plant Breeding.	
Objective:	To develop hands on training skills in Cytogenetics and Plant Breeding.	
Content:	1. Mitotic studies in suitable material: Squashing of the root tip and selection of metaphase plate. 2. Mitotic studies in suitable material*:* Camera Lucida drawing, Karyotype analysis, ideogram and derivation of karyotypic formula. 3. To study chromosomal aberrations in *Rheo sp.* 4. Meiosis in *Allium cepa.* 5. Induction of polyploidy in onion root tips**.** 6. Observation of B chromosomes in suitable material – *Zea mays.* 7. Centre of origin of some economically important crop plants. 8. Floral biology of *Oryza sativa*. 9. Floral biology of *Zea mays.* 10. Effect of chemical mutagen (DES/HZ/EMS) on germination, growth and yield characteristics in *Brassica juncea /Impatiens balsamina.* 11. Crossing techniques in *Oryza sativa.* 12. Crossing techniques in *Zea mays.* 13. *In vitro* embryo culture of pea (*Pisum sativum*)	**2 hours** **6 hours** **2 hours** **2 hours** **2 hours** **2 hours** **2 hours** **2 hours** **2 hours** **4 hours** **2 hours** **2 hours** **4 hours**
Pedagogy:	Laboratory practicals.	
References/Readings	**1. Strickberger, M. W.** (1985). Genetics. 3rd Edition. MacMillan Pub. Co., Philadelphia. **2. Gupta, P. K.** (2000). Cytology, Genetics and Evolution. 6th Edition. Rastogi Publications,	

	Meerut. 3. **Lewin, B.** (2008) Genes IX. Oxford Univ. Press, New York. 4. **Darlington, C. D.** (1965) Cytology, Churchill. London. 5. **De Robertis, E.D.P. and E.M.F. De Robertis** (1987) Cell and Molecular Biology. 8th Edition. B. I. Waverly, New Delhi. 6. **Watson, J. D. et al.,** (2009) Molecular Biology of the Gene. 6th Edition. Benjamin Cummings, New York. 7. **Broda, P. W.** (1979) Plasmids. Freeman. Oxford. 8. **Swaminathan, M. S., P. K. Gupta and U. Sinha** (1983) Cytogenetics of crop plants. MacMillan India Pvt. Ltd., New Delhi. 9. **Swanson, C. P. and P. L. Webster** (1989) The Cell. 7th Edition Prentice-Hall of India Pvt. Ltd. New Delhi. 10. **Sinha, U and S. Sinha** (1989) Cytogenetics, Plant Breeding and Evolution. Vikas Publishing House Pvt. Ltd. New Delhi. 11. **Allard, R. W.** (1999) Priniciples of Plant Breeding. 2nd Edition. John Wiley, New York. 12. **Singh, B. D.** (2003) Plant Breeding – Principles and Methods. Kalyani Publishers, New Delhi. 13. **Sharma, J. R.** (1994) Principles and Practice of Plant Breeding. Tata Mc Graw-Hill Publishing Co. Ltd., New Delhi. 14. **Poehlman, J. M. and D. Borthakur** (1969) Breeding Asian Field Crops. Oxford and IBH Publishing Co. New Delhi.	
Learning Outcomes	Upon completion of this course, the students will be able to take up job assignments in agri-based industries or work as research assistants on research projects.	