

**Proposed Curriculum and Syllabus
For B. Sc. (Honours) Botany
Submitted to**

VISVA-BHARATI

Under

Choice Based Credit System (CBCS)

(w.e.f. Academic Year 2017-2018)

Structure of B.Sc.(Honours) Botany under CBCS

Core Courses

- CCBO - 1. Algae and Microbiology
- CCBO -2. Biomolecules and Cell Biology
- CCBO -3. Mycology and Phytopathology
- CCBO -4. Archegoniatae
- CCBO -5. Morphology and Anatomy of Angiosperms
- CCBO -6. Economic Botany
- CCBO -7. Basics of Genetics
- CCBO -8. Molecular Biology
- CCBO -9. Plant Ecology and Phytogeography
- CCBO -10. Plant Systematics
- CCBO -11. Reproductive Biology of Angiosperm
- CCBO -12. Plant Physiology
- CCBO -13. Plant Metabolism
- CCBO -14. Plant Biotechnology

Semester I	Tagore Studies
Semester II	Tagore Studies

Ability Enhancement Compulsory Courses (AEC)

Semester I	AEC - 1	English Communication
Semester III	AEC - 2	Environmental Science

Skill Enhancement Courses: Elective (Two)

Semester III	SECBO – 1 (Any one)	1. Biofertilizer 2. Mushroom Culture Technology
Semester IV	SECBO – 2 (Any one)	1. Herbal Technology 2. Ethnobotany

Discipline Specific Elective: (Four)

Semester V	DSEBO -1: Analytical Techniques in Plant Sciences DSEBO -2: Plant Breeding
Semester IV	DSEBO -3: Industrial and Environmental Microbiology DSEBO -4: Biostatistics

Generic Electives (GE): Four Courses offered to the students of other Departments

Semester I	GEBO - 1: Biodiversity (Microbes, Algae, Fungi, Archegoniatae)
Semester II	GEBO - 2: Plant Ecology and Taxonomy
Semester III	GEBO – 3: Plant Anatomy and Embryology
Semester IV	GEBO - 4: Plant Physiology and Metabolism

Syllabus for B. Sc. Hons. in Botany (CBCS)

Distribution of credits and marks

Semester	Course Opted	Course Name	Course code	Theory/ Practical	Credits	Full Marks
I	Core Course I	Algae and Microbiology	CCBO - 1A	Theory	4	50
			CCBO – 1B	Practical	2	25
	Core Course II	Biomolecules and Cell Biology	CCBO - 2A	Theory	4	50
			CCBO – 2B	Practical	2	25
	Generic Elective	Biodiversity (Microbes, Algae, Fungi and Archegoniate)	GEBO - 1A	Theory	4	50
			GEBO – 1B	Practical	2	25
	Ability Enhancement Compulsory Course	English/MIL			2	25
	Tagore Studies			4		
II	Core Course III	Mycology and Phytopathology	CCBO - 3A	Theory	4	50
			CCBO – 3B	Practical	2	25
	Core Course IV	Archegoniate	CCBO - 4A	Theory	4	50
			CCBO – 4B	Practical	2	25
	Generic Elective	Plant Ecology and Taxonomy	GEBO - 2A	Theory	4	50
			GEBO – 2B	Practical	2	25
		Tagore Studies			4	
III	Core Course V	Morphology and Anatomy of Angiosperms	CCBO - 5A	Theory	4	50
			CCBO – 5B	Practical	2	25
	Core Course VI	Economic Botany	CCBO - 6A	Theory	4	50
			CCBO – 6B	Practical	2	25
	Core Course VII	Basics of Genetics	CCBO - 7A	Theory	4	50
			CCBO – 7B	Practical	2	25
	Generic Elective	Plant Anatomy and Embryology	GEBO - 3A	Theory	4	50
			GEBO – 3B	Practical	2	25
	Skill Enhancement Course	Biofertilizers/ Mushroom Culture Technology	SECBO - 1		2	25
	Environmental Science			2	25	

Semester	Course Opted	Course Name	Course code	Theory/ Practical	Credits	Full Marks
IV	Core Course VIII	Molecular Biology	CCBO - 8A	Theory	4	50
			CCBO – 8B	Practical	2	25
	Core Course IX	Plant Ecology and Phytogeography	CCBO - 9A	Theory	4	50
			CCBO – 9B	Practical	2	25
	Core Course X	Plant Systematics	CCBO - 10A	Theory	4	50
			CCBO – 10B	Practical	2	25
Generic Elective	Plant Physiology and Metabolism	GEBO - 4A	Theory	4	50	
		GEBO – 4B	Practical	2	25	
Skill Enhancement Course	Herbal Technology/ Ethnobotany	SECBO - 2		2	25	
V	Core Course XI	Reproductive Biology of Angiosperms	CCBO - 11A	Theory	4	50
			CCBO – 11B	Practical	2	25
	Core Course XII	Plant Physiology	CCBO - 12A	Theory	4	50
			CCBO – 12B	Practical	2	25
	Discipline Specific Elective	Analytical Techniques in Plant Sciences	DSEBO - 1A	Theory	4	50
			DSEBO – 1B	Practical	2	25
Discipline Specific Elective	Plant Breeding	DSEBO - 2A	Theory	4	50	
		DSEBO – 2B	Practical	2	25	
VI	Core Course XIII	Plant Metabolism	CCBO - 13A	Theory	4	50
			CCBO – 13B	Practical	2	25
	Core Course XIV	Plant Biotechnology	CCBO - 14A	Theory	4	50
			CCBO – 14B	Practical	2	25
	Discipline Specific Elective	Industrial and Environmental Microbiology	DSEBO - 3A	Theory	4	50
			DSEBO – 3B	Practical	2	25
Discipline Specific Elective	Biostatistics	DSEBO - 4A	Theory	4	50	
		DSEBO - 4A	Practical	2	25	

Total Credits = 148

Core Courses

Semester-I

Core Course I: Algae and Microbiology

THEORY (Credits: 4) Lectures: 60

Unit 1: Introduction to microbial world (6 lectures)

General concept of microbial world; contribution of Leuwenhoek, Louis Pasteur, Robert Koch
Microbial nutrition, growth and metabolism. Growth curve, batch and continuous culture.
Economic importance of viruses with reference to vaccine production, role in medicine and as
causal organisms of plant diseases. Economic importance of bacteria with reference to their role
in agriculture and industry (fermentation and antibiotics).

Unit 2: Viruses (6 lectures)

Discovery, physiochemical and biological characteristics; classification (Baltimore), general
structure with special reference to TMV, T2-Phage and HIV; viroids and prions; Replication
(general account), DNA (T-phage) and RNA (TMV); lytic(T₂) and lysogenic (λ phage) cycle.

Unit 3: Bacteria (9 lectures)

Discovery, general characteristics; Principles in Bacterial Taxonomy. Types - Archaea,
Eubacteria, wall-less forms (mycoplasma and spheroplasts); Cell structure; Cell wall: physical
and chemical nature of Gram +ve and Gram -ve bacteria; Surface structure - capsule and slime
layer; Cell appendages: flagella and pilli; Cell inclusions; Ribosomes, Chromatophores, reserve
materials; Endospore: formation, structure and significance; Bacterial Chromosome & extra-
chromosomal genetic elements; Nutritional types; Vegetative Reproduction and genetic
recombination (conjugation, transformation and transduction).

Unit 4: Algae (11 lectures)

General characteristics; range of thallus organization; Basic life cycle patterns; Cell structure and
components; cell wall, pigment system, reserve food (of only groups represented in the syllabus),
flagella; methods of reproduction; Classification; criteria, general concept of endosymbiosis,
Modern system of classification up to division; Significant contributions of important
phycologists (F.E. Fritsch, G.M. Smith, R.N. Singh, T.V. Desikachary, H.D. Kumar & M.O.P.
Iyengar); Role of algae in the environment, agriculture, biotechnology and industry.

Unit 5: Cyanophyta (Cyanobacteria) (8 lectures)

Salient features; Ecology and occurrence; Cell structure; Chromatic adaptation; N₂ fixation;
Reproduction, Genetic recombination (in Cyanophyta); reason for renaming the group as
Cyanobacteria; Classification up to order.

Unit 6: Chlorophyta (Chlorophyceae and Charophyceae) (8 lectures)

General characteristics; Occurrence; Cell structure. Life-cycles of *Volvox*, *Oedogonium*,
Zygnema, *Coleochaete* and *Chara*.

Unit 7: Heterochontophyta- Xanthophyceae, Bacillariophyceae, Phaeophyta (8 lectures)

Characteristics; Occurrence; Cell structure; Reproduction. life-cycles of *Vaucheria*, Diatoms, *Fucus*.

Unit 8 : Rhodophyta (4 lectures)

Characteristics; Occurrence; Cell structure; Reproduction. life-cycles of *Polysiphonia*

**Core Course I: Algae and Microbiology
Practical (Credits: 2)**

Microbiology

1. Aseptic method
 - a) Sterilization technique by Autoclaving, Hot air oven and surface sterilization.
 - b) Preparation of standard bacteriological medium (PDA, Nutrient agar, Nutrient broth medium).
 - c) Preparation of slant and plates.
 - d) Subculturing of pure bacteriological culture.
2. Simple staining; Differential staining: Gram staining.
3. Endospore staining with malachite green (endospores taken from soil bacteria).
4. Microscopic examination of bacteria from natural habitats: curd and root nodules of leguminous plants.

Phycology

1. Study and Camera Lucida drawings of vegetative and reproductive structures of *Nostoc*, *Scytonema*, *Coleochaete*, *Zygnema*, *Oedogonium*, *Chara*, *Vaucheria*, *Polysiphonia* temporary preparations and identification from permanent slides.
2. Identification of all the genera included in the theoretical syllabus from Permanent slides (vegetative and reproductive structures).

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. 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.
5. Pelczar, M.J. (2001). Microbiology, 5th edition, Tata McGraw-Hill Co, New Delhi.
6. Banerjee A.K., Banerjee N. 2006. Fundamentals of Microbiology and Immunology. New Central Book Agency (P) Ltd., Kolkata
7. Hait G., Bhattacharya K., Ghosh A.K.(2007). A Text Book of Botany. Volume1. New Central Book Agency (P) Ltd., Kolkata

Core Course II: Biomolecules and Cell Biology

THEORY (Credits: 4) Lectures: 60

Unit 1: Biomolecules (20 lectures)

Types and significance of chemical bonds; Significance of C,H,N,O as essential elements of organic molecules, Structure, properties and biological significance 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 quaternary; 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, Z types of DNA; Types of RNA; Structure of tRNA

Unit 2: Bioenergetics (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 theory), Michaelis-Menten equation, enzyme inhibition and factors affecting enzyme activity

Unit 4: The Cell: Unit of structure and function; Plasma membrane, Cell organelles and Cytoskeleton (12 lectures)

Characteristics of prokaryotic and eukaryotic cells: Overview of membrane structure and function; fluid mosaic model, chemical composition of cell membrane; Chloroplast, mitochondria and peroxisomes: structural organization and function;

Cytoskeleton: Structure of microtubules, microfilaments and intermediary filament

Unit 5: Nucleic acids: Carrier of genetic information (10 lectures)

DNA as the genetic information (Griffith, Avery, MacLeod and McCarty, Hershey and Chase experiments). Molecular structure of DNA: Watson Crick model, Salient features of DNA double helix, Types of DNA

Nucleus and organization of chromatin and chromosome structure

Ultrastructure of nuclear envelope, nuclear pore complex, nuclear lamina, nucleolus: structure and function; molecular organization of chromatin, Nucleosome model, Higher order structure of chromatin organization

Unit 6: Cell Cycle (4 lectures)

Phases and their significance; Cell division: Mitosis and Meiosis: important events and their significance

Unit 7: Chromosome aberration (4 lectures)

Structure and numerical aberration and their genetic significance

Core Course II: Biomolecules and Cell Biology Practical (Credits: 2)

1. Qualitative tests for carbohydrates, reducing sugars, non-reducing sugars, lipids and proteins.
2. Study of somatic and meiotic chromosome: Background knowledge of preparation and biological use of different kinds of pretreating agents, fixatives and chromosome stains.
3. Study different stages of mitosis through root tip squash technique
4. Study of different stages of meiosis from flower buds
5. Study of somatic chromosome morphology from root tips of *Allium cepa/ Lens culinaris*

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
10. Ghosh A.K., Bhattacharya K., Hait G., (2016). A Text Book of Botany. Volume 3. New Central Book Agency (P) Ltd., Kolkata

Semester-II

Core Course III: Mycology and Phytopathology THEORY (Credits: 4) Lectures: 60

Unit 1: Introduction to true fungi (4 lectures)

General characteristics; Classification by Ainsworth (1973) up to subdivision with characters and examples; Affinities with plants and animals; Thallus organization; Cell wall composition; Nutrition.

Unit 2: Chytridiomycota and Zygomycota (5 lecture)

Characteristic features; Ecology and significance; Thallus organisation; Reproduction; Life cycle with reference to *Synchytrium*, *Rhizopus* .

Unit 3: Ascomycota (8 lectures)

General characteristics (asexual and sexual fruiting bodies); Development of ascus and ascospores, Types of ascospores, Heterokaryosis and parasexuality in asexual members; Life cycle and classification with reference to *Saccharomyces*, *Aspergillus*, *Penicillium*, *Alternaria*, *Neurospora* and *Ascobolus*.

Unit 4: Basidiomycota (8 lectures)

General characteristics; Phenomenon of dikaryotization; Development of basidia, basidiospores, and basidiocarp; Life cycle of *Puccinia* (Physiological Specialization), *Agaricus*, *Polyporus*; Bioluminescence, Fairy Rings and Mushroom Cultivation.

Unit 5: Allied Fungi (3 lectures)

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

Unit 6: Oomycota (4 lectures)

General characteristics; Ecology; Life cycle and classification with reference to *Phytophthora*, *Albugo*.

Unit 7: Symbiotic associations (4 lectures)

Lichen – Occurrence; General characteristics; Growth forms and range of thallus organization; Nature of associations of algal and fungal partners; Reproduction; Mycorrhiza-Ectomycorrhiza, Endomycorrhiza with special reference to VAM and their significance.

Unit 8: Applied Mycology (6 Lectures)

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

Unit 9: Phytopathology (18 lectures)

Terms and concepts; General symptoms; Geographical distribution of diseases; Etiology; Symptomology; Koch's postulate, Host-Pathogen relationships; pathogenic entry, role of toxin; Disease cycle and environmental relation; Types of disease, host defence mechanism, prevention and control of plant diseases, and role of quarantine. Plant disease management: Quarantine, Physical, Chemical, Biological and Integrated; Disease forecasting; Disease diagnosis

Bacterial diseases – Bacterial blight of rice.

Viral diseases – Tobacco Mosaic viruses.

Fungal diseases – Early blight of potato, Black stem rust of wheat, Brown spot of rice, Blast disease of rice, Late blight of potato, Ergot of rye, Wilt of *Cajanus cajan*

Core Course III: Mycology and Phytopathology Practical (Credits: 2)

1. Introduction to the world of fungi (Unicellular, coenocytic/septate mycelium, ascocarps & basidiocarps).
2. *Rhizopus*: study of asexual stage from temporary mounts and sexual structures through permanent slides.
3. *Aspergillus* and *Penicillium*: study of asexual stage from temporary mounts. Study of Sexual stage from permanent slides/photographs.
4. *Ascobolus*: sectioning through ascocarp.
5. *Alternaria*: Specimens/photographs and temporary mounts.
6. *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.
7. *Agaricus*: Specimens of button stage and full grown mushroom; sectioning of gills of *Agaricus*, fairy rings and bioluminescent mushrooms to be shown.
8. Study of phaneroplasmodium from actual specimens and /or photograph. Study of *Stemonitis* sporangia.
9. *Albugo*: Study of symptoms of plants infected with *Albugo*; asexual phase study through section/temporary mounts and sexual structures through permanent slides.
10. 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)
11. Phytopathology: Herbarium specimens of bacterial diseases; Viral diseases: TMV, Fungal diseases: Early blight of potato, Black stem rust of wheat, Brown spot of rice, Blast of rice, Late blight of potato, Ergot of rye, Wilt of *Cajanus cajan*
12. Isolation of pathogens from infected plants.
13. Study of air-mycoflora by exposed plate technique

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. Hait G., Bhattacharya K., Ghosh A.K.(2007). A Text Book of Botany. Volume1. New Central Book Agency (P) Ltd., Kolkata

Core Course IV: Archegoniate THEORY (Credits: 4) Lectures: 60

Unit 1: Introduction (4 lectures)

Concept of archegoniate, Unifying features of archegoniate; Transition and adaptation to land habit; Alternation of generations.

Unit 2: Bryophytes (8 lectures)

General characteristics; Amphibious nature; A modern classification of bryophytes into three divisions- Hepatophyta, Anthocerotophyta and Bryophyta; Range of thallus organization; Phylogeny: Origin of bryophytes; Homologous and Antithetic theory; evolution of gametophytes and sporophytes (Progressive and Regressive concept), Ecological and economic significance of bryophytes .

Unit 3: Type Studies- Bryophytes (8 lectures)

Morphology, anatomy, reproduction and evolutionary trends in *Marchantia*, *Porella*, *Anthoceros*, *Sphagnum* and *Funaria*. Ecological and economic importance of bryophytes (a brief account).

Unit 4: Pteridophytes (6 lectures)

General characteristics; Modern system of Classification up to class with characters and examples; Adaptive features for land habit; Origin of Pteridophytes; Early land plants (Rhyniopsida and Zosterophylopsida); Early gametophytic structure.

Unit 5: Type Studies- Pteridophytes (14 lectures)

Morphology, anatomy and reproduction of *Lycopodium*, *Selaginella*, *Equisetum*, *Ophioglossum*, *Pteris* and *Marsilea*. Morphological and anatomical features and causes of extinction of the following: *Lepidodendron* (reconstructed), *Calamites* (reconstructed), Heterospory and seed habit, Telome theory, Enation theory, Stellar evolution; Ecological and economic importance

Unit 6: Gymnosperms and Palaeobotany (20 lectures)

General characteristics and classification of gymnosperms up to order. Morphology, anatomy and reproduction of *Cycas*, *Pinus* and *Gnetum*; Pteridospermales: General characteristics; Structural features of *Lyginopteris oldhamia* (reconstructed); Cordaitales: General characteristics and its role in the origin of seed cone complex. Bennettitales: General characteristics; Structural features of *Williamsonia seawardiana* (reconstructed); Geological

time scale and distribution of major fossil groups in different geologic ages. Fossils: Definition; types; nomenclature; mode of preservation (after Schopf, 1975), factors for fossilization. Radiometric dating: Basic principle with reference to C¹⁴ dating. A brief idea about three-fold division of Indian Gondwana system. Ecological and economic importance of gymnosperms.

Core Course IV: Archegoniate Practical (Credits 2)

1. ***Marchantia***- Morphology of thallus, whole mount of rhizoids & Scales, vertical section of thallus through Gemma cup, whole mount of Gemmae (all temporary slides), vertical section of Antheridiophore, Archegoniophore, longitudinal section of Sporophyte (from permanent slides).
2. ***Anthoceros***- Morphology of thallus, dissection of sporophyte (to show stomata, spores, pseudoelaters, columella) (temporary slide), vertical section of thallus (from permanent slide).
3. ***Porella*** - Study from Permanent slides.
4. ***Funaria***- Morphology, whole mount of leaf, rhizoids, operculum, peristome, annulus, spores (temporary slides); permanent slides showing antheridial and archegonial heads, longitudinal section of capsule.
5. ***Lycopodium***- Morphology, whole mount of leaf, transverse section of stem (temporary slide), longitudinal section of strobilus (from permanent slide).
6. ***Selaginella***- Morphology, whole mount of leaf with ligule, transverse section of stem, whole mount of strobilus, whole mount of microsporophyll and megasporophyll (temporary slides), longitudinal section of strobilus (from permanent slide).
7. ***Equisetum***- Morphology, transverse section of internode, longitudinal section of strobilus, transverse section of strobilus, whole mount of sporangiophore, whole mount of spores (temporary slide), transverse section of rhizome (from permanent slide).
8. ***Ophiglossum*** - Morphology, longitudinal section of strobilus, transverse section of strobilus, whole mount of spores (temporary slide).
9. ***Pteris***- Morphology, transverse section of rachis, vertical section of sporophyll, whole mount of sporangium, whole mount of spores (temporary slides), transverse section of rhizome, whole mount of prothallus with sex organs and young sporophyte (from permanent slide).
10. ***Cycas***- Morphology (coralloid roots, bulbil, leaf), whole mount of microsporophyll, transverse section of coralloid root, transverse section of rachis, vertical section of leaflet, vertical section of microsporophyll, whole mount of spores (temporary slides), longitudinal section of ovule, transverse section of root (permanent slide).

11. *Pinus*- Morphology (long and dwarf shoots, male and female cones), transverse section of Needle, longitudinal section of / transverse section of male cone, whole mount of microsporophyll, whole mount of Microspores (temporary slides), longitudinal section of female cone (Permanent slide), tangential longitudinal section & radial longitudinal sections stem (permanent slide).

12. *Gnetum*- Morphology (stem, male & female cones), transverse section of stem, vertical section of ovule (permanent slide).

13. Study of Megafossils(Impression. Compression, Petrification). T.S of *Rhynia*, *Lyginopteris*, *Lepidodendron*, *Stigmaria*, *Calamites*, *Cordaites*, *Cordaianthus* (from permanent slides)

Suggested Readings

1. Bhatnagar, S.P., Moitra, A. (1996). Gymnosperms. New Age International (P) Ltd Publishers, New Delhi, India.
2. Hait G., Bhattacharya K., Ghosh A.K.(2007). A Text Book of Botany. Volume1. New Central Book Agency (P) Ltd., Kolkata
3. Bhattacharya K., Hait G., Ghosh A.K.(2008). A Text Book of Botany. Volume 2. New Central Book Agency (P) Ltd., Kolkata
4. Gifford E.M., Foster A.S. 1989. Morphology and evolution of vascular plants(3rd ed). W.H.freeman and Company, New York.
5. Parihar, N.S. (1991). An introduction to Embryophyta: Vol. I. Bryophyta. Central Book Depot. Allahabad.
6. Rashid A. 1990. An introduction to Pteridophyta(Diversity and Differentiation). Vikash Pub. House Pvt. Ltd., New Delhi
7. Stewart W.N, Rothwell G.W. 1993. Paleobotany and evolution of plants. Cambridge University Press

Semester-III

Core Course V: Morphology and Anatomy of Angiosperms THEORY (Credits: 4) Lectures: 60

MORPHOLOGY

Unit 1. (8 Lectures)

Roots, stems and leaves: Their structures with reference to modification with examples

Unit 2. (3 Lectures)

Inflorescence: Types with examples, evolution (brief idea)

Unit 3. (6 Lectures)

Flowers: Types, calyx (modifications), corolla (forms, aestivation, modification), stamen (cohesion & adhesion, attachment of anther), carpel - apocarpous & syncarpous, evolution

Unit 4. (3 Lectures)

Placentation: types with examples, evolution (brief idea)

Unit 5. (6 Lectures)

Fruits and seeds: Types with examples, Dispersal mechanism.

Unit 6. (4 Lectures)

Defensive mechanism of plants (Homologous and analogous organs)

ANATOMY

Unit 1: Introduction and scope of Plant Anatomy (2 Lectures)

Applications in systematics, forensics and pharmacognosy.

Unit 2: Structure and Development of Plant Body (5 Lectures)

Internal organization and development of plant body: Brief idea. The tissue systems – dermal, ground tissue and vascular tissue. Types of vascular bundles, stomata and trichomes, Root-stem transition.

Unit 2: Tissues (7 Lectures)

Classification of tissues: Simple tissues - types, nature, distribution and functions; Complex tissues - Xylem and Phloem: Structure, ontogeny of tracheary elements and sieve elements; Transfer cells. Secretory structures and ergastic substances- brief idea.

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Unit 3: Apical meristems (5 Lectures)

Concept of organization of shoot and root apices (Apical cell theory, Histogen theory, Tunica Corpus theory, Korper-Kappe theory). Structure of primary bodies (dicot and monocot root, stem and leaf). Kranz anatomy.

Unit 4: Vascular Cambium and Wood (6 Lectures)

Cambium: structure and function. Secondary growth in root and stem. Sapwood and heartwood; Ring and diffuse porous wood; Early and late wood; Dendrochronology. Anomalous secondary growth in stem of *Bignonia*, *Strychnos*, *Tinospora* and root of *Beta*.

Unit 5: Adaptive and Protective Systems (3 Lectures)

Periderm- brief idea. Anatomical adaptations of xerophytes, hydrophytes and halophytes.

Unit 6: Cell wall (2 Lectures)

Structure, chemical composition, wall thickening with reference to pits.

Core Course V: Morphology and Anatomy of Angiosperms Practical (Credits: 2)

1. Study of anatomical details through permanent slides/temporary stain mounts/ macerations/ museum specimens with the help of suitable examples.
2. Xylem: Tracheary elements-tracheids, vessel elements; thickenings; perforation plates; xylem fibres.
3. Wood: ring porous; diffuse porous; tyloses; heart- and sapwood – Permanent slides.
4. Phloem: Sieve tubes-sieve plates; companion cells; phloem fibres - Permanent slides.
5. Epidermal system: stomatal types; trichomes: non-glandular and glandular. Crystals and lithocysts.
6. Primary and secondary structure: Root and Stem (monocot and dicot).
7. Secondary anomalous structure in stem.
8. Adaptive Anatomy: xerophytes, hydrophytes.
9. Study of different types of roots, stem, leaves, stipules, flowers, fruits and seeds.
10. Modification of roots, stem, leaves, flowers, fruits and seeds
11. Study of homologous and analogous organs of plants
12. Adaptive features in fruits and seeds for their dispersal

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. Bhattacharya K., Hait G., Ghosh A.K.(2008). A Text Book of Botany. Volume 2. New Central Book Agency (P) Ltd., Kolkata.

6. Bhattacharya K., Ghosh A.K., Hait G., (2017). A Text Book of Botany. Volume 4. New Central Book Agency (P) Ltd., Kolkata.

7. Pandey B.P. (2012) Plant Anatomy. S.Chand & Company Ltd., New Delhi.

Core Course VI: Economic Botany THEORY (Credits: 4) Lectures: 60

Unit 1: Origin of Cultivated Plants (6 lectures)

Concept of Centres of Origin, their importance with reference to Vavilov's work. Examples of major plant introductions; Crop domestication and loss of genetic diversity; 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.

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

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

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

Fixed Oils: General description, classification, extraction, their uses and health implications; groundnut, linseed, soybean, mustard and coconut (Botanical name, family and uses).

Essential Oils: General account, extraction methods, comparison with fatty oils, sources and uses of some common essential oils.

Unit 8: Natural Rubber (3 lectures)

Para-rubber: tapping, processing and uses.

Unit 9: Drug-yielding plants (8 lectures)

Therapeutic and habit-forming drugs with special reference to *Withania*, *Andrographis*, *Zingiber* (Ginger), *Curcuma* (Turmeric), *Bacopa*, *Cinchona*, *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; Cotton, Coir and Jute (morphology, extraction and uses).

Core Course VI: Economic Botany Practical (Credits: 2)

1. **Cereals:** Wheat (starch grains, micro-chemical tests), Rice (study of paddy and grain, starch grains, micro-chemical tests).
2. **Legumes:** Soybean, Groundnut, (seed structure, micro-chemical tests).
3. **Sources of sugars and starches:** Sugarcane (cane juice - micro-chemical tests), Potato (starch grains, micro-chemical tests).
4. **Spices:** Black pepper, Fennel and Clove (habit and sections).
5. **Beverages:** Tea (plant specimen, tea leaves), Coffee (plant specimen, beans).
6. **Sources of oils and fats:** Mustard and ground nut – seeds; tests for oil droplets in crushed seeds.
7. **Rubber:** specimen, photograph/model of tapping, samples of rubber products.
8. **Drug-yielding plants:** Specimens of *Digitalis*, *Andrographis*, Ginger, Turmeric, *Alstonia*, *Withania* – powder drug study.
9. **Fiber-yielding plants:** Cotton (specimen, whole mount of seed to show lint and fuzz; whole mount of fiber), Jute (specimen, lignin on transverse section of stem and fiber).

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. Bhattacharya K., Ghosh A.K., Hait G. (2017). A Text Book of Botany. Volume 4. New Central Book Agency (P) Ltd., Kolkata.
5. Samba Murty AVSS and Subrahmanyam NS(1989) A Text Book of Economic Botany. Wiley Eastern Limited, India.

Core Course VII: Basics of Genetics THEORY (Credits: 4) Lectures: 60

Unit 1: Mendelian genetics and its extension (10 lectures)

Mendelism: History; Principles of inheritance; Recessive and Dominant traits, Incomplete dominance and codominance; Multiple alleles, Lethal alleles, Epistasis, Pleiotropy, Penetrance and Expressivity, Numericals; Polygenic inheritance

Unit 2: Extrachromosomal Inheritance (6 lectures)

Chloroplast mutation: Variegation in Four o'clock plant; Mitochondrial mutations in yeast; Maternal effects-shell coiling in snail; Infective heredity- Kappa particles in Paramecium

Unit 3: Linkage, crossing over and chromosome mapping (10 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

Unit 4: Chromosome and its inheritance (10 lectures)

Chromosome theory of inheritance; Autosomes and sex chromosomes; Sex Linkage, Numericals and pedigree analysis

Unit 5: Gene mutations (8 lectures)

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

Unit 6: Fine structure of gene (6 lectures)

Classical vs molecular concepts of gene; Cis-Trans complementation test for functional allelism; Structure of Phage T4, rII Locus

Unit 7. Population and Evolutionary Genetics (10 lectures)

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

Core Course VII: Basics of Genetics Practical (Credits: 2)

1. Mendel's laws through seed ratios. Laboratory exercises in probability and chi-square.
2. Chromosome mapping using point test cross data.
3. Pedigree analysis for dominant and recessive autosomal and sex linked traits.
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. Blood Typing: ABO groups & Rh factor.
6. Study of chromosome abnormality.
7. Problems base on sex linkage in plants animals and humans.

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. Ghosh A.K., Bhattacharya K., Hait G., (2015). A Text Book of Botany. Volume 3. New Central Book Agency (P) Ltd., Kolkata

Semester-IV

Core Course VIII: Molecular Biology THEORY (Credit: 4) Lectures: 60

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, types of DNA, types of genetic material, denaturation and renaturation, cot curves; RNA Structure, Organelle DNA - mitochondria and chloroplast DNA. Euchromatin, Heterochromatin- Constitutive and Facultative heterochromatin

Unit 3: The replication of DNA (10 lectures)

Chemistry of DNA synthesis (Kornberg's discovery); General principles – bidirectional, semiconservative and semi discontinuous replication, RNA priming; DNA replication; rolling circle and θ (theta) mode of replication, replication of linear ds-DNA, replication of the 5' end of linear chromosome; Enzymes involved in DNA replication

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

The Central Dogma (Adaptor hypothesis and discovery of mRNA template), Genetic code (deciphering & salient features)

Unit 5: Transcription (18 lectures)

Transcription in prokaryotes. Principles of transcriptional regulation;
Regulation of lactose metabolism in *E. coli*, transcription factors, Co-transcriptional regulation

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

Split genes-concept of introns and exons, processing of pre-RNA molecules, catalytic activity of RNA molecules

Unit 7: Translation in prokaryotes (8 lectures)

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; Basic concept of Post-translational modifications of proteins

Core Course VIII: Molecular Biology Practical (Credit: 2)

1. Isolation of genomic DNA from *E. Coli*/ DNA isolation from cauliflower head
2. DNA estimation by diphenylamine reagent/UV Spectrophotometry

3. Agarose gel electrophoresis
4. Study of DNA replication mechanisms through photographs (Rolling circle, Theta replication and semi-discontinuous replication)
5. Study of structures of prokaryotic RNA polymerase through photographs
6. Photographs establishing nucleic acid as genetic material (Messelson and Stahl's, Avery et al, Griffith's, Hershey & Chase's experiments)

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.
6. Ghosh A.K., Bhattacharya K., Hait G., (2015). A Text Book of Botany. Volume 3. New Central Book Agency (P) Ltd., Kolkata

Core Course IX: Plant Ecology and Phytogeography THEORY (Credits: 4) Lectures: 60

Unit 1: Introduction (4 lectures)

Ecology-definition, subdivisions and scope; Progress of ecology in India.

Unit 2: Soil (5 lectures)

Lithosphere, Major elements of crust, Origin of soil, Composition of soil: Physical, Chemical and Biological components; Soil profile.

Unit 3: Water (4 lectures)

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

Unit 4: Light, temperature, wind and fire (5 lectures)

Atmospheric zonations (Troposphere, stratosphere, Mesosphere, Thermosphere and Exosphere); Light, temperature, wind and fire as ecological factors, their interactions and variations, adaptations of plants to their variations; Ecads and Ecotypes; Microclimate.

Unit 5: Biotic interactions (2 lectures)

Competition, Pedation, Parasitism, Amensalism, Commensalism, Protooperation, Symbiosis.

Unit 6: Population ecology (4 lectures)

Characteristics – density, dispersion, natality, mortality, life tables, survivorship curves, age structure; Dynamics- concept; Ecological Speciation- mechanism, causes and types.

Unit 7: Plant communities (12 lectures)

Concept of ecological amplitude; Habitat and niche; Niche - types, partitioning and construction. Community characteristics, diversity and their measurement; Shannon's diversity index; Alpha, Beta and Gamma diversity: concept. Dynamics: Ecological succession - Primary and Secondary; climax concepts. Seral stages with reference to Hydrosere and Xerosere; Autogenic and allogenic succession.

Unit 8: Ecosystems (4 lectures)

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

Unit 9: Functional aspects of ecosystem (8 lectures)

Ecological Energetics: 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- types and theories; Biome - Brief description of major terrestrial biomes (one each from tropical, temperate & tundra); Phytogeographical divisions of India; characteristic vegetation of each phytogeographic zone. Biological hotspots with reference to Indian hotspots.

**Core Course IX: Plant Ecology and Phytogeography
Practical (Credits: 2)**

1. Determination of pH of various soil and water samples (pH meter, universal indicator/Lovibond comparator and pH paper)
2. Analysis for carbonates, nitrates, organic matter and base deficiency from two soil samples by rapid field tests.
3. Comparison of bulk density, porosity and soil texture of soils from three habitats.
4. Determination of COD, Free CO₂, alkalinity of water samples from polluted and unpolluted sources.
5. (a). Study of morphological and anatomical adaptations of hydrophytes and xerophytes (four each).
(b). Study of biotic interactions of the following: Stem parasite (*Cuscuta*), Root parasite (*Orobanch*) Epiphytes, Predation (Insectivorous plants).
6. Determination of minimal quadrat size for the study of herbaceous vegetation in the college campus, by species area curve method (species to be listed).
7. Determination of minimum number of quadrats for the study of herbaceous vegetation in the college campus
8. Quantitative analysis of herbaceous vegetation in the college campus for frequency and comparison with Raunkiaer's frequency distribution law.
9. 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. Bhattacharya K., Ghosh A.K., Hait G., (2017). A Text Book of Botany. Volume 4. New Central Book Agency (P) Ltd., Kolkata
4. Sharma, P.D. (2010). Ecology and Environment. Rastogi Publications, Meerut, India. 8th edition.
5. Wilkinson, D.M. (2007). Fundamental Processes in Ecology: An Earth Systems Approach. Oxford University Press. U.S.A.
6. Kormondy, E.J. (1996). Concepts of ecology. PHI Learning Pvt. Ltd., Delhi, India. 4th edition.

Core Course X: Plant Systematics THEORY (Credits: 4) Lectures: 60

Unit 1: Significance of Plant systematics (10 lectures)

Introduction to systematics; Plant identification, Classification, Nomenclature. Evidences from palynology, cytology, phytochemistry and molecular data. Field inventory; Functions of Herbarium; Important herbaria and botanic gardens of the world and India; Virtual herbarium; E-flora; Documentation: Flora, Monographs, Journals; Keys: Single access and Multi-access.

Unit 2: Taxonomic hierarchy (4 lectures)

Concept of taxa (family, genus, species); Categories and taxonomic hierarchy; Species concept (taxonomic, biological, evolutionary).

Unit 3: Botanical nomenclature (6 lectures)

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

Unit 4: Systems of classification (8 lectures)

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

Unit 5: Biometrics, numerical taxonomy and cladistics (8 lectures)

Characters; Variations; OTUs, character weighting and coding; Cluster analysis; Cladistics Vs Phenetics, Phenograms, cladograms (definitions and differences).

Unit 6: Phylogeny of Angiosperms (10 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.

Unit 7: family characteristics (14 lectures)

Diagnostic features, systematic position (Bentham & Hooker), economic importance of the following families:

DICOTS: Magnoliaceae, Cruciferae (Brassicaceae), Malvaceae, Leguminosae (Fabaceae) [including subfamilies], Euphorbiaceae, Solanaceae, Scrophulariaceae, Acanthaceae, Labiatae (Lamiaceae), Rubiaceae, Compositae (Asteraceae).

MONOCOT: Palmae (Arecaceae), Graminae (Poaceae), Cyperaceae, Musaceae, Zingiberaceae, Orchidaceae

Core Course X: Plant Systematics Practical (Credits: 2)

1. Study of vegetative and floral characters of the following families with local representatives (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, Malvaceae, Euphorbiaceae, Umbelliferae, Rubiaceae, Asteraceae, Solanaceae, Scrophulariaceae, Lamiaceae, Acanthaceae, Compositae, Poaceae, Zingiberaceae

2. Field visit (local) – Subject to grant of funds from the university.

3. Preparation and submission of herbarium specimen & field record.

Suggested Readings

1. Jeffrey, C. (1982). An Introduction to *Plant Taxonomy*. Cambridge University Press, Cambridge.
2. 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.
3. Bhattacharya K., Hait G., Ghosh A.K., (2008). *A Text Book of Botany*. Volume 2 . New Central Book Agency (P) Ltd., Kolkata
4. Radford, A.E. (1986). *Fundamentals of Plant Systematics*. Harper and Row, New York.

Semester-V

Core Course XI: Reproductive Biology of Angiosperms THEORY (Credits: 4) Lectures: 60

Unit 1: Introduction (4 lectures)

History (contributions of G.B. Amici, W. Hofmeister, E. Strasburger, S.G. Nawaschin, G.Erdtman, K. Faegri, 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: Molecular aspects (ABC model).

Unit 3: Anther and pollen biology (14 lectures)

Anther wall: Structure and functions, microsporogenesis, callose deposition and its significance. Microgametogenesis; Pollen unit, Polarity & symmetry, Pollen wall structure and its stratification, Sporoderm ornamentation, LO analysis, NPC system of pollen/spore classification; Palynology and its applications (a brief account); Pollen viability, storage and germination.

Unit 4: Ovule (8 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 5: Pollination and fertilization (6 lectures)

Pollination types and significance; Contrivances; pollen pistil interaction. double fertilization.

Unit 6: Self incompatibility (8 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; Cybrids, *in vitro* fertilization.

Unit 7: Embryo, Endosperm and Seed (10 lectures)

Structure and types; General pattern of development of dicot and monocot embryo and endosperm; Suspensor: structure and functions; Molecular aspect of embryo development. Seed structure, importance.

Units 8: Polyembryony and apomixis (4 lectures)

Introduction; Classification; Causes and applications.

Core Course XI: Reproductive Biology of Angiosperms Practical (Credits: 2)

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 and *in vitro* test.
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; Study of suspensor through electron micrographs.

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. Bhattacharya, K., Majumdar M.R., Gupta Bhattacharya, S. 2007. A Textbook of Palynology. New Central Book Agency, Kolkata
4. Raghavan, V. (2000). Developmental Biology of Flowering plants, Springer, Netherlands.
5. Johri, B.M. 1 (1984). Embryology of Angiosperms, Springer-Verlag, Netherlands.

Core Course XII: Plant Physiology THEORY (Credits: 4) Lectures: 60

Unit 1: Plant-water relations (14 lectures)

Water Potential and its components; pathways of water movement in plant: symplast, apoplast, transmembrane pathways, water absorption by roots, root pressure and guttation. Ascent of sap—cohesion-tension theory. Transpiration and factors affecting transpiration, mechanism of stomatal movement

Unit 2: Mineral nutrition (8 lectures)

Essential elements, macro and micronutrients, criteria for essentiality, mineral deficiency symptoms and roles of essential elements

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 and antiport channels

Unit 4: Translocation in the phloem (8 lectures)

Source–sink relationship, experimental evidence in support of phloem as the site of sugar translocation. Phloem loading and unloading, Pressure-Flow hypothesis for long-distance transport

Unit 5: Plant growth regulators (14 lectures)

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

Unit 6: Physiology of flowering (8 lectures)

Photoperiodism, role of phytochrome; flowering stimulus, florigen concept; vernalization

**Core Course XII: Plant Physiology
Practical (Credits: 2)**

1. Determination of osmotic pressure by plasmolytic method.
2. To study the effect of seed coat on imbibition of water by seeds
3. Determination of rate of transpiration by two surfaces of a leaf
4. Calculation of stomatal index and stomatal frequency of a leaf
5. Calculation of total stomatal pore area of a surface of a leaf

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. and Huner, A. (2008). Introduction to Plant Physiology. John Wiley and Sons. U.S.A. 4th edition.
3. Ghosh A.K., Bhattacharya K., Hait G., (2015). A Text Book of Botany. Volume 3. New Central Book Agency (P) Ltd., Kolkata
4. Bajracharya D. (1999). Experiments in Plant Physiology-A Laboratory Manual. Narosa Publishing House, New Delhi.

Semester-VI

Core Course XIII: Plant Metabolism THEORY (Credits: 4) Lectures: 60

Unit 1: Concept of metabolism (6 lectures)

Introduction, anabolic and catabolic pathways; regulation of metabolism: types of regulation (allosteric and covalent modulation) and regulatory enzymes, Isozymes

Unit 2: Carbon assimilation (14 lectures)

Historical background, photosynthetic pigments (chlorophylls and accessory pigments) and their role, antenna molecules and reaction centres, photosystems and photochemical reactions, photosynthetic electron transport; CO₂ fixation: C₃ pathway, photorespiration, C₄ pathways, Crassulacean acid metabolism; Factors affecting photosynthesis

Unit 3: Carbohydrate metabolism (10 lectures)

Glycolysis, fate of pyruvate, oxidative pentose phosphate pathway, TCA cycle, mitochondrial electron transport, factors affecting respiration

Unit 4: ATP-Synthesis (10 lectures)

Mechanism of ATP synthesis, substrate level phosphorylation, chemiosmotic mechanism (oxidative and photophosphorylation), ATP synthase complex

Unit 5: Lipid metabolism (10 lectures)

Breakdown of triglycerides, β -oxidation, glyoxylate cycle, gluconeogenesis

Unit 6: Nitrogen metabolism (10 lectures)

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

Core Course XIII: Plant Metabolism (Credits: Practical-2)

1. Chemical separation of photosynthetic pigments.
2. To study the effect of light intensity on the rate of photosynthesis
3. Demonstration of fluorescence by isolated chlorophyll pigments
4. Effect of carbon dioxide on the rate of photosynthesis.
5. To compare the rate of respiration in different parts of a plant.

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. and Huner, A. (2008). Introduction to Plant Physiology. John Wiley and Sons. U.S.A. 4th edition.
3. Harborne, J.B. (1973). Phytochemical Methods. John Wiley & Sons. New York.
4. Ghosh A.K., Bhattacharya K., Hait G., (2015). A Text Book of Botany. Volume 3 . New Central Book Agency (P) Ltd., Kolkata

Core Course XIV: Plant Biotechnology THEORY (Credits: 4) Lectures: 60

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 (LUC, 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); Genetically Engineered Products–Human Growth Hormone; Humulin; Biosafety concerns.

Core Course XIV: Plant Biotechnology Practical (Credits: 2)

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.
6. Ghosh A.K., Bhattacharya K., Hait G., (2015). A Text Book of Botany. Volume 3 . New Central Book Agency (P) Ltd., Kolkata

Discipline Specific Elective Courses

Semester V

DSE-1: Analytical Techniques in Plant Sciences THEORY (Credits: 4) Lectures: 60

Unit 1: Imaging and related techniques (12 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, CsCl₂ gradient, analytical centrifugation, ultracentrifugation, marker enzymes.

Unit 3: Radioisotopes (4 lectures)

Use in biological research, radio-immuno assay, 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 (10 lectures)

Mass spectrometry; X-ray diffraction; X-ray crystallography; MALDI TOFF. Characterization of proteins and nucleic acids; Electrophoresis: 1-D, 2-D, AGE, PAGE, SDS-PAGE, ELISA, Western blotting.

Unit 7: Biostatistics (14 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.

DSE-1: Analytical Techniques in Plant Sciences Practical (Credits: 2)

1. Study of Blotting techniques: Southern, Northern and Western, DNA fingerprinting, DNA sequencing, PCR through photographs.
2. Demonstration of ELISA.
3. To separate nitrogenous bases by paper chromatography.

4. To separate sugars by thin layer chromatography.
5. Isolation of chloroplasts by differential centrifugation.
6. To separate chloroplast pigments by column chromatography.
7. To estimate protein concentration through Lowry's methods.
8. To separate proteins using PAGE.
9. To separation DNA (marker) using AGE.
10. Study of different microscopic techniques using photographs/micrographs (freeze fracture, freeze etching, negative staining, positive staining, fluorescence and FISH).
11. Preparation of permanent slides (double staining).

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.

DSE-2: Plant Breeding THEORY (Credit: 4) Lectures: 60

Unit 1: Plant Breeding (10 lectures)

Introduction and objectives. Breeding systems: modes of reproduction in crop plants. Important achievements and undesirable consequences of plant breeding.

Unit 2: Methods of crop improvement (20 lectures)

Introduction: Centres of origin and domestication of crop plants, plant genetic resources; Acclimatization; Selection methods: For self pollinated, cross pollinated and vegetatively propagated plants; Hybridization: For self, cross and vegetatively propagated plants – Procedure, advantages and limitations.

Unit 3: Quantitative inheritance (10 lectures)

Concept, mechanism, examples of inheritance of Kernel colour in wheat, Skin colour in human beings. Monogenic vs polygenic Inheritance.

Unit 4: Inbreeding depression and heterosis (10 lectures)

History, genetic basis of inbreeding depression and heterosis; Applications.

Unit 5: Crop improvement and breeding (10 lectures)

Role of mutations; Polyploidy; Distant hybridization and role of biotechnology in crop improvement.

DSE-2: Plant Breeding Practical (Credit: 2)

1. Practice of different method of vegetative propagation: cutting, layering, grafting, gootie
2. Practice of hybridization: emasculation, pollination, bagging
3. Estimation of lethal doses of mutagen based on seed germination percentage
4. Study of effect of colchicine on bulb of *Allium* sp.
5. Study of field designs frequently used in plant breeding

Suggested Readings

1. Singh, B.D. (2005). Plant Breeding: Principles and Methods. Kalyani Publishers. 7th edition.
2. Chaudhari, H.K. (1984). Elementary Principles of Plant Breeding. Oxford – IBH. 2nd edition.
3. Acquaah, G. (2007). Principles of Plant Genetics & Breeding. Blackwell Publishing.

Semester VI

DSE-3: Industrial and Environmental Microbiology THEORY (Credits: 4) Lectures: 60

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

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

Concept of different types of culture media; Importance of different macro and micro nutrients used in culture media; Importance of microorganisms being used in industries; Microbial growth in solid and liquid culture media; Concept of pure culture and consortium; Solid-state and liquid-state (stationary and submerged) fermentations; Batch and continuous fermentations; Components of a typical bioreactor; 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)

Specific media and culture conditions involved in screening of different enzymes; 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); Steps in optimization of production; Hydrolytic enzymes from microorganisms for industrial applications: casein hydrolysis; lipid hydrolysis; starch hydrolysis; and cellulose hydrolysis. Methods of immobilization, advantages and applications of immobilization, large scale applications of immobilized enzymes (glucose isomerase and penicillin acylase); Single cell proteins; Probiotics and prebiotics; Biofuels and biogas production

Unit 4: Environmental Microbiology and Microbial Ecology (8 lectures)

Biogeochemical cycling of Carbon and Nitrogen and role of microorganisms therein; The great plate count anomaly; Concept of cultivable and uncultivable microorganisms; Brief idea about the study of uncultivable microorganisms from environmental samples

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

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

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: coliform in water samples.

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

Biological nitrogen fixation; Mycorrhizae; Isolation of root nodulating bacteria, Biofertilizers; endophytic microorganisms; Bioremediation of contaminated soils; Xenobiotic compounds; Role of plasmids in bioremediation.

**DSE-3: Industrial and Environmental Microbiology
Practical (Credits: 2)**

1. Principles and functioning of instruments in microbiology laboratory
2. Hands on sterilization techniques and preparation of culture media
3. Demonstration of isolation of bacteria from air
4. Demonstration of ready plates for understanding the screening of some industrial important enzymes
5. A visit to any educational institute/industry to see an industrial fermenter, and other downstream processing operations.

Suggested Readings

Madigan, M.T., Martinko, J.M., Stahl, D.A., Clark, D.P. (2014). Brock Biology of Microorganisms; Pearson Education; 14th Edition.

**DSE- 4: Biostatistics
THEORY (Credits: 4) Lectures: 60****Unit 1: Biostatistics (12 lectures)**

Definition - statistical methods - basic principles. Variables - measurements, functions, limitations and uses of statistics.

Unit 2: Collection of data primary and secondary (12 lectures)

Types and methods of data collection procedures - merits and demerits. Classification - tabulation and presentation of data - sampling methods.

Unit 3: Measures of central tendency (14 lectures)

Mean, median, mode, geometric mean - merits and demerits. Measures of dispersion - range, standard deviation, mean deviation, quartile deviation - merits and demerits; Co-efficient of variations.

Unit 4: Correlation (12 lectures)

Types and methods of correlation, regression, simple regression equation, fitting prediction, similarities and dissimilarities of correlation and regression

Unit 5: Statistical inference (10 lectures)

Hypothesis - simple hypothesis - student 't' test - chi square test.

**DSE- 4: Biostatistics
Practical (Credits: 2)**

- 1) Calculation of mean, standard deviation and standard error
- 2) Calculation of correlation coefficient values and finding out the probability
- 3) Calculation of 'F' value and finding out the probability value for the F value.

Suggested Readings

1. Biostatistic, Danniell, W.W., 1987. New York, John Wiley Sons.
2. An introduction to Biostatistics, 3rd edition, Sundarrao, P.S.S and Richards, J. Christian Medical College, Vellore
3. Statistical Analysis of epidemiological data, Selvin, S., 1991. New York University Press.
4. Statistics for Biology, Boston, Bishop, O.N. Houghton, Mifflin.
5. The Principles of scientific research, Freedman, P. New York, Pergamon Press.
6. Statistics for Biologists, Campbell, R.C., 1998. Cambridge University Press.

Generic Elective Courses

Semester I

GE-1: Biodiversity (Microbes, Algae, Fungi and Archegoniate) THEORY (Credits: 4) Lectures: 60

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 archegoniate, 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.

GE-1: Biodiversity (Microbes, Algae, Fungi and Archegoniate) Practical (Credits: 2)

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; EM bacterium; 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. (* *Fucus* - Specimen and permanent slides)
5. *Rhizopus* and *Penicillium*: Asexual stage from temporary mounts and sexual structures through permanent slides.
6. *Alternaria*: Specimens/photographs and tease mounts.
7. *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.
8. *Agaricus*: Specimens of button stage and full grown mushroom; Sectioning of gills of *Agaricus*.
9. Lichens: Study of growth forms of lichens (crustose, foliose and fruticose)
14. Mycorrhiza: ecto mycorrhiza and endo mycorrhiza (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. 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.

2. Tortora, G.J., Funke, B.R., Case, C.L. (2010). Microbiology: An Introduction, Pearson Benjamin Cummings, U.S.A. 10th 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 and Sons (Asia), Singapore. 4th edition.
5. Banerjee A.K., Banerjee N. 2010. Microbiology. New Central Book Agency (P) Ltd., Kolkata
6. Hait G., Bhattacharya K., Ghosh A.K., (2007). A Text Book of Botany. Volume 1 . New Central Book Agency (P) Ltd., Kolkata
7. Bhattacharya K., Hait G., Ghosh A.K., (2008). A Text Book of Botany. Volume 2 . New Central Book Agency (P) Ltd., Kolkata
8. Vashishta, P.C., Sinha, A.K., Kumar, A., (2010). Pteridophyta, S. Chand. Delhi, India.
9. Bhatnagar, S.P. and Moitra, A. (1996). Gymnosperms. New Age International (P) Ltd Publishers, New Delhi, India.

Semester II

GE-2: Plant Ecology and Taxonomy THEORY (Credits: 4) Lectures: 60

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, Seral stages- hydrosere

Unit 4: Ecosystem (8 lectures)

Structure; Ecological 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 of India; Endemism- concept and theories, Biological hotspots

Unit 6 Introduction to plant taxonomy (2 lectures)

Identification, Classification, Nomenclature.

Unit 7 Identification (4 lectures)

Functions of Herbarium, important herbaria and botanic 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).

GE-2: Plant Ecology and Taxonomy Practical (Credits: 2)

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, and analysis of two soil samples for carbonates, chlorides, nitrates, sulphates, organic matter and base deficiency by rapid field test.
3. Comparison of bulk density, porosity and rate of infiltration of water in soil of three habitats.
4. (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)
5. Determination of minimal quadrat size for the study of herbaceous vegetation in the college campus by species area curve method. (species to be listed)
6. Quantitative analysis of herbaceous vegetation in the college campus for frequency and comparison with Raunkiaer's frequency distribution law
7. 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 Asteraceae; Solanaceae; Lamiaceae; Euphorbiaceae, Rubiaceae, Liliaceae.
8. Mounting of properly dried and pressed specimen of 20 wild plants with herbarium label (to be submitted along with 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. Bhattacharya K., Hait G., Ghosh A.K., (2008). A Text Book of Botany. Volume 2 . New Central Book Agency (P) Ltd., Kolkata

5. Bhattacharya K., Ghosh A.K., Hait G., (2017). A Text Book of Botany. Volume 4 . New Central Book Agency (P) Ltd., Kolkata

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

Semester III

GE-3: Plant Anatomy and Embryology **THEORY (Credits: 4) Lectures: 60**

Unit 1: Meristematic and permanent tissues (8 lectures)

Root and shoot apical meristems; Simple and complex tissues.

Unit 2: Organs (4 lectures)

Structure of dicot and monocot root, stem and leaf.

Unit 3: Secondary Growth (8 lectures)

Vascular cambium – structure and function. Secondary growth in root and stem, Wood (heartwood and sapwood).

Unit 4: Adaptive and protective systems (8 lectures)

Epidermis, cuticle, stomata. Anatomical adaptations in xerophytes and hydrophytes.

Unit 5: Structural organization of flower (8 lectures)

Structure of anther and pollen. Structure and types of ovules. Embryo sacs : Types, organization and ultrastructure of mature embryo sac.

Unit 6: Pollination and fertilization (8 lectures)

Pollination mechanisms and adaptations; Double fertilization. Seed-structure appendages and dispersal mechanisms.

Unit 7: Embryo and endosperm (8 lectures)

Endosperm types, structure and functions; Dicot and monocot embryo; Embryo endosperm relationship.

Unit 8: Apomixis and polyembryony (8 lectures)

Definition, types and practical applications.

GE-3: Plant Anatomy and Embryology Practical (Credits: 2)

1. Study of meristems through permanent slides and photographs.
2. Tissues (parenchyma, collenchyma and sclerenchyma); Macerated xylary elements, Phloem (Permanent slides, photographs)
3. Stem: Monocot: *Zea mays*; Dicot: *Helianthus*; Secondary: *Cassia* tree (only Permanent slides).
4. Root: Monocot: *Colocasia*; Dicot: *Cicer* ; Secondary: *Tinospora* (only Permanent slides).
5. Leaf: Dicot and Monocot leaf (only Permanent slides).
6. Adaptive anatomy: Xerophytes (*Nerium* leaf); Hydrophyte (*Hydrilla* stem).
7. Structure of anther (young and mature), tapetum (amoeboid and secretory) (Permanent slides).
8. Types of ovules: anatropous, orthotropous, circinotropous, amphitropous/campylotropous.
9. Female gametophyte: *Polygonum* (monosporic) type of embryo sac development (Permanent slides/photographs).
10. Ultrastructure of mature egg apparatus cells through electron micrographs.
11. Pollination types and seed dispersal mechanisms (including appendages, aril, caruncle) (Photographs and specimens).
12. Dissection of embryo/endosperm from developing seeds.
13. Calculation of percentage of germinated pollen in a given medium.

Suggested Readings

1. Bhojwani, S.S. & Bhatnagar, S.P. (2011). Embryology of Angiosperms. Vikas Publication House Pvt. Ltd. New Delhi. 5th edition.
2. Mauseth, J.D. (1988). Plant Anatomy. The Benjamin/Cummings Publisher, USA
3. Bhattacharya K., Hait G., Ghosh A.K., (2008). A Text Book of Botany. Volume 2 . New Central Book Agency (P) Ltd., Kolkata
4. Bhattacharya, K., Majumdar M.R., Gupta Bhattacharya, S. 2007. A Textbook of Palynology. New Central Book Agency, Kolkata

Semester IV

GE-4: Plant Physiology and Metabolism THEORY (Credits: 4) Lectures: 60

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

U nit 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; C₃, C₄ and CAM pathways of carbon fixation; Photorespiration.

Unit 5: Respiration (6 lectures)

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

U nit 6: Enzymes (4 lectures)

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

U nit 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.

**GE-4: Plant Physiology and Metabolism
Practical (Credits: 2)**

1. Determination of osmotic potential of plant cell sap by plasmolytic method.
2. To study the effect of two environmental factors (light and wind) on transpiration by excised twig.
3. Calculation of stomatal index and stomatal frequency of a mesophyte and a xerophyte.
4. Demonstration of Hill reaction.
5. Demonstrate the activity of catalase and study the effect of pH and enzyme concentration.
6. To study the effect of light intensity and bicarbonate concentration on O₂ evolution in photosynthesis.
7. Comparison of the rate of respiration in any two parts of a plant.
8. Separation of amino acids by paper chromatography.

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.
4. Ghosh A.K., Bhattacharya K., Hait G., (2015). A Text Book of Botany. Volume 3 . New Central Book Agency (P) Ltd., Kolkata

Skill Enhancement Courses

Semester III

SEC- 1: Biofertilizers (Credits 2) Lectures: 30

Unit 1: (5 lectures)

Importance of essential elements in biological system. Role of micro-organisms in mobilization of such elements with special emphasis of nitrogen fixation and phosphate solubilisation. Concept of plant growth promoting bacteria in making biofertilizers

Unit 2: (4 lectures)

General account about the microbes used as biofertilizer – Rhizobium – isolation, identification, mass multiplication, carrier based inoculants, Actinorrhizal symbiosis.

Unit 3: (4 lectures)

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.

Unit 4: (4 lectures)

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

Unit 5: (8 lectures)

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.

Unit 6: (5 lectures)

Organic farming – Green manuring and organic fertilizers, Recycling of biodegradable municipal, agricultural and Industrial wastes – biocompost making methods, types and method of vermicomposting – field Application.

Suggested Readings

1. Subha Rao, N.S. 2000, Soil Microbiology, Oxford & IBH Publishers, New Delhi.
2. Kumaresan, V. 2005, Biotechnology, Saras Publications, New Delhi.
3. John Jothi Prakash, E. 2004. Outlines of Plant Biotechnology. EmkayPublication, New Delhi.
4. Sathe, T.V. 2004 Vermiculture and Organic Farming. Daya publishers.
5. Vayas, S.C, Vayas, S. and Modi, H.A. 1998. Bio-fertilizers and organic Farming. Akta Prakashan, Nadiad

SEC-1: Mushroom Culture Technology **(Credits 2) Lectures: 30**

Unit 1: (5 Lectures)

Introduction, history. Nutritional and medicinal value of edible mushrooms; Poisonous mushrooms. Types of edible mushrooms available in India - *Volvariella volvacea*, *Pleurotus citrinopileatus*, *Agaricus bisporus*.

Unit 2: (12 Lectures)

Cultivation Technology: Infrastructure: substrates (locally available) Polythene bag, vessels, Inoculation hook, inoculation loop, low cost stove, sieves, culture rack, mushroom unit (Thatched house) water sprayer, tray, small polythene bag. Pure culture: Medium, sterilization, preparation of spawn, multiplication. Mushroom bed preparation - paddy straw, sugarcane trash, maize straw, banana leaves. Factors affecting the mushroom bed preparation - Low cost technology, Composting technology in mushroom production.

Unit 3: (8 Lectures)

Storage and nutrition: Short-term storage (Refrigeration - upto 24 hours) Long term Storage (canning, pickles, papads), drying, storage in salt solutions. Nutrition - Proteins - amino acids, mineral elements nutrition - Carbohydrates, Crude fibre content - Vitamins.

Unit 4: (5 lectures)

Food Preparation: Types of foods prepared from mushroom. Research Centres - National level and Regional level. _ Cost benefit ratio - Marketing in India and abroad, Export Value.

Suggested Readings

1. Marimuthu, T. Krishnamoorthy, A.S. Sivaprakasam, K. and Jayarajan. R (1991) Oyster Mushrooms, Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore.
2. Swaminathan, M. (1990) Food and Nutrition. Bappco, The Bangalore Printing and Publishing Co. Ltd., No. 88, Mysore Road, Bangalore - 560018.
3. Tewari, Pankaj Kapoor, S.C., (1988). Mushroom cultivation, Mittal Publications, Delhi.
4. Nita Bahl (1984-1988) Hand book of Mushrooms, II Edition, Vol. I & Vol. II

Semester IV

SEC-2: Herbal Technology (Credits 2) Lectures: 30

Unit 1: (6 Lectures)

Herbal medicines: History and scope. Importance of medicinal plants in Indian systems of medicine (Ayurveda, Unani & Siddha). Harvesting - processing - storage -marketing and utilization of medicinal plants. Cultivation of medicinal plants- *Andrographis*, *Rauwolfia* and *Withania* .

Unit 2: (6 Lectures)

Pharmacognosy: Definition and scope. Classification of crude drugs. Systematic position and medicinal uses of the following plants in curing various ailments: Tulsi, Ginger, Fenugreek, Indian Goose berry and Ashoka.

Unit 3: (8 Lectures)

Phytochemistry: Drug constituents – chemistry of major phytochemical groups (in brief). Active principles and their microchemical tests, organoleptic fetures, macro and microscopic features and utilization of the medicinal plants : *Catharanthus roseus* (anticancerous), *Digitalis purpurea* (cardiotonic), *Withania somnifera* (adaptogenic), *Terminalia chebula* (laxative) , *Strychnos nux-vomica* (circulatory stimulant & digestive) and *Cinchona* spp. (antimalarial).

Unit 4: (6 Lectures)

Analytical pharmacognosy: Drug adulteration – types. Methods of drug evaluation; Biological testing of herbal drugs; Phytochemical screening tests for secondary metabolites (alkaloids, glycosides, steroids, triterpenoids, flavonoids, tannins and other phenolic compounds).

Unit 5: (4 Lectures)

Medicinal plant germplasm banks, micro propagation of important species (*Withania somnifera*, *Rauwolfia serpentina* and tulsi). Herbal foods- future of Pharmacognosy.

Suggested Readings

- 1) Agnes A. (1999) Herbal plants and Drugs. Mangal Deep Publication. Jaipur, India.
- 2) Ali M. (1998) Textbook of Pharmacognosy. CBS Publishers and Distributors, New Delhi.
- 3) Bhattacharya K., Ghosh A.K. and Hait G. (2015) A Text Book of Botany. Volume 3 . New Central Book Agency (P) Ltd., Kolkata.
- 4) Chopra R.N., Nayar S.L. and Chopra I.C. (1956) Glossary of Indian Medicinal Plants. C.S.I.R., New Delhi.
- 5) Evans W.C. (2008) Trease and Evans Pharmacognosy. 15th edn. Saunders- Elsevier.
- 6) Green A. (2000) Principles of Ayurveda. Thorsons, London.

- 7) Kanny L. D. and Bahadur R. (1896) The indigenous drugs of India: Short descriptive notice of the principle medicinal products met with in British India. Thacker, Spink. London.
- 8) Kokate C.K., Purohit A.P. and Gokhale S.B. (1999) Pharmacognosy. Nirali Prakashan, Pune, India.
- 9) Miller L. and Miller B. (1998) Ayurveda and Aromatherapy: The Earth Essential Guide to Ancient Wisdom and Modern Healing. Motilal Banarsidass Publ., Delhi, India.
- 10) Sivarajan V.V. and Balachandran I. (1994) Ayurvedic drugs and their plant sources. Oxford & IBH Publishing Co., India.

SEC-2: Ethnobotany (Credits 2) Lectures: 30

Unit 1: Ethnobotany (8 Lectures)

Ethnobotany: Introduction, scope and objectives. Ethnobotany as an interdisciplinary science; its relevance in the present context. Ethnic groups or Tribals of India: A brief introduction. Plants used by the tribals – as food, intoxicants and beverages, for household materials, musical instruments, tattooing, magico-religious belief, and for ethnoveterinary and ethnomedicinal purposes.

Unit 2: Methodology of Ethnobotanical studies (6 lectures)

a) Field work: Prior informed consent (PIC), common methods for data collection; a few statistical tools for data analysis; documentation of the ethnobotanical knowledge. Collection of ethnobotanical data from other sources: a) Herbarium b) Ancient Literature c) Archaeological findings d) temples and sacred places.

Unit 3: Role of ethnobotany in modern Medicine (10 lectures)

Medico-ethnobotanical sources in India. Significance of the following plants in ethnobotanical practices (along with their general description, distribution, habitat and morphology of the parts used): a) *Azadirachta indica*, b) *Ocimum sanctum*, c) *Vitex negundo*, d) *Gloriosa superba*, e) *Tribulus terrestris*, f) *Pongamia pinnata*, g) *Madhuca indica*, h) *Indigofera tinctoria*.

Ethnobotany and Bioprospecting : Role of ethnobotany in modern medicine with examples of *Rauvolfia serpentina*, *Trichopus zeylanicus*, *Bacopa monnieri*, *Commiphora wightii*, *Picrorrhiza kurrooa*, *Artemisia annua* and *Withania somnifera*.

Ethno-conservation: Role of ethnic practices in conservation of plant genetic sources; sacred groves. Tribal people and forest management (participatory forest management).

Unit 4: Ethnobotany and legal aspects (6 lectures)

Ethnobotany as a tool to protect the interests of ethnic groups. Sharing of benefit concept with few examples from India. Biopiracy; Intellectual Property Rights and Traditional Knowledge.

Suggested Readings

- 1) Bhattacharya K., Ghosh A.K., Hait G., (2017). A Text Book of Botany. Volume 4. New Central Book Agency (P) Ltd., Kolkata, India.
- 2) Cotton C.M. (1997) Ethnobotany – Principles and Applications. John Wiley and sons.
- 3) Faulks P.J. (1958) An introduction to Ethnobotany. Moredale Pub. Ltd.
- 4) Jain S.K. (ed.) (1981) Glimpses of Indian Ethnobotany. Oxford and I B H Publishing Co., New Delhi.
- 5) Jain S.K. (1995) Manual of Ethnobotany. Scientific Publishers, Jodhpur, India.
- 6) Jain S.K. (ed.) (1989) Methods and Approaches in Ethnobotany. Society of Ethnobotanists, NBRI, Lucknow, India.
- 7) Jain S.K. (1990) Contribution to Indian Ethnobotany. Scientific Publishers, Jodhpur, India.
- 8) Jain S.K. and Mudgal V (1999) A Handbook of Ethnobotany. Bishen Singh and Mahendra Pal Singh, Dehra Dun, India.
- 9) Lone et al., Palaeoethnobotany
- 10) Martin, G.J. 1995. Ethnobotany: A methods manual. Chapman and Hall, London.
- 11) Pal D.C. and Jain S.K. (1989) Tribal Medicine. Naya Prakash, Kolkata.
- 12) Rama R.N. and Henry A.N. (1996) The Ethnobotany of Eastern Ghats in Andhra Pradesh, India. Botanical Survey of India, Howrah, India.
- 13) Sinha R. K. (1996) Ethnobotany: The Renaissance of Traditional Herbal Medicine. INA – SHREE Publishers, Jaipur, India.