

Syllabus

**M.Sc. Botany (Choice Based Credit System)
(To be implemented from the Academic Year 2017-18)**



**DEPARTMENT OF BOTANY
UNIVERSITY OF ALLAHABAD**



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M.Sc. Syllabus (Choice Based Credit System)
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Semester – I

Course Code	Marks	Course Title	Credits
BOT501	100	Phycology and Limnology	3
BOT502	100	Mycology and Plant Pathology	3
BOT503	100	Bryology and Pteridology	3
BOT504	100	Gymnosperm and Palaeobotany	3
BOT531	100	Lab Work I (based on Course BOT501 and BOT502) (Excursion/field work/ Project)	4
BOT532	100	Lab Work II (based on Course BOT503 and BOT504) (Excursion/field work/Project)	4
Total credits			20

Semester – II

Course Code	Marks	Course Title	Credits
BOT505	100	Plant Morphology and Anatomy	3
BOT506	100	Reproductive Biology, Morphogenesis and Tissue culture	3
BOT507	100	Taxonomy of Angiosperm and Economic Botany	3
BOT508	100	Ecology and Phytogeography	3
BOT533	100	Lab Work III (based on Course BOT505 and BOT506) (Field work/ Project)	4
BOT534	100	Lab Work IV (based on Course BOT507 and BOT508) (Field work/ Project)	4
Total credits			20

Semester – III

Course Code	Marks	Course Title	Credits
BOT601	100	Plant Physiology	3
BOT602	100	Plant Biochemistry and Biochemical Techniques	3
BOT603	100	Cytogenetics, Plant Breeding and Biostatistics	3
BOT604	100	Microbiology	3
BOT631	100	Lab Work V (based on Course BOT601 and BOT602)	4
BOT632	100	Lab Work VI (based on Course BOT603 and BOT604)	4
Total credits			20

Semester – IV

Course Code	Marks	Course Title	Credits
BOT605	100	Plant Molecular Biology and Molecular Techniques	3
BOT606	100	Plant Biotechnology, Bioinformatics and IPR	3
BOT651-662	100	Elective Paper	3
BOT607	100	Dissertation/Thesis	3
BOT633	100	Lab Work VII (based on Course BOT605 and BOT606)	4
BOT634-645	100	Lab Work VIII (based on Course Elective Paper BOT651-662 and 607)	4
Total credits			20

Elective Papers:

Course Code	Marks	Elective	Credits
BOT651	100	Applied Phycology	3
BOT652	100	Plant Pathology and Plant Protection	3
BOT653	100	Biology of Bryophytes	3
BOT654	100	Taxonomy of Angiosperms	3
BOT655	100	Biology and diversity of Pteridophytes and Gymnosperms	3
BOT656	100	Advanced Plant Anatomy and Palynology	3
BOT657	100	Ecology and Environment	3
BOT658	100	Advanced Cytogenetics	3
BOT659	100	Advanced Plant Physiology	3
BOT660	100	Palaeobotany	3
BOT661	100	Applied Microbiology	3
BOT662	100	Advanced Molecular Biology and Genetic Engineering	3
BOT634	100	Lab Work VIII (based on Course BOT651 and BOT607)	4
BOT635	100	Lab Work VIII (based on Course BOT652 and BOT607)	4
BOT636	100	Lab Work VIII (based on Course BOT653 and BOT607)	4
BOT637	100	Lab Work VIII (based on Course BOT654 and BOT607)	4
BOT638	100	Lab Work VIII (based on Course BOT655 and BOT607)	4
BOT639	100	Lab Work VIII (based on Course BOT656 and BOT607)	4
BOT640	100	Lab Work VIII (based on Course BOT657 and BOT607)	4
BOT641	100	Lab Work VIII (based on Course BOT658 and BOT607)	4
BOT642	100	Lab Work VIII (based on Course BOT659 and BOT607)	4
BOT643	100	Lab Work VIII (based on Course BOT660 and BOT607)	4
BOT644	100	Lab Work VIII (based on Course BOT661 and BOT607)	4
BOT645	100	Lab Work VIII (based on Course BOT662 and BOT607)	4

**The candidates are required to choose only one elective paper*

Examination Scheme for theory and related practical work is configured as follows:

	Internal Assessment				External Exam
Weightage (%)	40				60
Components	Best of Class Test 1 & 2	Mid Semester exam	Assignment	PowerPoint Presentation	
Weightage distribution	10	20	5	5	

INSTRUCTIONS FOR THE PAPER- SETTER

The question paper will consist of five units I, II, III, IV and V. Each unit will have two questions, out of that one question must be answered, and each question will carry 12 marks. Total five questions must be answered.

INSTRUCTION FOR THE CANDIDATES

Candidates are required to attempt FIVE questions; each question will carry 12 marks.

SEMESTER – I

BOT501: Phycology and Limnology

Credits: 3

Unit I

Introduction to Limnology, Properties of water, Lake ontogeny, morphometry, Physical factors: Light Temperature, Heat, and Stratification. Chemical factors: DIC, Oxygen in lakes, profiles, seasonal effects, primary production, effect of DOC and BOD

Unit II

Redox reactions in the water column and sediment, Size spectrum of planktonic organisms, Size efficiency hypothesis, Food webs: benthic-pelagic coupling, paleolimnology, Human impact on lake ecosystem

Unit III

Introduction to Phycology, Principles and systems of classification of algae, Comparative account of algal pigments, food reserves, cell wall, flagellation, chloroplasts and eyespots, their phylogenetic and taxonomic importance

Unit IV

Cell structure and thallus organization, heterocyst and akinete development and their role; chromatic adaptations and reproduction in Cyanophyta, distribution and ecology of cyanobacteria

Unit IV

Range of thalli and methods of reproduction in Chlorophyta, evolutionary tendencies in Chlorophyta. A brief account of Bacillariophyta, Pyrrophyta, Haplophyta, Crysophyta, Xanthophyta, Euglenophyta and Prochlorophyta, and other related and recent new groups. Thallus organization and reproduction in Phaeophyta and Rhodophyta

Suggested readings:

1. Dodson, S. (2005). Introduction to Limnology. New York. McGraw-Hill.
2. Bronmark, C. and L.A. Hansson (2005). The biology of lakes and ponds. 2nd Edition. New York, Oxford University Press.
3. Moss, B. (1998). Ecology of fresh waters: man and medium, past to future. Oxford, Blackwell Science.
4. Horne, A. J. and C. R. Goldman (1994). Limnology. Toronto, McGraw-Hill.
5. Wetzel, R. G. (2001). Limnology: lake and river ecosystems. San Diego, Academic Press.
6. Carpenter, S. R. and J. F. Kitchell (1993). The trophic cascade in lakes. Cambridge, Cambridge University Press.
7. Kerr, S. R. and L. M. Dickie (2001). The biomass spectrum: a predator-prey theory of aquatic production. New York, Columbia University Press.
8. Smol, J. P. (2002). Pollution of lakes and rivers: a paleoenvironmental perspective. London, Arnold.
9. North American Lake Management Society and the Terrene Institute. (2001). Managing lakes and reservoirs. Madison, WI
10. Lehmkuhl, D. M. 1979. How to know the aquatic insects. Dubuque, Iowa, W.C. Brown Co.
11. Dillard, G. E. (1999). Common freshwater algae of the United States. Berlin, Gebr. Borntraeger Lee, Robert Edeward, 2008, Phycology, Fourth edition, Cambridge University Press
12. Graham Robin South and Alan Whittick, 1998, Introduction to Phycology, Blackwell Scientific Publication
13. Bold, H.C. and Wynne, M.J., 1985, Introduction to the Algae, 2nd Edition, Prentice-Hall Inc.
14. Dixon, R., Biology of Rhodophyta, Koelt Science Publisher, West Germany
15. Fritsch, F.E., Structure and Reproduction of Algae, Vol. I & II, Cambridge University Press, Cambridge

BOT502: Mycology and Plant Pathology

Credits: 3

Unit I

Introduction to fungi and their significance to humans, general characteristics of fungi, Fungal Cell, fungal cell walls and fungal organelles, systematics, molecular methods of fungal taxonomy, reproduction and spores in fungi, heterothallism, parasexual cycle and sex hormones in fungi. Biology, general characteristics and importance of Plasmodiophora, dietyosteliomycota, acrasiomycota and myxomycota. Biology, general characteristics, classification and brief introduction of –Mastigomycotina-Chytridiomycetes, Hypochytridiomycetes and Oomycetes Zygomycotina - Mucorales, Endogonales, Glomales, Entomophthorales and Zoopagales with special reference to evolutionary tendencies in thallus, asexual and sexual reproduction

Unit II

Ascomycotina- General characteristics and brief introduction of Taphrinales, Schizosaccharomycetales, Saccharomycetales, Eurotiales, Hypocerales, Melanosporales, Phyllachorales, Ophiostomatales, Dioporthales, Xylariales,

Sordariales, Meliolales, Rhytismales, Helotiales, Pezizales, Dothidiales, Pleosporales and Erysiphales with special reference to evolutionary tendencies in asexual and sexual reproduction. Basidiomycotina- General characteristics of Agaricales, Lycoperdales, Sclerodermatales, Phallales, Nidulariales, Aphylllophorales, Uredinales, Ustilaginales, Auriculariales and Tremellales, Deuteromycotina- Hyphomycetes, Coelomycetes.

Unit III

Introduction to lichens, the symbiotic relationship and classification of lichens, methodology for lichens taxonomy, morphology and anatomy of thallus, reproduction, physiology, ecological aspects and chemistry, conservation, culture, bioprospection and economic importance of lichens.

Unit IV

General introduction to Plant Pathology, History of Plant Pathology, Classification of Plant Diseases, Kinds and amount of losses, chemical weapons of pathogens – Enzymes and toxins; Role of growth hormones in plant diseases, Preexisting structural and chemical defense, induced structural and chemical defense, hypersensitive reaction, role of phytoalexins and other phenolic compound., how the pathogen affects plant physiological functions. Parasitism and disease development, symptoms, effect of environmental factors on the plant disease development, plant disease epidemiology

Unit V

Some important diseases caused by fungi, bacteria, viruses and mycoplasma. Control of plant diseases, quarantines and inspection, physical, chemical, cultural and biological methods of disease control, integrated pest management.

Suggested readings:

1. Webster, John, 1980, Introduction to Fungi, Cambridge University Press
2. Alexopoulos, C.J., Mims, C.W. and Blackwell, M. 1996, Introductory Mycology, Wiley
3. Carlile, M.J., Watkinson S.C. and Booday, G.W. , 2001, The Fungi, Academic Press
4. Deacon, J.W., Blackwell, M, 1997, Introduction to Modern Mycology, Oxford
5. Webster, John and Roland, W.S., 2007, Introduction to Fungi, Cambridge University Press.
6. Hale, M.E. (1983), The biology of lichens (3rd ed.). Edward Arnold.
7. Hawksworth, DL & Hill, DJ 1984: The Lichen-Forming Fungi. - Blackie, Glasgow and London. 158 pp
8. Galun, M. (ed.) (1988) CRC Handbook of Lichenology. Volume III. - CRC Press, Inc., Boca Raton
9. Brown D. H., Hawksworth D. L. & Bailey R. H. 1976, Lichenology: Progress & problems, Academic Press. London.
10. Willey, J.M., Sherwood, L., Woolverton, C.J., 2010. Prescott's Microbiology. 8th edition, McGraw-Hill.
11. Agrios, G. N., 1988. Plant Pathology, Academic Press.
12. John A Lucas, 1998. Plant Pathology and Plant Pathogens, Wiley-Blackwell, CRC Press.
13. Dickinson, C. M., 2003. Molecular Plant Pathology, Bios Scientific Publisher
14. Bridge, P.D and Clarkson, J.M., 1998. Molecular Variability of Fungal Pathogens, CAB, International
15. Singh, R. S., 2008. Principles of Plant Pathology, Oxford and IBH Publishing Co. Pvt Ltd.
16. Dhingra, O.D. and James, B. Sinclair, 1995. Basic Plant Pathology Methods, CRC Press
17. Pelczar, JM, Chan, ECS and Krieg, MR. 1993. Microbiology. Tata McGraw Hill.

BOT 503: Bryology and Pteridology

Credits: 3

Unit I

General introduction including broad outline of classification and evolutionary trends. Distribution of the group in India, general features and adaptation to land habit. Origin and evolution of gametophyte and sporophyte generation. Endemism and endemic liverwort genera of India. Bryophyte ecology, Moss protonema, protonemal differentiation and bud induction. Regeneration in bryophytes. Economic uses, chemistry of bryophytes, fossil history. Hepaticopsida / Marchantiophyta: distribution: Global and Indian. General characteristics, morphology, anatomy and life history of Marchantiales: *Plagiochasma*, *Asterella*, *Cryptomitrium*, *Targionia*, *Cyathodium*; Monocleales: *Monoclea* Sphaerocarpaceles: *Sphaerocarpaceles*, *Riella*; Calobryales: *Calobryum*, *Haplomitrium*; Metzgeriales: *Riccardia*, *Metzgeria*, *Pallavicinia*; Jungermanniales: *Radula*, *Herberta*, *Porella*, *Frullania*, etc.; Treubiales: *Apotreubia*

Unit II

Anthocerotophyta: distribution: Global and Indian, general features, Morphology, anatomy and life history of Anthocerotales: *Anthoceros*, *Notothylas* etc. Bryopsida/Musci: distribution: Global and Indian, general features, morphology and anatomy, life history of Sphagnales: *Sphagnum*, Andreaeales: *Andreaea*, Andreaeobryales: *Takakia*, Polytrichales: *Polytrichum*, *Pogonatum*; Tetrarhiales: *Tetrarhis* (*Georgia*), Buxbaumiales: *Buxbaumia*, Bryales: *Bryum*, *Rhodobryum*, *Funaria*, etc.

Unit III

General Introduction of pteridophytes, their peculiar features and similarities and dissimilarities with bryophytes and gymnosperms, pteridophytes classification based on molecular data by Smith et al. 2006. World distribution of pteridophytes with special reference to India, Endangered pteridophytes their conservation.

Unit IV

Origin and Evolution of pteridophytes, Gametophytes of pteridophytes, ecology of pteridophytes. Stomatal structures in pteridophytes, Spores of pteridophytes. Apogamy, Apospory and parthenogenesis. Sex organs and embryogeny in Pteridophytes. Ecology of pteridophytes, Economic importance of the pteridophytes, Cytogenetics of pteridophytes.

Unit V

Comparative morphology, anatomy, reproductive biology and evolutionary studies of the following groups: Early land plant and their evolutionary significance, Psilopsida, Lycopsidea, Sphenopsida, Filicopsida. Coenopteridales, Ophioglossales, Marattiales, Osmundales and filicales;; Monographic study of *Isoetes*, *Psilotum*, *Ophioglossum*, *Osmunda*, *Lygodium*, *Cyathea*, *Gleichenia*, *Adiantum*, *Pteris*, *Christella* and aquatic ferns.

Suggested readings:

1. Gangulee, H.C. and Kar, A.K., 2011, College Botany Vol. II (Algae+Fungi+Bryophyta+Pteridophyta), New Central Book Agency, Kolkata
2. Singh, Pande, Jain, 2010, A Text Book of Botany (Algae+Fungi+Bryophyta+Pteridophyta), Pub. Rastogi Publication, Meerut
3. Parihar N. S. 1965, An Introduction to Embryophyta- Bryophyta. Central Book Depot. Allahabad.
4. Kashyap S. R. 1972, Liverworts of the Western Himalayas & the Punjab Plains. Part 1 & 2.
5. Richardson D. H. S, The Biology of Mosses.
6. Janice. M. Glime, 2006, Bryophyte Ecology.
7. Goffinet B. & Shaw. A. J. 2008, Bryophyte Biology.
8. Rashid, A, 2011, An Introduction to Pteridophyta, 2nd edition, (Reprint), Pub. Vikas Publishing House Pvt. Ltd., Noida.
9. Gifford, Ernest, M., Foster, Adriance.S., 1989, Morphology and Evolution of vascular plant. W. H. Freeman; Third Edition.
10. Ogura, Yuzuru., 1972, Comparative Anatomy of Vegetative Organs of The Pteridophytes. Gebr. Borntraeger; 2nd edition.
11. Rashid, A.1999, An Introduction to Pteridophyta: Diversity,Development,Differentiation. Vikas Publishing House Pvt Ltd.
12. Parihar, Narayan Singh., 1977, The Biology and Morphology of The Pteridophyte. Central Book Depot.

BOT504: Gymnosperms and Palaeobotany

Credits: 3

Unit I

General introduction of gymnosperms with special reference to its salient features, similarities and dissimilarities with other groups like pteridophytes and angiosperms. Classifications of gymnosperms. Origin and Evolution of gymnosperms with special reference to Progymnosperms, Devonian pre ovules and origin of seed.

Unit II

Comparative morphology, anatomy, reproductive biology and phylogenetic studies of the following groups: Pteridospermopsida-Lyginopteridales, Medullosales, Callistophytales, Glossopteridales, Peltaspermales, Corystospermales and Caytoniales. Cycadopsida, Pentoxyllopsida, Bennetttiopsida, Ginkgopsida Coniferopsida and Gnetales.

Unit III

Global distribution of gymnosperms with special reference to Indian plants. Endangered gymnosperms, their conservation and present status. Cytogenetics of Gymnosperms; Economic importance and biotechnology of gymnosperms.

Unit IV

Basic geological information – structure of Earth, Types of rocks, stratigraphy, basic concepts of continental drift and plate tectonics. Dating the past, Geological time scale. Fossilization process, Types of fossils, including chemical fossils and fossil techniques to study fossils, reconstruction and nomenclature of fossil, concepts of Parataxa and Eutaxa, objectives of palaeobotany. Prebiotic Environment, chemical evolution and origin of life, Pre-Cambrian life. Indian Pre-cambrian stratigraphy and life forms.

Unit V

Applied Palaeobotany Life as fuel maker, sources of natural fossil fuels, Peat, coal and its varieties, constitution of coal, Coal Palynology, coal maceral, Petroleum – its origin, Palynology in oil exploration. Fundamentals of Paleofloristics, Palaeogeography and Palaeoclimatology. Application of Palaeopalynology. Plant and animal interactions correlation Archaeobotany with special reference to phytoliths and palynological studies.

Suggested readings:

1. Eames, A.J. (1936) Morphology of Vascular plant-lower group. Tata Mc Graw Hill, New Delhi.
2. Chamberlain, Charles Joseph, b.(1863), Gymnosperm; Structure and Evolution. Chicago, Ill., The University of Chicago Press
3. Chhaya Biswas and B.M.Johri. The Gymnosperm. Springer; 1997, edition (16 April 2014)
4. Bhatnagar, S.P. Moitra, Alok. (1996). Gymnosperms. New Age International.
5. Pant DD. (2002), An Introduction to Gymnosperms, Cycas, and Cycadales, Birbal Sahni Institute of Palaeobotany.
6. Steward W.N., Palaeobotany and evolution of plant. Cambridge University Press, New York 405 p.(1)
7. Stewart, W.N., and G.W.Rothwell. (1993) Palaeobotany and the evolution of plant. 2nd ed. Cambridge University Press, New York. 521 p.(1)
8. Andrews, H.N., jr. 1974 Palaeobotany (1947-1972) Annals of the Missouri Botanical Garden 61:179-202.(8)

9. Thomas N. Taylor, Edith L. Taylor, Michael Krings (2009) *Palaeobotany: The biology and Evolution of Fossil Plants* Amsterdam ; Boston, Mass. : Academic Press, c2009
10. Wilson N Stewart and Gar W. Rothwell - 1993. *Palaeobotany and the evolution of plants*. Cambridge university press.
11. Edith L. Taylor, Thomas N. Taylor, Michael Krings – 2009. *Palaeobotany: The Biology and Evolution of Fossil Plants*. Academic Press.

BOT531: Lab Work I (based on Course BOT501 and BOT502)

Credits: 4

BOT532: Lab Work II (based on Course BOT503 and BOT504)

Credits: 4

SEMESTER – II

BOT505: Plant Morphology and Anatomy

Credit: 3

Unit I

Introduction of morphology and anatomy including brief historical account; External and internal organization of higher plants; Morphology of root and stem and their modifications, Ergastic substances; Microscopic and sub-microscopic structure and organization of cell wall

Unit II

Meristems: Organization of root apical meristem (RAM) and shoot apical meristem (SAM) differentiation; Quiescent center, Xylem and phloem: Ontogeny and structure of components and phylogeny, transfer cells.

Unit III

Secretary and excretory structures; Primary structure of root and stem, Origin of lateral roots, root-stem transition, nodal anatomy and its evolutionary significance; Leaf –structure and function with special reference to epidermis. Systematic significance of trichomes and stomata;

Unit IV

Vascular cambium and its derivatives, Primary anomalies in stem and anomalous secondary growth, Floral morphology and anatomy, fruits and seeds

Unit V

Periderm, Wood structure, Sapwood and Heartwood, Growth rings

Suggested readings:

1. Carlquist, S. (1961), *Comparative Plant Anatomy*, Holt, Rinehart and Winston, New York Press
2. Cutter, Elizabeth (1969), *Plant Anatomy part –I Cells and Tissues* 11nd edition, Edward Arnold, London
3. Cutter, Elizabeth (1971), *Plant Anatomy Part- II Organs*, Edward Arnold London
4. Dickison William C. (2000), *Integrative Plant Anatomy*. Academic Press
5. Eames, A. J. & Mac Daniels Laurence H. (1951), *An Introduction To Plant Anatomy*, Mc Graw Hill.
6. Eames A.J (1961), *Morphology of Angiosperms*, Mc Graw-Hill, New York.
7. Esau, Katherine (1965), *Plant Anatomy*, John Wiley and Sons. Inc, New York.
8. Esau, Katherine, *Anatomy of seed Plants* (1960), Wiley, New York.
9. Evert, Ray.F. (1960), *Esau's Plant Anatomy*. John Wiley & Sons.
10. Fahn, A. (1982), *Plant Anatomy Vol I and Vol II* Pergamon Press. Oxford New York
11. Mauseth, James D. (1988) *Plant Anatomy*. Benjamin/Cummings.

BOT506: Reproductive biology, Morphogenesis and Tissue culture

Credit: 3

Unit I

Introduction to life history of angiosperms, brief history of plant embryology; Anther: Structure and development wall layers and their role; Microsporogenesis; Cytoplasmic reorganization during microsporogenesis, Pollen wall morphogenesis and anther dehiscence; Pollen morphogenesis, Development of male gametophyte, ultrastructure, abnormal male gametophyte, Pollen germination

Unit II

Ovule: Ontogeny, structure, integuments and nucellus specialized structures, megasporogenesis; Development of embryo sac, subcellular details of constituent cells and their function, major types.

Unit III

Pollen-pistil interaction: Role of pollen wall proteins and stigma surface proteins, pollen tube growth in pistil, fertilization and apomixes; Endosperm: Major types, ultrastructure and histochemistry; Embryo: major types, polyembryony; Embryology in relation to Taxonomy

Unit IV

Morphogenetic phenomenon: Symmetry and polarity, concepts of cell differentiation and totipotency; Plant cell and tissue culture: General introduction, history and scope; Tissue culture techniques and culture media; Experimental embryology, anther, ovary and endosperm culture; somatic embryogenesis and androgenesis

Unit V

Somatic hybridization: Protoplast isolation, culture and regeneration, Somatic hybridization and hybrid selection; Possibilities, achievements and limitations of protoplast research; Applications of plant tissues culture: clonal propagation, artificial seed, production of hybrids and soma clones, production of secondary metabolites/ natural products; Cryopreservation and germplasm storage

Suggested readings:

1. Bhojwani, S.S. and Bhatnagar, S.P.(1985), Embryology of Angiosperms, Vikash Publishing House, New Delhi
2. Johri, B.M (1984) Embryology of Angiosperms. Springer-Verlog Berlin Heidelberg.
3. Maheshwari, P. (1950) An Introduction to the Embryology of Angiosperms. Tata McGraw Hill.
4. Pandey, B.P., Angiosperms-Taxonomy, Embryology and Anatomy, S. Chand and Co., New Delhi
5. Bhojwani, S.S. and Bhatnagar, S.P., Embryology of Angiosperms, Vikash Publishing House, New Delhi
6. Butenko RG (2000) Plant Cell Culture, University Press of Pacific.
7. Davies PJ (2004) Plant Hormones, Kluwer Academic Publishers, Netherlands.
8. Halford N (2006) Plant Biotechnology - Current and future applications of genetically modified crops, John Wiley and Sons, England.

BOT507: Taxonomy of Angiosperms and Economic Botany

Credit: 3

Unit I

Latin diagnosis, definition and use of Taxonomic terms, History of Plant Taxonomy, in India, History of Plant Classification, Need and aim of classification, Units of classification, delimitations of taxa and their practical consideration, Artificial, Natural and Phylogenetic system classification, a critical study of Takhtajan, Modern system of classification, An introduction of angiosperm Phylogeny Group (APG), Characteristics and phylogeny of orders

Unit II

Need and aim of nomenclatures, International rules of Botanical Nomenclature, Concept of species, genus and family with special reference to the type concept

Unit III

Interrelationship of plant taxonomy with morphology, anatomy, embryology, palynology, cytology, genetics, Biosystematics, biochemical and molecular systematics, Numerical taxonomy, Phytogeography and phytochemistry

Unit IV

Indigenous flora of India with special reference to local flora (Uttar Pradesh), A general knowledge of Herbarium, and Botanical garden of the world and India, Identification keys

Unit V

An introduction to plant utilization, Economic importance of plant for food (cereals, pulses, vegetables, fruits, oils sugar, spices and condiments), non-alcoholic beverages (Tea, coffee, cocoa), medicines, fiber, timber, rubber, tannins and dyes, masticatories, fumicatories, contribution of plants in the development of industries

Suggested readings:

1. Sambamurty, A.V. S. S. 2005. *Taxonomy of Angiosperms*. I. K. International Pvt. Ltd., New Delhi.
2. APG III 2009. An update of the Angiosperm Phylogeny Group Classification for the Orders and Families of Flowering Plants: APG III. *Bot. J. Linn. Soc.* 161: 105-121.
3. Bhattacharyya, B. and B. M. Johri. 1998. Flowering Plants - Taxonomy and Phylogeny. Narosa Publishing House, New Delhi.
4. Heywood, V. H. and Moore, D. M. 1984. Current Concepts in Plant Taxonomy. Oxford University Press.
5. Duthie, J. F. "Flora of upper gangetic plain and of the adjacent siwalik & sub-himalayan tracts," Calcutta, Vol. 3, No. 1, 1915.
6. Sharma, O. P. 1993. *Plant Taxonomy*. Tata McGraw Hill Publishing Co. Ltd., New Delhi.
7. Stace, C. A. 1989. Plant Taxonomy and Biosystematics. University Park Place, Baltimore (2nd edn.)
8. Takhtajan A. 2009. *Diversity and classification of flowering plants*, 2nd edn. Berlin: Springer.
9. Verma, B. K. 2010. *An introduction to Taxonomy of Angiosperms*. PHI Learning Pvt. Ltd. New Delhi.
10. Jones, SB Jr. and Luchsinger, AE. 1986. Plant Systematics (2nd edition). McGraw Hill Book Co., New York.

BOT508: Ecology and Phytogeography

Credit: 3

Unit I

Introduction to ecology, and environmental terminology, population dynamics, vegetation organization and development: population characteristics, population growth forms, density dependent and density independent controls, population structure (distribution, aggregation, isolation territoriality) energy partitioning, r - and k-selection, concept of carrying capacity; Wild life sanctuaries, botanical gardens

Unit II

Concepts of community and continuum, analysis of communities (analytical and synthetic characters), community coefficients, competition, ecological niche, succession, mechanism of ecological succession (relay floristic and initial floristic composition facilitation, tolerance and inhibition models), concept of climax

Unit III

Ecosystem organization, structure and function: primary production (methods of measurement), energy dynamics (tropic organization, energy flow pathway, energy quality, ecological efficiencies), biogeochemical cycles

Unit IV

Pollution and climate change: kinds, sources and effects of pollution, heavy metals (Pb, Cd, Hg), green house gases (CO₂, CH₄, N₂O, CFCs), Green-house effect and global warming, ozone layer depletion and ozone hole, acid rain

Unit V

Environmental impact assessment, threatened and endangered plant species, role of diversity in ecosystem stability, general account of remote sensing and its application, sustainable development. Major terrestrial biomes, biogeographical area of India, major vegetations

Suggested reading:

1. Odum, E. P. and Barret G.W. 2005. Fundamentals of Ecology. Cengage publication
2. Odum, E.P., 1983. Basic Ecology., Saunders College Publishing
3. Singh, J.S., Singh S.P. and Gupta S.R. 2006. Ecology Environment and Resource Conservation. Anamaya Publishers

BOT 533: Lab Work III (based on Course BOT 505 and BOT 506)

Credits: 4

BOT 534: Lab Work IV (based on Course BOT 507 and BOT 508)

Credits: 4

SEMESTER – III

BOT601: Plant Physiology

Credits: 3

Unit I

Plant water relations: Transport and translocation of water and solutes, water potential and components, mechanism of water transport, mineral nutrition, nutrient uptake, solute transport, phloem loading and unloading.

Unit II

Nitrogen metabolism, respiration and lipid metabolism: Biological nitrogen fixation, nodule formation and nod factors, mechanism of nitrate uptake and reduction, ammonium assimilation, Interaction of nitrogen assimilation with carbon metabolism. Glycolysis, TCA cycle, electron transport and ATP synthesis, pentose phosphate pathway, Cyanide resistant respiration, Lipid metabolism

Unit III

Photochemistry and photosynthesis: History of photosynthesis, photosynthetic apparatus, photoreceptor, light reaction of photosynthesis, photo oxidation of water mechanism photophosphorylation, Structure and function of Rubisco and PEP Carboxylase, carbon assimilation, Calvin cycle, photorespiration and its significance, C₄ cycle, CAM pathway

Unit IV

Plant growth substances and signal molecules: Chemical structure, physiological effects and mechanism of action of auxin, gibberellins, cytokinins, ethylene, abscisic acid. Growth regulator nature of Polyamines, Jasmonic acid, Salicylic acid and Brassinosteroids, systemin, secondary metabolite and plant defense

Unit V

Growth and Development Aspects: Metabolic changes during seed germination, factors affecting seed germination and dormancy, breaking of dormancy, biochemistry of flowering: initiation and development of flower, induction of flowering- vernalization, physiology and biochemistry of leaf abscission and senescence. Sensory photobiology: Phytochromes and cryptochromes and their photochemical and biochemical properties, photophysiology of light-induced responses, cellular localization, molecular mechanism of action of photomorphogenic receptors, signaling and gene expression

Suggested readings:

1. Taiz and Zeiger, 2010, Plant Physiology, 5th Edition, Sinauer Associates
2. Hopkins, W.G. and Huner N.P.A., 2009, Introduction to Plant Physiology, 4th Edition Wiley International Edition, John Wiley & Sons, USA
3. Jones, Russell L. Buchanan, Bob B. Guissem, Wilhelm., 2002, Biochemistry and Molecular Biology of Plants. American Society of Plant Physiologists.
4. Peter Scott, Physiology and Behaviour of Plants. Wiley-Blackwell.
5. Frank Boyer Salisbury and Cleon Ross, 1991, Plant Physiology, CA

BOT602: Plant Biochemistry and Biochemical Techniques

Credits: 3

Unit I

Bioenergetics: Law of thermodynamics, concept of enthalpy and entropy and their significance in biological systems, Water biochemistry, high energy molecules, redox potential; Amino acids and proteins: Structure and physicochemical properties of amino acids; Proteins: Primary, secondary, tertiary and quaternary structure of proteins, physical and chemical properties of proteins and biological significance. Enzymes: Classification, physicochemical nature, enzyme kinetics, mechanism of action and regulation, allosteric enzyme, isoenzyme, zymogen

Unit II

Carbohydrates: Structure and physico-chemical properties of carbohydrates, biological significance, important glycoprotein, Lipids: Classification, structure and properties of important lipids, biological significance of glycolipids, fatty acid biosynthesis and storage lipids and their catabolism, Vitamins and Coenzymes: Structure and general biochemistry.

Unit III

Buffers and Solutions, Definition and Principle of Electrophoresis, Agarose Gel Electrophoresis, Polyacrylamide Gel Electrophoresis (PAGE), Native PAGE, SDS-PAGE; 2D-Electrophoresis, Isoelectric Focusing (IEF): Principles and Kinds of pH Gradients used In IEF- Immobilized pH Gradients, DIGE; Principle and Techniques of Centrifugation, Separation of Sub-cellular Fractions, Ultracentrifugation, isopycnic, density gradient centrifugation

Unit IV

Chromatography: Basic concept, Paper, TLC, HPLC, GC, Size-exclusion chromatography, Ion-exchange chromatography, Hydrophobic Interaction chromatography and Affinity chromatography; Labeling Techniques: Radiolabeling and Fluorescent labeling of biomolecules and their detection, Safety guidelines

Unit V

Biophysical Techniques: Spectroscopy - Basic Concept, MALDI-TOF, Mass Spectroscopy, X-Ray Diffraction, FTIR, NMR and ESR Spectroscopy; Microscopy: Light, Phase Contrast, Confocal, Fluorescence, Scanning and Transmission Electron Microscopy

Suggested readings:

1. Wilson, K. and Walker, J., 2000, Practical Biochemistry: principles & techniques. Cambridge University Press. ISBN 0521799651.
2. Buchanan, B., Gruissem, W., & Jones, R.L., 2002, Biochemistry and Molecular Biology of Plants. American Society of Plant Biologists, USA.
3. Watson, JD, Baker, TA, Bell, SP, Gann, A, Levine, M and Richard, L. 2008. Molecular Biology of the Gene. Pearson Education Inc.
4. Nelson, D.L. and Cox, M.M., 2008, Lehninger Principles of Biochemistry, W. H. Freeman & Co, New York, USA

5. Murray, R, Murray, RK, Bender, D, Gotham, KM, Kennelly, PJ, Rodwell, V and Weil, PA. 2012. Harper's Illustrated Biochemistry McGraw Hill
6. Wilhelm Gruissem, Russell L.Jones, 2000, Biochemistry and molecular biology of plants. American Society of Plant Physiologists,
7. Berg, J.M., Tymoczko, J.L. & Stryer, L. 2011, Biochemistry, Freeman & Co., New York, USA.
8. Weil, J.H., 1990, General Biochemistry, Wiley Eastern Limited, New Age International Limited. New Delhi.
9. Lea P.J. and Leegood R.C., 1999, Plant Biochemistry & Molecular Biology, John Wiley & Sons, New York.

BOT603: Cytogenetics, Plant Breeding and Biostatistics

Credits: 3

Unit I

Basic concept and organization: Chromosome structure, special type of chromosomes- Polytene chromosomes, lamp brush chromosomes, B chromosomes. Gene concept; allele concept, multiple alleles, isoalleles, Pseudoalleles, Cell division, Inheritance Genetics: Principles of Mendelian Inheritance and interaction of genes

Unit II

Cytoplasmic inheritance involving chloroplast and mitochondria, interaction between nuclear and cytoplasmic genes, Sex determination in plants, Cytogenetics and Induced Variations: Linkage and recombination: Concept of Linkage, evolution of linkage concept, cis and trans arrangement of linked gene, kinds of linkage, germinal and somatic crossing over, detection of crossing over, kinds of crossing-over

Unit III

Mutation: Spontaneous and induced mutations, point mutation, transitions, transversions, physical and chemical mutagens, molecular basis of mutations. Numerical alterations in chromosomes: Euploidy, polyploidy and its significance, aneuploidy, Structural changes in chromosomes: Deficiency, duplication, inversion, translocation heterozygotes

Unit IV

Plant Breeding: Breeding systems, methods, selection in self and cross pollinated crops, male sterility, self-incompatibility, heterosis and hybrid vigor

Unit V

Biostatistics: General concepts and terminology, sampling methods, Measures of location, scale and shape, contingency tables and chi-square test, comparison of means: t-test, multiple range tests, Simple experimental design and analysis of variance, correlation and regression analysis, Introduction to multivariate methods, Types of statistical software and their application in analysis of data

Suggested reading:

1. Clark, M.S. and Wall, W.J. 1996, Chromosomes : The Complex Code. Chapman & Hall, London.
2. Stebbins, G.L. 1950, Variation and Evolution in Plants. Columbia Univ. Press, New York.
3. Swanson, C. P., Mertz, T.F. and Young, W.J. Cytogenetics : The Chromosomes in Division, Inheritance and Evolution (2nd Edn). Englewood Cliff, Prentice-Hall, New Jersey.
4. Sharma, A.K. and Sharma, Archana. 1985. Advances in Chromosome and Cell Genetics. Oxford & IBH Publishing Co., Calcutta.
5. Schnedl, W.. Banding patterns in chromosomes. In: International Review of Cytology (Suppl. 4).
6. Lewine, Benjamin, Jones and Bartlet, Genes X, Sudbury, Massachusetts
7. Gupta, P.K., Cytogenetics, Rastogi Publication, Meerut
8. Peter, D, Snustand and Simmons, M.J., John Wiley and Sons Inc.

BOT604: Microbiology

Credits: 3

Unit I

Introduction to microbiology, history and scope of microbiology, tools and techniques used in microbiology laboratory, Microbial evolution, Systematics and taxonomy of microorganisms. Primitive organisms, their metabolic strategies and molecular coding. Microbes of the extreme environment and their metabolic strategies. The microbial cell: general organization of cell and cell wall of prokaryotes, eukaryotes and Archaea, prokaryotic and eukaryotic cell structure and function,

Unit II

Introduction and general characteristics of Viruses, bacteriophages, Plant Viruses—their morphology, taxonomy, reproduction and transmission, Viruses of algae, fungi and insects. General account of Mycoplasma

Unit III

Microbial nutrition, microbial growth, Gram negative and Gram positive bacteria, Archaeobacteria, actinomycetes, Quorum sensing in Bacteria: gram negative bacteria: LUXI LUXR-Type: gram positive bacteria: peptide mediated quorum sensing, genetics, bacterial recombination and plasmids, Bacterial conjugation, DNA transformation, Transduction,

Unit IV

Microbiology of food, food spoilage and preservation processes, microbiology of fermented foods, oriental foods, dairy foods, wine, beer and other fermented alcoholic beverages, bread and other fermented plant products, Microbial production of organic acids, antibiotics, amino acids, vitamins, recombinant products, microorganisms as source of foods.

Unit -V

Rhizosphere, Phyllosphere, Mycorrhizae, Actinorrhizae, Tripartite associations, PGPRs, microbes in agriculture

Suggested readings:

1. Madigan, M.T., Martinko, J.M., Dunlap, P.V., Clark, D.P., 2011. Brock Biology of Microorganiss. 13th edition, Pearson Education Inc.
2. Stanier, R.Y., Ingraham, J.L., Wheelis, M.L., Painter, P.R., 1987. General Microbiology. Fifth edition. MacMillan.
3. Atlas, R.M. 1995. Principles of Microbiology. Mobsy.
4. Lim, DV. 2003. Microbiology. Kendall/Hunt.
5. Boundless.2013. Microbiology. Boundless Learning, Incorporated.
6. Comelissen, CN, Harvey, RA and Fisher, BD. 2012. Microbiology. Lippincott Williams & Wilkins.
7. Talaro, K.P., Chess, B. 2011, Foundations in Microbiology. 8th edition. McGraw-Hill.
8. Willey, J.M., Sherwood, L., Woolverton, C.J., 2010. Prescott's Microbiology. 8th edition, McGraw-Hill.
9. Agrios, G. N., 1988. Plant Pathology, Academic Press.
10. John A Lucas, 1998. Plant Pathology and Plant Pathogens, Wiley-Blackwell, CRC Press.
11. Dickinson, C. M., 2003. Molecular Plant Pathology, Bios Scientific Publisher
12. Robert, N., Trigiano, Windham, M. T. and Windham, A.S., 2003. Plant Pathology: Concepts and Laboratory Exercises, CRC Press.
13. Bridge, P.D and Clarkson, J.M., 1998. Molecular Variability of Fungal Pathogens, CAB, International
14. Singh, R. S., 2008. Plant Diseases, Oxford and IBH Publishing Co. Pvt Ltd
15. Pelczar, JM, Chan, ECS and Krieg, MR. 1993. Microbiology. Tata McGraw Hill.

BOT 631: Lab Work V (based on Course BOT601 and BOT602)

Credits: 4

BOT 632: Lab Work VI (based on Course BOT603 and BOT604)

Credits: 4

SEMESTER – IV

BOT605: Molecular Biology and Molecular Techniques

Credits: 3

Unit I

Structure and conformation of nucleic acids; Replication of DNA; DNA damage and repair; Gene structure; Transcription of gene; Structure of mRNA, rRNA and tRNA, Regulation of transcription, Posttranscriptional modification of RNA, RNA editing; Transport of RNA

Unit II

Protein synthesis: Genetic code, Mechanism of translation (initiation, elongation and termination); Post-translational modification; Protein sorting in the cell, Regulation of protein synthesis in prokaryotes and eukaryotes.

Unit III

Signal transduction: Overview of receptors and G-proteins, phospholipids signifying role of cyclic nucleotides, calcium-calmodulin cascade diversity in protein kinase and phosphates specific signaling mechanism, Secondary messengers; Gene silencing mechanisms, Epigenetics

Unit IV

Isolation and Purification of Nucleic Acids, Electrophoresis and quantification of nucleic acids, DNA Sequencing: Sanger's Dideoxy Method, Maxam and Gilbert Method, High throughput sequencing, Nuclear run-on assay, Nucleic acid blotting techniques, DNA Synthesis, Chromatin remodeling

Unit V

Isolation and purification of protein, Electrophoresis and quantification of proteins, Western Blotting, Protein-nucleic acid interaction analysis, Protein-protein interaction analysis; ELISA, RIA; Protein immunoprecipitation, Protein sequencing strategies, Radioactive isotope labeling, Mass spectrometry

Suggested readings:

1. Buchanan, B., Gruissem, W., & Jones, R.L., 2002, Biochemistry and Molecular Biology of Plants. American Society of Plant Biologists, USA.
2. Lodish, Harvey, Berk, Arnold, Chris A. Kaiser, Monty Krieger, Matthew P. Scott, Anthony Bretscher, Hidde Ploegh, Paul Matsudaira Molecular Cell Biology, 6th Ed. W.H. Freeman and Comp., New York
3. Bourton E. Tropp, Molecular Biology, 4th Ed., Jones & Barlett learning
4. Brown, T.A., DNA Cloning and Gene Sequencing Willey-Blackwell, Oxford
5. Genes IX by Benjamin Lewin, Jones and Barlett
6. Y Gerald Karp, Cell and Molecular Biology 6th Ed., John Willey & Sons
7. Nelson, D. L. and Cox, M.M., 2008, Lehninger Principles of Biochemistry, Fifth Edition, W. H. Freeman & Co, New York, USA.
8. Cooper, G.M. and Robert, E. Hausman The Cell: A Molecular Approach 5th Ed. (Co-published by ASM Press and Sinauer Assoc. Inc.)
9. Watson, JD, Baker, TA, Bell, SP, Gann, A, Levine, M and Richard, L. 2008. Molecular Biology of the Gene. Pearson Education Inc.

BOT 606: Plant Biotechnology, Bioinformatics and IPR

Credits: 3

Unit I

A brief introduction to Biotechnology; Recombinant DNA technology: Restriction endonucleases, DNA Modifying enzymes, DNA polymerases; Vectors, Markers and reporter genes, Cloning, Screening of recombinant clone; Polymerase chain reaction: Principle, method, variants and practical applications; cDNA

Unit II

Gene cloning and identification: Genomic and cDNA library, Hybridization techniques: Southern, northern and western hybridization; FISH; Molecular markers: RFLP, RAPD, AFLP, SSR, SNP; Functional genomics: Quantitative Real Time PCR, Microarray, RNA interference, Mutagenesis and Genome editing, Protein Production strategies in Expression System; Metagenomics

Unit III

Methods of gene transfer, Agrobacterium mediated genetic transformation of plants, Regeneration methodologies and Screening of transformants; Genetic engineering and its applications in Agriculture: Genetic manipulation of pest resistance, abiotic and biotic stress tolerance, Molecular farming; Transformation of chloroplast genome and its advantage; Biosafety concerns in Plant Biotechnology

Unit IV

Bioinformatics: Introduction, Databases (Genomic and Protein Database), Similarity Searching: BLAST and FASTA; Tools for DNA, RNA and Protein sequence analysis, ExPASy-PROSITE, Sequence Retrieval Methods, Primer Designing tools, Gene Prediction, Restriction Site Annotation, ORF Finder, Sequence Alignment; Molecular evolution and analysis methods

Unit V

Bioethics: Concept of bioethics, benefits and harm, consent, privacy and confidentiality, sharing of benefits; Intellectual Property Right: Definition of IPR, World Intellectual Property Organization (WIPO) and its role; Patent: kinds of patent classification, patent criteria, Procedure of obtaining patent, copy right and trade mark, Organization of patent offices in India

Suggested readings:

1. J. D. Watson, T. A. Baker, S. P. Bell, A. Gann, M. Levine & R. Losick Molecular Biology of the Gene, Cold Spring Harbor Laboratory
2. Bernard R. Glick and Jack J. Pasternak, Molecular Biotechnology: Principles and application of recombinant DNA ASM Press, Washington, D.C
3. T. A. Brown, Genomes - Garland Science (Taylor & Francis Group), New York & London
4. Alberts Bruce, Johnson Alexander, Lewis Julian, Raff Martin, Roberts Keith and Walter Peter Molecular Biology of the Cell - Garland Science
5. Lodish, Harvey, Berk Arnold, et. al.,-Molecular Cell Biology.
6. Introduction to plant biotechnology by H S Chawla

7. Elements of biotechnology by P K Gupta
8. S H Mantell, *et. al.* by Principles of Plant Biotechnology: An introduction to genetic engineering in plants
9. Plant Biotechnology by B. D. Singh, Kalyani Publications

BOT633: Lab Work VII (based on Course BOT605 and BOT606)

Credits: 4

Elective Paper

BOT651: Applied Phycology

Credits: 3

Unit I

Marine environment an introduction, Culture medium and methods, Cultivation of macro and microalgae, Seaweed farming for potential application in food industries

Unit II

Seaweeds used as a source of agar, carrageenan, Alginate, Seaweeds used as human food, Fertilizers and soil conditioners, Animal feed, Fish feed

Unit III

Bioactive phenolic compounds in seaweeds, seaweed as a source of bioactive proteins, peptides and amino acids, lipid and fatty acid profile of major seaweeds, Minerals in edible seaweeds

Unit IV

Biomass for fuel, Cosmetics, Integrated aquaculture, Wastewater treatment, Treatment of wastewater to reduce nitrogen- and phosphorus-containing compounds, Removal of toxic metals from industrial wastewater

Unit V

Algae and human affairs: edible algae, algae in single cell protein production, algal biofertilisers, phycocolloids and other useful products of algae, biotechnological application of algae.

Suggested readings:

1. Lee, Robert Edward, Phycology, Fourth edition 2008, Cambridge University Press
2. Graham Robin South and Alan Whittick, 1998, Introduction to Phycology, Blackwell Scientific Publication
3. Bold, H.C. and Wynne, M.J., 1985, Introduction to the Algae, 2nd Edition, Prentice-Hall Inc.
4. Dixon, R., Biology of Rhodophyta, Koelt Science Publisher, West Germany
5. Fritsch, F.E., Structure and Reproduction of Algae, Vol. I & II, Cambridge University Press, Cambridge
6. Gangulee, H.C. and Kar, A.K., 2011, College Botany Vol. II (Algae+Fungi+Brophyta+Pteridophyta), New Central Book Agency, Kolkata
7. Singh, Pande, Jain, 2010, A Text Book of Botany (Algae+Fungi+Brophyta+Pteridophyta), Pub.Rastogi Publication, Meerut
- 8.

BOT652: Plant Pathology and Plant Protection

Credits: 3

Unit-I

General introduction to Plant Pathology, chemical weapons of pathogens – Enzymes and toxins; Role of growth hormones in plant diseases, Defense mechanism of the host, how the pathogen affects plant physiological functions

Unit-II

Genetics of plant disease, effect of environmental factors on the plant disease development, Plant disease epidemiology: Preexisting structural and chemical defense, induced structural and chemical defense, hypersensitive reaction, role of phytoalexins and other phenolic compounds

UNIT III

Management of plant diseases: Cultural, chemical, biological, biopesticides, breeding for resistant varieties, plant quarantine, integrated pest management

Unit-IV

Diseases caused by fungi, bacteria, viruses and mycoplasma

Unit-V

Molecular plant pathology: Molecular aspects of host pathogen interactions - PR proteins, degradation of phytoalexins, systemic resistance mechanism; application of molecular biology to plant disease control - transgenic approach for crop protection, engineering chemicals that elicit defense response to plants

Suggested readings:

1. Willey, J.M., Sherwood, L., Woolverton, C.J., 2010. Prescott's Microbiology. 8th edition, McGraw-Hill.
2. Agrios, G. N., 1988. Plant Pathology, Academic Press.
3. John A Lucas, 1998. Plant Pathology and Plant Pathogens, Wiley-Blackwell, CRC Press.
4. Dickinson, C. M., 2003. Molecular Plant Pathology, Bios Scientific Publisher
5. Robert, N., Trigiano, Windham, M. T. and Windham, A.S., 2003. Plant Pathology: Concepts and Laboratory Exercises, CRC Press.
6. Bridge, P.D and Clarkson, J.M., 1998. Molecular Variability of Fungal Pathogens, CAB, International
7. Singh, R. S., 2008. Plant Diseases, Oxford and IBH Publishing Co. Pvt Ltd
8. Singh, R. S., 2008. Principles of Plant Pathology, Oxford and IBH Publishing Co. Pvt Ltd.
9. Dhingra, O.D. and James, B. Sinclair, 1995. Basic Plant Pathology Methods, CRC Press
10. Pelczar, JM, Chan, ECS and Krieg, MR. 1993. Microbiology. Tata McGraw Hill.
11. Bishen, PS. 2014. Microbes in Practice. I.K. International Publishing House Pvt. Ltd.
12. Aneja, KR, Jain, P and Aneja, KR. 2008. A Text book of Basic and Applied Microbiology. New Age International Publishers, New Delhi.

BOT653: Biology of Bryophytes

Credits: 3

Unit I

Classification, structure and life history of some Hepatics, Anthocerotes and mosses with special reference to Indian forms

Unit II

Ecology and geographical distribution with special reference to Bryogeographical units of India flora

Unit III

Physiology in relation to environment and reproduction, Conducting tissues and water relation. Some naturally occurring growth substances

Unit IV

Regeneration and vegetative reproduction. Apogamy and apospory. Spore germination and initial stages in gametophyte development. Protonemal differentiation and bud induction

Unit V

Antibiotic activities of bryophytes, bryophytes and pollution, local bryophyte flora, Fossil history and recent advances in Bryology

Suggested readings:

1. Parihar N. S. 1965, An Introduction to Embryophyta- Bryophyta. Central Book Depot. Allahabad.
2. Kashyap S. R. 1972, Liverworts of the Western Himalayas & the Punjab Plains. Part 1 & 2.
3. Richardson D. H. S, The Biology of Mosses.
4. Janice. M. Glime, 2006, Bryophyte Ecology.
5. Goffinet B. & Shaw. A. J. 2008, Bryophyte Biology.
6. Gangulee, H.C. and Kar, A.K., 2011, College Botany Vol. II (Algae+Fungi+Bryophyta+Pteridophyta) , New Central Book Agency, Kolkata
7. Singh, Pande, Jain, 2010, A Text Book of Botany (Algae+Fungi+Bryophyta+Pteridophyta) , Pub.Rastogi Publication, Meerut

BOT654: Taxonomy of Angiosperm

Credits: 3

Unit I

History of plant Taxonomy of the world, history of plant classification of the world, Modern system of classification. Angiosperm Phylogeny Group (APG): Outline of Classification, function and Application

Unit II

International Code of Nomenclature (ICN): Principles, rules and recommendations and appendices; application of nomenclature.

Unit III

Biodiversity: characterization, generation maintenance and loss, magnitude, distribution and conservation, remote sensing. Indigenous flora of the country with special reference to local flora and flora of the special habitats, Methods of plant identification

Unit IV

Inter relationship of plant taxonomy with morphology, anatomy, embryology, palynology, cytology, genetics, phytogeography and Chemistry. Biosystematics, serology and molecular systematic and numerical taxonomy.

Unit V

Botanical gardens, Herbarium, digital herbarium and their significance, Herbarium techniques, Applications of plant taxonomy in medicine, forensic science and urbanization (indoor and outdoor plants)

Suggested readings:

1. Sambamurty, A.V. S. S. 2005. *Taxonomy of Angiosperms*. I. K. International Pvt. Ltd., New Delhi.
2. APG III 2009. An update of the Angiosperm Phylogeny Group Classification for the Orders and Families of Flowering Plants: APG III. *Bot. J. Linn. Soc.* 161: 105-121.
3. Bhattacharyya, B. and B. M. Johri. 1998. *Flowering Plants - Taxonomy and Phylogeny*. Narosa Publishing House, New Delhi.
4. Heywood, V. H. and Moore, D. M. 1984. *Current Concepts in Plant Taxonomy*. Oxford University Press.
5. Duthie, J. F. "Flora of upper gangetic plain and of the adjacent siwalik & sub-himalayan tracts," Calcutta, Vol. 3, No. 1, 1915.
6. Jain, S.K. and Rao, R.R. 1977. *A Handbook of Field and Herbarium Methods*. Today and Tomorrow's Printers and Publishers, New Delhi.
7. Rao, R. R. 1994. *Biodiversity in India (Plant Aspects)*, Bishan Singh Mahandrapal Singh, Dehradun.
8. Sharma, O. P. 1993. *Plant Taxonomy*. Tata McGraw Hill Publishing Co. Ltd., New Delhi.
9. Singh, V. & Jain, D.K. 2006. *Taxonomy of Angiosperms*. : [Rastogi Publications](#), Meerut.
10. [Singh](#), Gurcharan 2012. *Plant Systematics: An Integrated Approach-* [Science Publishers](#), Enfield, (3rd edn.)
11. Stace, C. A. 1989. *Plant Taxonomy and Biosystematics*. University Park Place, Baltimore (2nd edn.)
12. Takhtajan A. 2009. *Diversity and classification of flowering plants*, 2nd edn. Berlin: Springer.
13. Verma, B. K. 2010. *An introduction to Taxonomy of Angiosperms*. PHI Learning Pvt. Ltd. New Delhi.
14. Jones, SB Jr. and Luchsinger, AE. 1986. *Plant Systematics (2nd edition)*. McGraw Hill Book Co., New York.
15. Pandey, A. K., J.V.V. Dogra & Wen, J. 2006. *Plant Taxonomy: Advances and Relevance*. CBS Publishers & Distributors Pvt. Ltd.
16. Subrahmanyam, N. S. *Taxonomy of Angiosperm*, Vikas publishing house Pvt Ltd.
17. Pullaihi, T. 2007. *Taxonomy of angiosperm*. Regency publications, New Delhi.

BOT655: Biology & Diversity of Pteridophytes and Gymnosperms

Credits: 3

Unit I

Salient features of pteridophytes and gymnosperms, their origin, evolution and distribution in Geological Time Scale. Classification of pteridophytes and gymnosperms- traditional and modern system

Unit II

Comparative studies on the vegetative and reproductive organographics, evolutionary tendencies and affinities of members belonging to Psilophytales, Psilotales, Lycopodiales, Sphenophyllales, Coenopteridales and Filicales

Unit III

Cytogenetics and Ferns, Nature of Ferns Breeding systems, genetic load. Culture of fern gametophytes, photomorphogenesis in fern gametophytes. Ecological diversity and pteridophytes, pteridophytic flora of India, endangered pteridophytes and their conservation

Unit IV

Vegetative morphology and reproductive biology of Pteridosperms, Cycadales, Benneitales, Pentoxilales, Ginkgoales, Coniferales, Taxales, Gnetales

Unit V

Ecological of modern gymnosperms, distribution of gymnosperms in India, endangered gymnosperms and their conservation, Tissue culture and biotechnology of gymnosperms, Economical importance of gymnosperms

Suggested readings:

1. Gangulee, H.C. and Kar, A.K., 2011, *College Botany Vol. II (Algae+Fungi+Brophyta+Pteridophyta)*, New Central Book Agency, Kolkata
2. Singh, Pande, Jain, 2010, *A Text Book of Botany (Algae+Fungi+Brophyta+Pteridophyta)*, Pub. Rastogi Publication, Meerut
3. Rashid, A, 2011, *An Introduction to Pteridopyta*, 2nd edition, (Reprint), Pub. Vikas Publishing House Pvt. Ltd., Noida.
4. Gifford, Ernest, M., Foster, Adriance.S., 1989, *Morphology and Evolution of vascular plant*. W. H. Freeman; Third Edition.
5. Ogura, Yuzuru., 1972, *Comparative anatomy of vegetative organs of the pteridophytes*. Gebr. Borntraeger; 2nd edition.
6. Rashid, A.1999, *An introduction to pteridophyta: Diversity,Development,Differentiation*. Vikas Publishing House Pvt Ltd.
7. Parihar, Narayan Singh., 1977, *The biology and Morphology of the pteridophyte*. Central Book Depot

8. Eames, A. J. (1936) Morphology of Vascular plant-lower group. Tata Mc Graw Hill, New Delhi.
9. Chamberlain, Charles Joseph, b. 1863, Gymnosperm S; Structure and Evolution. Chicago, III., The University of Chicago Press
10. Chhaya Biswas and B. M. Johri. The Gymnosperm. Springer; 1997 edition (16 April 2014)
11. Bhatnagar, S. P. Moitra, Alok. 1996. Gymnosperms. New Age International.
12. Pant DD. 2002, An introduction to gymnosperms, cycas, and cycadales, Birbal Sahni Institute of Palaeobotany.

BOT656: Advanced Plant Anatomy and Palynology

Credits: 3

Unit-I

Cell, cell wall, biochemical and structural organization of cell wall, Meristems – Organizations of root apical meristem (RAM), shoot apical meristem (SAM), Tissue and tissue systems.

Unit-II

Xylem and phloem – Ontogeny, phylogeny, and ultrastructure, transfer cells, Secretory and excretory structures. Primary and secondary structure of root and stem. Origin and development of lateral roots, nodal anatomy and root stem transition.

Unit-III

Leaf structure, systematic significance of trichomes and stomata, Vascular cambium and derivatives, periderm, anomalous secondary growth, Floral morphology and anatomy, Applications of anatomy.

Unit-IV

Structure of wood, physical properties of wood and taxonomic significance, anatomy in relation to taxonomy, Ecological anatomy, methods used in anatomy

Unit-V

Palynology: Definition, subdivision of palynology, application of palynology, Pollen morphology: Polarity, symmetry, apertures, sporoderm, palynotaxonomy. aeropalynology. Palaeopalynology, Melissopalynology, Palynological techniques

Suggested readings:

1. Agashe, S.N. (2006), Palynology and its applications. Oxford & IBH Publishing Co. Pvt. Ltd.
2. Bhattacharya, K.N., Majumdar, M. R., Bhattacharya, Swati Gupta (2006), A Text of Palynology, New Central Book Agency.
3. Butterfield B.G & Meylan B.A (1980)-Three- Dimensional structure of wood. Landon New York.
4. Carlquist, S.C. (1961), Comparative Plant Anatomy Holt, Rinehart and Winston, New York Press.
5. Carlquist S. (2001), Comparative Wood Anatomy Systematic, Ecological and Evolutionary Aspects of Dicotyledon Wood.
6. Cutter, Elizabeth (1969), Plant Anatomy part –I Cells and Tissues IInd edition, Edward Arnold, London
7. Cutter, Elizabeth (1971), Plant Anatomy Part- II Organs, Edward Arnold London
8. Dickison W.C. (2000), Integrative Plant Anatomy. Academic Press
9. Eames, Arthur J. & Mac Daniels Laurence H. (1951), An Introduction To Plant Anatomy, McGraw Hill.
10. Erdtman, G. (1986), Pollen Morphology and Plant Taxonomy, published by Brill Archive,
11. Esau, Katherine, (1965), Plant Anatomy, , John Wiley and Sons. Inc. New York.
12. Esau, Katherine, (1960), Anatomy of seed Plants. Wiley, New York.
13. Evert, Ray. F. (1960), Esau's Plant Anatomy. John Wiley & Sons.
14. Fahn, A. (1982), Plant Anatomy Vol I and Vol II Pergamon Press. Oxford New York.
15. Jane F.W (1934)-Aspects of the Study of Wood Anatomy. Science Reviews 2000 Ltd.
16. J. Mauseth, James D. (1988) Plant Anatomy. Benjamin/Cummings.
17. Pearson and Brown, (1981) -Commercial Timbers of India.
18. Rao K.R and Purakayastha S.K.(1972) - Indian woods:their identification , properties and uses.
19. Wodehouse, R.P. (1935). Pollen grains, their structure identification and significance in science and medicine. McGraw-Hill. New York.
20. Wilson K, James D, White, B. (1986) - The Anatomy of Wood, it Diversity and Variability. Stobart&Son Ltd.

BOT657: Ecology and Environment

Credits: 3

Unit-I

Plant Ecology: Characteristics of a population, population growth curves, population regulation and r and k selection, concept of metapopulation

Unit-II

Community Ecology: Nature of communities, community structure and attributes, analytical, quantitative and qualitative characters and synthetic characters, levels of species diversity and its measurement edges and ecotones, life forms.

Unit-III

Ecological succession: Types, mechanisms, change involved in succession.

Unit-IV

Ecosystem Ecology: Ecosystem – structure and function, major ecosystems, energy flow, mineral cycling (C,N,P), primary production and measurement, structure and function of terrestrial and aquatic ecosystems.

Unit-V

Applied Ecology: Environmental pollution, biodiversity, biodiversity management, Project tiger, biosphere reserves, conservation biology, principles of conservation, conservation and management strategy, green house gases and sources

Suggested reading:

1. Odum, E. P. and Barret G.W. 2005. Fundamentals of Ecology. Cengage publication
2. Odum, E.P., 1983. Basic Ecology., Saunders College Publishing
3. Singh, J.S., Singh S.P. and Gupta S.R. 2006. Ecology Environment and Resource Conservation. Anamaya Publishers

BOT658: Advanced Cytogenetics

Credits: 3

Unit I

Ultrastructure of chromosomes, karyotype analysis, structural changes in chromosomes, numerical changes in chromosomes, Human karyotype

Unit II

Mendelian inheritance, Epistasis, Linkage, Crossing over, non- mendelian inheritance

Unit III

Quantitative inheritance, Induced mutagenesis, Molecular basis of mutation, Mechanisms of sex determination, sex linked inheritance.

Unit IV

Gene concept, Modern concept of gene, genetic code, gene mapping, gene expression and regulation

Unit V

Plant genetic engineering-tools and techniques, Applications of genetic engineering, *nif*-genes

Suggested reading:

1. Clark, M.S. and Wall, W.J. 1996, Chromosomes : The Complex Code. Chapman & Hall, London.
2. Stebbins, G.L.1950, Variation and Evolution in Plants. Columbia Univ. Press, New York.
3. Swanson, C. P., Mertz, T.F. and Young, W.J. Cytogenetics : The Chromosomes in Division, Inheritance and Evolution (2nd Edn). Englewood Cliff, Prentice-Hall, New Jersey.
4. Sharma, A.K. and Sharma, Archana. 1985. Advances in Chromosome and Cell Genetics. Oxford & IBH Publishing Co., Calcutta.
5. Schnedl, W.. Banding patterns in chromosomes. In: International Review of Cytology (Suppl. 4).
6. Lewine, Benjamin, Jones and Bartlet, Genes X, Sudbury, Masschusetts
7. Gupta, P.K., Cytogenetics, Rastogi Publication, Meerut
8. Peter, D, Snustand and Simmons, M.J., John Wiley and Sons Inc.

BOT659: Advanced Plant Physiology

Credits: 3

Unit I

Biological membrane: Structure and function of biological membrane, Experimental evidence for dynamic nature of membrane; Assimilation of nutrients: Nitrogen, sulfur, phosphorus and oxygen.

Unit II

Respiration: Respiration under aerobic and anaerobic conditions and its regulatory mechanism, significance of anaerobic respiration, Citric acid cycle and its amphibolic nature, Respiration is coupled to other pathways.

Unit III

Photosynthesis: Excitation energy and fate of excitation, Key experiments in understanding of light reaction, Repair and regulation of the photosynthetic machinery, Regulation of C₃ cycle and C₄ cycle, Photosynthetic responses to light, temperature and carbon dioxide, Experimental evidence for ATP generation.

Unit IV

Signaling pathway: Signaling pathway of Phytochrome, Auxin, Gibberellins, Cytokinins, Ethylene, Abscisic acid, Brassinosteroids; Vernalization: Vernalization and biochemical signaling in flowering

Unit V

Stress physiology: Abiotic stress - Water deficit and drought tolerance, Heat stress and heat shock, Chilling and freezing stress, salinity stress, Oxygen deficiency; Biotic stress; Oxidative stress: generation of oxidants, indicators of oxidative stress, antioxidants- enzymatic and non-enzymatic antioxidants.

Suggested readings:

1. Taiz and Zeiger, 2010, Plant Physiology, 5th Edition, Sinauer Associates
2. Hopkins, W.G. and Huner N.P.A., 2009, Introduction to Plant Physiology, 4th Edition Wiley International Edition, John Wiley & Sons, USA
3. Jones, Russell L. Buchanan, Bob B. Guissem, Wilhelm., 2002, Biochemistry and Molecular Biology of Plants. American Society of Plant Physiologists.
4. Peter Scott, Physiology and Behaviour of Plants. Wiley-Blackwell.
5. Frank Boyer Salisbury and Cleon Ross, 1991, Plant Physiology, CA

BOT660: Palaeobotany

Credits: 3

Unit I

Basic geological information – structure of Earth Types of rocks, stratigraphy, basic concepts of continental drift and plate tectonics; Dating the past, Geological time scale.. Fossilization process, Types of fossils; techniques to study fossils, reconstruction and nomenclature of fossil--- concepts of Parataxa and Eutaxa, objectives of palaeobotany

Unit II

Prebiotic Environment, chemical evolution and origin of life, Pre-Cambrian life; Indian Pre-cambrian stratigraphy and life forms; Diversification of algae, fungi and bryophytes through the ages; Origin and evolution of land plants, earliest records of pteridophytes and their evolutionary tendencies

Unit III

Emergence of first seeds plants, preovules, diversification of Gymnosperms in geological time scale. First Angiosperms, Angiosperm palaeofloristics; Concept of Indian Gondwana sequence, stratigraphy and correlation of Gondwana sequence in Peninsular Indian basins; Mega and microfloristics of Indian Gondwana formation; Indian Perigondwana floras

Unit IV

Applied Palaeobotany Life as fuel maker, sources of natural fossil fuels, Peat, coal and its varieties, constitution of coal, Coal Palynology, coal maceral, Petroleum – its origin, migration and concentration, palynology in oil exploration

Unit V

Fundamentals of Paleofloristics, Palaeogeography and Palaeoclimatology; Application of Palaeopalynology .Plant and animal interactions correlation, Archaeobotany with special reference to phytoliths and palynological studies

Suggested readings:

1. Steward W.N., Palaeobotany and evolution of plant. Cambridge University Press, New York. 405 p.(1)
2. Stewart, W.N., and G.W. Rothwell. 1993 Palaeobotany and the evolution of plant. 2nd ed. Cambridge University Press, New York. 521 p.(1)
3. Andrews, H.N., jr. 1974 Palaeobotany 1947-1972 Annals of the Missouri Botanical Garden 61:179-202.(8)
4. Thomas N. Taylor. Edith L. Taylor. Michael Krings Palaeobotany: The biology and Evolution of Fossil Plants Amsterdam ; Boston, Mass.

BOT661: Applied Microbiology

Credits: 3

Unit-I

Microbiology of Air, allergic disorders by air microflora, outdoor and indoor aero-microbiology, air sampling and sampling devices. Microbiology of water, types of aquatic environments, microbial components of water, water pollution, pollution indicator microorganisms, bacteriological analysis of water, water treatment. Microbiology of Solid Wastes, Sewage (Waste water) and Industrial Waste, sewage treatment (domestic)

Unit-II

Food Microbiology: Food spoilage, microbes associated with food spoilage, food preservation methods, microbiology of milk and dairy products, microbiology of fermented foods. Industrial Microbiology: microbes in medicines, in production of organic acids, amino acids, enzymes, solvents, fuels, alcoholic beverages, vinegar, vitamins etc., microbes in metal recovery.

Unit-III

Agriculture Microbiology: Microbes-Plant Associations, free-living, associative, symbiotic nitrogen fixers, actinorrhizae, stem nodulating Rhizobia, mycorrhizal associations, Microbial Biofertilizers and Biopesticides,

Unit-IV

Environmental Microbiology: Composting, vermicomposting, Biogas production, microbial leaching, microbial degradation of petroleum, xenobiotics, microbial bioremediation, merit, scope and approaches of bioremediation, ecology and technology of bioremediation., bio-deterioration of stored plant food materials, lather, paper, fuel and lubricants, plastics, cosmetics etc.

Unit-V

Medical Microbiology: Infection and Diseases, Human Diseases caused by Fungi (mycoses; superficial, cutaneous, sub-cutaneous, systemic), Bacteria: (air-borne diseases; tuberculosis, meningitis, pneumonia, whooping cough, food-borne and water-borne diseases; botulism, Clostridial food poisoning, typhoid fever, cholera; soil-borne diseases, tetanus) and Viruses (influenza, herpes simplex, chicken pox, measles, mumps, small pox, dengue, rabies, polio, viral hepatitis, AIDS, Ebola, chicken flu, chikungunya, Swine flu, mad cow disease etc.), their diagnostics and managements

Suggested readings:

1. Stanier, R.Y., Ingraham, J.L., Wheelis, M.L., Painter, P.R., 1987. General Microbiology. Fifth edition. MacMillan.
2. Dubey, RC and Maheshwari, DK. 1999. A Textbook of Microbiology. S. Chand & Company Ltd.
3. Atlas, RM. 1995. Principles of Microbiology. Mobsy.
4. Lim, DV. 2003. Microbiology. Kendall/Hunt.
5. Boundless.2013. Microbiology. Boundless Learning, Incorporated.
6. Comelissen, CN, Harvey, RA and Fisher, BD. 2012. Microbiology. Lippincott Williams & Wilkins.
7. Talaro, K.P., Chess, B. 2011, Foundations in Microbiology. 8th edition. McGraw-Hill.
8. Tortora, G.J., Funke, B.R., Case, C.L. 2003, Microbiology: An Introduction. Benjamin Cummins
9. Willey, J.M., Sherwood, L., Woolverton, C.J., 2010. Prescott's Microbiology. 8th edition, McGraw-Hill
10. Pelczar, JM, Chan, ECS and Krieg, MR. 1993. Microbiology. Tata McGraw Hill.

BOT662: Advanced Molecular Biology and Genetic Engineering

Credits: 3

Unit I

Nucleic acid: Structure, Replication and Repair; Transcription: Gene structure, RNA synthesis, RNA processing, RNA editing, Translation: Genetic code, Mechanism of translation, Protein sorting, Post-translational modifications, Regulation of gene expression: Transcriptional and post-transcriptional control of genes.

Unit II

Genome study: Structure, Organization, Mapping and Sequencing genomes, Fifth generation DNA sequencing methods (Pyrosequencing, Ion-torrent, Nanopore sequencing), Genome evolution: Comparative and Functional Genomics, Mutation, Recombination and Repair, molecular Phylogenetics

Unit III

Proteomics: Protein structure and function, Study of Proteome, 2-D gel electrophoresis, DIGE, Peptide Mass Spectroscopy, Protein-DNA interaction, Protein Mapping (expression and interaction mapping by Yeast-2-hybrid methods and variations) Cloning and expression of cloned genes in prokaryotic and eukaryotic systems, Considerations for Heterologous protein expression and purification, Molecular farming, ELISA, Western blotting

Unit IV

Isolation, Purification, Detection and Hybridization of Nucleic Acids, Recombinant DNA Technology, Polymerase Chain Reaction, Construction of genomic and cDNA libraries, screening and selection of recombinants, Analysis of Gene Expression: SAGE, qPCR, Microarray; Random and site-directed mutagenesis, Developing transgenic plants, Knock-in, Knock-out, Genome Editing- CRISPR

Unit V

Bioinformatics: Databases, Retrieval of biological data, Sequence alignment, Restriction site annotation; Repeat Annotation of sequence Repeat Masker; ORF annotation – using ORF finder; Gene Prediction – using Gene Scan and Glimmer; Primer designing using Primer 3; Homology Search – BLAST and its variants, BLAT; Multiple Sequence Alignment – Clustal W and ClustalX; Phylogeny and molecular evolution – MEGA, EXPASY Server, RCSB Protein data banks, BLASTp; Primary structure analysis tools (Translate and reverse translate, Codon Usage, FindPept, pI/Mw computation, Peptide cutter, Mascot)

Suggested readings:

1. Molecular Biology of Cell by Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter
2. Molecular Biology by Lodish Darnell and Baltimore
3. Molecular Biology of the Gene by Watson et al 4th ed.
4. Genes-X by Benjamin Lewin
5. Principles of Gene manipulation- Twyman & Primrose
6. Biotechnology by B D Singh

BOT619: Dissertation / Thesis

Credits: 4

The topic would be decided by the candidate in consultation with the respective supervisor. Dissertation/thesis will be based on existing branches of botany and the title will be decided keeping the view on the modern aspect in the related discipline. It will be the part of semester IV; however, the title of dissertation / thesis will be assigned by concerned faculty member/board in the beginning of semester III to provide sufficient time to complete dissertation / thesis.

BOT634: Lab Work VIII (based on Course BOT651 and BOT607)	Credits: 4
BOT635: Lab Work VIII (based on Course BOT652 and BOT607)	Credits: 4
BOT636: Lab Work VIII (based on Course BOT653 and BOT607)	Credits: 4
BOT637: Lab Work VIII (based on Course BOT654 and BOT607)	Credits: 4
BOT638: Lab Work VIII (based on Course BOT655 and BOT607)	Credits: 4
BOT639: Lab Work VIII (based on Course BOT656 and BOT607)	Credits: 4
BOT640: Lab Work VIII (based on Course BOT657 and BOT607)	Credits: 4
BOT641: Lab Work VIII (based on Course BOT658 and BOT607)	Credits: 4
BOT642: Lab Work VIII (based on Course BOT659 and BOT607)	Credits: 4
BOT643: Lab Work VIII (based on Course BOT660 and BOT607)	Credits: 4
BOT644: Lab Work VIII (based on Course BOT661 and BOT607)	Credits: 4
BOT645: Lab Work VIII (based on Course BOT662 and BOT607)	Credits: 4