CHOICE BASED CREDIT SYSTEM

Syllabus

For

B.Sc. BOTANY HONOURS

DEPARTMENT OF BOTANY
ORIENTAL COLLEGE (AUTONOMOUS)
TAKYEL, IMPHAL-795001

Effective from Academic Session 2020-2021

Scheme for Choice Based Credit System in B. Sc. Botany Honours

Semester		CORE COURSE(14)	Ability Enhancement Compulsory Course (AEC) (2)	Skill Enhancement Course (SEC) (2)	Discipline Specific Elective (DSE)(4)	Generic Elective: (GE) (4)
I	Core Course I	Phycology and Microbiology	English Communication			GE-1
	Core Course II	Biomolecules and Cell Biology				
II	Core Course III	Mycology and Phytopathology	Environmental Studies			GE-2
	Core Course IV	Archegoniate				
III	Core Course V	Morphology and Anatomy of Angiosperm		SEC -1		GE-3
	Core Course VI	Economic Botany				
	Core Course V II	Genetics				
IV	Core Course VIII	Molecular Biology		SEC -2		GE-4
	Core Course IX	Plant Ecology and Phytogeography				
	Core Course X	Plant Systematics				
V	Core Course XI	Reproductive Biology of Angiosperms			DSE-1	
					DSE-2	
	Core Course XII	Plant Physiology				
VI	Core Course XIII	Plant Metabolism			DSE-3	
	Core Course XIV	Plant Biotechnology			DSE-4	

Course Structure for CBCS in B. Sc. Botany Honours as per requirement of UGC

SEMESTER	COURSE OPTED	COURSE NAME	Credits
I	ENG-AE-1014	English communications	4
	BOT-HC-1016	Phycology and Microbiology	4
	BOT-HC-1016 (**Practical)**	Phycology and Microbiology	2
	BOT-HC-1026	Biomolecules and Cell Biology	4
	BOT-HC-1026 (**Practical)**	Biomolecules and Cell Biology-	2
	BOT-HG-1016 **Generic Elective -1**	Biodiversity (Microbes, Algae, Fungi and Archegoniate) GE-1	4
	BOT-HG-1016 **Generic Elective -1 Practical/ Tutorial**	GE-1 Practical	2
II	ENV-AE-2014	Environmental Studies	4
	BOT-HC-2016	Mycology and Phytopathology	4
	BOT-HC-2016 **(Practical)**	Mycology and Phytopathology-	2
	BOT-HC-2026	Archegoniate	4
	BOT-HC-2026 **(Practical)**	Archegoniate- Practical	2
	BOT-HG-2016 **Generic Elective -2**	Plant Ecology and Taxonomy GE-2	4
	BOT-HG-2016 **Generic Elective -2 -- Practical**	GE-2 Practical	2
III	BOT-HC-3016	Morphology and Anatomy of Angiosperm	4
	BOT-HC-3016 (**Practical)**	Morphology and Anatomy of Angiosperm –Practical	2
	BOT-HC-3026	Economic Botany	4
	BOT-HC-3026 (**Practical)**	Economic Botany-Practical	2
	BOT-HC-3036	Genetics	4
	BOT-HC-3036 (**Practical)**	Genetics- Practical	2
	1. BOT-SE-3014 2. BOT-SE-3024	SEC-1 (any one) 1. Biofertilizers 2. Herbal Technology	4
	BOT-HG-3016 **Generic Elective -3**	Plant Physiology and Metabolism GE-3	4
	BOT-HG-3016 **Generic Elective -3 Practical**	GE-3 Practical	2
IV	BOT-HC-4016	Molecular Biology	4
	BOT-HC-4016 (**Practical)**	Molecular Biology- Practical	2
	BOT-HC-4026	Plant Ecology and Phytogeography	4
	BOT-HC-4026 (**Practical)**	Plant Ecology and Phytogeography	2
	BOT-HC-4036	Plant Systematics	4
	BOT-HC-4036 (**Practical)**	Plant Systematics Practical	2
	1. BOT-SE-4014 2. BOT-SE-4024 3. BOT-SE-4034	SEC-II (any one) 1. Nursery and Gardening 2. Floriculture 3. Intellectual Property Rights	4

	BOT-HG-3026 Generic Elective -4	Environmental Biotechnology GE-4	4
	Generic Elective – 4 **Practical**	GE-4 Practical	2
V	BOT-HC-5016	Reproductive Biology of Angiosperms	4
	BOT-HC-5016 (**Practical)**	Reproductive Biology of Angiosperm – Practical	2
	BOT-HC-5026	Plant Physiology	4
	BOT-HC-5026 (**Practical)**	Plant Physiology- Practical	2
	BOT-HE-5016	DSE-1 Natural Resource Management	4
	BOT-HE-5016 (**Practical)**	DSE-1 Practical Natural Resource Management – Practical	2
	BOT-HE-5026	DSE-2 Horticultural Practices and Post- Harvest Technology	4
	BOT-HE-5026 **(Practical)**	DSE-2 Practical Horticultural Practices and Post-Harvest Technology-Practical	2

VI	BOT-HC-6016	Plant Metabolism		4
	BOT-HC-6016 (**Practical)**	Plant Metabolism- Practical		2
	BOT-HC-6026	Plant Biotechnology		4
	BOT-HC-6026 (**Practical)**	Plant Biotechnology- Practical		2
	BOT-HE-6016	DSE-3 Industrial and Environmental Microbiology		4
	BOT-HE-6016 (**Practical)**	DSE-3 Industrial and Environmental Microbiology-Practical		2
	Discipline Centric Elective-4 (Theory & practical / Project Work)	Either 1 or 2 below		
	1.BOT-HE-6026	DSE-4 1.Analytical Techniques in Plant Sciences	4	6
	1.BOT-HE-6026 (**Practical)**	DSE-4 1.Analytical Techniques in Plant Sciences-Practical	2	
	2.BOT-HE-6036	DSE-4 2. Project Work/ Dissertation	6	

Total Credits in B. Sc. Botany Honours: 148

List of Papers
B. Sc. Honours Botany Under CBCS

Core Papers

1	BOT-HC-1016	: Phycology and Microbiology
2	BOT-HC-1026	: Biomolecules and Cell Biology
3	BOT-HC-2016	: Mycology and Phytopathology
4	BOT-HC-2026	: Archegoniate
5	BOT-HC-3016	: Morphology and Anatomy of Angiosperm
6	BOT-HC-3026	: Economic Botany
7	BOT-HC-3036	: Genetics
8	BOT-HC-4016	: Molecular Biology
9	BOT-HC-4026	: Plant Ecology and Phytogeography
10	BOT-HC-4036	: Plant Systematics
11	BOT-HC-5016	: Reproductive Biology of Angiosperms
12	BOT-HC-5026	: Plant Physiology
13	BOT-HC-6016	: Plant Metabolism
14	BOT-HC-6026	: Plant Biotechnology

Discipline Specific Elective (DSE) Papers

1	BOT-HE-5016	: Natural Resource Management
2	BOT-HE-5026	: Horticultural Practices and Post-Harvest Technology
3	BOT-HE-6016	: Industrial and Environmental Microbiology
4	BOT-HE-6026	: Analytical Techniques in Plant Sciences
5	BOT-HE-6036	: Project work/Dissertation

Generic Elective (GE)

1	BOT-HG-1016	: Biodiversity (Microbes, Algae, Fungi and Archegoniate)
2	BOT-HG-2016	: Plant Ecology and Taxonomy
3	BOT-HG-3016	: Plant Physiology and Metabolism
4	BOT-HG-3026	: Environmental Biotechnology

Ability Enhancement Compulsory Course

1	ENG-AE-1014	: English/MIL communication
2	ENV-AE-2014	: Environmental Studies

Skill Enhancement Paper

1	BOT-SE-3014	: Biofertilizers (SEC-I)
2	BOT-SE-3024	: Herbal Technology (SEC-I)
3	BOT-SE-4014	: Nursery and Gardening (SEC-II)
4	BOT-SE-4024	: Floriculture (SEC-II)
5	BOT-SE-4034	: Intellectual Property Rights (SEC-I)

Core Course

Semester-I

BOT-HC-1016

Core Course 1: Phycology and Microbiology

Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Develop understanding on the concept of microbial nutrition
- Classify viruses based on their characteristics and structures
- Develop critical understanding of plant diseases and their remediation.
- Examine the general characteristics of bacteria and their cell reproduction/recombination.
- Increase the awareness and appreciation of human friendly viruses, bacteria, algae and their economic importance.
- Conduct experiments using skills appropriate to subdivisions.

Objective of the Course

- Highlight general characteristics of microbes and their classifications.
- Impart ideas of the economic importance of microbes and its application in the field of agriculture and industry.
- Discuss on Algal classification, Economic and ecological importance of Algae.
- Provide practical knowledge on structure of T-Phage and TMV, lytic and lysogenic life cycle, and knowledge on microscopy of bacteria and algae.

1.1 THEORY

Unit 1: *Introduction to microbial world* (10 lectures)

History of microbiology; Scope and relevance of microbes in industry and environment; Microbial nutrition, growth and metabolism [Only an overview of microbial metabolism- the concept of anabolism (Biosynthesis) and catabolism (ATP-generating Pathways-Respiration and Fermentation)]; major groups of the microbial world.

Unit 2: *Viruses* (7 lectures)

Discovery, physiochemical and biological characteristics; classification (Baltimore), general structure with special reference to viroids and prions; replication (general account), DNA virus (T-phage), lytic and lysogenic cycle; RNA virus (TMV). Economic importance of viruses with reference to vaccine production, role in research, medicine and diagnostics, as causal organisms of plant diseases.

Unit 3: *Bacteria* (7 lectures)

Discovery, general characteristics; Types-archaebacteria, eubacteria, actinomycetes, mycoplasma, rickettsia, chlamydiae and sphaeroplasts; Cell structure; Nutritional types; Reproduction-vegetative, asexual and recombination (conjugation, transformation and transduction). Economic importance of bacteria with reference to their role in agriculture and industry (Alcohol and Antibiotic production).

Unit 4: *Algae* (10 lectures)

General characteristics; Ecology and distribution; range of thallus and structure of vegetative body; Cell structure and components; cell wall, pigment system, reserve food (of only groups represented in the syllabus), flagella; methods of reproduction; Classification; Evolutionary significance of *Prochloron*; criteria, system of Fritsch, and evolutionary classification of Lee (only upto groups); Role of algae in the environment, agriculture, biotechnology and industry, Economic importance of Diatoms.

Unit 5: *Cyanophyta and Xanthophyta* (8 lectures)

Ecology and occurrence; Range of thallus organization; Cell structure; Reproduction, Morphology and life-cycle of *Nostoc* and *Vaucheria.*

Unit 6: *Chlorophyta, Charophyta and Bacillariophyta* (10 lectures)

General characteristics; Occurrence; Range of thallus organization; Cell structure; Reproduction. Morphology and life-cycles of *Volvox, Oedogonium, Coleochaete, Chara.* General Account of Bacillariophyta.

Unit 7: *Phaeophyta and Rhodophyta* (8 lectures)

Characteristics; Occurrence; Range of thallus organization; Cell structure; Reproduction. Morphology and life-cycles of *Ectocarpus*, *Fucus* and *Polysiphonia.*

1.2 PRACTICAL

Microbiology

1. Electron micrographs/Models of viruses – T-Phage and TMV/ Line drawings/ Photographs of Lytic and Lysogenic Cycle.

2. Types of Bacteria to be observed from temporary/permanent slides/photographs. Electron micrographs of bacteria, binary fission, endospore, conjugation, root Nodule.

3. Gram staining.

4. Isolation of soil microflora.

5. Endospore staining with malachite green using the (endospores taken from soil bacteria).

Phycology

1. Study of vegetative and reproductive structures of *Nostoc, Volvox, Oedogonium, Chara, Vaucheria, Ectocarpus, Fucus* and *Polysiphonia,Procholoron* through electron micrographs, permanent slides.

Suggested Readings

1. Lee, R.E. (2008). Phycology, Cambridge University Press, Cambridge. 4th edition.
2. Wiley JM, Sherwood LM and Woolverton CJ. (2013). Prescott's Microbiology. 9th Edition. McGraw Hill International.

3. Kumar, H.D. (1999). Introductory Phycology. Affiliated East-West Press, Delhi.

4. Sahoo, D. (2000). Farming the ocean: seaweeds cultivation and utilization. Aravali International, New Delhi.

5. Campbell, N.A., Reece J.B., Urry L.A., Cain M.L., Wasserman S.A. Minorsky P.V., Jackson R.B. (2008). Biology, Pearson Benjamin Cummings, USA. 8th edition.

6. Pelczar, M.J. (2001). Microbiology, 5th edition, Tata McGraw-Hill Co, New Delhi.

7. Sharma, P.D. (2009). Microbiology, latest edition, Rastogi Publication, Meerut.

BOT-HC-1026
Core Course 2: Biomolecules and Cell Biology

Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Develop understanding on chemical bonding among molecules.
- Describe the relationship between the structure and function of biomolecules.
- Classify the enzymes and explain mechanism of action and structure.
- Compare the structure and function of cells & explain the development of cells.
- Identify the concept that explains chemical composition and structure of cell wall and membrane.
- Explain the structures, function and molecular organization of cell organelles.

Objective of the Course

- Explain the concepts of biomolecules by highlighting their structures, properties and functions.
- Provide knowledge about the structure of enzymes and their classification.
- To discuss about the types of cell, structure of cell wall and plasmamembrane, cell organelles and cell-cycle.
- Impart practical knowledge on properties of cell and cell membrane, DNA staining techniques and microscopy of plant cell.

2.1 THEORY

Unit 1: *Biomolecules* (20 lectures)

Types and significance of chemical bonds; Structure and properties of water; pH and buffers.
Carbohydrates : Nomenclature and classification; Monosaccharides; Disaccharides; Oligosaccharides and polysaccharides.
Lipids: Definition and major classes of storage and structural lipids; Fatty acids structure and functions; Essential fatty acids; Triacyl glycerols structure, functions and properties; Phosphoglycerides.
Proteins: Structure of amino acids; Levels of protein structure-primary, secondary, tertiary and quarternary; Protein denaturation and biological roles of proteins.
Nucleic acids : Structure of nitrogenous bases; Structure and function of nucleotides; Types of nucleic acids; Structure of A, B, C, D, Z types of DNA; Types of RNA.

Unit 2: *Bioenergenetics* (4 lectures)

Laws of thermodynamics, concept of free energy, endergonic and exergonic reactions, coupled reactions, redox reactions. ATP: structure, its role as a energy currency molecule.

Unit 3: *Enzymes* (6 lectures)

Structure of enzyme: holoenzyme, apoenzyme, cofactors, coenzymes and prosthetic group; Classification of enzymes; Features of active site, substrate specificity, mechanism of action (activation energy, lock and key hypothesis, induced - fit theroy), Michaelis – Menten equation, enzyme inhibition and factors affecting enzyme activity.

Unit 4: *The cell* (4 lectures)

Cell as a unit of structure and function; Characteristics of prokaryotic and eukaryotic cells; Origin of eukaryotic cell (Endosymbiotic theory).

Unit 5: *Cell wall and plasma membrane* (4 lectures)

Chemistry, structure and function of Plant cell wall. Overview of membrane function; fluid mosaic model; Chemical composition of membranes; Membrane transport – Passive, active and facilitated transport, endocytosis and exocytosis.

Unit 6: *Cell organelles* (16 lectures)

Nucleus: Structure-nuclear envelope, nuclear pore complex, nuclear lamina, molecular organization of chromatin; nucleolus.
Cytoskeleton: Role and structure of microtubules, microfilaments and intermediary filament.
Chloroplast, mitochondria and peroxisomes: Structural organization; Function; Semiautonomous nature of mitochondria and chloroplast.
Endomembrane system: Endoplasmic Reticulum – Structure, targeting and insertion of proteins in the ER, protein folding, processing; Smooth ER and lipid synthesis, export of proteins and lipids; Golgi Apparatus – organization, protein glycosylation, protein sorting and export from Golgi Apparatus; Lysosomes

Unit 7: *Cell division* (6 lectures)

Phases of eukaryotic cell cycle, mitosis and meiosis; Regulation of cell cycle-checkpoints, role of protein kinases.

2.2 PRACTICAL

1. Qualitative tests for carbohydrates, reducing sugars, non-reducing sugars, lipids and proteins.

2. Study of plant cell structure with the help of epidermal peel mount of Onion/*Rhoeo/Crinum*.

3. Demonstration of the phenomenon of protoplasmic streaming in *Hydrilla* and *Vallisnaria* leaf.

4. Counting the cells per unit volume with the help of haemocytometer. (Yeast/pollen grains).

5. Cytochemical staining of : DNA- Feulgen and cell wall in the epidermal peel of onion using Periodic Schiff's (PAS) staining technique.

6. Study the phenomenon of plasmolysis and deplasmolysis.

7. Study different stages of mitosis and meiosis (Demostration).

Suggested Readings

1. Campbell, MK (2012). Biochemistry, 7th ed., Published by Cengage Learning

2. Campbell, PN and Smith AD (2011). Biochemistry Illustrated, 4th ed., Published by Churchill Livingstone

3. Tymoczko JL, Berg JM and Stryer L (2012). Biochemistry: A short course, 2nd ed., W.H.Freeman

4. Berg JM, Tymoczko JL and Stryer L (2011). Biochemistry, W.H.Freeman and Company

5. Nelson DL and Cox MM (2008). Lehninger Principles of Biochemistry, 5th Edition., W.H. Freeman and Company.

6. Karp, G. (2010). Cell Biology, John Wiley & Sons, U.S.A. 6th edition.

7. Hardin, J., Becker, G., Skliensmith, L.J. (2012). Becker's World of the Cell, Pearson Education Inc. U.S.A. 8th edition.

8. Cooper, G.M. and Hausman, R.E. (2009). The Cell: A Molecular Approach. 5th edition. ASM Press & Sunderland, Washington, D.C.; Sinauer Associates, MA.

9. Becker, W.M., Kleinsmith, L.J., Hardin. J. and Bertoni, G. P. (2009). The World of the Cell. 7th edition. Pearson Benjamin Cummings Publishing, San Francisco

Semester-II

BOT-HC-2016

Core Course 3: Mycology and Phytopathology

Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Identify true fungi and demonstrate the principles and application of plant pathology in the control of plant disease.
- Demonstrate skills in laboratory, field and glasshouse work related to mycology and plant pathology.
- Develop an understanding of microbes, fungi and lichens and appreciate their adaptive strategies.
- Identify the common plant diseases according to geographical locations and device control measures.

Objective of the Course

- To provide knowledge of general characteristics, life cycle and classification of fungi.
- Discuss on the aspects of plant diseases and pathological distribution.
- To highlight structural analysis of different classes of fungi and their reproductive stages.
- Impart knowledge on structures of symbiotic associations (Lichens, Mycorrhiza).

3.1 THEORY

Unit 1: *Introduction to Fungi* (10 lectures)

General characteristics; Status of Fungi in living system; Thallus organization, modification of hyphae; Cell and Cell wall composition; Nutrition, flagella, septum, homothallism and heterothallism, cell division.
History of Classification (Hidetta *et al.* 2007); Classification of Fungi (Ainsworth, 1973, Webster, 1977) up to sub-division with diagnostic characters and examples.
General characteristics of Myxomycota, Oomycota, Zygomycota, Ascomycota, Basidiomycota and Deuteromycota.

Unit 2: *Mastigomycotina (Chytridiomycetes and Oomycetes)* (6 lecture)

Characteristic features; Reproduction; Life cycle with reference to *Synchytrium*, *Phytophthora* and *Albugo.*

Unit 3: *Zygomycotina* (2 lecture)

Characteristic features; Reproduction; Life cycle with reference to Rhizophus.

Unit 4: *Ascomycotina* (10 lectures)

General characteristics (asexual and sexual fruiting bodies); Life cycle, Heterokaryosis and parasexuality; Life cycle and classification with reference to *Saccharomyces, Aspergillus, Penicillium, Neurospora* and *Peziza*.

Unit 5: *Basidiomycotina* (8 lectures)

General characteristics; Life cycle and Classification with reference to black stem rust on wheat *Puccinia* (Physiological Specialization), loose and covered smut (symptoms only), *Agaricus*; Bioluminescence, Fairy Rings and Mushroom Cultivation.

Unit 6: *Deuteromycotina (Fungi Imperfecti)(5 Lectures)*

General characteristics; Thallus organization; Reproduction; Classification with special reference to *Alternaria* and *Colletotrichum.*

Unit 7: *Allied Fungi- Myxomycota* (3 lectures)

General characteristics; Status of Slime molds, Classification; Occurrence; Types of plasmodia; Types of fruiting bodies.

Unit 8: *Symbiotic associations* (3 lectures)

Lichen – Occurrence; General characteristics; Range of thallus organization; Internal structure and nature of associations of algal and fungal partners; Reproduction.
Mycorrhiza- Ectomycorrhiza, Endomycorrhiza and their significance.

Unit 9: *Applied Mycology* (5 Lectures)

Role of fungi in biotechnology; food industry (Flavour & texture, Fermentation, Baking, Organic acids, Enzymes, Mycoproteins); Pharmaceutical (Secondary metabolites); Agriculture (Biofertilizers); Mycotoxins; Biological control (Mycofungicides, Mycoherbicides, Mycoinsecticides, Myconematicides); Medical mycology.

Unit 10: *Phytopathology* (10 lectures)

Terms and concepts; General symptoms; Geographical distribution of diseases; Etiology; Symptomology; Host-Pathogen relationships; Disease cycle and environmental relation; prevention and control of plant diseases, and role of quarantine.
Bacterial diseases – Citrus canker and angular leaf spot of cotton. Viral diseases – Tobacco Mosaic viruses, vein clearing. Fungal diseases – Early & Late blight of potato, Black stem rust of wheat, White rust of crucifers, Blast of rice, Powdery mildew of pea.

3.2 PRACTICAL

1. *Rhizopus*: study of asexual stage from temporary mounts and sexual structures through permanent slides.

2. *Aspergillus* and *Penicillium*: study of asexual stage from temporary mounts. Study of Sexual stage from permanent slides/photographs.
3. *Peziza*: sectioning through ascocarp.

4. *Alternaria:* Specimens/photographs and temporary mounts.

5. *Puccinia*: Herbarium specimens of Black Stem Rust of Wheat and infected Barberry leaves; sections/ mounts of spores on wheat and permanent slides of both the hosts.

6. *Agaricus*: Specimens of button stage and full grown mushroom; sectioning of gills of *Agaricus*, fairy rings and bioluminescent mushrooms to be shown.

7. Study of phaneroplasmodium from actual specimens and /or photograph.Study of *Stemonitis* sporangia.

8. *Albugo:* Study of symptoms of plants infected with *Albugo*; asexual phase study through section/ temporary mounts and sexual structures through permanent slides.

9. Lichens: Study of growth forms of lichens (crustose, foliose and fruticose) on different substrates. Study of thallus and reproductive structures (soredia and apothecium) through permanent slides. Mycorrhizae: ectomycorrhiza and endomycorrhiza (Photographs)

10. Phytopathology: Bottle specimens, Herbarium specimens should be made of bacterial diseases, Viral diseases, Fungal diseases (Locally available).

11. Applied mycology: Photographs of Mycorrhizae, Fungi used in medicine (Cylindriocarpon, Tolyposporium, Ganoderma, Cephalosporium – any one), fungi used as biological control agents (fungi used in control of seedling, soil borne, post-harvest diseases and in control of nematodes, insects and weeds – any one), photographs/mounts of spores of fungi causing human infections (Aspergillus, Candida, Cryptococcus, Histoplasma, Microsporum, Trichophyton – any one).

Suggested Readings

1. Agrios, G.N. (1997). Plant Pathology, 4th edition, Academic Press, U.K.

2. Alexopoulos, C.J., Mims, C.W., Blackwell, M. (1996). Introductory Mycology, John Wiley & Sons (Asia) Singapore. 4th edition.

3. Webster, J. and Weber, R. (2007). Introduction to Fungi, Cambridge University Press, Cambridge. 3rd edition.

4. Sethi, I.K. and Walia, S.K. (2011). Text book of Fungi and Their Allies, Macmillan Publishers India Ltd.

5. Sharma, P.D. (2011). Plant Pathology, Rastogi Publication, Meerut, India.

6. College Botany, Vol. II. – Gangulee and Kar, New Central Book Agency, Kolkata.

7. Studies in Botany, Vol. I. – Mitra, Mitra, Choudhury. Moulik Library, Kolkata.

8. Text Book of Botany, Vol. I & II. – Hait, Ghosh and Bhattacharya, New Central Book Agency, Kolkata.

9. an introduction to Mycology-R.S. Mehrota and K.R. Aneja, New Age International Publishers.

10. Plant Pathology- R.S. Mehrota, New Age International Publishers.

BOT-HC-2026
Core Course 4: Archegoniate

Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Demonstrate an understanding of Archegoniatae, Bryophytes, Pteridophytes and Gymnosperms.
- Develop critical understanding on morphology, anatomy and reproduction of Bryophytes, Pteridophytes and Gymnosperms.
- Understand plant evolution and their transition to land habitat.
- Demonstrate proficiency in the experimental techniques and methods of appropriate analysis of Bryophytes, Pteridophytes, Gymnosperms.

Objective of the Course

- Throw light on the general characteristics and adaptation of Archaaegoniate (Bryophytes, Pteridophytes and Gymnosperms).
- Highlight the classification and range of thallus organization.
- Explain morphology, anatomy ad reproduction of Bryophytes, Pteridophytes and Gymnosperms.
- Provide practical knowledge on morphology and reproductive structures of archegoniates
- Elaborate on spore morphology analysis and detailed knowledge on male and female reproductive structures in gymnosperms.

4.1 THEORY

Unit 1: *Introduction* (4 lectures)

Unifying features of archegoniates; Transition to land habit; Alternation of generations.

Unit 2: *Bryophytes* (6 lectures)

General characteristics; Adaptations to land habit; Classification; Range of thallus organization.

Unit 3: *Type Studies- Bryophytes* (12 lectures)

Classification, morphology, anatomy and reproduction of *Riccia, Marchantia, Anthoceros, Sphagnum* and *Polytrichum*; Reproduction and evolutionary trends in *Riccia, Marchantia, Anthoceros, Sphagnum* and *Polytrichum.* Ecological and economic importance of bryophytes.

Unit 4: *Pteridophytes* (6 lectures)

General characteristics; Classification; Early land plants (*Cooksonia* and *Rhynia*).

Unit 5: *Type Studies- Pteridophytes* (14 lectures)

Classification, morphology, anatomy and reproduction of *Psilotum, Lycopodium, Selaginella, Equisetum, Pteris* and *Marsilea*. Apogamy and apospory, heterospory and seed habit, telome theory, stelar evolution; Ecological and economic importance.

Unit 6: *Gymnosperms* (18 lectures)

General characteristics, classification (up to family), morphology, anatomy and reproduction of *Cycas*, *Pinus*, *Ginkgo* and *Gnetum*; Ecological and economic importance.

4.2 PRACTICAL

1. **Riccia** – Morphology of thallus.

2. **Marchantia**- Morphology of thallus and reproductive parts; vertical and transverse section

of thallus; vertical section of Gemma cup, Antheridiophore and Archegoniophore.Sphagnum- Morphology of plant, whole mount of leaf.
3. **Sphagnm**- Morphology of plant; whole mount of leaf.

4. **Polytrichum**- Morphology of vegetative and reproductive parts; Transverse Section of rhizome, whole mount of leaf; Longitudinal Section through antheridial and archegonial heads; L.S. of capsule.

5. **Lycopodium**- Morphology of plant, whole mount of leaf; transverse section of stem; Longitudinal Section of strobilus; morphology of sporophyll.

6. **Selaginella**- Morphology of plant, whole mount of leaf with ligule, transverse section of stem and rhizophore; longitudinal section of strobilus; morphology of sporophyll.

7. **Equisetum**- Morphology of plant, transverse section of internode, longitudinal and transverse section of strobilus, whole mount of sporangiophore and spore.

8. **Pteris**- Morphology of plant, transverse section of rachis, vertical section of leaflets through sorus; whole mount of prothallus with sex (permanent slide).

9. **Marsilea**- Morphology of plant, transverse section of rhizome and petiole; vertical transverse and vertical longitudinal section of sporocarp.

10. **Cycas**- Morphology of plant; morphology and transverse section of coralloid roots; transverse section of leaflets; Longitudinal Section of male and female cone; morphology of microsporophyll and megasporophyll; Longitudinal section of ovule (permanent slide).

11. **Pinus**- Morphology of plant; transverse section of Needle; longitudinal section of male cone and female cone; whole mount of Microspores.

12. **Ginkgo**- Morphology of plants and reproductive structures (only photographs).

13. **Gnetum**- Morphology of plant; Morphology of male and female strobilus; vertical section of ovule (permanent slide).

Suggested Readings

1. Vashistha, P.C., Sinha, A.K., Kumar, A. (2010). Pteridophyta. S. Chand. Delhi, India.

2. Bhatnagar, S.P. & Moitra, A. (1996). Gymnosperms. New Age International (P) Ltd Publishers, New Delhi, India.

3. Parihar, N.S. (1991). An introduction to Embryophyta: Vol. I. Bryophyta. Central Book Depot. Allahabad.

4. Raven, P.H., Johnson, G.B., Losos, J.B., Singer, S.R. (2005). Biology. Tata McGraw Hill, Delhi.

5. Vanderpoorten, A. & Goffinet, B. (2009). Introduction to Bryophytes. Cambridge University Press.

6. Vashistha, B. R., Sinha, A.K. and Kumar, A. (Latest edition). Botany for Degree Students: Bryophyta. S. Chand Publishing 7361, Ram Nagar, Qutab Road, New Delhi-110055.

7. Vashistha, B. R., Sinha, A.K. and Kumar, A. (Latest edition). Botany for Degree Students: Gymnosperm. S. Chand Publishing 7361, Ram Nagar, Qutab Road, New Delhi-110055.

8. Vashistha, B. R., Sinha, A.K. and Kumar, A. (Latest edition). Botany for Degree Students: Pteridophytes. S. Chand Publishing 7361, Ram Nagar, Qutab Road, New Delhi-110055.

9. Gymnosperms, Extinct and Extant- C.M. Govil, Krishna Prakshan Media (P) Ltd. Meerut.

10. An Introduction to Pteridophyta- A. Rashid, Vikas Publishing House Pvt. Ltd., New Delhi.

Semester-III
BOT-HC-3016
Core Course 5: Morphology and Anatomy of Angiosperms

Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Develop an understanding of concepts and fundamentals of plant morphology and anatomy.
- Examine the morphological characters of plants and apply in identification and classification.
- Examine the internal anatomy of plant systems and organs.
- Develop critical understanding on the evolution of concept of organization of shoot and root apex.
- Analyze the composition of different parts of plants and their relationships.
- Evaluate the adaptive and protective systems of plant.

Objective of the Course

- To impart knowledge of the morphological characteristics and its importance in plant classification.
- To discuss on the application of plant anatomy in other scientific fields.
- To talk on types of tissues, the tissue systems and organization of plant body.

5.1 THEORY

Unit 1: *Morphology* (4 Lectures)

Morphology of inflorescence, stamens and carpel, fruit; Telome theory, phyllode theory; Role of morphology in plant classification.

Unit 2: *Introduction and scope of plant Anatomy* (4 Lectures)

Application in systematics, forensics and pharmacognosy.

Unit 3: *Structure and Development of Plant Body* (6 Lectures)

Internal organization of plant body: The three tissue systems, types of cells and tissues. Development of plant body: Polarity, Cytodifferentiation and organogenesis during embryogenic development.

Unit 4: *Tissues* (11 Lectures)

Classification of tissues; Simple and complex tissues (no phylogeny); cytodifferentiation of tracheary elements and sieve elements; Pits and plasmodesmata; Wall ingrowths and transfer cells, adcrustation and incrustation, Ergastic substances. Hydathodes, cavities, lithocysts and laticifers.

Unit 5: ***Apical meristems*** **(14 Lectures)**

Evolution of concept of organization of shoot apex (Apical cell theory, Histogen theory, Tunica Corpus theory, continuing meristematic residue, cytohistological zonation); Types of vascular bundles; Structure of dicot and monocot stem. Origin, development, arrangement and diversity in size and shape of leaves; Structure of dicot and monocot leaf, Kranz anatomy. Organization of root apex (Apical cell theory, Histogen theory, Korper-Kappe theory); Quiescent centre; Root cap; Structure of dicot and monocot root; Endodermis, exodermis and origin of lateral root.

Unit 6: ***Vascular Cambium and Wood*** **(14 Lectures)**

Structure, function and seasonal activity of cambium; Secondary growth in root and stem. Axially and radially oriented elements; Types of rays and axial parenchyma; Cyclic aspects and reaction wood; Sapwood and heartwood; Ring and diffuse porous wood; Early and late wood, tyloses; Dendrochronology. Development and composition of periderm, rhytidome and lenticels.

Unit 7: ***Adaptive and Protective Systems*** **(7 Lectures)**

Epidermal tissue system, cuticle, epicuticular waxes, trichomes(uni-and multicellular, glandular and nonglandular, two examples of each), stomata (classification); Adcrustation and incrustation; Anatomical adaptations of xerophytes and hydrophytes.

5.2 PRACTICAL

1. Study of special types of inflorescence – Cyathium, Hypanthodium, Verticillaster, Hypanthium.

2. Study of special types of fruits- Superior fruits (*Dillenia*); Aggregate fruits (Custard apple, *Michelia*, Periwinkles, *Polyalthia*); Multiple fruits (Pine apple, Jack fruits).

3. Study of anatomical details through permanent slides/temporary stain mounts / macerations / museum specimens with the help of suitable examples.

4. Apical meristem of root, shoot and vascular cambium.

5. Epidermal system: cell types, stomata types; trichomes: non-glandular and glandular.

6. Root: monocot, dicot, secondary growth.

7. Stem: monocot, dicot - primary and secondary growth; periderm; lenticels.

8. Leaf: isobilateral, dorsiventral, C4 leaves (Kranz anatomy).

9. Adaptive Anatomy: xerophytes, hydrophytes.

10. Secretory tissues: cavities, lithocysts and laticifers.

Suggested Readings

1. Dickison, W.C. (2000). Integrative Plant Anatomy. Harcourt Academic Press, USA.

2. Fahn, A. (1974). Plant Anatomy. Pergmon Press, USA.

3. Mauseth, J.D. (1988). Plant Anatomy. The Benjammin/Cummings Publisher, USA.

4. Evert, R.F. (2006). Esau's Plant Anatomy: Meristems, Cells, and Tissues of the Plant Body:
Their Structure, Function and Development. John Wiley and Sons, Inc.

5. the Morphology of angiosperms- K.R. Sporne, B.I. Publication, Delhi.

BOT-HC-3026

Core Course 6: Economic Botany

Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Understand core concepts of Economic Botany and relate with environment, populations, communities, and ecosystems.
- Develop critical understanding on the evolution of concept of organization of apex new crops/varieties, importance of germplasm diversity, issues related to access and ownership.
- Develop a basic knowledge of taxonomic diversity and important families of useful plants.
- Increase the awareness and appreciation of plants & plant products encountered in everyday life.
- Appreciate the diversity of plants and the plant products in human use.

Objective of the Course

- To highlight the detailed background of crops in terms of their origin and changing diversity.
- To discuss the importance of the crops, methods of propagation and their uses.
- Provide knowledge on uses of industrially important plants.
- Impart practical knowledge of economically important plant parts and their products.

6.1 THEORY

Unit 1: *Origin of Cultivated Plants* (6 lectures)

Centres of Origin, their importance with reference to Vavilov's work. Introductions, domestication and loss of crop genetic diversity; evolution of new crops/varieties, importance of germplasm diversity.

Unit 2: *Cereals* (6 lectures)

Wheat and Rice (origin, morphology, processing & uses); Brief account of millets.

Unit 3: *Legumes* (6 lectures)

Origin, morphology and uses of Chick pea, Pigeon pea and fodder legumes. Importance to man and ecosystem.

Unit 4: *Sources of sugars and starches* (4 lectures)

Morphology and processing of sugarcane, products and by-products of sugarcane industry.
Potato – morphology, propagation & uses.

Unit 5: *Spices* (6 lectures)

Listing of important spices, their family and part used. Economic importance with special reference to fennel, saffron, clove and black pepper.

Unit 6: *Beverages* (4 lectures)

Tea, Coffee (morphology, processing & uses).

Unit 7: *Sources of oils and fats* (10 lectures)

General description, classification, extraction, their uses and health implications groundnut, coconut, linseed, soybean, mustard and coconut (Botanical name, family & uses). Essential Oils: General account, extraction methods, comparison with fatty oils & their uses.

Unit 8: *Natural Rubber*

Para-rubber: tapping, processing and uses. **(3 lectures)**

Unit 9: *Drug-yielding plants* (8 lectures)

Therapeutic and habit-forming drugs with special reference to C*inchona, Digitalis, Papaver* and *Cannabis*; Tobacco (Morphology, processing, uses and health hazards).

Unit 10: *Timber plants* (3 Lectures)

General account with special reference to teak and pine.

Unit 11: *Fibers* (4 lectures)

Classification based on the origin of fibers; Cotton, Coir and Jute (morphology, extraction and uses).

6.2 PRACTICAL

1. **Cereals**: Study of useful parts: Rice/Bean (habit sketch, study of paddy and grain, starch grain, micro-chemical test).

2. **Legumes**: Bean, Groundnut, (habit, fruit, seed structure, micro-chemical tests).

3. **Beverages**: Tea (plant specimen, tea leaves), Coffee (plant specimen, beans).

4. **Sources of oils and fats**: Coconut and Mustard.

5. **Rubber**:Specimen, photograph/model of tapping, samples of rubber products.

6. **Test for alkaloids:** Neem, *Vinca rosea*.

7. **Fiber-yielding plants**: Cotton (specimen, whole mount of seed to show lint and fuzz; whole mount of fiber and test for cellulose), Jute (specimen, transverse section of stem, test for lignin).

Suggested Readings

1. Kochhar, S.L. (2012). Economic Botany in Tropics, MacMillan & Co. New Delhi, India.

2. Wickens, G.E. (2001). Economic Botany: Principles & Practices. Kluwer Academic Publishers,The Netherlands.

3. Chrispeels, M.J. and Sadava, D.E. 1994 Plants, Genes and Agriculture. Jones & Bartlett Publishers.

4. Economic Botany-S.Sen, NCBA (Publisher).

5. Hill's Economic Botany- Albert F. Hill, Tata McGraw-Hill.

BOT-HC-3036
Core Course 7: Genetics
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Possess conceptual understanding of laws of inheritance, genetic basis of loci and alleles and their linkage.
- Comprehend the effect of chromosomal abnormalities in numerical as well as structural changes leading to genetic disorders.
- Develop critical understanding of chemical basis of genes and their interactions at population and evolutionary levels.
- Analyze the effect of mutations on gene functions and dosage.
- Examine the structure, function and replication of DNA.

Objective of the Course

- To highlight the principles of inheritance and types of expressions resulting from the interaction of genes.
- To discuss on how mutation occurs at the genetic level and agents that cause mutation.
- To give stress on the importance of theories of genetics in relation with genetic variation and speciation.
- Provide knowledge on Mendelian concepts in genetics; structure, functions and properties of chromosome; chromosomal aberration.
- Provide practical knowledge on chromosomal mapping and gene interaction studies.

7.1 THEORY

Unit 1: *Mendelian genetics and its extension* (16 lectures)

Mendelism: History; Principles of inheritance; Chromosome theory of inheritance; Autosomes and sex chromosomes; Probability and pedigree analysis; Incomplete dominance and codominance; Multiple alleles, Lethal alleles, Epistasis, Pleiotropy, Recessive and Dominant traits, Penetrance and Expressivity, Numericals; Polygenic inheritance.

Unit 2: *Extrachromosomal Inheritance* (7 lectures)

Chloroplast inheritance: Variegation in Four o'clock plant; Mitochondrial inheritance in yeast; Maternal effects-shell coiling in snail; Kappa particles in *Paramecium.*

Unit 3: *Linkage, crossing over and chromosome mapping* (12 lectures)

Linkage and crossing over-Cytological basis of crossing over; Recombination frequency, two factor and three factor crosses; Interference and coincidence; Numericals based on gene mapping; Sex Linkage.

Unit 4: *Variation in chromosome number and structure* (8 lectures)

Deletion, Duplication, Inversion, Translocation, Position effect, Euploidy and Aneuploidy

Unit 5: *Gene mutations* (7 lectures)

Types of mutations; Molecular basis of Mutations; Mutagens – physical and chemical (Base analogs, deaminating, alkylating and intercalating agents); Detection of mutations: ClB method. Role of Transposons in mutation. DNA repair mechanisms.

Unit 6: *Fine structure of gene* (4 lectures)

Classical vs molecular concepts of gene; Cistron, Recon, Muton, rII locus

Unit 7: *Population and Evolutionary Genetics* (6 lectures)

Allele frequencies, Genotype frequencies, Hardy-Weinberg Law, role of natural selection, mutation, genetic drift. Genetic variation and Speciation.

7.2 PRACTICAL

1. Meiosis through temporary squash preparation.

2. Mendel's laws through seed ratios.

3. Chromosome mapping using point test cross data.

4. Incomplete dominance and gene interaction through seed ratios (9:7, 9:6:1, 13:3, 15:1, 12:3:1, 9:3:4).

5. Permanent Slides showing Translocation Ring, Photograph showing Laggards and Inversion Bridge.

Suggested Readings

1. Gardner, E.J., Simmons, M.J., Snustad, D.P. (1991). Principles of Genetics, John Wiley & sons, India. 8th edition.

2. Snustad, D.P. and Simmons, M.J. (2010). Principles of Genetics, John Wiley & Sons Inc., India. 5th edition.

3. Klug, W.S., Cummings, M.R., Spencer, C.A. (2009). Concepts of Genetics. Benjamin Cummings, U.S.A. 9th edition.

4. Griffiths, A.J.F., Wessler, S.R., Carroll, S.B., Doebley, J. (2010). Introduction to Genetic Analysis.
W. H. Freeman and Co., U.S.A. 10th edition.

5. Genetics- P.K.Gupta, Rastogi Publications, Meerut.

Semester-IV
BOT-HC-4016
Core Course 8: Molecular Biology
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Analyse the structures and chemical properties of DNA and RNA through experiments.
- Differentiate the main types of prokaryotes through their grouping abilities and their characteristic.
- Evaluate the experiments establishing central dogma and genetic code.
- Gain an understanding of various steps in transcription, protein synthesis and protein modification.

Objective of the Course

- To provide detailed knowledge about the structures and chemical properties of DNA and RNA.
- To discuss on Central dogma, transcription and protein synthesis.
- Provide practical acquaintance of isolation and quantification of DNA from plants.
- Provide knowledge on photographic study of RNA polymerases and RNA modification machinery.

8.1 THEORY

Unit 1: ***Nucleic acids: Carriers of genetic information*** **(4 lectures)**

Historical perspective; DNA as the carrier of genetic information (Griffith's, Hershey & Chase, Avery, McLeod & McCarty, Fraenkel-Conrat's experiment.

Unit 2: ***The Structures of DNA and RNA / Genetic Material*** **(10 lectures)**

DNA Structure: Miescher to Watson and Crick- historic perspective, DNA structure, Salient features of double helix, denaturation and renaturation, cot curves; Organization of DNA- Prokaryotes, Viruses, Eukaryotes. Organelle DNA -- mitochondria and chloroplast DNA. The Nucleosome Chromatin structure- Euchromatin, Heterochromatin- Constitutive and Facultative heterochromatin.

Unit 3: ***The replication of DNA*** **(10 lectures)**

Chemistry of DNA synthesis (Kornberg's discovery); General principles – bidirectional, semi-conservative and semi discontinuous replication, RNA priming; Various models of DNA replication, including rolling circle, θ (theta) mode of replication, replication of linear ds-DNA; Enzymes involved in DNA replication.

Unit 4: ***Central dogma and genetic code*** **(2 lectures)**

Key experiments establishing-The Central Dogma (Adaptor hypothesis and discovery of mRNA template), Genetic code (deciphering & salient features**)**

Unit 5: *Transcription* (18 lectures)

Transcription in prokaryotes and eukaryotes. Principles of transcriptional regulation; Prokaryotes: Regulation of lactose metabolism and tryptophan synthesis in *E.coli*. Eukaryotes: transcription factors, heat shock proteins, steroids and peptide hormones; Gene silencing.

Unit 6: *Processing and modification of RNA* (8 lectures)

Split genes-concept of introns and exons, removal of introns, spliceosome machinery, splicing pathways, group I and group II intron splicing, alternative splicing eukaryotic mRNA processing (5' cap, 3' poly A tail); Ribozymes; RNA editing and mRNA transport.

Unit 7: *Translation* (8 lectures)

Ribosome structure and assembly, mRNA; Charging of tRNA, aminoacyl tRNA synthetases; Various steps in protein synthesis, proteins involved in initiation, elongation and termination of polypeptides; Fidelity of translation; Inhibitors of protein synthesis; Post-translational modifications of proteins.

8.2 PRACTICAL

1. DNA isolation from any plant material.

2. DNA estimation by diphenylamine reagent/UV Spectrophotometry (Demostration).

3. Study of DNA replication mechanisms through photographs (Rolling circle, Theta replication and semi-discontinuous replication).

4. Study of structures of prokaryotic RNA polymerase and eukaryotic RNA polymerase II through photographs.

5. Study of the following through photographs: Assembly of Spliceosome machinery; Splicing mechanism in group I & group II introns; Ribozyme and Alternative splicing.

Suggested Readings

1. Watson J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M., Losick, R. (2007). Molecular Biology of the Gene, Pearson Benjamin Cummings, CSHL Press, New York, U.S.A. 6th edition.

2. Snustad, D.P. and Simmons, M.J. (2010). Principles of Genetics. John Wiley and Sons Inc., U.S.A. 5th edition.

3. Klug, W.S., Cummings, M.R., Spencer, C.A. (2009). Concepts of Genetics. Benjamin Cummings. U.S.A. 9th edition.

4. Russell, P. J. (2010). i-Genetics- A Molecular Approach. Benjamin Cummings, U.S.A. 3rd edition.

5. Griffiths, A.J.F., Wessler, S.R., Carroll, S.B., Doebley, J. (2010). Introduction to Genetic Analysis. W. H. Freeman and Co., U.S.A. 10th edition.

BOT-HC-4026
Core Course 9: Plant Ecology and Phytogeography
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Understand core concepts of biotic and abiotic.
- Classify the soils on the basis of physical, chemical and biological components.
- Analyze the phytogeography or phytogeographical division of India.
- Evaluate energy sources of ecological system.
- Assess the adaptation of plants in relation to light, temperature, water, wind and fire.
- Conduct experiments using skills appropriate to subdivisions.

Objective of the Course

- To discuss in detail about the concepts of ecology and interaction between biotic and abiotic components of the environment.
- To talk on the origin and formation of soil.
- To highlight on the importance of abiotic factors and their effects on plants.
- To provide knowledge about the phytogeographical divisions of India and types of vegetation of NE with special reference to Manipur.
- Provide practical knowledge of vegetation study and different ecological sites.

9.1 THEORY

Unit 1: *Introduction* (4 lectures)

Basic concepts; Levels of organization. Inter-relationships between the living world and the environment, the components and dynamism, homeostasis.

Unit 2: *Soil* (8 lectures)

Importance; Origin; Formation; Composition; Physical; Chemical and Biological components; Soil profile; Role of climate in soil development.

Unit 3: *Water* (4 lectures)

Importance: States of water in the environment; Atmospheric moisture; Precipitation types (rain, fog, snow, hail, dew); Hydrological Cycle; Water in soil; Water table.

Unit 4: *Adaptation of plants to various environmental factors* (6 lectures)

Variations in adaptation of plants in relation to light, temperature, water, wind and fire.

Unit 5: *Biotic interactions* (2 lectures)

Trophic organization, basic source of energy, autotrophy, heterotrophy; symbiosis, commensalism, parasitism; food chains and webs; ecological pyramids; biomass, standing crop.

Unit 6: *Population ecology* (4 lectures)

Population characteristics, Growth curve, population regulation, r and k selection. Ecological speciation: Allopatric/ Sympatric and Parapatric speciation.

Unit 7: *Plant communities* (8 lectures)

Concept of ecological amplitude; Habitat and niche; Characters: analytical and synthetic; Ecotone and edge effect; Dynamics: succession – processes, types; climax concepts.

Unit 8: *Ecosystems* (4 lectures)

Structure; Processes; Trophic organisation; Food chains and Food webs; Ecological pyramids.

Unit 9: *Functional aspects of ecosystem* (8 lectures)

Principles and models of energy flow; Production and productivity; Ecological efficiencies; Biogeochemical cycles; Cycling of Carbon, Nitrogen and Phosphorus.

Unit 10: *Phytogeography* (12 lectures)

Principles; Continental drift; Theory of tolerance; Endemism; Brief description of major terrestrial biomes (one each from tropical, temperate & tundra); Phytogeographical division of India; Vegetation types of NE India with special reference to Manipur.

9.2 PRACTICAL

1. Study of instruments used to measure microclimatic variables: Soil thermometer, maximum and minimum thermometer, anemometer, psychrometer/hygrometer, rain gauge and lux meter.

2. Determination of pH of various soil and water samples using pH meter.

3. Analysis for carbonates, chlorides, nitrates, sulphates, organic matter and base deficiency from two soil samples by rapid field tests.

4. Determination of organic matter of different soil samples by Walkley & Black rapid titration method.

5. Determination of dissolved oxygen of water samples from polluted and unpolluted sources.

6. (a). Study of morphological adaptations of hydrophytes and xerophytes (four each).

(b). Study of biotic interactions of the following: Stem parasite (*Cuscuta*), Root parasite (*Orobanche*) Epiphytes, Predation (Insectivorous plants).

7. Determination of minimal quadrat size for the study of herbaceous vegetation in the college campus, by species area curve method (species to be listed).

8. Quantitative analysis of herbaceous vegetation in the college campus for frequency and comparison with Raunkiaer's frequency distribution law.

9. Quantitative analysis of herbaceous vegetation for density and abundance in the college campus.

10. Field visit to familiarise students with ecology of different sites.

Suggested Readings

1. Odum, E.P. (2005). Fundamentals of ecology. Cengage Learning India Pvt. Ltd., New Delhi. 5th edition.

2. Singh, J.S., Singh, S.P., Gupta, S. (2006). Ecology Environment and Resource Conservation. Anamaya Publications, New Delhi, India.

3. Sharma, P.D. (2010). Ecology and Environment. Rastogi Publications, Meerut, India. 8th edition.

4. Wilkinson, D.M. (2007). Fundamental Processes in Ecology: An Earth Systems Approach. Oxford University Press. U.S.A.

5. Kormondy, E.J. (1996). Concepts of ecology. PHI Learning Pvt. Ltd., Delhi, India. 4th edition.

6. Smith and Smith (2012): Elements of Ecology. Pearson Publisher (Sixth edition).

7. Bhattacharya, K., Ghosh, A.K. and Hait, G. (2017). A text Book of Botany (Ecology, Environmental Biology, Economic Botany and Pharmacognosy). New Central Book Agency (P) Ltd.

8. Ambasht and Ambasht (2002): A text book of Plant Ecology. CBS publisher and Distributors.

9. Agarwal, A.K. and Deo, P.P. (2006). Plant Ecology. Agrobios (India)

10. William D Bowmen, Sally D Hacker and Michael L. Cain (2018). Ecology, Oxford University Press

11. Verma, P.S. and Agarwal V. K. (2003). Environmental Biology-Principles of Ecology. S Chand & Company Ltd, Ramnagar, New Delhi-110055.

BOT-HC-4036
Core Course 10: Plant Systematics
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Classify Plant systematics and recognize the importance of herbarium and Virtual herbarium.
- Evaluate the important herbaria and botanical gardens.
- Interpret the rules of ICN in botanical nomenclature.
- Assess terms and concepts related to Phylogenetic Systematics.
- Generalize the characters of the families according to Bentham & Hooker's system of classification.

Objective of the Course

- Provide knowledge about the plant systematic and the importance of herbaria.
- Highlight on principles and rules of ICN.
- Discuss on different systems of plant classification.
- Explain origin and evolution of angiosperm.
- To elaborate on the detailed background of angiospermic families.
- Provide practical knowledge on foliar morphology and taxonomical study of angiosperms

10.1 THEORY

Unit 1: *Significance of Plant systematics* (8 lectures)

Introduction to systematics; Plant identification, Classification, Nomenclature. Evidences from palynology, cytology, phytochemistry and molecular data. Functions and importance of Herbarium; Important herbaria and botanical gardens of the world and India; Virtual herbarium; E-flora; Concept of taxa (family, genus, species); Categories and taxonomic hierarchy.

Unit 2: *Botanical nomenclature* (10 lectures)

Principles and rules (ICN); Ranks and names; Typification, author citation, Effective and valid publication, rejection of names, principle of priority and its limitations; Names of hybrids.

Unit 3: *Systems of classification* (12 lectures)

Major contributions of Theophrastus, Bauhin, Tournefort, Linnaeus, Adanson, de Candolle, Bessey, Hutchinson, Takhtajan and Cronquist; Classification systems of Bentham and Hooker (up to series) and Engler and Prantl (up to series); Brief reference of Angiosperm Phylogeny Group (APG) classification.

Unit 4: *Numerical taxonomy and cladistics* (10 lectures)
Characters; Variations; OTUs, character weighting and coding; Cluster analysis; Phenograms, cladograms (definitions and differences).

Unit 5: *Phylogeny of Angiosperms* (12 lectures)

Terms and concepts (primitive and advanced, homology and analogy, parallelism and convergence, monophyly, Paraphyly, polyphyly and clades). Origin and evolution of angiosperms; Co-evolution of angiosperms and animals; Methods of illustrating evolutionary relationship (phylogenetic tree, cladogram).

Unit 6: *Angiospermic Families* (8 lectures)

Detail study of the following families:
Magnoliaceae, Fabaceae, Asteraceae, Solanaceae, Acanthaceae, Lamiaceae, Euphorbiaceae, Orchidaceae, Musaceae, Zingiberaceae, Poaceae, Malvaceae, Rosaceae, Apiaceae, Ranunculaceae, Liliaceae, Brassicaceae.

10.2 PRACTICAL

1. Study of vegetative and floral characters of locally available angiospermic plants belonging to the following families (Description, V.S. flower, section of ovary, floral diagram/s, floral formula/e and systematic position according to Bentham & Hooker's system of classification): Fabaceae, Solanaceae, Acanthaceea, Lamiaceae, Euphorbiaceae, Musaceae, Orchidaceae, Malvaceae, Brassicaceae.

2. Field visit to familiarise students with vegetation of an area and identification of plant species / Visit to Academic or Research Institutions.

3. Mounting of a properly dried and pressed specimen of any wild plant with herbarium label (to be submitted in the record book).

Suggested Readings

1. Singh, (2012). *Plant Systematics:* Theory and Practice Oxford & IBH Pvt. Ltd., New Delhi. 3rdedition.
2. Jeffrey, C. (1982). An Introduction to *Plant Taxonomy.* Cambridge University Press, Cambridge.

3. Judd, W.S., Campbell, C.S., Kellogg, E.A., Stevens, P.F. (2002). Plant Systematics-A Phylogenetic Approach. Sinauer Associates Inc., U.S.A. 2nd edition.

4. Maheshwari, J.K. (1963). *Flora* of Delhi. CSIR, New Delhi.

5. Radford, A.E. (1986). Fundamentals of *Plant Systematics*. Harper and Row, New York.

6. Pandey, B.P. (2018). A Textbook of Botany: Angiosperm. S. Chand Publishing, 7361, Ram Nagar, Qutab Road, New Delhi-110055.

BOT-HC-5016
Semester-V
Core Course 11: Reproductive Biology of Angiosperms
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Understand morphological and anatomical aspects of reproductive structures of angiospermic plants.
- Explain embryology and embryological abnormalities in angiosperms.
- Structural documentation of reproductive structures of angiosperms.
- Apply practical knowledge on developmental biology of embryo and endosperms.

Objective of the Course

- To provide knowledge of detailed morphological and anatomical study of reproductive structures of angiospermic plants.
- Discuss embryology and embryological abnormalities in angiosperms.
- To highlight in detail on reproductive structures of angiosperms.
- To throw light on the types pollination and fertilization.
- Provide practical knowledge on developmental biology of embryo and endosperms.

11.1 THEORY

Unit 1: *Introduction* (4 lectures)

History (contributions of G.B. Amici, W. Hofmeister, E. Strasburger, S.G. Nawaschin, P. Maheshwari, B.M. Johri, W.A. Jensen, J. Heslop-Harrison) and scope.

Unit 2: *Reproductive development* (6 lectures)

Induction of flowering; flower as a modified determinate shoot. Flower development: genetic and molecular aspects.

Unit 3: *Anther and pollen biology* (10 lectures)

Anther wall: Structure and functions, microsporogenesis, callose deposition and its significance. Microgametogenesis; Pollen wall structure, MGU (male germ unit) structure, NPC system; Palynology and scope (a brief account); Pollen wall proteins; Pollen viability, storage and germination; Abnormal features: Pseudomonads, polyads, massulae, pollinia.

Unit 4: *Ovule* (10 lectures)

Structure; Types; Special structures- endothelium, obturator, aril, caruncle and hypostase; Female gametophyte- megasporogenesis (monosporic, bisporic and tetrasporic) and megagametogenesis (details of *Polygonum* type); Organization and ultrastructure of mature embryo sac.

Unit 4: ***Pollination and fertilization*** **(6 lectures)**

Pollination types and significance; adaptations; structure of stigma and style; path of pollen tube in pistil; double fertilization.

Unit 5: ***Self incompatibility*** **(10 lectures)**

Basic concepts (interspecific, intraspecific, homomorphic, heteromorphic, GSI and SSI); Methods to overcome self- incompatibility: mixed pollination, bud pollination, stub pollination; Intra-ovarian and *in vitro* pollination; Modification of stigma surface, parasexual hybridization; Cybrids, *in vitro* fertilization.

Unit 6: ***Embryo, Endosperm and Seed*** **(8 lectures)**

Structure and types; General pattern of development of dicot and monocot embryo and endosperm; Suspensor: structure and functions; Embryo-endosperm relationship; Nutrition of embryo; Unusual features; Embryo development in *Paeonia*. Seed structure, importance and dispersal mechanisms.

Units 7: ***Polyembryony and apomixis*** **(6 lectures)**

Introduction; Classification; Causes and applications.

11.2 PRACTICAL

1. ***Anther*****:** Wall and its ontogeny; Tapetum (amoeboid and glandular); MMC, spore tetrads, uninucleate, bicelled and dehisced anther stages through slides/micrographs, male germ unit (MGU) through photographs and schematic representation.

3. ***Pollen grains:*** Fresh and acetolyzed showing ornamentation and aperture, psuedomonads, polyads, pollinia (slides/photographs,fresh material), ultrastructure of pollen wall(micrograph); Pollen viability: Tetrazolium test.germination: Calculation of percentage germination in different media using hanging drop method.

4. ***Ovule:*** Types-anatropous, orthotropous, amphitropous/campylotropous, circinotropous, unitegmic, bitegmic; Tenuinucellate and crassinucellate; Special structures: Endothelium, obturator, hypostase, caruncle and aril (permanent slides/specimens/photographs).

5. ***Female gametophyte through permanent slides/ photographs:*** Types, ultrastructure of mature egg apparatus.

6. Intra-ovarian pollination; Test tube pollination through photographs.

7. ***Endosperm:*** Dissections of developing seeds for endosperm with free-nuclear haustoria.

8. ***Embryogenesis:*** Study of development of dicot embryo through permanent slides; dissection of developing seeds for embryos at various developmental stages.

Suggested Readings

1. Bhojwani, S.S. and Bhatnagar, S.P. (2011). The Embryology of Angiosperms, Vikas Publishing House. Delhi. 5th edition.

2. Shivanna, K.R. (2003). Pollen Biology and Biotechnology. Oxford and IBH Publishing Co. Pvt. Ltd. Delhi.

3. Raghavan, V. (2000). Developmental Biology of Flowering plants, Springer, Netherlands.

4. Johri, B.M. l (1984). Embryology of Angiosperms, Springer-Verlag, Netherlands.

5. Bhattacharya, Majimdar and Bhattacharya. (2012). A Textbook of Palynology: Basic and Applied. New Central Book Agency (P) Ltd. Guwahati.

BOT-HC-5026
Core Course 12: Plant Physiology
Total Lectures: 60 Credits : 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Understand Water relation of plants with respect to various physiological processes.
- Explain chemical properties and deficiency symptoms in plants.
- Classify aerobic and anaerobic respiration.
- Explain the significance of Photosynthesis and respiration.
- Assess dormancy and germination in plan.

Objective of the Course

- Provide knowledge of mechanisms of water, minerals and nutrient absorption of plants.
- Explain the roles of plant hormones and mechanism of flowering in plants.
- To highlight on determination of osmotic and water potential.
- To illuminate on photoperiodism and the factors that induce flowering.
- Provide practical knowledge on effects of growth regulators on plant parts.

12.1 THEORY

Unit 1: *Plant-water relations* (10 lectures)

Different types of solution, Water Potential and its components, water absorption by roots, aquaporins, pathway of water movement, symplast, apoplast, transmembrane pathways, root pressure, guttation. Ascent of sap- cohesion-tension theory. Transpiration and factors affecting transpiration, antitranspirants, mechanism of stomatal movement. Plant response to water stress.

Unit 2: *Mineral nutrition* (8 lectures)

Essential and beneficial elements, macro and micronutrients, methods of study and use of nutrient solutions, criteria for essentiality, mineral deficiency symptoms, roles of essential elements, chelating agents, Ion antagonism and toxicity.

Unit 3: *Nutrient Uptake* (8 lectures)

Soil as a nutrient reservoir, transport of ions across cell membrane, passive absorption, electrochemical gradient, facilitated diffusion, active absorption, role of ATP, carrier systems, proton ATPase pump and ion flux, uniport, co-transport, symport, antiport.

Unit 4: *Translocation in the phloem* (8 lectures)

Experimental evidence in support of phloem as the site of sugar translocation. Pressure–Flow Model; Phloem loading and unloading; Source–sink relationship.

Unit 5: *Plant growth regulators* (14 lectures)

Discovery, chemical nature (basic structure), bioassay and physiological roles of Auxin, Gibberellins, Cytokinin, Abscisic acid, Ethylene, Brassinosteroids and Jasmonic acid.

Unit 6: *Physiology of flowering* (6 lectures)

Photoperiodism, flowering stimulus, florigen concept, vernalization, seed dormancy.

Unit 7: *Phytochrome, cytochromes and phototropins* (6 lectures)

Discovery, chemical nature, role in photomorphogenesis, low energy responses (LER) and high irradiance responses (HIR), mode of action.

12.2 PRACTICAL

1. Determination of osmotic potential of plant cell sap by plasmolytic method.

2. Determination of water potential of given tissue (potato tuber) by weight method.

3. Study of the effect of light on the rate of transpiration in excised twig/leaf.

4. Calculation of stomatal index and stomatal frequency from the two surfaces of leaves of a mesophyte and xerophyte.

5. To study the effect of different concentrations of IAA on Gram/Pea/Moong root (IAA Bioassay).

6. To study the induction of amylase activity in germinating Maize/Bean grains.

7. Effect of carbon dioxide concentration on the rate of photosynthesis.

Demonstration experiments

1. To demonstrate suction due to transpiration.

2. Fruit ripening/Rooting from cuttings (Demonstration).

Suggested Readings

1. Hopkins, W.G. and Huner, A. (2008). Introduction to Plant Physiology. John Wiley and Sons. U.S.A. 4th edition.

2. Taiz, L., Zeiger, E., Møller, I.M. and Murphy, A (2015). Plant Physiology and Development. Sinauer Associates Inc. USA. 6th edition.

3. Bajracharya D. (1999). Experiments in Plant Physiology-A Laboratory Manual. Narosa Publishing House, New Delhi.

Semester-VI
BOT-HC-6016
Core Course 13: Plant Metabolism
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

On completion of this course, students will be able to:

- Differentiate anabolic and catabolic pathways of metabolism
- Recognize the importance of Carbon assimilation in photorespiration
- Explain the ATP-Synthesis
- Interpret the Biological nitrogen fixation in metabolism

Objective of the Course

- To provide knowledge of photosynthesis and nutrient metabolism.
- Discuss on C_4-pathway and Crassulacean acid metabolism.
- Throw light on Glycolysis, ATP-synthesis and Lipid metabolism.
- Provide practical knowledge on different types of chromatographic techniques.
- Estimation of TAN, sugar and protein contents in plant sample.

13.1 THEORY

Unit 1: *Concept of metabolism* (8 lectures)

Introduction, anabolic and catabolic pathways, regulation of metabolism, role of regulatory enzymes; classification, nomenclature and importance of enzyme; concept of coenzyme, apoenzyme and prosthetic group; enzyme inhibition (allosteric, covalent modulation and Isozymes).

Unit 2: *Carbon assimilation* (12 lectures)

Historical background, photosynthetic pigments, role of photosynthetic pigments (chlorophylls and accessory pigments), antenna molecules and reaction centres, photochemical reactions, photosynthetic electron transport, PSI, PSII, Q cycle, CO_2 reduction, photorespiration, C_4-pathways; Crassulacean acid metabolism; Factors affecting CO_2 reduction.

Unit 3: *Carbohydrate metabolism* (2 lectures)

Synthesis and catabolism of sucrose and starch.

Unit 4: *Carbon Oxidation* (10 lectures)

Glycolysis, fate of pyruvate, regulation of glycolysis, oxidative pentose phosphate pathway, oxidative decarboxylation of pyruvate, regulation of PDH, NADH shuttle; TCA cycle, amphibolic role, anaplerotic reactions, regulation of the cycle, mitochondrial electron transport, oxidative phosphorylation, cyanide-resistant respiration, factors affecting respiration.

Unit 5: *ATP-Synthesis* (8 lectures)

Mechanism of ATP synthesis, substrate level phosphorylation, chemiosmotic mechanism (oxidative and photophosphorylation), ATP synthase, Boyers conformational model, Racker's experiment, Jagendorf's experiment; role of uncouplers.

Unit 6: *Lipid metabolism* (8 lectures)

Synthesis and breakdown of triglycerides, β-oxidation, glyoxylate cycle, gluconeogenesis and its role in mobilisation of lipids during seed germination, α oxidation.

Unit 7: *Nitrogen metabolism* (8 lectures)

Nitrate assimilation, biological nitrogen fixation (examples of legumes and non-legumes); Physiology and biochemistry of nitrogen fixation; Ammonia assimilation and transamination.

Unit 8: *Mechanisms of signal transduction* (4 lectures)

Receptor-ligand interactions; Second messenger concept, Calcium calmodulin, MAP kinase cascade.

13.2 PRACTICAL

1. Chemical separation of photosynthetic pigments.

2. Estimation of sugar content by Somogyi method.

3. Determination of TAN in plant materials.

4. To compare the rate of respiration in different parts of a plant (Demonastration).

5. Estimation of protein in a sample by Biuret method.

6. Separation of amino acids by paper chromatography.

7. Demonstration of Thin layer chromatography (TLC).

8. Quantitative analysis of absorption spectrum of photosynthetic pigments.

Suggested Readings

1. Hopkins, W.G. and Huner, A. (2008). Introduction to Plant Physiology. John Wiley and Sons. U.S.A. 4th edition.

2. Taiz, L., Zeiger, E., Møller, I.M. and Murphy, A (2015). Plant Physiology and Development. Sinauer Associates Inc. USA. 6th edition.

3. Harborne, J.B. (1973). Phytochemical Methods. John Wiley & Sons. New York.

BOT-HC-6026
Core Course 14: Plant Biotechnology
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

On completion of this course, students will be able to:

- Understand the applications of tissue culture techniques, construction of recombinant DNA and transformation into hosts, construction of DNA libraries
- Explain on the development of transgenic plants for agricultural or industrial use
- Prepare media for tissue culture techniques and photographic study of plant tissue culture.

Objective of the Course

- To provide knowledge of plant tissue culture technique.
- Discuss the importance of recombinant DNA technology.
- Throw light on Gene transfer and applications of biotechnology.
- Provide knowledge on practical utility of isolation of plasmid DNA, its digestion and separation of fragments through gel electrophoresis.
- Preparation of media for tissue culture techniques and photographic study of plant tissue culture.

14.1 THEORY

Unit 1: *Plant Tissue Culture* (16 lectures)

Historical perspective; Composition of media; Nutrient and hormone requirements (role of vitamins and hormones); Totipotency; Organogenesis; Embryogenesis (somatic and zygotic); Protoplast isolation, culture and fusion; Tissue culture applications (micropropagation, androgenesis, virus elimination, secondary metabolite production, haploids, triploids and hybrids; Cryopreservation; Germplasm Conservation).

Unit 2: *Recombinant DNA technology* (12 lectures)

Restriction Endonucleases (History, Types I-IV, biological role and application); Restriction Mapping (Linear and Circular); Cloning Vectors: Prokaryotic (pUC 18 and pUC19, pBR322, Ti plasmid, BAC); Lambda phage, M13 phagemid, Cosmid, Shuttle vector; Eukaryotic Vectors (YAC).

Unit 3: *Gene Cloning* (10 lectures)

Recombinant DNA, Bacterial Transformation and selection of recombinant clones, PCR-mediated gene cloning; Gene Construct; construction of genomic and cDNA libraries, screening DNA libraries to obtain gene of interest by genetic selection; complementation, colony hybridization; PCR

Unit 4: *Methods of gene transfer* (8 lectures)

Agrobacterium-mediated, Direct gene transfer by Electroporation, Microinjection, Microprojectile bombardment; Selection of transgenics– selectable marker and reporter genes (Luciferase, GUS, GFP).

Unit 5: ***Applications of Biotechnology*** **(14 lectures)**

Pest resistant (Bt-cotton); herbicide resistant plants (RoundUp Ready soybean); Transgenic crops with improved quality traits (Flavr Savr tomato, Golden rice); Improved horticultural varieties (Moondust carnations); Role of transgenics in bioremediation (Superbug); edible vaccines; Industrial enzymes (Aspergillase, Protease, Lipase); Gentically Engineered Products– Human Growth Hormone; Humulin; Biosafety concerns.

14.2 PRACTICAL

1. (a) Preparation of MS medium.

(b) Demonstration of *in vitro* sterilization and inoculation methods using leaf and nodal explants of tobacco, *Datura*, *Brassica* etc.

2. Study of anther, embryo and endosperm culture, micropropagation, somatic embryogenesis & artificial seeds through photographs.

3. Isolation of protoplasts.

4. Construction of restriction map of circular and linear DNA from the data provided.

5. Study of methods of gene transfer through photographs: *Agrobacterium*-mediated, direct gene transfer by electroporation, microinjection, microprojectile bombardment.

6. Study of steps of genetic engineering for production of Bt cotton, Golden rice, Flavr Savr tomato through photographs.

7. Isolation of plasmid DNA.

8. Restriction digestion and gel electrophoresis of plasmid DNA.

Suggested Readings

1. Bhojwani, S.S. and Razdan, M.K., (1996). Plant Tissue Culture: Theory and Practice. Elsevier Science Amsterdam. The Netherlands.

2. Glick, B.R., Pasternak, J.J. (2003). Molecular Biotechnology- Principles and Applications of recombinant DNA. ASM Press, Washington.

3. Bhojwani, S.S. and Bhatnagar, S.P. (2011). The Embryology of Angiosperms. Vikas Publication House Pvt. Ltd., New Delhi. 5th edition.

4. Snustad, D.P. and Simmons, M.J. (2010). Principles of Genetics. John Wiley and Sons, U.K. 5th edition.

5. Stewart, C.N. Jr. (2008). Plant Biotechnology & Genetics: Principles, Techniques and Applications. John Wiley & Sons Inc. U.S.A.

Discipline Specific Elective

BOT-HE-5016
Discipline Specific Elective Course 1: Natural Resource Management
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes:

On completion of this course, students will be able to:

- Understand the concept of different natural resources and their utilization.
- Critically analyze the sustainable utilization land, water, forest and energy resources.
- Evaluate the management strategies of different natural resources.
- Reflect upon the different national and international efforts in resource management and their conservation.

Objective of the Course

- Provide comprehensive knowledge regarding different types of natural resources and their ecological, economical and socio-cultural values.
- Highlight the backgrounds of land, water and forest resources.
- Discuss on resource degradation, importance of their judicious use and management for sustainability.
- Discuss on 'biodiversity' - its importance, management and Bioprospecting

1.1 THEORY

Unit 1: ***Natural resources*** **(2 lectures)**

Definition and types.

Unit 2: ***Sustainable utilization*** **(8 lectures)**

Concept, approaches (economic, ecological and socio-cultural).

Unit 3: ***Land*** **(8 lectures)**

Utilization (agricultural, pastoral, horticultural, silvicultural); Soil degradation and management.

Unit 4: ***Water*** **(8 lectures)**

Fresh water (rivers, lakes, groundwater, aquifers, watershed); Marine; Estuarine; Wetlands; Threats and management strategies.

Unit 5: ***Biological Resources*** **(10 lectures)**

Biodiversity-definition and types; Significance; Threats; Management strategies; Bio-prospecting; IPR; CBD; National Biodiversity Action Plan).

Unit 6: ***Forests*** **(6 lectures)**

Definition, Cover and its significance (with special reference to India); Major and minor forest products; Depletion; Management.

Unit 7: *Energy* (6 lectures)

Renewable and non-renewable sources of energy.

Unit 8: *Contemporary practices in resource management* (8 lectures)

EIA, GIS, Participatory Resource Appraisal, Ecological Footprint with emphasis on carbon footprint, Resource Accounting; Waste management.

Unit 9: *National and international efforts in resource management and conservation* (4 lectures)

1.2 PRACTICAL

1. Estimation of solid waste generated by a domestic system (biodegradable and non-biodegradable) and its impact on land degradation.

2. Collection of data on forest cover of specific area.

3. Measurement of dominance of woody species by DBH (diameter at breast height) method.

4. Calculation and analysis of ecological footprint.

5. Uses of GPS and GIS (Mapping of an area).

Suggested Readings

1. Vasudevan, N. (2006). Essentials of Environmental Science. Narosa Publishing House, New Delhi.

2. Singh, J. S., Singh, S.P. and Gupta, S. (2006). Ecology, Environment and Resource Conservation. Anamaya Publications, New Delhi.

3. Rogers, P.P., Jalal, K.F. and Boyd, J.A. (2008). An Introduction to Sustainable Development. Prentice Hall of India Private Limited, New Delhi.

BOT-HE-5026
Discipline Specific Elective Course 2: Horticultural Practices and Post-Harvest Technology
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes:

On completion of this course, students will be able to:

- Understand the concept of different types of horticultural crops, their conservation and management.
- Examine the various branches of horticulture, fruit and vegetable crops, floriculture, medicinal and aromatic plants.
- Critically evaluate different cultivation practices and disease management.
- Reflect upon different Landscaping practices and garden design.
- Understand the concept of different types of horticultural practices for value addition.
- Visualize the post-harvest problems likely to be confronted.
- Know the tricks of the trade and how to increase the longevity of the produce.

Objective of the Course

- Provide knowledge of Horticultural science and its importance in employment generation and socio-economic development.
- Highlight on classification of horticultural crops, identification of potential horticultural crops – their cultivation, production, management and commercialization.
- Discuss in detail on post-harvest technology, disease management, and germplasm management for horticulture.
- Impart field knowledge of gardening, nurseries, standing crops of horticultural importance.

2.1 THEORY

Unit 1: *Introduction* (4 lectures)

Scope and importance, Branches of horticulture; Role in rural economy and employment generation; Importance in food and nutritional security; Urban horticulture and ecotourism.

Unit 2: *Ornamental plants* (4 lectures)

Types, classification (annuals, perennials, climbers and trees); Identification and salient features of some ornamental plants [Rose, Marigold, Gladiolus, Carnations, Orchids, Poppies, Gerberas, Tuberose, Sages, Cacti and Succulents (Opuntia, Agave and Spurges)] Ornamental flowering trees (Indian Laburnum, Gulmohar, Jacaranda, Lagerstroemia, Fishtail and Areca palms, Semul, Coral tree).

Unit 3: *Fruit and vegetable crops* (4 lectures)
Production, origin and distribution; Description of plants and their economic products; Management and marketing of vegetable and fruit crops; Identification of some fruits and vegetable varieties (citrus, banana, mango, chillies and cucurbits).

Unit 4: *Horticultural techniques* (8 lectures)

Application of manure, fertilizers, nutrients and PGRs; Weed control; Biofertilizers, biopesticides; Irrigation methods (drip irrigation, surface irrigation, furrow and border irrigation); Hydroponics; Propagation Methods: asexual (grafting, cutting, layering, budding), sexual (seed propagation), Scope and limitations.

Unit 5: *Landscaping and garden design* (6 lectures)

Planning and layout (parks and avenues); gardening traditions - Ancient Indian, European, Mughal and Japanese Gardens; Urban forestry; policies and practices.

Unit 6: *Floriculture* (6 lectures)

Cut flowers, bonsai, commerce (market demand and supply); Importance of flower shows and exhibitions.

Unit 7: *Post-harvest technology* (10 lectures)

Importance of post harvest technology in horticultural crops; Evaluation of quality traits; Harvesting and handling of fruits, vegetables and cut flowers; Principles, methods of preservation and processing; Methods of minimizing loses during storage and transportation; Food irradiation - advantages and disadvantages; food safety.

Unit 8: *Disease control and management* (8 lectures)

Field and post-harvest diseases; Identification of deficiency symptoms; remedial measures and nutritional management practices; Crop sanitation; IPM strategies (genetic, biological and chemical methods for pest control); Quarantine practices; Identification of common diseases and pests of ornamentals, fruits and vegetable crops.

Unit 9: *Horticultural crops - conservation and management* (10 lectures)

Documentation and conservation of germplasm; Role of micropropagation and tissue culture techniques; Varieties and cultivars of various horticultural crops; IPR issues; National, international and professional societies and sources of information on horticulture.

Unit 10: *Field trip*

Field visits to gardens, standing crop sites, nurseries, vegetable gardens and horticultural fields at suitable locations.

Suggested Readings

1. Singh, D. & Manivannan, S. (2009). Genetic Resources of Horticultural Crops. Ridhi International, Delhi, India.

2. Swaminathan, M.S. and Kochhar, S.L. (2007). Groves of Beauty and Plenty: An Atlas of Major Flowering Trees in India. Macmillan Publishers, India.

3. NIIR Board (2005). Cultivation of Fruits, Vegetables and Floriculture. National Institute of Industrial Research Board, Delhi.

4. Kader, A.A. (2002). Post-Harvest Technology of Horticultural Crops. UCANR Publications, USA.

5. Capon, B. (2010). Botany for Gardeners. 3rd Edition. Timber Press, Portland, Oregon.

BOT-HE-6016
Discipline Specific Elective Course 3: Industrial and Environmental Microbiology
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes

On completion of this course, students will be able to:

- Understand the concept and role of microbes in industry and environment.
- Critically analyze the types of bioreactors and the fermentation process.
- Evaluate the role of microorganisms in industry and microbes in agriculture.
- Reflect upon different Landscaping practices and garden design
- Develop skills on the remediation process of contaminated soils

Objective of the Course

- Highlight the roles of microbes in industries and environment.
- Provide basic knowledge of different kinds of bioreactors and fermentation processes.
- Impart knowledge of production processes of some microbial products in industries through site visits.
- Discuss on the applications of enzymes in industries.
- Discuss in detail on the diversity and distribution of microbes in air, water and soil.
- Highlight on water microbiology and water analysis methods.
- Discuss the usefulness of microbes in agriculture and bioremediation of contaminated soils.
- Provide practical experiences on basic microbiological techniques and handlings.

3.1 THEORY

Unit 1: Scope of microbes in industry and environment (6 lectures)

Unit 2: Bioreactors/Fermenters and fermentation processes (12 lectures)

Solid-state and liquid-state (stationary and submerged) fermentations; Batch and continuous fermentations. Components of a typical bioreactor, Types of bioreactors-laboratory, pilot scale and production fermenters; Constantly stirred tank fermenter, tower fermenter, fixed bed and fluidized bed bioreactors and air-lift fermenter.
A visit to any educational institute/ industry to see an industrial fermenter, and other downstream processing operations.

Unit 3: Microbial production of industrial products (12 lectures)

Microorganisms involved, media, fermentation conditions, downstream processing and uses; Filtration, centrifugation, cell disruption, solvent extraction, precipitation and ultrafiltration, lyophilization, spray drying; Hands on microbial fermentations for the production and estimation (qualitative and quantitative) of Enzyme: amylase or lipase activity, Organic acid (citric acid or glutamic acid), alcohol (Ethanol) and antibiotic (Penicillin)

Unit 4: Microbial enzymes of industrial interest and enzyme immobilization (8 lectures)

Microorganisms for industrial applications and hands on screening microorganisms for casein hydrolysis; starch hydrolysis; cellulose hydrolysis. Methods of immobilization, advantages and applications of immobilization, large scale applications of immobilized enzymes (glucose isomerase and penicillin acylase).

Unit 5: Microbes and quality of environment (6 lectures)

Distribution of microbes in air; Isolation of microorganisms from soil, air and water.

Unit 6: Microbial flora of water. (8 lectures)

Water pollution, role of microbes in sewage and domestic waste water treatment systems. Determination of BOD, COD, TDS and TOC of water samples; Microorganisms as indicators of water quality, check coliform and fecal coliform in water samples.

Unit 7: Microbes in agriculture and remediation of contaminated soils. (8 lectures)

Biological fixation; Mycorrhizae; Bioremediation of contaminated soils. Isolation of root nodulating bacteria, arbuscular mycorrhizal colonization in plant roots.

3.2 PRACTICAL

1. Principles and functioning of instruments in microbiology laboratory

2. Hands on sterilization techniques and preparation of culture media.

3. Pure culture techniques.

Suggested Readings

1. Pelzar, M.J. Jr., Chen E.C. S., Krieg, N.R. (2010). Microbiology: An application based approach. Tata McGraw Hill Education Pvt. Ltd., Delhi.

2. Tortora, G.J., Funke, B.R., Case. C.L. (2007). Microbiology. Pearson Benjamin Cummings, San Francisco, U.S.A. 9th edition.

BOT-HE-6026
Discipline Specific Elective Course 4: Analytical Techniques in Plant Sciences
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes:

On completion of this course, students will be able to:

- Explain the principles of Light microscopy, Compound microscopy, Fluorescence microscopy and Confocal microscopy.
- Develop conceptual understanding of cell fractionation.
- Classify different types of chromatography techniques.
- Apply suitable strategies in data collections and disseminating research findings.

Objective of the Course

- Provide knowledge on microscopy and imaging in plant science.
- Highlight principles and application of centrifuge, spectroscopy and chromatography in biology.
- Impart basic knowledge of biostatistics including measures of central tendency and dispersions, statistical data analysis and representations.
- Enabling students imbibe practical knowledge on microscopy, chromatography, centrifugation and spectroscopy.

4.1 THEORY

Unit 1: Imaging and related techniques (15 lectures)

Principles of microscopy; Light microscopy; Fluorescence microscopy; Confocal microscopy; Use of fluorochromes: (a) Flow cytometry (FACS); (b) Applications of fluorescence microscopy: Chromosome banding, FISH, chromosome painting; Transmission and Scanning electron microscopy – sample preparation for electron microscopy, cryofixation, negative staining, shadow casting, freeze fracture, freeze etching.

Unit 2: Cell fractionation (8 lectures)

Centrifugation: Differential and density gradient centrifugation, sucrose density gradient, $CsCl_2$ gradient, analytical centrifugation, ultracentrifugation, marker enzymes.

Unit 3: Radioisotopes (4 lectures)

Use in biological research, auto-radiography, pulse chase experiment.

Unit 4: Spectrophotometry (4 lectures)

Principle and its application in biological research.

Unit 5: Chromatography (8 lectures)

Principle; Paper chromatography; Column chromatography, TLC, GLC, HPLC, Ion-exchange chromatography; Molecular sieve chromatography; Affinity chromatography.

Unit 6: Characterization of proteins and nucleic acids (6 lectures)

Mass spectrometry; X-ray diffraction; X-ray crystallography; Characterization of proteins and nucleic acids; Electrophoresis: AGE, PAGE, SDS-PAGE

Unit 7: Biostatistics (15 lectures)

Statistics, data, population, samples, parameters; Representation of Data: Tabular, Graphical; Measures of central tendency: Arithmetic mean, mode, median; Measures of dispersion: Range, mean deviation, variation, standard deviation; Chi-square test for goodness of fit.

4.2 PRACTICAL

1. Study of Blotting techniques: Southern, Northern and Western, DNA fingerprinting, DNA sequencing, PCR through photographs.

2. Demonstration of ELISA.

3. To separate sugars by thin layer chromatography.

4. Isolation of chloroplasts by differential centrifugation.

5. To separate chloroplast pigments by column chromatography.

6. To estimate protein concentration through Lowry's methods.

7. To separate proteins using PAGE.

8. To separation DNA (marker) using AGE.

9. Study of different microscopic techniques using photographs/micrographs (freeze fracture, freeze etching, negative staining, positive staining, fluorescence and FISH).

Suggested Readings

1. Plummer, D.T. (1996). An Introduction to Practical Biochemistry. Tata McGraw-Hill Publishing Co. Ltd. New Delhi. 3rd edition.

2. Ruzin, S.E. (1999). Plant Microtechnique and Microscopy, Oxford University Press, New York. U.S.A.

3. Ausubel, F., Brent, R., Kingston, R. E., Moore, D.D., Seidman, J.G., Smith, J.A., Struhl, K. (1995). Short Protocols in Molecular Biology. John Wiley & Sons. 3rd edition.

4. Zar, J.H. (2012). Biostatistical Analysis. Pearson Publication. U.S.A. 4th edition.

BOT-HE-6036
Project Work/Dissertation
Credits: 6

Generic Elective Courses

BOT-HG-1016
Generic Elective Course 1: Biodiversity (Microbes, Algae, Fungi and Archegoniate)
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes:

On completion of this course, students will be able to:

- Understand the fundamental concepts related to microbes, algae, fungi and embryophytes.
- Analyze the discovery and general structure of viruses.
- Examine the morphology and life-cycles of trentepohlia, ulva, kappaphycus, sargassum, turbinaria, grailaria, porphyra.
- Evaluate the significance of fungi and its different types.
- Analyze the anatomy and reproduction of Cycas and Pinus along with their ecological and economical importance.

Objective of the course:

- Elaborate on structure and reproduction of viruses and bacteria, and their economic importance
- Explain the general characteristics, morphological diversity, thallus organization, life cycles, ecological and economic importance of algae, fungi
- To highlight general characteristics, classification, morphology of bryophytes, pteridophytes and gymnosperms.
- Provide practical knowledge on staining and slide preparation to study bacteria, algae and fungi under the microscope.
- Provide practical knowledge on vegetative and reproductive structures of some representative bryophytes, pteridophytes and gymnosperms.

1.1 THEORY

Unit 1: *Microbes* (10 lectures)

Viruses - Discovery, general structure, replication (general account), DNA virus (T-phage); Lytic and lysogenic cycle, RNA virus (TMV); Economic importance; Bacteria – Discovery, General characteristics and cell structure; Reproduction – vegetative, asexual and recombination (conjugation, transformation and transduction); Economic importance.

Unit 2: *Algae* (12 lectures)

General characteristics; Ecology and distribution; Range of thallus organization and reproduction; Classification of algae; Morphology and life-cycles of the following: *Nostoc*, *Chlamydomonas*, *Oedogonium*, *Vaucheria*, *Fucus*, *Polysiphonia*. Economic importance of algae.

Unit 3: *Fungi* (12 lectures)

Introduction- General characteristics, ecology and significance, range of thallus organization, cell wall composition, nutrition, reproduction and classification; True Fungi- General characteristics, ecology and significance, life cycle of *Rhizopus* (Zygomycota) *Penicillium,Alternaria* (Ascomycota), *Puccinia, Agaricus* (Basidiomycota); Symbiotic Associations-Lichens:
General account, reproduction and significance; Mycorrhiza: ectomycorrhiza and endomycorrhiza and their significance.

Unit 4: Introduction to Archegoniate (**2 lectures)**

Unifying features of archegoniates, Transition to land habit, Alternation of generations.

Unit 5: *Bryophytes* (10 lectures)

General characteristics, adaptations to land habit, Classification, Range of thallus organization. Classification (up to family), morphology, anatomy and reproduction of *Marchantia* and *Funaria*.(Developmental details not to be included). Ecology and economic importance of bryophytes with special mention of *Sphagnum*.

Unit 6: *Pteridophytes* (8 lectures)

General characteristics, classification, Early land plants (*Cooksonia* and *Rhynia*). Classification (up to family), morphology, anatomy and reproduction of *Selaginella*, *Equisetum* and *Pteris*. (Developmental details not to be included). Heterospory and seed habit, stelar evolution. Ecological and economical importance of Pteridophytes.

Unit 7: Gymnosperms (6 lectures)

General characteristics; Classification (up to family), morphology, anatomy and reproduction of *Cycas* and *Pinus* (Developmental details not to be included). Ecological and economical importance.

1.2 PRACTICAL

1. EMs/Models of viruses – T-Phage and TMV, Line drawing/Photograph of Lytic and Lysogenic Cycle.

2. Types of Bacteria from temporary/permanent slides/photographs; Binary Fission; Conjugation; Structure of root nodule.

3. Gram staining

4. Study of vegetative and reproductive structures of *Nostoc, Chlamydomonas* (electron micrographs), *Oedogonium, Vaucheria, Fucus* and Polysiphonia* through temporary preparations and permanent slides.

5. ***Rhizopus and Penicillium*:** Asexual stage from temporary mounts and sexual structures through permanent slides.

6. ***Puccinia***: Herbarium specimens of Black Stem Rust of Wheat and infected Barberry leaves; section/tease mounts of spores on Wheat and permanent slides of both the hosts.

7. ***Agaricus***: Specimens of button stage and full grown mushroom; Sectioning of gills of *Agaricus*.

8. **Lichens**: Study of growth forms of lichens (crustose, foliose and fruticose)

9. **Mycorrhiza**: ectomycorrhiza and endomycorrhiza (Photographs)

10. ***Marchantia***- morphology of thallus, w.m. rhizoids and scales, v.s. thallus through gemma

cup, w.m. gemmae (all temporary slides), v.s. antheridiophore, archegoniophore, l.s.60 sporophyte (all permanent slides).

11. ***Funaria***- morphology, w.m. leaf, rhizoids, operculum, peristome, annulus, spores (temporary slides); permanent slides showing antheridial and archegonial heads, l.s. capsule and protonema.

12. ***Selaginella***- morphology, w. m. leaf with ligule, t. s. stem, w. m. strobilus, w. m. microsporophyll and megasporophyll (temporary slides), l. s. strobilus (permanent slide).

13. ***Equisetum***- morphology, t. s. internode, l. s. strobilus, t. s. strobilus, w. m. sporangiophore, w. m. spores (wet and dry) (temporary slides); t. s. rhizome (permanent slide).
14. ***Pteris***- morphology, t. s. rachis, v. s. sporophyll, w. m. sporangium, w. m. spores (temporary slides), t. s. rhizome, w. m. prothallus with sex organs and young sporophyte (permanent slide).

15. **Cycas**- morphology (coralloid roots, bulbil, leaf), t. s. coralloid root, t. s. rachis, v. s. leaflet, v. s. microsporophyll, w. m. spores (temporary slides), l. s. ovule, t. s. root (permanent slide).

16. ***Pinus***- morphology (long and dwarf shoots, w. m. dwarf shoot, male and female), w. m. dwarf shoot, t. s. needle, t. s. stem, , l. s./t. s. male cone, w. m. microsporophyll, w. m. microspores (temporary slides), l. s. female cone, t. l. s. & r. l. s. stem (permanent slide).

Suggested Readings

1. Kumar, H.D. (1999). Introductory Phycology. Affiliated East-West. Press Pvt. Ltd. Delhi. 2nd edition.
Tortora, G.J., Funke, B.R., Case, C.L. (2010). Microbiology: An Introduction, Pearson th Benjamin Cummings, U.S.A. 10 edition.
3. Sethi, I.K. and Walia, S.K. (2011). Text book of Fungi & Their Allies, MacMillan Publishers Pvt. Ltd., Delhi.

4. Alexopoulos, C.J., Mims, C.W., Blackwell, M. (1996). Introductory Mycology, John Wiley th

and Sons (Asia), Singapore. 4 edition.
5. Raven, P.H., Johnson, G.B., Losos, J.B., Singer, S.R., (2005). Biology. Tata McGraw Hill, Delhi, India.

6. Vashishta, P.C., Sinha, A.K., Kumar, A., (2010). Pteridophyta, S. Chand. Delhi, India.

7. Bhatnagar, S.P. and Moitra, A. (1996). Gymnosperms. New Age International (P) Ltd Publishers, New Delhi, India.

8. Parihar, N.S. (1991). An introduction to Embryophyta. Vol. I. Bryophyta. Central Book Depot, Allahabad.

BOT-HG-2016
Generic Elective Course 2: Plant Ecology and Taxonomy
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes:

On completion of this course, students will be able to:

- Comprehend the basic concepts of plant ecology and taxonomy and botanical nomenclature.
- Analyze the characteristics of different plant communities.
- Examine the structure and functions of eco-system.
- Evaluate the significance of herbarium.
- Analyze the implications of biometrics, numerical taxonomy and cladistics.

Objective of the course:

- Provide knowledge on soil, water, light and temperature as ecological factors.
- Highlight on plant community types and their succession.
- Throw light on ecosystem, trophic levels and energy flow in the ecosystems.
- Provide knowledge on plant taxonomy, principles, ICN rules, ranks and hierarchy
- Discuss on different systems of plant classification and cluster analysis
- Knowledge on Quadrate size determination for herbaceous plant studies in ecology.
- Provide Practical knowledge on plant identification up to the family level and preparation of herbarium specimens.

2.1 THEORY

Unit 1: *Introduction* (2 lectures)

Unit 2: *Ecological factors* (10 lectures)

Soil: Origin, formation, composition, soil profile. Water: States of water in the environment, precipitation types. Light and temperature: Variation Optimal and limiting factors; Shelford law of tolerance. Adaptation of hydrophytes and xerophytes

Unit 3: *Plant communities* (6 lectures)

Characters; Ecotone and edge effect; Succession; Processes and types

Unit 4: *Ecosystem* (8 lectures)

Structure; energy flow trophic organisation; Food chains and food webs, Ecological pyramids production and productivity; Biogeochemical cycling; Cycling of carbon, nitrogen and Phosphorous

Unit 5: *Phytogeography* (4 Lectures)

Principle biogeographical zones; Endemism.

Unit 6: *Introduction to plant taxonomy* (2 Lectures)

Identification, Classification, Nomenclature.

Unit7: *Identification* (4 Lectures)

Functions of Herbarium, important herbaria and botanical gardens of the world and India; Documentation: Flora, Keys: single access and multi-access

Unit 8: *Taxonomic evidences from palynology, cytology, phytochemistry and molecular data*. (6 lectures)

Unit 9: Taxonomic hierarchy (2 lectures)

Ranks, categories and taxonomic groups

Unit 10: Botanical nomenclature (6 lectures)

Principles and rules (ICN); ranks and names; binominal system, typification, author citation, valid publication, rejection of names, principle of priority and its limitations.

Unit 11: Classification (6 lectures)

Types of classification-artificial, natural and phylogenetic. Bentham and Hooker (upto series), Engler and Prantl (upto series).

Unit 12: Biometrics, numerical taxonomy and cladistics (4 lectures)

Characters; variations; OTUs, character weighting and coding; cluster analysis; phenograms, cladograms (definitions and differences).

2.1 PRACTICAL

1. Study of instruments used to measure microclimatic variables: Soil thermometer, maximum and minimum thermometer, anemometer, psychrometer/hygrometer, rain gauge and lux meter.

2. Study of morphological adaptations of hydrophytes and xerophytes (four each).

3. Determination of minimal quadrat size for the study of herbaceous vegetation in the college campus by species area curve method. (species to be listed)

4. Quantitative analysis of herbaceous vegetation in the college campus for frequency and comparison with Raunkiaer's frequency distribution law.

5. Study of vegetative and floral characters of the following families (Description, V.S. flower, section of ovary, floral diagram/s, floral formula/e and systematic position according to Bentham & Hooker's system of classification): Brassicaceae , Solanaceae, Lamiaceae.
6. Mounting of a properly dried and pressed specimen of any wild plant with herbarium label (to be submitted in the record book).

Suggested Readings

1. Kormondy, E.J. (1996). Concepts of Ecology. Prentice Hall, U.S.A. 4th edition.
2. Sharma, P.D. (2010) Ecology and Environment. Rastogi Publications, Meerut, India. 8th edition.

3. Simpson, M.G. (2006). *Plant Systematics.* Elsevier Academic Press, San Diego, CA, U.S.A.

4. Singh, G. (2012). *Plant Systematics:* Theory and Practice. Oxford & IBH Pvt. Ltd., New Delhi. 3rd edition.

BOT-HG--3016
Generic Elective Course 3: Plant Physiology and Metabolism
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes:

On completion of this course, students will be able to:

- Comprehend the basic concepts of plant-water relations understanding transpiration and its significance.
- Elaborate on the role of essential elements and mechanism of ion transport across cell membrane.
- Understand the concept of photosynthesis, Electron transport, mechanism of ATP synthesis and Photorespiration.
- Imbibe the concepts of Glycolysis, anaerobic respiration, TCA cycle and Oxidative phosphorylation.
- Examine the structure and properties of enzymes.
- Analyze the implications of biometrics, numerical taxonomy and cladistics.

Objective of the course:

- Provide knowledge on plant-water relations and various factors affecting tanspiration.
- Highlight on the role of micro- and macro-elements in plants.
- Discuss on photosynthesis and carbon fixation pathways.
- Provide knowledge on enzyme properties, actions and inhibitions.
- Highlight on biological nitrogen fixation.
- Discuss on plant hormones, and plant responses to light and temperature.
- Demonstrate the effect of pH and concentrations in catalase activity.

3.1 THEORY

Unit 1: *Plant-water relations* (8 lectures)

Importance of water, water potential and its components; Transpiration and its significance; Factors affecting transpiration; Root pressure and guttation.

Unit 2: *Mineral nutrition* (8 lectures)

Essential elements, macro and micronutrients; Criteria of essentiality of elements; Role of essential elements; Transport of ions across cell membrane, active and passive transport, carriers, channels and pumps.

Unit 3: *Translocation in phloem* (6 lectures)

Composition of phloem sap, girdling experiment; Pressure flow model; Phloem loading and Unloading.

Unit 4: *Photosynthesis* (12 lectures)

Photosynthetic Pigments (Chl a, b, xanthophylls, carotene); Photosystem I and II, reaction center, antenna molecules; Electron transport and mechanism of ATP synthesis; C_3, C_4 and CAM pathways of carbon fixation; Photorespiration.

Unit 5: *Respiration* (6 lectures)

Glycolysis, anaerobic respiration, TCA cycle; Oxidative phosphorylation, Glyoxylate, Oxidative Pentose Phosphate Pathway.

Unit 6: *Enzymes* (4 lectures)

Structure and properties; Mechanism of enzyme catalysis and enzyme inhibition.

Unit 7: Nitrogen metabolism (4 lectures)

Biological nitrogen fixation; Nitrate and ammonia assimilation.

Unit 8: Plant growth regulators (6 lectures)

Discovery and physiological roles of auxins, gibberellins, cytokinins, ABA, ethylene.

Unit 9: Plant response to light and temperature (6 lectures)

Photoperiodism (SDP, LDP, Day neutral plants); Phytochrome (discovery and structure), red and far red light responses on photomorphogenesis; Vernalization.

3.2 PRACTICAL

1. Determination of osmotic potential of plant cell sap by plasmolytic method.

2. To study the effect of light on transpiration by excised twig.

3. Calculation of stomatal index and stomatal frequency.

4. Demonstrate the activity of catalase and study the effect of pH and enzyme concentration.

5. To study the effect of bicarbonate concentration on O_2 evolution in photosynthesis.

Demonstration experiments

1. Bolting.
2. Effect of auxins on rooting.
3. Suction due to transpiration.
4. R.Q.
5. Respiration in roots.

Suggested Readings

1. Taiz, L., Zeiger, E., Møller, I.M. and Murphy, A (2015). Plant Physiology and Development. Sinauer Associates Inc. USA. 6th edition.

2. Hopkins, W.G., Huner, N.P., (2009). Introduction to Plant Physiology. John Wiley & Sons, U.S.A. 4th Edition.

3. Bajracharya, D., (1999). Experiments in Plant Physiology- A Laboratory Manual. Narosa Publishing House, New Delhi.

BOT-HG-3026
Generic Elective Course 4: Environmental Biotechnology
Total Lectures: 60 Credits: 6 (Theory - 4, Practical - 2)

Learning outcomes:

On completion of this course, students will be able to:

- Perceive the global environmental issues and their impacts.
- Understand different causes of environmental pollution and their remedies.
- Analyze microbiology of waste water and its implications.
- Understand the concepts of bioremediation and its role in the environment.
- Examine the role of immobilized cells/enzymes in treatment of toxic compounds.
- Reflect upon various sustainable environmental protection strategies.
- Evaluate the implications of international legislations, policies for environmental protection.

Objective of the course:

- Provide knowledge on environment and the cause of environmental pollutions
- Highlight on the methods of pollution measurement and bioremediation
- Discuss waste water treatment processes.
- Discuss on xenobiotics – their types and bioremediation.
- Provide knowledge on application of immobilized cells/enzymes in industries.
- Discuss on national legislations and international treaties for environmental protection and pollution management
- Provide practical knowledge on determining basic properties of soil and water like DO, salinity, pH, total hardness, etc.

4.1 THEORY

Unit 1: *Environment* (4 lectures)

Basic concepts and issues, global environmental problems - ozone depletion, UV-B, greenhouse effect and acid rain due to anthropogenic activities, their impact and biotechnological approaches for management.

Unit 2: *Environmental problems* (6 lectures)

Environmental pollution - types of pollution, sources of pollution, measurement of pollution, methods of measurement of pollution, fate of pollutants in the environment, Bioconcentration, bio/geomagnification.

Unit 3: *Microbiology of waste water treatment* (8 lectures)

Aerobic process - activated sludge, oxidation ponds, trickling filter, towers, rotating discs, rotating drums, oxidation ditch. Anaerobic process - anaerobic digestion, anaerobic filters, up-flow anaerobic sludge blanket reactors. Treatment schemes for waste waters of dairy, distillery, tannery, sugar and antibiotic industries.

Unit 4: ***Xenobiotic compounds*** **(10 lectures)**

Organic (chlorinated hydrocarbons, substituted simple aromatic compounds, polyaromatic hydrocarbons, pesticides, surfactants) and inorganic (metals, radionuclides, phosphates, nitrates) compounds. Bioremediation of xenobiotics in environment - ecological consideration, decay behavior and degradative plasmids, molecular techniques in bioremediation.

Unit 5: ***Role of immobilized cells/enzymes in treatment of toxic compounds*** **(6 lectures)**

Biopesticides, bioreactors, bioleaching, biomining, biosensors, biotechniques for air pollution abatement and odour control.

Unit 6: ***Sustainable Development*** **(8 lectures)**

Economics and Environment: Economic growth, Gross National Productivity and the quality of life, Tragedy of Commons, Economics of Pollution control, Cost-benefit and cost effectiveness analysis, WTO and Environment, Corporate Social Responsibility, Environmental awareness and Education; Environmental Ethics.

Unit 7: ***International Legislations, Policies for Environmental Protection*** **(6 lectures)**

Stockholm Conference (1972) and its declaration, WCED (1983) and Brundtland Report (1987), Rio Earth Summit-UNCED (1992) and its declaration, Montreal Protocol - 1987, Basel Convention (1989), Kyoto Protocol- 1997, Ramsar Convention 1971.

Unit 8: ***National Legislations, Policies for Pollution Management*** **(6 lectures)**

Salient features of Wild life protection act 1972, Water Pollution (Prevention and Control) Act-1974, Forest conservation act 1980, Air Pollution (Prevention and Control) Act-1981, National Environmental Policy -2006, Central and State Pollution Control Boards: Constitution and power.

Unit 9: ***Public Participation for Environmental Protection*** **(6 lectures)**

Environmental movement and people's participation with special references to Gandhamardan, Chilika and Narmada Bachao Andolan, Chipko and Silent valley Movement; Women and Environmental Protection, Role of NGO in bringing environmental awareness and education in the society.

4.2 PRACTICAL

1. Water/Soil analysis – DO, salinity, pH, chloride, total hardness, alkalinity, acidity, nitrate, calcium, Magnesium and phosphorus.

2. Gravimetric analysis-Total solid, dissolved solid, suspended solid in an effluent

3. Microbial assessment of air (open plate and air sample) and water

Suggested Readings

1. Waste water engineering - treatment, disposal and reuse, Metcalf and Eddy Inc., Tata McGraw Hill, New Delhi.

2. Environmental Chemistry, AK. De, Wiley Eastern Ltd, New Delhi.

3. Introduction to Biodeterioration, D.Allsopp and K.J. Seal, ELBS / Edward Arnold.

4. Bioremidation, Baaker, KH and Herson D.S., 1994. Mc.GrawHill Inc, NewYork.

5. Industrial and Environmental Biotechnology - Nuzhat Ahmed, Fouad M. Qureshi and Obaid Y. Khan, 2006. Horizon Press.

6. Environmental Molecular Biology, Paul. A, Rochelle, 2001.Horizon Press.

7. Environmental Protection and Laws by Jadhav and Bhosale, V.M.Himalaya publ. House 13. Biodiversity Assessment and Conservation by PC Trivedi, Agrobios publ.

Skill Enhancement Courses

BOT-SE-3014
Skill Enhancement Course 1: Biofertilizers
Total Lectures: 60 Credits: 4

Learning outcomes:

On completion of this course, students will be able to:

- Develop their understanding on the concept of bio-fertilizer.
- Identify the different forms of biofertilizers and their uses.
- Compose the Green manuring and organic fertilizers.
- Develop the integrated management for better crop production by using both nitrogenous and phosphate bio fertilizers and vesicular arbuscular mycorrhizal (VAM).
- Interpret and explain the components, patterns, and processes of bacteria for growth in crop production.

Objective of the course:

- Provide basic knowledge on the microbes used as biofertilizer and understand the process of their isolation, identification, mass multiplication, carrier based inoculants and knowledge on Actinorrhizal symbiosis
- Impart concept on the general characteristics, isolation, mass multiplication carrier based inoculants of *Azospirillum* and *Azotobacter* also the knowledge on the crop response to *Azotobacter*.
- Highlight basic knowledge on Cyanobacteria including factors affecting growth of Cyanobacteria, concept on the nitrogen fixation and use of blue green algae in rice cultivation
- Discuss in brief on the Mycorrhizal association and types, taxonomy, occurrence, distribution and growth parameters of Mycorrhiza
- Explain in detail about the organic farming, maintenance and recycling of biodegradable waste material and understand the methods of making biocompost and vermicompost with application.

Unit 1: General account about the microbes used as biofertilizer – Rhizobium – isolation, identification, mass multiplication, carrier based inoculants, Actinorrhizal symbiosis. **(8 lectures)**

Unit 2: *Azospirillum:* isolation and mass multiplication – carrier based inoculant, associative effect
of different microorganisms.*Azotobacter*: classification, characteristics – crop response to *Azotobacter* inoculum, maintenance and mass multiplication. **(16 lectures)**

Unit 3: Cyanobacteria (blue green algae), *Azolla* and *Anabaena azollae* association, nitrogen fixation, factors affecting growth, blue green algae and *Azolla* in rice cultivation. **(8 lectures)**

Unit 4: Mycorrhizal association, types of mycorrhizal association, taxonomy, occurrence and distribution, phosphorus nutrition, growth and yield – colonization of VAM – isolation and inoculum production of VAM, and its influence on growth and yield of crop plants. **(16 lectures)**

Unit 5: Organic farming – Green manuring and organic fertilizers, Recycling of bio-degradable municipal, agricultural and Industrial wastes – biocompost making methods, types and method of vermicomposting – field Application. **(12 lectures)**

Suggested Readings

1. Dubey, R.C., 2005. A Text book of Biotechnology S.Chand & Co, New Delhi.

2. Kumaresan, V. 2005. Biotechnology, Saras Publications, New Delhi.

3. John Jothi Prakash, E. 2004. Outlines of Plant Biotechnology. Emkay Publication, New Delhi.

4. Sathe, T.V. 2004. Vermiculture and Organic Farming. Daya publishers.

5. Subha Rao, N.S. 2000, Soil Microbiology, Oxford & IBH Publishers, New Delhi.

6. Vayas,S.C, Vayas, S. and Modi, H.A. 1998. Bio-fertilizers and organic Farming Akta Prakashan, Nadiad

BOT-SE-3024
Skill Enhancement Course 2: Herbal Technology
Total Lectures: 60 Credits: 4

Learning outcomes:

On completion of this course, students will be able to:

- Develop their understanding on Herbal Technology
- Define and describe the principle of cultivation of herbal products.
- List the major herbs, their botanical name and chemical constituents.
- Evaluate the drug adulteration through the biological testing
- Formulate the value added processing / storage / quality control for the better use of
- herbal medicine
- Develop the skills for cultivation of plants and their value added processing / storage / quality control.

Objective of the course:

- Impart concept on the plants used as traditional medicine, and understanding the process of cultivation, harvesting, processing, storage, marketing and utilization of medicinal plants
- Discuss in brief about the medicinal drugs obtained from plants and comprehensive idea about systematic position, medicinal uses of Tulsi, Ginger, Fenugreek, Indian gooseberry and Ashoka.
- Explain phytochemistry of medicinal herbs and identification, utilization of medicinal plants.
- Highlight basic knowledge on quality control, owing the medicinal properties of herbal drugs including the secondary metabolites and concept of drug adulteration, types, methods of drug evaluation
- Impart the knowledge on micro propagation of important medicinal plant species.

Unit 1: Herbal medicines: history and scope - definition of medical terms - role of medicinal plants in Siddha systems of medicine; cultivation - harvesting - processing - storage - marketing and utilization of medicinal plants. **(12 Lectures)**

Unit 2: Pharmacognosy - systematic position m edicinal uses of the following herbs in curing various ailments; Tulsi, Ginger, Fenugreek, Indian Goose berry and Ashoka. **(12 Lectures)**

Unit 3: Phytochemistry - active principles and methods of their testing - identification and utilization of the medicinal herbs; *Catharanthus roseus* (cardiotonic), *Withania somnifera* (drugs acting on nervous system), *Clerodendron phlomoides* (anti-rheumatic) and *Centella asiatica* (memory booster). **(12 Lectures)**

Unit 4: Analytical pharmacognosy: Drug adulteration - types, methods of drug evaluation - Biological testing of herbal drugs - Phytochemical screening tests for secondary metabolites (alkaloids, flavonoids, steroids, triterpenoids, phenolic compounds) **(16 Lectures)**

Unit 5: Medicinal plant banks micro propagation of important species (*Withania somnifera*, neem and tulsi- Herbal foods-future of pharmacognosy) **(8 Lectures)**

Suggested Readings

1. Glossary of Indian medicinal plants, R.N.Chopra, S.L.Nayar and I.C.Chopra, 1956. C.S.I.R, New Delhi.

2. The indigenous drugs of India, Kanny, Lall, Dey and Raj Bahadur, 1984. International Book Distributors.

3. Herbal plants and Drugs Agnes Arber, 1999. Mangal Deep Publications.

4. Ayurvedic drugs and their plant source. V.V. Sivarajan and Balachandran Indra 1994. Oxford IBH publishing Co.

5. Ayurveda and Aromatherapy. Miller, Light and Miller, Bryan, 1998. Banarsidass, Delhi.

6. Principles of Ayurveda, Anne Green, 2000. Thomsons, London.

7. Pharmacognosy, Dr.C.K.Kokate et al. 1999. Nirali Prakashan.

BOT-SE-4014
Skill Enhancement Course 3: Nursery and Gardening
Total Lectures: 60 Credits: 4

Learning outcomes:

On completion of this course, students will be able to:

- Understand the process of sowing seeds in nursery.
- List the various resources required for the development of nursery.
- Distinguish among the different forms of sowing and growing plants.
- Analyse the process of Vegetative propagation.
- Appreciate the diversity of plants and selection of gardening.
- Examine the cultivation of different vegetables and growth of plants in nursery and gardening.

Objective of the course:

- Explain in brief on the objectives, scope, infrastructure and maintenance of Nursery.
- Explain the structure, types and dormancy of seeds and highlight in brief on seed storage including types and process, and knowledge on seed production technology.
- Provide knowledge on various modes of vegetative propagation and maintenance of plants in green house.
- Explain in brief about the development and maintenance of gardening including scope and types and understand the various gardening operations including management of pests and diseases.
- Throw light on the managements of seeds and seedlings and concept about cultivation, storage and marketing of important vegetables.

Unit 1: Nursery: definition, objectives and scope and building up of infrastructure for nursery, planning and seasonal activities - Planting - direct seeding and transplants. **(8 Lectures)**

Unit 2: Seed: Structure and types - Seed dormancy; causes and methods of breaking dormancy - Seed storage: Seed banks, factors affecting seed viability, genetic erosion – Seed production technology - seed testing and certification. **(12 Lectures)**

Unit 3: Vegetative propagation: air-layering, cutting, selection of cutting, collecting season, treatment of cutting, rooting medium and planting of cuttings - Hardening of plants – green house - mist chamber, shed root, shade house and glass house. **(12 Lectures)**

Unit 4: Gardening: definition, objectives and scope - different types of gardening - landscape and home gardening - parks and its components - plant materials and design - computer applications in landscaping - Gardening operations: soil laying, manuring, watering, management of pests and diseases and harvesting. **(16 Lectures)**

Unit 5: Sowing/raising of seeds and seedlings - Transplanting of seedlings - Study of cultivation of different vegetables: cabbage, brinjal, lady's finger, onion, garlic, tomatoes, and carrots - Storage and marketing procedures. **(12 Lectures)**

Suggested Readings

1. Bose T.K. & Mukherjee, D., 1972, Gardening in India, Oxford & IBH Publishing Co., New Delhi.

2. Sandhu, M.K., 1989, Plant Propagation, Wile Eastern Ltd., Bangalore, Madras.

3. Kumar, N., 1997, Introduction to Horticulture, Rajalakshmi Publications, Nagercoil.

4. Edmond Musser & Andres, Fundamentals of Horticulture, McGraw Hill Book Co., New Delhi.

5. Agrawal, P.K. 1993, Hand Book of Seed Technology, Dept. of Agriculture and Cooperation, National Seed Corporation Ltd., New Delhi.

6. Janick Jules. 1979. Horticultural Science. (3rd Ed.), W.H. Freeman and Co., San Francisco, USA.

BOT-SE-4024
Skill Enhancement Course 4: Floriculture
Total Lectures: 60 Credits: 4

Learning outcomes

On completion of this course, students will be able to:

- Develop conceptual understanding of gardening from historical perspective
- Analyze various nursery management practices with routine garden operations.
- Distinguish among the various Ornamental Plants and their cultivation
- Evaluate garden designs of different countries
- Appraise the landscaping of public and commercial places for floriculture.
- Diagnoses the various diseases and uses of pests for ornamental plants.

Objective of the course:

- Highlight the basic knowledge of history, importance and scope of floriculture.
- Explain the idea of Nursery management and garden operations and knowledge on the terms related to gardening and concept about role of plant growth regulators.
- Discuss about various ornamental plants and concept of cultivations of plants in pots and knowledge about Bonsai.
- Highlight on various garden designs and features of such gardens and knowledge about some famous gardens of India.
- Provide knowledge about the process of making garden more attractive by altering the existing design in places of public importance, highways and educational institute.

Unit 1: Introduction: History of gardening; Importance and scope of floriculture and landscape gardening. **(4 Lectures)**

Unit 2: Nursery Management and Routine Garden Operations: Sexual and vegetative methods of propagation; Soil sterilization; Seed sowing; Pricking; Planting and transplanting; Shading; Stopping or pinching; Defoliation; Wintering; Mulching; Topiary; Role of plant growth regulators. **(16 lectures)**

Unit 3: Ornamental Plants: Flowering annuals; Herbaceous perennials; Divine vines; Shade and ornamental trees; Ornamental bulbous and foliage plants; Cacti and succulents; Palms and Cycads; Ferns and Selaginellas; Cultivation of plants in pots; Indoor gardening; Bonsai. **(8 lectures)**

Unit 4: Principles of Garden Designs: English, Italian, French, Persian, Mughal and Japanese gardens; Features of a garden (Garden wall, Fencing, Steps, Hedge, Edging, Lawn, Flower beds, Shrubbery, Borders, Water garden. Some Famous gardens of India. **(8 lectures)**

Unit 5: Landscaping Places of Public Importance: Landscaping highways and Educational institutions. **(8 lectures)**

Unit 6: Commercial Floriculture: Factors affecting flower production; Production and packaging of cut flowers; Flower arrangements; Methods to prolong vase life; Cultivation of Important cut flowers (Carnation, Aster, Chrysanthemum, Dahlia, Gerbera, Gladiolous, Marigold, Rose, Lilium, Orchids). **(12 lectures)**

Unit 7: Diseases and Pests of Ornamental Plants. **(4 lectures)**

Suggested Readings

1. Randhawa, G.S. and Mukhopadhyay, A. 1986. Floriculture in India. Allied Publishers.

BOT-SE-4034
Skill Enhancement Course 5: Intellectual Property Rights
Total Lectures: 60 Credits: 4

Learning outcomes

On completion of this course, students will be able to:

- Understand the concept of IPR
- Differentiate between various agreements of IPR
- Compare copyrights, patents and Geographical Indicators
- Examine various legal issues related to IPR
- Relate to various cyber issues concerning IPR

Objective of the course

- Provide knowledge on IPR, their types and infringement.
- Throw light on traditional knowledge and their protection, bio-prospecting and bio-piracy.
- Highlight on protection of plant varieties and farmer rights.
- Elaborate on Information technology related IPR; data, database, chips and domain name protection.

Unit 1: Introduction to Intellectual Property Rights (IPR) (4 lectures)

Concept and kinds. Economic importance. IPR in India and world: Genesis and scope, some important examples. IPR and WTO (TRIPS, WIPO).

Unit 2: Patents (6 Lectures)

Objectives, Rights, Patent Act 1970 and its amendments. Procedure of obtaining patents, Working of patents. Infringement.

Unit 3: Copyrights (6 Lectures)

Introduction, Works protected under copyright law, Rights, Transfer of Copyright, Infringement.

Unit 4: Trademarks (6 Lectures)

Objectives, Types, Rights, Protection of goodwill, Infringement, Passing off, Defences, Domain name.

Unit 5: Geographical Indications (6 Lectures)

Objectives, Justification, International Position, Multilateral Treaties, National Level, Indian Position.

Unit 6: Protection of Traditional Knowledge (8 Lectures)

Objective, Concept of Traditional Knowledge, Holders, Issues concerning, Bio-Prospecting and Bio-Piracy, Alternative ways, Protectability, needfor a Sui-Generis regime, Traditional Knowledge on the International Arena, at WTO, at National level, Traditional Knowledge Digital Library.

Unit 7: Industrial Designs (4 Lectures)

Objectives, Rights, Assignments, Infringements, Defences of Design Infringement

Unit 8: Protection of Plant Varieties (4 Lectures)

Plant Varieties Protection-Objectives, Justification, International Position, Plant varieties protection in India. Rights of farmers, Breeders and Researchers. National gene bank, Benefit sharing. Protection of Plant Varieties and Farmers' Rights Act, 2001.

Unit 9: Information Technology Related Intellectual Property Rights (8 Lectures)

Computer Software and Intellectual Property, Database and Data Protection, Protection of Semi-conductor chips, Domain Name Protection

Unit 10: Biotechnology and Intellectual Property Rights (8 Lectures)

Patenting Biotech Inventions: Objective, Applications, Concept of Novelty, Concept of inventive step, Microorganisms, Moral Issues in Patenting Biotechnological inventions.

Suggested Readings

1. N.S. Gopalakrishnan & T.G. Agitha, (2009). Principles of Intellectual Property Eastern Book Company, Lucknow.

2. Kerly's Law of Trade Marks and Trade Names (14th Edition) Thomson, Sweet & Maxweel.

3. Ajit Parulekar and Sarita D' Souza, (2006). Indian Patents Law – Legal & Business Implications; Macmillan India Ltd.

4. B.L.Wadehra (2000). Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications; Universal law Publishing Pvt. Ltd., India.

5. P. Narayanan (2010). Law of Copyright and Industrial Designs; Eastern law House, Delhi.

APPENDIX I

SEMESTER	COURSE OPTED	COURSE NAME	Credits
I	**Ability Enhancement Compulsory Course-I**	English communications	4
	Core course-I	Phycology and Microbiology	4
	Core Course-I Practical	Phycology and Microbiology	2
	Core course-II	Biomolecules and Cell Biology	4
	Core Course-II Practical	Biomolecules and Cell Biology- Practical	2
	Generic Elective -1	GE-1	4
	Generic Elective -1 Practical/ Tutorial	GE-1 Practical	2
II	**Ability Enhancement Compulsory Course-II**	Environmental Studies	4
	Core course-III	Mycology and Phytopathology	4
	Core Course-III Practical	Mycology and Phytopathology-Practical	2
	Core course-IV	Archegoniate	4
	Core Course-IV Practical	Archegoniate- Practical	2
	Generic Elective -2	GE-2	4
	Generic Elective -2 -- Practical	GE-2 Practical	2
III	**Core course-V**	Morphology and Anatomy of Angiosperm	4
	Core Course-V Practical	Morphology and Anatomy of Angiosperm- Practical	2
	Core course-VI	Economic Botany	4
	Core Course-VI Practical	Economic Botany-Practical	2
	Core course-VII	Genetics	4
	Core Course-VII Practical	Genetics-Practical	2
	Skill Enhancement Course- 1	SEC-1	4
	Generic Elective -3	GE-3	4
	Generic Elective -3 Practical	GE-3 Practical	2
IV	**Core course-VIII**	Molecular Biology	4
	Course-VIII Practical	Molecular Biology- Practical	2
	Core course-IX	Plant Ecology and Phytogeography	4
	Course-IX Practical	Plant Ecology and Phytogeography - practical	2
	Core course-X	Plant Systematics	4
	Core Course- X Practical	Plant Systematics-Practical	2
	Skill Enhancement Course-2	SEC-2	4
	Generic Elective-4	GE-4	4
	Generic Elective-4 Practical	GE-4 Practical	2
V	**Core course-XI**	Reproductive Biology of Angiosperms	4

	Core Course-XI Practical	Reproductive Biology of angiosperms- Practical	2
	Core course-XII	Plant Physiology	4
	Core Course-XII Practical	Plant Physiology- Practical	2
	Discipline Specific Elective -1	DSE-1	4
	Discipline Specific Elective -1 Practical	DSE-1 Practical	2
	Discipline Specific Elective -2	DSE-2	4
	Discipline Specific Elective-2 -Practical /Tutorial	DSE-2 Practical	2
VI	**Core course-XIII**	Plant Metabolism	4
	Core Course-XIII -Practical / Tutorial	Plant Metabolism- Practical	2
	Core course-XIV	Plant Biotechnology	4
	Core Course-XIV - Practical /Tutorial	Plant Biotechnology- Practical	2
	Discipline Centric Elective -3	DSE-3	4
	Discipline Centric Elective -3 Practical /Tutorial	DSE-3 Practical	2
	Discipline Centric Elective-4 (Theory & practical / Project Work/Dissertation)	DSE-4 DSE-4 Practical Or Project Work/ Dissertation	6
			Total: 148