# Department of Botany

# University of Delhi

# POST-GRADUATE CURRICULAR FRAMEWORK IN BOTANY - 2025

## (BASED ON NEP 2020)

## (Students opting for two-year M.Sc. Botany program will study courses listed in Semesters I & II)

## M.Sc. I$^{st}$ year syllabus (w.e.f. July 2025)

# POST-GRADUATE CURRICULAR FRAMEWORK IN BOTANY - 2025

# (BASED ON NEP 2020) - COURSEWORK + RESEARCH

### M.Sc. Botany Ist Year Syllabus w.e.f. 2025

| SEMESTER | DSC (4x3=12 credits) (2 Credits Theory + 2 Credits Practical) | DSE & GE (4x2=8 Credits)* (2 Credits Theory + 2 Credits Practical) | SKILL BASED COURSE/SPECIALISED LABORATORY (2 Credits) | DISSERTATION | TOTAL CREDITS |
|---|---|---|---|---|---|
| I | **DSC-1** Biology of Algae and Microbes | **DSE-1** Traditional Knowledge Systems | **SBC-1** Laboratory and Field Experiments in Plant Biology | NIL | 22 |
| | **DSC-2** Biology of Bryophytes, Pteridophytes and Gymnosperms | **DSE-2** Recombinant DNA Technology | | | |
| | | **DSE-3** Molecular Biology | | | |
| | **DSC-3** Plant Taxonomy and Evolution | Choose any two **DSE** Or one **DSE** and any one **GE** offered by other Departments | | | |
| II | **DSC-4** Developmental Biology of Plants | **DSE-3** Industrial Microbiology | **SBC-2** Analytical Techniques in Plant Biology | NIL | 22 |
| | | **DSE-4** Evolutionary Biology | | | |
| | **DSC-5** Pathogens and Pests of Crop Plants | **DSE-5** Basics of Proteomics | | | |
| | **DSC-6** Physiology and Biochemistry | Choose any two **DSE** Or one **DSE** and any one **GE** offered by other Departments | | | |

* Students can opt for two DSE papers OR one DSE and one GE paper offered by other Departments.

The following GEs will be offered by the Department for students other than M.Sc. Botany:
**GE-1** Plants, People and The Planet (To be offered in Semester I)
**GE-2** Climate Change and Ecosystem Function (To be offered in Semester II)

# Index and syllabus of courses being offered in M.Sc. Botany Semester I & II

# Semester I

## DISCIPLINE SPECIFIC CORE COURSE-1

## Biology of Algae and Microbes

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Biology of Algae and Microbes DSC-1** | **4** | **2** | **0** | **2** | **Graduate with Botany as one of the subjects** | **Nil** |

**Course Objectives:**

This course aims to enhance students' understanding of the diversity, ecological significance, and economic importance of algae, bacteria, and viruses. It covers their classification, structural characteristics, life cycles, and growth patterns.

**Course Learning Outcomes:**

1. The course will increase the understanding of the students about the diversity, classification, structure, and growth of algae and microorganisms.
2. It will also develop theoretical knowledge and technical skills in fundamental of Phycology and microbiology.
3. Students will realize the heterogeneity and polyphyletic nature of the algae as a group. They will also be apprised of their diversity in form, structure and reproduction and the diverse habitats where algae abound.
4. Students will become aware of algae's evolving systematics and become familiar with the characteristics of presently accepted different groups and interrelationships among these groups.
5. Students will realize the vast economic, ecological and biotechnological project and realized potential of this group. They will learn basic knowledge of microbiology. Isolate and culture bacteria from nature, learn important microscopic characteristics, adaptation to hosts, modes of infections, intra-cellular and genetic/genomic features.

**Theory: 15 x 2 hrs.= 30 hours**

**Contents:**

**Unit I: Algal diversity and Systematics: (10 hours)**

Cell structure, thallus organization, reproductive strategies and types of life cycles (Haplontic, diplontic, and haplodiplontic cycles). Diversity of algal groups and their evolutionary relationships: Cyanophyta (Cyanobacteria), Glaucophyta, Rhodophyta (Red Algae), and Viridiplantae (Green Algae and related lineages). Heterokontophyta (Bacillariophyceae - Diatoms, Phaeophyceae - Brown Algae, and other classes). Dinophyta (Dinoflagellates), Cryptophyta, Euglenophyta, Haptophyta, and Chlorarachniophyta. Advances in molecular systematics and phylogenetics of algae.

**Unit II: Ecological and economical importance of algae: (6 hours)**

Ecological significance: algae as primary producers and $CO_2$ fixers in global carbon cycles; algal blooms, eutrophication, and their environmental impact. Biotechnological and industrial applications: algae as biofactories: production of bioactive compounds, biofuels, bioplastics, and sustainable resource utilization.

**Unit III: Bacteria (10 hours)**

Classification of bacteria according to Berger's Manual of Determinative Bacteriology. Ultra structure of bacteria and archaea (cell wall, flagella, fimbriae, pilli, slime layer, S-layers; cell membrane; mesosomes, ribosomes, cytoplasmic inclusion bodies and nucleoid). Bacterial nutrition and growth. Genetic recombination and transformation.

**Unit IV**: **Viruses (4 hours)**

General properties of viruses; Viral genomes; Plant viruses – replication, transmission and interaction with host plants, Phage biology: features and economic importance; natural mechanisms and transgenic strategies for virus resistance, relevance to Indian agriculture.

**Practicals: 15 x 4 hrs.= 60 hours.**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. To study different types of algae by collecting water samples from different water bodies.
2. To study thallus, cryptostomata and reproductive structure of *Sargassum*.
3. To study thallus, and reproductive structure (carpogonium, conceptacles and cystocarp) of *Gracilaria*.
4. To study morphology of museum specimens.

5. To study the vegetative and reproductive structures using permanent slides: Chlorophycean, Cyanophycean, Xanthophycean, Rhodophycean and Phaeophycean members.
6. To study sterilization, isolation, culturing, and preservation of bacteria.
7. To measure dimension of microbial spores using stage and ocular micrometers.
8. To determine the density of given spore suspension using a haemocytometer.
9. Isolation of microbes producing enzymes of industrial importance.
10. Identification of disease symptoms caused by common plant viruses in field-collected samples.
11. Principles of serology and data analysis for ELISAs to identify plant viruses.

**Suggested Readings:**

1. Sahoo, D. (2000). *Farming the ocean: seaweeds cultivation and utilization.* 1st edition. Aravali International, New Delhi.
2. Sahoo, D. and Seckbech, J. (Eds) (2015). *The Algae World*, 1st edition. Springer, Dordrecht.
3. Willey, J M., Sandman, K. and Wood, D. (2022). *Prescott's Microbiology*, 12th Edition, McGraw-Hill Education, USA
4. Hull, R. (2013). *Plant Virology*, 5th edition. Academic Press, Elsevier, USA**.**
5. Lee, R.E. (2018). *Phycology*, Fifth Edition. Cambridge University Press, Cambridge.

**Additional Readings:**

6. Barsanti, L. and Gualtieri, P. (2021). *Algae: Anatomy, Biochemistry, and Biotechnology*, 3rd edition. CRC Press, New York.
7. Graham, L.E., Graham, J.M. and Wilcox, L.W. (2009) *Algae*, 2nd Edition. Benjamin Cummings, California.
8. Maloy, S.R., Cronan, J.E. and Freifelder, D. (1994). *Microbial Genetics*, 2nd edition. Jones & Bartlett Publishers, USA.
9. Pelczar M.J., Chan E.C.S and Krieg N.R. (1997). *Microbiology: An Application Based Approach*, 5th edition. Tata McGraw-Hill, India.
10. Van Den Hoek, C., Mann, D.G. and Jhans, H.M. (1995). *Algae: An Introduction to Phycology*, 1st edition. Cambridge University Press, Cambridge.
11. Whitman, W.B., Goodfellow, M., Kämpfer, P., Busse, H.-J., Trujillo, M.E., Ludwig, W. and Suzuki, K.-i. (eds., 2012). Bergey's Manual of Systematic Bacteriology, 2nd ed., vol. 5, parts A and B, Springer-Verlag, New York, NY.

## DISCIPLINE SPECIFIC CORE COURSE - 2

### Biology of Bryophytes, Pteridophytes and Gymnosperms

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Biology of Bryophytes, Pteridophytes and Gymnosperms DSC-2 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives:**

The course aims to have understanding of evolutionary diversification of early land plants and morphological and reproductive innovations in land plants, bryophytes, pteridophytes and gymnosperms and to have understanding the process of evolution in a broad sense. To have a knowledge base in understanding plant diversity, economic values, taxonomy of lower group of plants through study of morphology, anatomy, reproduction and developmental changes in these plants.

**Course Learning Outcomes:**

The students will be learning about

1. The organ formation occurred in the early land plants that resulted in the diversity of species of "bryophytes", "pteridophytes" and "gymnosperms"?
2. The strategies for conduction of water and photosynthates?
3. The reproductive strategies and breeding systems in bryophytes, pteridophytes and gymnosperms?
4. The ecological and economic importance of bryophytes, pteridophytes and gymnosperms that help to understand their role in ecosystem functioning.
5. The threats to biodiversity and sensitize towards the Biodiversity Conservation for sustainable development.

**Theory: 15 x 2 hrs.= 30 hours**

**Contents:**

**Unit I:** **(8 hours)**
Vegetative and Reproductive innovations in land plants; Comparative morphology and developmental anatomy of Anthocerophyta, Marchantiophyta and Bryophyta.; Vegetative and reproductive innovations, Breeding system in bryophytes;

**Unit II** **(5 hours)**
Plant substratum relationship, Growth Forms and life strategies, Bryophytes as site indicators; Role of Bryophytes in Ecosystem Dynamics and in global carbon budget, Bryogeography and conservation of bryophytes.

**Unit III:** **(10 hours)**
Meristem organization and organ diversity in Pteridophytes, Comparative anatomy of vegetative and reproductive organs of Pteridophytes, Fern Classification, Biogeography, Diversity of Ferns - an ecological perspective, biogeography, Gametophyte ecology, Nutrient ecology.

**Unit IV:** **(7 hours)**
Comparative morphology and developmental anatomy of Gymnosperms, Reproductive Biology of Gymnosperms, Evolution of Pollination mechanism in Gymnosperms; Impact of coniferous forest on human life;

**Practicals: 15 x 4 hrs.= 60 hours**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Comparison of thyroid liverworts simple and complex thalli *Dumortiera*, *Conocephalum, Plagiochasma* through anatomical sections.

2. Comparison of various leafy liverworts to compare the leaf modifications, trigones and oil bodies.

3. Morphology and anatomy of gametophyte of Polytrichaceae member (*Pogonatum* or *Atrichum*) to see the lamellae and special conducting cells and nematodontous peristome.

4. Study of members of pottiaceae (moss) to observe the adaptations, alar cells, papillae, and conducting cells.

5. Study of Pleurocarpous mosses to observe the leaf modification for water retention.

6. Section of rhizome and petiole of commonly available fern species.

7. Section through sorus to study the morphology of sporangia and spores.

8. Salvinia morphology and anatomy of leaf and rhizome.

9. Herbarium specimen of unique fern species to study the soral patterns.
10. Anatomy of stem and leaf of *Agathis robusta*.
11. Anatomy of stem and leaf of *Thuja*.
12. Permanent slides of *Ginkgo biloba*.

**Suggested Readings:**

1. Schofield, W.B. (1985). Introduction to Bryology. Macmillan. ISBN, 0029496608, 9780029496602.

2. Vanderpoorten, A. and Goffinet, B. (2009). Introduction to bryophytes. Cambridge University Press, Cambridge .. ISBN 978-0-521-70073-3.

3. Goffinet, B. and Shaw, A. J. (Edited) (2008). Bryophyte biology. 2nd ed. – XIV + 565 pp., Cambridge University Press, Cambridge. ISBN 978-0-521-69322-6.

4. Dyer, A.F. (1979). Experimental biology of ferns. Academic Press

5. Ranker, T.A. and Haufler, C.H. (2008). Biology and Evolution of Ferns and Lycophytes. Cambridge University Press, Cambridge

**Additional Readings:**

6. Mehlereter, K., Walker, L.A. and Sharpe, J.M. (2010). Fern Ecology. Cambridge University Press, Cambridge

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

## DISCIPLINE SPECIFIC CORE COURSE-3

### Plant Taxonomy and Evolution

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Plant Taxonomy and Evolution DSC-3 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives:**

This course aims to introduce the students regarding significance of plant taxonomy in biological sciences and interpret the evolutionary relationships among taxa.

**Course Learning Outcomes:**

**The students will be learning about**

1. The importance of plant systematics and how is it useful.
2. The different methods and data of naming plants and how ICN governs it.
3. The patterns of biological variation and what are the underlying processes responsible for these patterns.
4. The evolution and evolutionary history of plants and what are the methods of study.
5. The evidence used to understand evolutionary changes.
6. The inferring phylogenetic trees and process of speciation?

**<u>Theory: 15 x 2 hrs.= 30 hours</u>**

**<u>Contents:</u>**

**Unit I** **(8 hours)**

Plant Systematics: Concepts and components; Plant collection and documentation: Methods of collecting plants, Herbaria and Botanical gardens; Plant Identification: Taxonomic Keys; taxonomic literature; Taxonomic evidences: Structural to molecular; Classification of flowering plants: APG system of classification

**Unit II** **(4 hours)**

Botanical Nomenclature: Principles of nomenclature; Scientific names; synonyms; ranks; author citations; typification; valid publication; priority of publication; conservation of names; orthography; gender; name changes.

**Unit III** **(9 hours)**

Introduction to Evolution – Pattern and process component of scientific theories; biological variation and evolutionary changes (evidences for evolution); Darwin and Wallace; Natural Selection; Adaptation; Microevolution and Macroevolution; Evolutionary history.

**Unit IV** **(9 hours)**

Molecular divergence; Molecular models; Reading trees; Inferring phylogenies; Gene tree; Species tree. Speciation.

**Practicals: 15 x 4 hrs.= 60 hours.**

**List of Practicals:** Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Study field collection techniques for different plant groups and the ethical considerations in plant collections.
2. Study methods of specimen preservation, mounting, and cataloguing (including a visit to Delhi University Herbarium (DUH)).
3. Learn methods of plant identification (including preparation of taxonomic keys).
4. Examine taxonomic literature to learn the rules of nomenclature as per ICNafp.
5. Morphological analysis of basal angiosperms (examples from ANA grade).
6. Comparison of traditional and current classification systems using Magnoliids as an example.
7. Study selected members of Monocots using morphological and anatomical data.
8. Comparative study of major Eudicot clades and understand their structural adaptations.
9. Understanding the role of integrative taxonomic approach in plant systematics and the significance of molecular phylogeny.
10. Analysis of taxonomic data using various Molecular Phylogenetic software.
11. Reading and interpretation of phylogenetic trees.

**Suggested Readings:**

1. Angiosperm Phylogeny Group (2016). An update of the Angiosperm Phylogeny Group Classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnaean Society 181: 1-20.

2. Pandey, A.K., & Kasana, S. (2021). Plant Systematics (1st ed.). CRC Press.
3. Judd, W.S., Campbell, C.S, Kellogg, E.A., Stevens, P.A. and Donoghue, M.J. (2016). Plant Systematics: A Phylogenetic Approach. Sinauer Associaes, Inc., Massachusetts.
4. Simpson, M.G. (2010). Plant Systematics. Elsevier, Amsterdam.
5. Stuessy, T.F. (2009). Plant Taxonomy: The systematic Evaluation of Comparative Data. Columbia University Press, New York.


**Additional Readings** :


1. Futuyma, D. J. (1998). Evolutionary Biology (3rd Edition). Sinauer Associates.
2. Stuessy, T.F., Crawford, D.J., Soltis, D.E. and Soltis, P.S. (2014). Plant Systematics: The origin, interpretation, and ordering, of plant biodiversity. Koeltz Scientific Books, Konigstein, Germany.
3. Crawford, D.J. (2003). Plant Molecular Systematics. Cambridge University Press, Cambridge, UK.

## DISCIPLINE SPECIFIC ELECTIVE-1

### Traditional knowledge systems

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Traditional Knowledge Systems DSE-1 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course objectives**

This is one of the major courses that is directly linked with human health. Students will gain exposure to knowledge regarding the major medicinal products/formulations being obtained from algae to higher plants. Progress in understanding the synthesis of characteristic medicinal metabolites/molecules produced naturally in plants and their mode of action will open up avenues for better implementation of such compounds for curing diseases. Knowledge of technological advancements for detection of these metabolites will broaden the skill base of students in medicinal botany.

**Course outcomes**

**The students will learn about**

1. The relevance of traditional knowledge in the present context, the ethnic groups and tribes of India.
2. The plants used by the indigenous societies for food, medicines plants, intoxicants and beverages, resins and oils.
3. The major natural products of medicinal importance being obtained from different sources.
4. The Intellectual Property Rights and Traditional Knowledge; databases and knowledge resource (Traditional Knowledge Digital Library);
5. The pathways by which medicinal compounds are produced in plants and what is their mode of action to cure diseases.
6. Biochemical and molecular pathways of specific metabolite production in plants (*viz.* antibacterial, antivirals, antimalarial, anticancerous, antidiabetics etc.)
7. The technologies involved in isolation & characterization of plant-based bioactive compounds useful for pharma industries

8. Cultivation practices and product development *In vivo* and *In vitro* strategies. Brief account on elicitation of bioactive compounds, bioreactors.

**<u>Theory: 15 x 2 hrs.= 30 hours</u>**

**Contents:**

**Unit I: (7 hours)**

The relevance of Traditional knowledge and practices with suitable examples; ethnic groups and tribes of India, and their lifestyles; Plants used by the indigenous societies: a) Food plants, b) Medicinal plants, c) intoxicants and beverages, d) Resins and oils and miscellaneous uses. Diversity of natural products used as medicine: Brief account of major sources cum formulations of current medicines from Lichens, Fungi, Algae, Archegoniatae, Higher plants. Significance of the selected plants in ethnobotanical practices (along with their habitat and morphology)

**Unit II: (7 hours)**

Folk lore, Narcotics, Biostimulants; Nutritional, Medicinal traditional knowledge; Ethnoveterinary knowledge. Sharing of wealth concept with few examples from India, Biopiracy, Intellectual Property Rights and Traditional Knowledge; databases and knowledge resource (Traditional Knowledge Digital Library); Natural pathways of medicinal compounds/molecules synthesis: Biochemical and molecular pathways of specific metabolite production in plants (*viz.* antibacterial, antivirals, antimalarials, anticancerous, antidiabetics etc.)

**Unit III: (9 hours)**

Ancient Literature and oral traditions; Archaeological finding inferences; Religious and sacred places. Protecting Knowledge; Traditional Herbal Medicine: Indigenous systems of medicine; international plant drugs, their export and import; important controversial medicinal plants and their substitutes; endangered and rare plants of India; role of plant drugs in pharmaceutical industry. protect interests of ethnic groups and benefit sharing, Case studies of traditional medicines leading to development of modern pharmaceutical products (use of *Trichopus zeylanicus* by Kaani tribe and *Artemesia* sp. for malaria cure). Role of traditional healers.

**Unit IV: (7 hours)**

Cultivation practices and product development: *In vivo* and *In vitro* strategies. Brief account on elicitation of bioactive compounds, bioreactors, extraction methods for plants used as drugs in pharma industries such as antimalarials, antidiabetics; current techniques used for detection and purity of bioactive compounds. Case studies on factors that influence the amount and quality of bioactive compounds during the process of collection and processing of medicinal plants (including packaging, storage). Regulations and biosafety.

**Practicals: 15 x 4 hrs.= 60 hours.**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Ancient use of algae and thalassotherapy.
2. Traditional uses of mosses, ferns and gymnosperms.
3. Study of plant parts used in aromatherapy.
4. Infusion and decoction method of extraction
5. Maceration based extraction
6. Essential oil hydro distillation, degree of volatility
7. Antimicrobial activity assay
8. Antioxidant activity assay
9. Anti-inflammatory activity assay
10. Cultivation practices of medicinal plants
11. Herbal gardens, germplasm repositories & Medicinal and Aromatic Plant (MAP) institutes
12. Study of ethnobotanicals used in medicine
13. Study of endangered medicinal plants
14. Visit to Ayurvedic pharmacy or MAP processing unit.

**Suggested readings**

1. Nakar, R.N., Dhaduk, H.L. and Chovatia, V.P. (2016). Medicinal plants- Cultivation and Uses, Daya Publishing House, India

2. Kayser, O. and Quax, W.J. (2007). Medicinal Plant Biotechnology, From Basic Research to Industrial Applications, Vol. I &II. Wiley-VCH, Weinheim

3. Ashhara, A., Crozier, A. and Komamine, A. (2011). Plant Metabolism and Biotechnology. John Wiley and Sons, England (UK).

4. Buchanan, B.B., Gruissem, W. and Jones, R.L (2015). Biochemistry and molecular biology of plants. John Wiley and Sons Ltd., UK.

5. Surajit Pathak, Antara Banerjee (2024) Plant Derived Bioactive Compounds in Human Health and Disease, 1$^{st}$ Ed, CRC Press

## DISCIPLINE SPECIFIC ELECTIVE-2

## Recombinant DNA Technology

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical /Practice | | |
| Recombinant DNA Technology DSE- 2 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives:**

1) To understand the principles of genetic engineering, its applications. Gain knowledge of DNA modifying enzymes and basic cloning vectors.
2) To gain hands-on expertise in recombinant DNA techniques. Develop practical knowledge of cloning strategies and molecular cloning techniques. Understand methods for gene isolation and library construction.
3) To learn PCR and sequencing methods for molecular biology applications.
4) To evaluate ethical considerations and biosafety regulations in genetic engineering.

**Course Learning Outcomes:**

This course is designed to provide a comprehensive foundation in the principles and methodologies of recombinant DNA technology. It gives in-depth knowledge of the molecular tools and enzymatic techniques that underpin genetic engineering. Students will gain hands-on training in important procedures including gene isolation, vector design, cloning strategies, PCR and its applications, DNA sequencing methods and library construction techniques for genomic and cDNA libraries. The course encourages students to critically engage with the ethical, regulatory, and biosafety considerations associated with genetic manipulation. The students will understand how recombinant DNA technology is applied in fields such as medicine, agriculture, and biotechnology preparing them for advanced research or careers in the life sciences.

**<u>Theory: 15 x 2 hrs.= 30 hours</u>**

**Contents:**

**Unit I: Fundamentals of Genetic Engineering and DNA Manipulation (7 hours)**

a) Introduction to genetic engineering and its applications
b) DNA modifying enzymes: restriction enzymes, ligases, polymerases

c) Overview of cloning strategies
d) Plasmids, bacteriophages, cosmids, BACs, PACs, YACs

**Unit II**

**Cloning Strategies and Molecular Tools (8 hours)**

a) Viral vectors for gene expression (Plant viral vectors)
b) Cloning techniques: Restriction enzyme-based cloning, TA cloning, Gateway, Gibson, TEDA, Golden Gate, Topoisomerase-based cloning
c) Construction and screening of genomic and cDNA libraries.
d) Methods for gene isolation: hybridization-based techniques, subtractive cloning, differential screening and differential displays.

**Unit III: Amplification and Sequencing Technologies (7 hours)**

a) PCR: principles and applications
b) Nested PCR, QPCR, TAIL-PCR, Inverse PCR
c) Sanger sequencing and Maxam-Gilbert sequencing
d) Introduction to Next-Generation Sequencing (NGS)

**Unit IV: Applications, Ethics, and Regulatory Framework (8 hours)**

a) Applications of recombinant DNA in medicine, agriculture and industry
b) Gene therapy and transgenic plants
c) Ethical issues and biosafety
d) Regulatory guidelines and public concerns

**<u>Practicals: 15 x 4 hrs.= 60 hours.</u>**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

**Basic Molecular Biology Techniques**
a) Isolation of plasmid DNA
b) Gel electrophoresis and DNA quantification.
c) Restriction digestion, elution and ligation of DNA.
d) PCR amplification of a gene, Primer design.

**Cloning and Transformation**
a) Preparation of competent cells.
b) Transformation and selection of recombinant clones.
c) Screening of transformed colonies (blue-white screening, colony PCR).

**Gene SOE-ing (Splicing by Overlap Extension) by PCR**
a) Principle and applications.
b) Designing primers for mutagenesis.
c) Performing SOEing-PCR and validation by gel electrophoresis.

**RNA Isolation and Quantification**

a) Extraction of total RNA from plant tissues.
b) RNA purity analysis using spectrophotometry.
c) Agarose gel electrophoresis for RNA integrity assessment.

**Construction of Restriction Maps and Analysis of restriction sites on a given DNA sequence**:

a) In silico restriction map construction using bioinformatics tools.
b) Validation of restriction patterns using restriction digestion and gel electrophoresis.

**Fragment size prediction and mapping**:

a) Digestion of plasmid DNA with single and double restriction enzymes.
b) Determination of fragment sizes by electrophoresis.

**Suggested Readings**:

1. Brown, T.A. (2016). Gene Cloning and Analysis: An Introduction. Seventh edition. Wiley-Blackwell Publishing, UK.
2. Dale J.W., Schantz M.V. and Plant N. (2011). From Genes to Genomes: Concepts and Applications of DNA Technology. Third edition. John Wiley & Sons, UK.
3. Glick, B.R., Pasternak, J.J. and Patten, C.L. (2010). Molecular Biotechnology: Principles and Applications of Recombinant DNA. Fourth edition. ASM Press, USA.
4. Primrose, S.B. and Twyman, R.M. (2006). Principles of Genetic Manipulation and Genomics. Seventh Edition. Blackwell Publishing, UK.
5. Voet, D., Voet, J.G. and Pratt, C.W. (2012). Principles of Biochemistry. Fourth edition. John Wiley & Sons, UK.

**Additional Readings:**

1. Wilson, K. and Walker, J. (2010). Principles and Techniques of Biochemistry and Molecular Biology, Seventh edition, Cambridge University Press, USA.

## DISCIPLINE SPECIFIC ELECTIVE- 3

## Molecular Biology

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical / Practice | | |
| MOLECULAR BIOLOGY DSE 3 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives:**

The objective of the present course content is to provide foundation and background in concepts and principles of molecular biology, primarily focused on the eukaryotic system. The course content has been designed to emphasize the relationship between genome structure (including nuclear and organellar), and mechanisms of replication, transcription, translation and gene regulation.

**Course Learning Outcomes:**

The students will be learning:

1. The various components of the eukaryotic nuclear and organellar genome, with special reference to their regulatory role.
2. The commonly used bioinformatics tool and their principles for analysis of genes, genetic elements and genomes.
3. The principle mechanisms of genome replication, maintenance, function and regulation of expression.
4. The relationship between organization of the genome and regulation.
5. The epigenetic modifications can lead to regulation of gene expression.
6. The non-coding RNAs and what are their role/s in gene regulation.

**<u>Theory: 15 x 2 hrs.= 30 hours</u>**

**Contents:**

**Unit I: Eukaryotic genome structure (8 hours)**

**Nuclear genome:** Eukaryotic genome and gene structure: Genomic components: Coding (protein/RNA coding) and non-coding regions; 3-D architecture and chromosomal territories; Gene and promoter structure: Variation in size and distribution of introns and exons, and function; promoter diversity and function; Other Cis-regulatory elements (enhancers, insulators, silencers; UTRs);

**Organellar genome:** Structure, organization, diversity and evolution; Cross-talk between nuclear and organellar genetic machinery and its implications: Applications of organellar genomics

Computational tools to analyze gene and genome structure.

**Unit II: Eukaryotic genome: replication and transcription (8 hours)**

Replication initiation; Replicative machinery; DNA polymerases and other components; structural insights; structure-function relationship; fidelity; end-replication problem; organellar replication

Transcriptional processes in nuclear genome: Transcription initiation- role of promoters and enhancers; Transcription factors; mediator complexes; Transcriptional process and control including promoter proximal pause, pause release; Co-transcriptional and Post-transcriptional processes:- Initiation, elongation, termination, polyadenylation, splicing, alternative splicing; Organellar transcription, backsplicing; Transcription termination.

**Unit III: Eukaryotic genome: translation (7 hours)**

Translation and post-translational modifications in nuclear and organellar genome; RNA surveillance mechanism and pioneering round of translation; Models of translation initiation; Translation (initiation, elongation, termination); Structural insights into translational controls; Alternative reading frames and Peptide diversity; small ORFs (sORFs) and Micropeptides (miRPeps)

**Unit IV: Principles of Eukaryotic gene regulation: TGS, PTGS, PTMs: (7 hours)**

Basic principles of epigenetics and non-coding RNA; epigenetic modifications-types; Epigenetic control of gene regulation; types and classes on non-coding RNA; non-coding RNAs in gene regulation-types, classes and modes of action; post-translational modifications (PTMs)

**Practicals: 15 x 4 hrs.= 60 hours.**

Practicals are based on the theoretical content of the syllabus.

1. To study gene structure and detect presence of exons-introns
2. To study replication, transcription and translational control using inhibitors on growth of *Escherichia coli*
3. To study replication, transcription and translational control using inhibitors on growth of *Saccharomyces cerevisiae* (budding yeast)
4. To use computational tools for detection of Open Reading Frames

5. To use computational tools for gene prediction and annotation using BLASTN and BLASTP
6. To use computational tools for prediction of secondary structure of RNA
7. To use computational tools for prediction of secondary structure of Protein
8. To study the application of organellar genome as molecular marker through bar-coding.
9. To study the application of organellar genome as molecular marker through PCR-RFLP
10. To perform functional analysis of eukaryotic promoter using promoter-reporter transcriptional fusions

**Suggested Readings:**

1. Bruce Alberts, Rebecca Heald, Alexander Johnson, David Morgan, Martin Raff (2022) Molecular Biology of the Cell. WW Norton & Co Publishers.; 1404 pages
2. Gerald Karp, Janet Iwasa, Wallace Marshall (2020) Karp's Cell and Molecular Biology, 9th Edition. John Wiley & Sons, USA. 944 pages
3. Brown, T. A. (2023) Genomes 5; 5$^{th}$ edition. CRC Press, Taylor & Francis Group, USA. 560 pages
4. Buchanan, B.B., Gruissem, W. and Jones, R.L (2015) Biochemistry and molecular biology of plants. 2$^{nd}$ edition; Wiley Publisher; pages: 1280 pages
5. Jonathan Pevsner (2015) Bioinformatics and Functional Genomics, 3rd edition. Wiley-Blackwell Publisher; pages: 1160 pages

**Additional Readings:**

**1.** Berk, A., Kaiser, C.A., Lodish, H., Amon, A., Ploegh, H, Bretscher (Author), Monty Krieger, A., Martin, K.C. (Eds). (2016) Molecular Cell Biology. Freeman & Co., USA.

## SKILL BASED COURSE / SPECIALISED LABORATORY

### SBC-1 Laboratory and Field Experiments in Plant Biology

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Laboratory and Field Experiments in Plant Biology SBC -1 | 2 | 0 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course objectives**

This course will train the students in various techniques related to plant biology. These techniques will build the foundation of students both for plant-related research activities and applied work.

**Practicals 15 x 4hr. = 60 hours**

1. Good laboratory practices and research ethics
2. Methods of collecting plant materials and their long-term preservations.
3. Preparation of herbarium specimens.
4. Fixation of plant tissues for microtomy, types of fixatives, tissue embedding media, and sectioning.
5. Vegetation sampling techniques
6. Use of weighing balances, pH meter, media preparation and sterilization, autoclave, filter sterilization.
7. Bacterial culture methods: streaking, plating, replica plating, inoculation in liquid media.
8. Chromosome preparation: mitosis and meiosis.
9. Plant propagation methods nursery methods.
10. Hydroponics system
11. Good agricultural agroecosystem practices.
12. Practices for high value botanicals.
13. Bioentrepreneurship.
14. Cultivation of high value microgreens.

**Suggested Readings:**


1. Evert, R. F., Eichhorn, S. E., Perry, J.B. (2012). Laboratory Topics in Botany. W.H. Freeman and Company.
2. Mesh, M.S., Kebede-Westhead, E. (2012). Essential Laboratory Skills for Biosciences. John Wiley & Sons, Ltd.
3. Mu, P., Plummer, D. T. (2001). Introduction to practical biochemistry. Tata McGraw-Hill Education.
4. Mann, S. P. (2016). Introductory Statistics, 9th edition. Hoboken, NJ, John Wiley and Sons Inc.
5. Danniel, W.W. (1987). Biostatistics. New York, NY: John Wiley Sons.


**Additional Readings:**


1. Jones, A.M., Reed, R., Weyers, J. (2016). Practical Skills in Biology, 6th Edition, Pearson
2. Bisen, P.S. (2014). Laboratory Protocols in Applied Life Sciences, 1st edition. CRC Press.
3. Zar, Z. H. (2010). Biostatistical Analysis, 5th edition, Pearson Prentice Hall, New Jersey, USA.

# Semester II

## DISCIPLINE SPECIFIC CORE COURSE – 4

## Developmental Biology of Plants

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical / Practice | | |
| DEVELOPMENTAL BIOLOGY OF PLANTS<br>DSC - 4 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives**

Unlike animals, plants are modular and characterized by developmental reiteration of organs in their body plan. In order to understand this complexity, one has to look into the various aspects of growth, development and reproduction. This course aims at making the students acquainted with the fundamentals, and current understanding of the mechanisms associated with specification, development and differentiation of various plant organs.

**Course Learning Outcomes**

The students will be learning the following main aspects.

1. The aspects of growth in plants different types of networks that regulate growth and development.
2. The main growing regions of the plant and maintenance of their meristematic identity while forming cells that are determined and undergo differentiation.
3. Different organs or tissues with specific structures and functions are formed in the plant body and what are the key mechanisms that regulate their development.
4. Formation of three-dimensional structures in plants and the mechanisms that are responsible for the diversity observed in their architecture.
5. Transformation of shoot apical meristem into an inflorescence and floral meristem, and their development.
6. Establishment of male and female germ lines, and coordination of a variety of tissues coordinate to form gametes.
7. Accomplishment of seed development, and the mechanisms by which rejection reaction occurs during the progamic phase.
8. Necessity of fertilization for a seed to be formed. A cross-talk between fertilized egg and central cells lead to embryo and endosperm formation.

**<u>Theory 15 x 2 hrs.= 30 hours</u>**

**Contents:**

**Section A**

**Unit I** **(7 hours)**

Key concepts in growth and development, plant growth vs animal growth, positive and negative regulatory networks; coordination of growth, isotropic and anisotropic growth, polarity, proliferation and termination of growth, growth and development of three-dimensional structures, developmental plasticity; Meristems, different types, RAM, SAM, Cell fate determination, lineage decisions, developmental patterning.

**Unit II** **(8 hours)**

Differentiation of cells: stomata, trichomes, tracheary elements etc.; development of organs, key regulatory mechanisms for organ identity, shape and size of specific organs such as leaf, stem, root; plant architecture, growth of main stem and lateral organs, determinate and indeterminate growth, branching pattern and apical dominance, root and shoot architecture, phyllotaxy.

**Section B**

**Unit III** **(8 hours)**

Transition to flowering; Inflorescence and floral meristems; maintenance of inflorescence and floral domains; Floral homeotic mutations in *Arabidopsis*, *Antirrhinum* and *Petunia*; Regulation of anther and ovule development, Microsporogenesis and microgametogenesis, Megasporogenesis and megagametogenesis, Domains of pollen-wall; Pollen embryogenesis, Male sterility.

**Unit IV** **(7 hours)**

Pollination; Progamic phase; *In vitro* pollen germination; Pollen tube growth and guidance; Double-fertilization; Self-incompatibility; Polarity during embryogenesis; Maternal to zygotic transition; Embryo pattern mutants, *In vitro* fertilization, endosperm development, Apomixis, Polyembryony, Somatic embryogenesis.

**<u>Practicals: 15 x 4 hrs.= 60 hours</u>**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below

**Section A**

1. Study of surface structures in plants-I Stomata
2. Study of surface structures in plants-II Trichomes
3. Study of planar structures in plants
4. Study of complex tissues xylem and phloem
5. Study of stem development in dicots and monocots
6. Study of root development in dicots and monocots

**Section B**

1. Assessment of pollen fertility and viability.
2. Comparative assessment of viability, germinability and vigour of pollen.
3. Role of transcriptional and translational inhibitors on pollen germinability and tube growth.
4. Assessment of stigma-receptivity by localising non-specific esterases, phosphatases and peroxidases.
5. Study of megasporogenesis, megagametogenesis and mature female gametophyte with the help of permanent slides and electron micrographs.
6. Study of the stages of pollen and ovule development in the wild and mutant plants using permanent slides, electron micrographs and available phenotypes.
7. Study of types and structures of stigma and style through sections in selected taxa.
8. Study of the embryo, endosperm and haustorium in selected taxa through dissections.

**Suggested Readings**


1. Beck, C.B. (2010). An Introduction to Plant Structure and Development, II edition
2. Howell, S.H. (1998). Molecular Genetics of Plant Development, Cambridge University Press.
3. Wolpert, L., Jessell, T., Meyerowitz, E., Robertson, E. and Smith, J. (2007). Principles of Development; Oxford, Oxford University Press.
4. Raghavan, V. (1997). Molecular Embryology of Flowering Plants. Cambridge. University Press.
5. Shivanna, K.R. (2003). Pollen Biology and Biotechnology, Science Publishers.
6. Shivanna, K.R. and Rangaswamy, N.S. (1992). Pollen Biology A Laboratory Manual, Springer.


**Additional Reading**


1. Pua, E-C. and Davey, M.R. (2010). Plant Developmental Biology-Biotechnological perspectives
2. Fosket, D.E. (1994). Plant, Growth and Development A Molecular Approach, Academic Press.
3. Hopkins, W.G. (2006). The Green World Plant Development, Chelsea House Publication
4. Leyser, O. and Day, S. (2003). Mechanism of Plant Development, Blackwell Press, 241p.
5. Raghavan, V. (2000). Developmental Biology of Flowering Plants, Springer, Netherlands
6. Bhojwani, S.S., and Razdan, M.K. (1996). Plant Tissue Culture Theory and Practice, Elsevier
7. Whitelam, G.C. and Halliday, K.J. (2007). Light and plant development; Blackwell Publishing.

## DISCIPLINE SPECIFIC CORE COURSE-5

### Pathogens and Pests of Crop Plants

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Pathogens and Pests of Crop Plants DSC-5 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

### Course Objectives

This course aims to enhance understanding of students in basic concepts of mycology and importance of fungi, as well as develop skills for handling fungi. An introduction to the diversity of pests encountered by crop plants and agricultural produce will be provided. The course deals with basic concepts in plant pathology and interaction of plants with herbivores. Introduction to agricultural pathogens and pests of national importance will be accompanied by basic concepts in integrated disease/pest management, and breeding plants for durable resistance against insect pests and pathogens.

### Course Learning Outcomes

The students will

1. Understand basic fungal biology, taxonomy of the fungi and major fungal lineages.
2. Gain skills necessary to isolate and handle fungi from nature, and to discern important microscopic characteristics of fungi.
3. Develop functional knowledge on differentiating disease caused by virus, fungi, and bacteria.
4. Learn about the biology of major, and emerging pathogens and pests of crop plants.
5. Examine advantages and disadvantages of current control practices based on chemical ecology, genetics of plant resistance and breeding including transgenic approaches.
6. Combine theoretical and practical knowledge of plant disease and pest management.

**Theory 15 x 2 hrs.= 30 hours**

**Contents:**

**Unit I**

**Overview of Fungi** **(6 hours)**

A higher-level phylogenetic classification of the Fungi.

True fungi: characteristics and important genera of Phyla – Chytridiomycota, Zygomycota, Glomeromycota, Ascomycota, and Basidiomycota. Physiology of fungal growth, reproduction (asexual and sexual), and mating compatibility.

**Unit II**

**Fungus-like organisms** **(4 hours)**

Characteristics and important genera of Phyla - Myxomycota, Acrasiomycota, Plasmodiophoromycota, and Oomycota

**Unit III**

**General concepts of plant pathology and agricultural pests** **(8 hours)**

General characteristics of plant pathogenic organisms and phytophagous pests. Molecular approaches for the investigation of plant diseases and pest outbreaks. Control mechanisms based on chemical treatments, biological control and genetic engineering.

**Unit IV**

**Plant interactions with pathogens and pests** **(12 hours)**

Plant-virus interactions with emphasis on potyviruses and horticultural crops; Plant-bacterial interactions with emphasis on *Erwinia* sp. and potatoes; Plant-fungus interactions with emphasis on *Magnaporthe* sp. and rice; Plant-nematode interactions with emphasis on *Meloidogyne* sp. and tomato; Plant-insect interactions with emphasis on *Pieris* sp. and crucifers.

**Practicals 15 x 4 hrs.= 60 hours**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below

1. Isolation and morphological identification of fungi from rotten food sample.
2. Antifungal screening using plant extract.
3. Demonstration of molecular identification of fungi.
4. Histochemical staining of intraradical colonization of arbuscular mycorrhizal fungi (AMF) in plant roots.
5. Estimation of cell wall degrading enzymes in pathogenic fungi.
6. To estimate and compare total phenol content in resistant and susceptible plants against fungal pathogens.

7. To estimate and compare the activity of polyphenol oxidase in resistant and susceptible plants against fungal pathogens.
8. To estimate and compare the activity of phenylalanine ammonia lyase in resistant and susceptible plants against fungal pathogens.
9. Identification of common insect pests and predators in agricultural fields.
10. Estimation of leaf damage caused by an economically important insect pest from crop fields sprayed with Bt biopesticide powder.
11. DAS-ELISA and data analysis for serological identification of economically important plant viruses in field-collected, symptomatic plant samples.

**Suggested Readings**

1. Alexopoulos, C.J., Mims, C.W. and Blackwell, M. (2007). Introductory Mycology. Fourth Edition Wiley India Pvt. Limited
2. Webster, J. and Weber, R. (2007). Introduction to Fungi. Third Edition. Cambridge University Press. Cambridge and New York
3. Sethi, I.K. and Walia, S.K. (2018). Text book of Fungi & Their Allies, Second Edition. MacMillan Publishers Pvt. Ltd., Delhi, India
4. Burchett, S. and Burchett, S. (2018). Plant Pathology, Garland Science, US
5. Koul, O., Dhaliwal, G.S. and Cuperus, G.W. (2004). Integrated Pest Management Potential, constraints and challenges, CABI Press, UK.

**Additional Readings**

1. Dickinson, M. (2003). Molecular Plant Pathology, Bios Scientific Publishers, London.
2. Dhaliwal, G.S. and Arora, R. (1996). Principles of Insect Pest Management, National Agricultural Technological Information Center, Ludhiana, India.
3. Recent and seminal articles from scientific journals.

# DISCIPLINE SPECIFIC CORE COURSE-6

## Physiology and Biochemistry

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Physiology and Biochemistry DSC-6 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives**

This course aims to educate student on concepts of proteins, enzymes, basic plant signaling mechanisms, sensory photobiology. The course further deals with physiology of nutrient uptake
mechanism, phytohormones signaling, and basics of flower evocation.

**Course Learning Outcomes**

1. Students will be learning about proteins, folding into specific structures, post translational modifications and degradation mechanisms. The course will also teach about catalytic mechanism of enzymes, its inhibitors and regulation.

2. The students will be learning about the various signal transduction mechanisms in plants. The concept of second messengers, calcium signaling, kinases/phosphatases in plant signaling would be delineated to enhance their grasping power for understanding of different signaling pathways operative in plants. Two component signaling concepts would be introduced and extended to plant hormone signaling. Quorum sensing and its potential biotechnological applications should be clear to students after these classes.

3. During the course students will gain knowledge about various mechanisms such as channel or transport proteins involved in nutrient uptake in plants. Further the course will deal with various phytohormones and their role in physiology of growth and development.

4. This course will introduce students to physiological advances in sensory photobiology. Students will gain the knowledge on physiology of flowering, molecular basis of light mediation of flowering mechanism.

**<u>Theory 15 x 2 hrs.= 30 hours</u>**

**Contents:**

**Unit I**

**Protein structure, Enzymes and Signal Transduction (10 hours)**

Hierarchical structure of proteins; folding; ticketing; degradation; molecular motors and pumps. Enzymes and regulation of enzymatic activity. Overview of signal transduction, second messengers, receptors, phospholipid signaling, calcium-calmodulin cascade, specific signaling mechanisms and their regulation, e.g. simple and hybrid type of two-component sensor-regulator system in bacteria and plants, quorum sensing.

**Unit II**

**Nutrient Uptake (6 hours)**

Apoplastic and symplastic transport mechanisms, role of aquaporins and transporter proteins, structure-function relationship of inward and outward ion channels, dual action of ATPases/pumps and modulation of their activity.

**Unit III**

**Phytohormones Biosynthesis, Signaling and Stress Responses (6 hours)**

Concept of phytohormones as chemical messengers, techniques for detection and quantification of phytohormones, classical approaches and use of mutants in understanding phytohormones actions, phytohormones under biotic and abiotic stresses, synthetic regulatory compounds and their diverse uses.

**Unit IV**

**Physiology of photomorphogenesis and flowering (8 hours)**

Structure, function and mechanisms of action of phytochromes, cryptochromes and phototropins; scotomorphogenesis and photomorphogenesis. Flowering as a multi-organ function, floral induction, evocation and development. Regulation of flowering by light and temperature and role of circadian rhythm.

**<u>Practicals 15 x 4 hrs.= 60 hours</u>**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below

1. Comparative assessment of methods for protein quantitation.
2. Study of enzyme kinetics for determination of Km value, nature of inhibition – competitive/non-competitive.
3. Study of enzyme kinetics for effect of time/ enzyme concentration/ pH.
4. Extraction of proteins from root and shoot of Brassica seedlings and comparative quantitative estimation of proteins by Bradford’s method.
5. Qualitative comparison of root and shoot protein profile on SDS PAGE
6. To determine molecular weight of polypeptides from root/ shoot samples from CBB stained SDS PAGE gel

7. To study the lipid peroxidation under salinity stress in Indian mustard leaf samples by estimating the malondialdehyde (MDA) content
8. To study the role of compatible osmolyte for salinity tolerance in Indian mustard by estimating the proline content in leaf samples
9. Analysis of total nitrogen and ammonium contents in leaves using Nessler's and other associated reagents to get an insight of N-metabolism in plants.
10. In vivo assay for nitrate reductase in leaf tissues.
11. Qualitative and quantitative analysis of photosynthetic pigments and anthocyanins by spectrophotometric and chromatographic techniques.

**Suggested Readings:**

1. Buchanan, B., Gruissem, G. and Jones, R. (2015). Biochemistry and Molecular Biology of Plants. 2nd Edition, American Society of Plant Physiologists, USA.
2. Davies P J. (2010). Plant Hormones Biosynthesis, Signal Transduction, Action. 3rd Edition, Kluwer Academic Publisher, Dordrecht, The Netherlands.
3. Jordan, B.R. (2006). The Molecular Biology and Biotechnology of Flowering, 2nd Edition, CAB International, U.K.
4. Nelson, D.L., and Cox, M.M. (2021). Lehninger Principles of Biochemistry (8th edition). W.H. Freeman & Co., New York.
5. Taiz, L. and Zeiger, E., Møller, I.M., Murphy, A. (2023) Plant Physiology and Development.. 7th Edition. Sinauer Associates, USA.

**Additional Readings:**

1. Heldt, H-W. and Piechulla, B. (2024). Plant Biochemistry, 6th Edition. Academic Press, NY.
2. Bhatla, S.C., Lal, M.A. (2024). Plant Physiology, Development and Metabolism. 2nd Edition. Springer Nature, Singapore.

## DISCIPLINE SPECIFIC ELECTIVE-4

## Industrial Microbiology

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Industrial Microbiology DSE-4 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

### Course Objectives

The course is designed to introduce students to the diversity and industrial relevance of microorganisms, including bacteria, fungi, yeasts, actinomycetes, and microalgae. It aims to develop a comprehensive understanding of fermentation technologies, key process parameters, and downstream processing techniques. The course highlights the application of microorganisms in the production of food, beverages, biofuels, pharmaceuticals, and agriculturally important products. It also familiarizes students with the use of both conventional and genetically engineered microorganisms for the production of enzymes and metabolites. Emphasis is placed on the role of industrial microbiology in promoting sustainable development across the food, pharmaceutical, agricultural, and bioprocessing sectors.

### Course Learning Outcomes

Students will be able learn identification and characterization of industrially important microorganisms and explain their maintenance and culture techniques. They will be able to differentiate between submerged and solid-state fermentation processes and evaluate the critical parameters that influence fermentation efficiency. Students will apply their knowledge of microbial processes in the production of fermented foods, dairy products, biofuels, organic acids, and amino acids. They will analyze the role of microorganisms in pharmaceutical manufacturing, including the production of antibiotics, vaccines, enzymes, and hormones. Additionally, students will evaluate the use of microorganisms in agriculture for biocontrol, plant growth promotion, and biofertilization.

**Theory 15 x 2 hrs.= 30 hours**

**Contents:**

**Unit I**

**Introduction to industrial microbiology & microorganisms (6 hours)**

Introduction to industrial microbiology and its significance. Industrially important microorganisms - Bacteria, filamentous fungi, yeasts, actinomycetes, microalgae. Culture techniques Isolation, identification, and maintenance of industrial microorganisms. Overview of microbial metabolic diversity relevant to industrial processes.

**Unit 2**

**Fermentation technology (8 hours)**

Types of fermentation Submerged fermentation, and solid-state fermentation. Key parameters and conditions for optimal fermentation pH, temperature, aeration, agitation, substrate concentration. Fermentation process optimization strategies. Downstream processing Isolation and purification of microbial products enzymes, antibiotics, and metabolites.

**Unit 3**

**Microorganisms in biomanufacturing of foods and industrial products (8 hours)**

Role of microorganisms in functional food production, Fermented foods, plant-based food additives, yeast-fermented products, mushroom, and microalgae-based products. Microbial contribution to dairy and dairy-based products. Microbial production of industrial chemicals Ethanol, amino acids, organic acids using conventional and recombinant organisms. Industrially important enzymes applications in food, leather, textile, paper, detergent, and pharmaceutical industries.

**Unit 4**

**Microorganisms in pharmaceuticals and agriculture industries (8 hours)**

Role of microbes in pharmaceutical biomanufacturing production of antibiotics, vaccines, hormones, diagnostic proteins, vitamins, steroids, enzymes, and amino acids. Microbial applications in agriculture biofertilizers, biopesticides, biocontrol of pathogens, plant growth promoters, secondary metabolites.

**Practicals 15 x 4 hrs.= 60 hours**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below

1. Determination of colony forming units (CFUs) using haemocytometer, dimensions of microbes using ocular- and stage-micrometer.

2. Differential staining of bacteria using Gram-stain; Endospore staining using Malachite Green; Methods for measurement of bacterial growth.

3. Isolation and estimation of bacterial proteins; Study of amylase and protease activity in bacteria.

4. Estimation of phosphate solubilizing capacity of microorganisms; Characterization of Plant Growth Promoting Rhizobacteria – Production of ammonia, IAA, siderophores, HCN, antibiotics, antifungal metabolites.

5. Isolation of *Rhizobium* from root nodules.

6. Isolation, identification and enumeration of AM fungal spores from soil.

7. Isolation of bacterial nucleic acids from soil to study microbial diversity of unculturables.

8. A visit to any educational institute/industry to see different parts of an industrial fermenter and downstream processing techniques.

**Suggested Readings**

1. Crueger W, Crueger A, Aneja KR (2017). *Biotechnology A Textbook of Industrial Microbiology*, 3rd edition. Medtech Publishers, India.Glazer AN, Nikaido H (2007). *Microbial Biotechnology Fundamentals of Applied Microbiology*, 2nd edition. Cambridge University Press, UK.
2. Okafor N, Okeke BC (2017). *Modern Industrial Microbiology and Biotechnology*, 2nd edition. CRC Press, UK.
3. Willey JM, Sandman K, Wood D (2023). *Prescott's Microbiology*, 12th edition. McGraw-Hill Education.
4. Stanbury PF, Whitaker A, Hall SJ (2016). *Principles of Fermentation Technology*, 3rd edition. Elsevier Science, Netherlands.
5. Subba Rao NS, Dommergues YR (eds.) (2000). *Microbial Interactions in Agriculture and Forestry*, Vol. 2. Science Publishers, Enfield, NH, USA.
6. Waites MJ, Morgan NL, Rockey JS, Higton G (2001). *Industrial Microbiology An Introduction*, 1st edition. Wiley-Blackwell, USA.

## DISCIPLINE SPECIFIC ELECTIVE-5

## Evolutionary Biology

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Evolutionary Biology DSE-5 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives**

The objective of the course is to provide an understanding of the meaning of Dobzhansky's oft-quoted statement, "Nothing in biology makes sense except in the light of evolution".

**Course Learning Outcomes**

The students will be learning

1. Evolutionary history and methods of study
2. Processes of evolution and patterns of biological variation and underlying processes responsible for these patterns.
3. Population thinking, skills in application

**<u>Theory 15 x 2 hrs.= 30 hours</u>**

**Contents**

**Unit I** **(4 hours)**

Evolutionary trends, distance based methods, Maximum parsimony, maximum likelihood, Bayesian analysis; origin and evolution of traits across life and green plants; Tree of life.

**Unit II** **(8 hours)**

Fossil records; Phylogeny; geological fundamentals; Evolutionary trends; Rates of evolution; Geography of life; Major patterns of distribution. Historical biogeography; phylogeography.

**Unit III** **(10 hours)**

The Modern synthesis Population genetics; Forces of evolution Genetic Drift – sampling error; Mutation. Migration/Gene Flow. Adaptation-Fitness, coefficient of selection. One locus model, multi locus models, modes of selection. Non adaptive traits. Molecular evolution. Neutral theory. Molecular clock. Testing for selection. Modes of selection.

**Unit IV** **(8 hours)**

Species concepts and processes of speciation. Drivers of speciation. Geographic patterns. Reproductive isolation. Evolutionary mechanisms. Post-zygotic and pre zygotic isolation in allopatry and sympatry, reinforcement, character displacement. Hybrid speciation, hybrid zones. Adaptive radiation.

**Practicals** **<u>15 x 4 hrs.= 60 hours</u>**

1. Studying variation in plant samples.
2. Reading phylogenetic trees. Distance based methods, MP method to reconstruct trees.
3. Introducing plant projects for poster presentation.
4. Studying evolutionary trends using Mesquite
5. Studying Fossils
6. Studying Biogeography using Cucurbitaceae/other as an example
7. Flow of Alleles in populations (through fish simulation game)
8. Poster presentations
9. Measuring fitness using seed germination as a criteria
10. Simulation of various evolutionary forces using PopGen
11. Molecular evolution and phylogenetic inference (MEGA)

**Suggested Readings**


1. Futuyma, D. J. (1998). Evolutionary Biology (3rd Edition). Sinauer Associates. Ridley, M. (2003). Evolution (3rd edition), Blackwell.
2. Page, R. D. M. and Holmes E. C. (1998). Molecular Evolution A Phylogenetic Approach, Blackwell. Herron J. C. and Freeman, S. C. (2015). Evolutionary Analysis (5th Edition). Prentice Hall.
3. Hall, B. K. and HallgrÃ-msson, B. (2014). Strickberger’s Evolution (4th Edition). Jones & Bartlett.

## DISCIPLINE SPECIFIC ELECTIVE-6

### Basics of Proteomics

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Basics of Proteomics DSE-6 | 4 | 2 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives**

This course is designed to provide a contextual and inquiry-based learning of modern-day advances in the field of basic proteomics.

**Course Learning Outcomes**

Students will acquire understanding of

1. Basic principles and modern age applications of proteomics. Understand primary to tertiary protein structure, peptide bonds, folding mechanisms, and the nature of non-covalent interactions.
2. Translational mechanisms in prokaryotes vs. eukaryotes and explain common post-translational modifications.
3. Understand expression systems and optimization strategies for recombinant protein production in different hosts.
4. Develop hands-on knowledge of electrophoresis and chromatographic separation based on protein properties.
5. Learning molecular and technical skills along with applications of the instrumentation.
6. Gain a comprehensive understanding of proteomics techniques, data interpretation, and functional application in biological systems. Application of proteomics knowledge in agriculture, medicine, and environmental biology.
7. Designing/conducting experiments and analyzing experimental data.

.**Theory 15 x 2 hrs.= 30 hours**

**Contents:**

**Unit I**

**Basics of Proteins structure, synthesis and post-translational modifications (6 hours)**

a) Introduction to protein structure, Peptide bonds, non-covalent forces in proteins.
b) Principles of folding; Hydrophilicity, hydrophobicity & amphipathicity in proteins.
c) Comparative account of translation in prokaryotes and eukaryotes.
d) Major Post translational modifications.

**Unit II**

**Protein Expression and Engineering (6 hours)**

a) Overview of over-expression of proteins in heterologous systems *E. coli*, yeast, baculovirus and mammals.
b) Over-expression and purification of proteins in *E. coli*-Use of vectors and hosts.

**Unit III**

**Protein Extraction and purification techniques (5 hours)**

a) History, principles of protein purification based on the properties of proteins using chromatographic techniques and electrophoresis.
b) Column chromatography, ion exchange and affinity chromatography.

**Unit IV**

**Proteomics in post genomic era (13 hours)**

a) Introduction to proteomics, comparative account with genomics and transcriptomics, overview of various techniques available in field and applications.
b) Proteome analysis-two dimensional - separation of total cellular proteins isolation and sequence analysis of individual protein spots by mass spectroscopy.
c) Applications of Proteomics as a tool for plant genetics, breeding and diversity studies.
d) Application of proteomics in drug development, agriculture for production of medically and agronomically useful proteins, application in fundamental biological research and environmental sciences and therapeutic applications.

**Practicals 15 x 4 hrs.= 60 hours**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below

1) Preparation of reagents and buffers for protein extraction, protein extraction from plant and bacterial cells followed by protein estimation using Bradford and UV spectroscopy.
2) Bacterial growth curve.

3) Transformation of pET vector based recombinant clones into *E. coli* overexpression host.
4) Recombinant protein induction using IPTG followed by sample preparation by sonication.
5) Preparation of different buffers and reagents for SDS PAGE. Gel preparation and running *E. coli* protein over- expression samples. Staining and destaining of gels followed by analysis.
6) Preparation of different buffers, reagents followed by Enzyme-Linked Immunosorbent Assay -Dot ELISA.
7) Western blotting.
8) Preparation of different buffers, reagents and nutritional selection media plates for yeast transformation.
9) Yeast competent cell preparation followed by transformation.
10) Yeast two hybrid analysis to identify protein-protein interaction.

**Suggested Readings:**


1. Voet, D., Voet, J.G. and Pratt, C.W. (2012). Principles of Biochemistry. Fourth edition. John Wiley & Sons, UK.
2. Wilson, K. and Walker, J. (2010). Principles and Techniques of Biochemistry and Molecular Biology, Seventh edition, Cambridge University Press, USA.
3. Daniel, C.L. (2002). Introduction to Proteomics-Tools for New Biology. Humana Press, Totowa, NJ.
4. Twyman, R. (2014). Principles of Proteomics. Second edition. Garland Science, Taylor and Francis group, UK Comai, L., Katz, J. and Mallick, P. (2017) Proteomics-Methods and Protocols, Springer Protocols, Springer New York.

## SKILL BASED COURSE/SPECIALISED LABORATORY

### SBC-2 Analytical Techniques in Plant Biology

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Analytical Techniques in Plant Biology SBC-2 | 2 | 0 | 0 | 2 | Graduate with Botany as one of the subjects | Nil |

**Course Objectives**

This course will train the students in various techniques related to plant biology. Students will learn foundational experiments including microscopy, molecular biology, bioinformatics and biotechnology.

**<u>Practicals 15 x 4 hrs.= 60 hours</u>**

1. Databases and online tools
2. Nucleic acid isolation and electrophoresis (DNA and RNA)
3. Protein extraction and electrophoresis
4. Microscopy bright field, fluorescence, confocal, phase contrast, differential interference contrast, scanning and transmission electron microscopy
5. Spectrophotometry
6. Bacterial transformation using different methods
7. Handling model systems in biology
8. Polymerase Chain Reaction
9. Thin layer chromatography for the separation of various metabolites
10. Analysis of nitrogenous compounds from plants.

**Suggested Readings:**

1. Cooper, G.M., Hausman, R.E. (2009). The Cell: A Molecular Approach, 5th edition. Washington, D.C.: ASM Press & Sunderland, Sinauer Associates, MA.
2. Iwasa, J., Marshall, W. (2016). Karps's Cell and Molecular Biology: Concepts and Experiments. New Jersey, U.S.A.: John Wiley & Sons.
3. Hofmann, A., & Clokie, S. (2018). Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology (8th ed.). Cambridge University Press.
4. Karp, G., Iwasa, J., & Marshall, W. (2019). Karp's Cell and Molecular Biology, 9th Edition: Wiley.
5. O' Brien, T.P. and Cully, M.E. (1981). The Study of Plant Structure. Principles and selected Methods, Termarcarphi Pty. Ltd., Melbourne.

## GENERIC ELECTIVE - 1

## Plants, People and the Planet

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| PLANTS, PEOPLE AND THE PLANET<br>GE-1 | 4 | 3 | 1 | 0 | Graduate in any discipline | Nil |

### Course Objectives

To present a dynamic history of plant use by humans and show the impact of plant life on human development.

### Course Learning Outcomes

Students will understand historical interactions between plants and humans. Influence of vegetation on the earth's landscape and beginning of agriculture and of human civilization. They wil get the insight on the Plant utilization, dispersal and genetics and influence of plant products on human migrations, colonization. They will learn about the science of crop domestication and improvement and genetically modified organisms and the contentious issues involved with their cultivation and utilization. Students will enhance their ability to deal with present planetary conditions and prepare for future challenges.

**<u>Theory 15 x 3 hrs. = 45 hours</u>**

### Contents

**Unit I** **(10 hours)**

Plants and earth's early landscape; origin of plants; plants as geo-engineers of early atmosphere, role of early plants in biogeochemical cycles; evolution of trees; first forests and their role in global climate change; formation of the first grasslands, plants and water bodies.

**UNIT II** **(15 hours)**

"Taming" of wild plants by man, Beginning of Agriculture- when, where and how; Story of transforming wild plants to modern day crops; Role of plants in human civilizations; Influence of plants on language, religious and cultural practices, folklore, fine arts and *vice-versa*; Plants in trade, and human migrations; plants/plant groups that affected human settlements such as wheat, rice, sugarcane, apple, spices, tea, cotton, potato, narcotic plants, etc.

**UNIT III** **(10 hours)**

Plants and Politics: specific plants/plant-related issues and politics; Ecological capitalism; Amaranth in indigenous civilizations of Mesoamerica and Spanish invasion- consequences; the 'Columbian exchange'; plant disease epidemics and famines; Indigo revolt and origin of India's non-violent struggle for independence; 'Chipko' movement; Reversing the Anthropocene.

**UNIT IV** **(10 hours)**

Genetically modified plants: contentious issues, apprehensions and fears - myths or reality, market forces versus scientific logic; 'Plants of the future and the future of plants'; Super-domestication; Novel uses of plants, new crop plants- permaculture, edible weeds; Vertical agriculture; Plants as candidates for colonization of other planets; plants in bioterrorism and biosecurity; Traditional knowledge benefit sharing; Intellectual property rights.

**Tutorials 15 x 1 hr. = 15 hours**

Group Discussions: Tutorials will provide an opportunity for students to discuss issues raised during the lectures.

**Suggested readings**

1. Laws, B. (2015). Fifty Plants that Changed the Course of History. Firefly Books Ltd. ISBN 978-1770855885.

2. Fowler, C. and Mooney, P. (1991). The Threatened Gene: Food, Politics, and the Loss of Genetic Diversity. Lutterworth press. ISBN 978-0-7188-2830-1.

3. Ladizinsky, G. (1998). Plant Evolution under Domestication. Kluwer. ISBN 978-0412822100.

4. Zohary, D., Hopf, M. and Weiss, E. (2012). Domestication of Plants in the Old World: The Origin and Spread of Domesticated Plants in Southwest Asia, Europe, and the Mediterranean Basin. Oxford University Press. ISBN 978-0-19-954906-1.

5. Anderson, D., Goudie, A.D. and Parker, A. (2013). Global Environments Through the Quaternary: Exploring Environmental Change. Oxford University Press. p. 283. ISBN 978-0-19-969726-7.

**Additional readings**

1. Sidney, M. (1986). Sweetness and Power: The place of sugar in modern history, Penguin. ISBN 978-0-14-009233-2.
2. Crosby, A.W. (1972) The Columbian Exchange: Biological and Cultural Consequences of 1492. Greenwood Publishing Co. ISBN 9780-837158211.
3. Pieroni, A. and Vandebroek, A.I. (2007). Traveling cultures and plants: The Ethnobiology and Ethnopharmacy of Human Migrations. Berghahn Books. ISBN 978-1-84545-373-2.
4. Office of International Affairs (1989). Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide Cultivation. National Academy Press.. p. 92. ISBN 030904264X.
5. Zabel, P., Bamsey, M., Schubert, D. and Tajmar, M. (2016). Review and analysis of over 40 years of space plant growth systems. Life Sciences in Space Research 10: 1-16.
6. Gaudet, J. (2015). Papyrus: The plant that changed the World from Ancient Egypt to Today's Water Wars. Pegasus. ISBN-13: 978-1605985664.

## GENERAL ELECTIVE 2

## CLIMATE CHANGE AND ECOSYSTEM FUNCTION

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Climate change and ecosystem function GE 2 | 4 | 3 | 1 | 0 | Graduate in any discipline | Nil |

**Course Objectives**

This course aims to introduce the students with the issues related to climate change and how it is affecting the functioning of various ecosystems on which human livelihood is dependent.

**Course Learning Outcomes**

The students will be learning

1. The meaning of terms weather, climate and how variability in weather is distinctly different from climate change.
2. The role of greenhouse gases in supporting life on earth and how anthropogenic activities changed the balance of these gases over time.
3. The past and present climate scenarios and how this information was derived?
4. What are ecosystem functions and how climate change affects them?
5. Climate change and species migration ecological, reproductive and genetic evidences
6. What are IPCC climate models? How modeling species in the light of climate change and socioeconomic relevance would help species conservation and ecosystem functioning?
7. Climate conventions and India's commitment to fight climate change.
8. Understanding climate change and the clean development mechanism.
9. Climate change mitigation, adaptational mechanisms and climate resilient technologies.
10. What is the role of International policy on climate mitigation?

**Theory <u>15 x 3 hrs.= 45 hours</u>**

**Unit I** **(4 hours)**

Definitions of terms – weather, climate and ecosystem functions. Climate change over different time scales (evolutionary and current).

**Unit II** **(4 hours)**

Drivers of ecosystem function change over temporal scale, abiotic factors and their impact on ecosystem function, anthropogenic disturbances in ecosystem function.

**Unit III** **(10 hours)**

Climate change and its consequences for – sea level, rainfall pattern, hydrological systems, extreme events, greenhouse gas emissions past, current and future trends, IPCC climate models and future scenarios, Modeling species and ecosystem response, estimating extinction risk from climate change, the Warsaw framework on REDD+, Impact of REDD+ projects on climate mitigation and people's livelihood, Clean development mechanism biological to industrial, International policy and action.

**Unit IV** **(12 hours)**

Expected impacts of climate change on major ecosystems and their consequences for human livelihood, Climate change and species range shift ecological and genetic evidences, climate change effects on plant reproductive traits, effect of climate change on plant-pathogen interaction, technologies for climate resilient agriculture, impact of climate change on cell signalling pathways, effect of heavy metal pollution on the environment and climate.

**Tutorials** **15 x 1 hrs.= 15 hours**

Group Discussions: Tutorials will provide an opportunity for students to discuss and clear doubts arising during the lectures.

**Suggested Readings:**

1. Bonan, G. 2015. Ecological Climatology Concepts and Applications. Cambridge University Press. ISBN 9781107339200. 692 pages.
2. Best, R.J., Stone, M.N. & Stachowicz, J.J. 2015. Predicting Consequences of Climate Change for Ecosystem Functioning Variation Across Trophic Levels, Species and Individuals. John Wiley & Sons Limited.
3. Hannah, L. 2022. Climate Change Biology. 3rd Edition, Academic Press, ISBN 9780081029756, https//doi.org/10.1016/B978-0-08-102975-6.18001-X. 508 pages.
4. Post, E. 2013. Ecology of Climate Change The Importance of Biotic Interactions. Princeton University Press. ISBN 978-0-691-14847-2. 376 pages.
5. Smith, T.M., Shugart, H.H. & Woodward, F.I. (Eds.) 1997. Plant Functional Types Their Relevance to Ecosystem Properties and Global Change. Cambridge University Press. ISBN 0 521 56643 6. 371 pages.

**Additional Readings:**

1. Romm, J. 2018. Climate Change. What Everyone Needs to Know. Second Edition. Oxford University Press. ISBN 978 0190866105. 300 pages.
2. UNFCC United Nations Framework Convention on Climate Change. https//unfccc.int/
3. IPCC Intergovernmental Panel on Climate Change. https//www.ipcc.ch/