University of Kalyani

কল্যাণী বিশ্ববিদ্যালয়

2-Year Post Graduate Curriculum for Botany
As per NEP-2020 Framework

2026 onwards

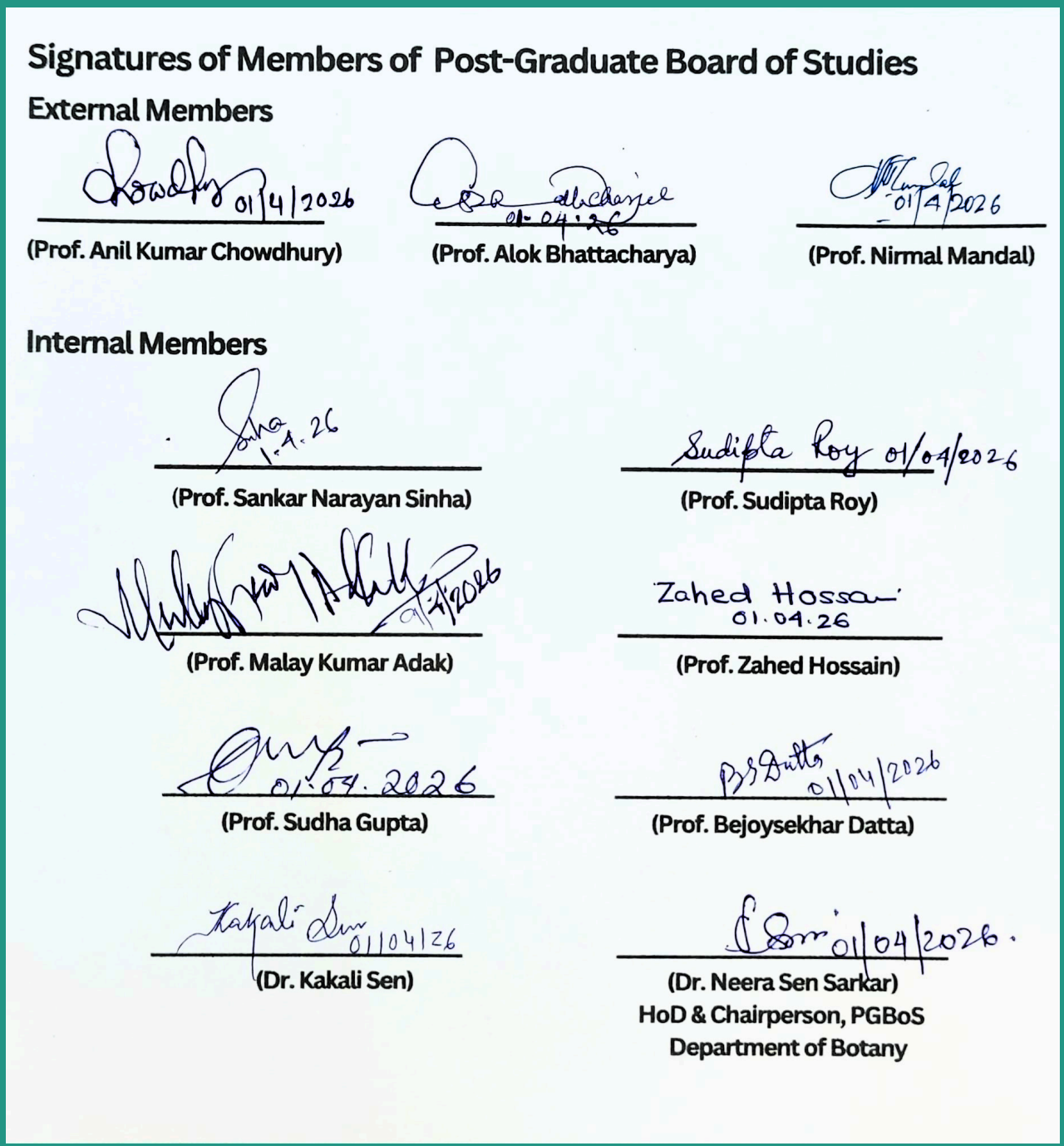
2-Year PG Curriculum for Botany

As per NEP-2020 Framework

Recommended by the Post-Graduate Board of Studies

Department of Botany, Faculty of Science

in its 18th Meeting held on 1st April 2026



Signatures of Members of Post-Graduate Board of Studies

External Members

01/4/2026
(Prof. Anil Kumar Chowdhury)

01.04.26
(Prof. Alok Bhattacharya)

01/4/2026
(Prof. Nirmal Mandal)

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Sudipta Roy 01/04/2026
(Prof. Sudipta Roy)

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(Prof. Bejoysekhar Datta)

01/04/26
(Dr. Kakali Sen)

01/04/2026.
(Dr. Neera Sen Sarkar)
HoD & Chairperson, PGBoS
Department of Botany

Preamble

M.Sc. in Botany

The M.Sc. Botany Programme has been designed in accordance with the guidelines of the National Education Policy (NEP) 2020 to provide advanced and integrative knowledge of plant diversity, structure, function, evolution, and their ecological and biotechnological significance. In alignment with the vision of the University of Kalyani and the guiding principles of the said policy, the curriculum seeks to strengthen disciplinary depth while promoting interdisciplinary engagement across allied domains such as environmental science, conservation biology, microbiology, biotechnology, and computational biology. The programme integrates classical foundations of plant sciences with emerging developments in areas such as molecular biology, genomics, bioinformatics, plant biotechnology, and climate change issues.

The curriculum emphasizes upon scientific inquiry, critical thinking, and evidence-based learning through a balanced combination of theoretical instruction, laboratory experimentation, field-based studies, self-study modules, and research training. Students are encouraged to develop competencies in hands-on application of modern analytical tools, designing experiments, data analysis, and scientific communication. Special attention has been given to the study and conservation of plant biodiversity, ecosystem functioning, and sustainable management of plant resources, with contextual relevance to regional and national ecological challenges.

Through its interdisciplinary and research-oriented approaches, the programme aims to prepare post-graduates for diverse professional pathways in higher education, scientific research, environmental management, biotechnology industries, and policy-related sectors. The programme also encourages innovation and plant-based entrepreneurship, including the development of products and sustainable enterprises derived from plant resources such as herbal products, natural dyes, nutraceuticals, and plant-based bioresources. At the same time, the programme seeks to cultivate ethical values, environmental stewardship, and an appreciation of Indian Knowledge Systems related to understanding plant systems, plant use, conservation, and sustainable living, thereby fostering responsible scholars committed to lifelong learning and societal well-being.

Content

About the Department

Department of Botany, University of Kalyani

Established in 1961 under the leadership of Prof. S. P. Sen, F.N.A., the Department of Botany at University of Kalyani has grown into a recognized centre for teaching and research in plant sciences. Over the decades, the department has developed strong postgraduate and doctoral programmes while contributing significantly to botanical research and training in eastern India.

The department is equipped with both postgraduate teaching laboratories and specialized research facilities, including a skill and entrepreneurship development laboratory, seminar spaces, and a reference library-cum-computer laboratory. Research infrastructure has been strengthened through support from national programmes such as UGC-DRS/SAP, UGC-COSIST, DBT initiatives, and DST-FIST. The department also maintains several outreach-oriented facilities including a Fossil Museum, Herbal Garden – Nature Intervention for Air Quality Enhancement, Fern and Gymnosperm Garden, and the Kalyani University Biodiversity Educational and Conservation Park, which serve as important platforms for experiential learning, biodiversity conservation, and public engagement.

The Department actively promotes interdisciplinary research and training in areas such as plant diversity and systematics, algal and microbial biology, plant physiology, molecular biology and biotechnology, environmental biology, and biodiversity conservation. Alongside academic and research programmes, the department encourages skill development and plant-based entrepreneurship through hands-on training in sustainable utilization and value addition of plant resources, thereby strengthening the interface between plant science, conservation, and societal needs.

Graduate Attributes

2-Year Post-Graduate Curriculum in Botany

The postgraduate programme in Botany aims to prepare graduates who are academically proficient in plant sciences while being socially responsible, ethically grounded, and environmentally conscious. The programme seeks to develop strong disciplinary foundations in diverse arenas of plant sciences. It aims to cultivate scientifically skilled professionals capable of advancing research, understanding plant health and disease, promoting biodiversity conservation, and applying modern biological knowledge to sustainable agriculture and environmental management. The programme also encourages innovation and plant-based entrepreneurship, enabling its graduates to contribute to scientific advancement and the ecological and socio-economic well-being of society.

1.Advanced Disciplinary Knowledge – Demonstrate comprehensive understanding of core and emerging areas of plant sciences, including extant and extinct plant diversity, systematics, plant developmental biology, physiology, biochemistry, genetics, cell biology, palaeobotany, palynology, microbiology, plant pathology, ecology, molecular biology, biotechnology, and environmental biology, with the ability to integrate theoretical knowledge with practical applications.

2.Research Competency – Design and conduct independent and collaborative research using appropriate experimental methods, field techniques, statistical tools, and ethical scientific practices to address biological and environmental questions.

3.Laboratory, Field, and Technical Skills – Demonstrate proficiency in laboratory techniques, field-based investigation, plant identification, biodiversity assessment, and the use of modern biological instruments, analytical tools, and scientific documentation methods.

4.Digital and Technological Fluency – Utilize digital resources, bioinformatics, scientific databases, and information technologies for data analysis, literature review, research communication, and knowledge management in plant sciences.

5.Critical Thinking and Problem-Solving – Apply analytical reasoning and scientific inquiry to evaluate ecological processes, experimental outcomes, and environmental challenges, developing evidence-based solutions to complex biological problems.

Graduate Attributes

2-Year Post-Graduate Curriculum in Botany

6.Application of Knowledge for Sustainability – Apply botanical knowledge to practical contexts such as biodiversity conservation, plant health advancement and combatting plant diseases, sustainable agriculture, environmental management, climate change mitigation, and restoration of ecosystems.

7.Interdisciplinary and Indigenous Knowledge Awareness – Recognize the relevance of interdisciplinary approaches and Indian Knowledge Systems related to plant use, traditional ecological knowledge, ethnobotany, and sustainable resource management.

8.Communication and Scientific Dissemination – Communicate scientific ideas, research findings, and technical information effectively through academic writing, presentations, field reports, and public outreach in both English and regional languages.

9.Teamwork and Leadership – Collaborate effectively in research groups, field teams, and institutional settings while demonstrating leadership potential in academic, research, and environmental initiatives.

10.Ethical Values and Social Responsibility – Uphold ethical standards, scientific integrity, environmental stewardship, intellectual property rights, and respect for biodiversity while demonstrating sensitivity to constitutional, humanistic, and societal values.

11.Employability and Professional Readiness – Develop job-ready competencies for careers in research, higher education, environmental consultancy, biotechnology, agriculture, conservation organizations, and related sectors through practical training and experiential learning.

12.Entrepreneurship, Innovation, and Lifelong Learning – Cultivate an entrepreneurial mindset by exploring plant-based enterprises such as herbal product development, plant tissue culture ventures, sustainable agriculture, and biodiversity-based industries while maintaining commitment to lifelong learning and professional growth.

Programme Learning Outcomes

(PLO)

After successful completion of the Postgraduate Programme in Botany, the learner will be able to:

PO1. Advanced Knowledge of Plant Diversity, Structure, Function and Evolution: Acquire comprehensive knowledge of plant diversity from algae to angiosperms, including phycology, bryology, pteridology, gymnosperms, palaeobotany, systematics, and evolutionary relationships.

PO2. Conceptual Integration of Classical and Modern Plant Sciences: Integrate classical botanical disciplines with modern areas such as genetics, plant physiology, biochemistry, molecular biology, and microbiology to understand plant life processes at multiple levels.

PO3. Critical Thinking, Scientific Reasoning and Evidence-Based Interpretation: Develop the ability to critically evaluate scientific literature, analyze biological data, and interpret experimental results using scientific reasoning and evidence-based approaches.

PO4. Scientific Inquiry, Experimental Design and Hypothesis Testing: Formulate research questions and design experiments in areas such as plant physiology, genetics, microbiology, and plant pathology using appropriate scientific methodologies.

PO5. Laboratory, Field and Instrumentation Skills in Plant Sciences: Demonstrate competence in laboratory techniques, plant identification, field survey methods, microscopy, biochemical analysis, and modern biological instrumentation.

PO6. Computational, Bioinformatics and Biostatistical Skills for Biological Data Analysis: Apply computational tools, bioinformatics resources, and statistical techniques to analyze genetic, molecular, ecological, and experimental biological datasets.

PO7. Interdisciplinary Application of Botanical Knowledge in Environmental and Biological Sciences: Apply botanical concepts to interdisciplinary domains such as environmental biology, biodiversity conservation, sustainable agriculture, crop protection, forensic botany and climate change studies.

Programme Learning Outcomes

(PLO)

PO8. Independent Research, Innovation and Scientific Problem Solving: Conduct independent research through dissertation work, employing research methodology, data analysis, and innovative problem-solving in plant science.

PO9. Scientific Communication, Technical Writing and Professional Presentation Skills: Effectively communicate research findings through scientific reports, dissertations, seminar presentations, and academic discussions.

PO10. Ethical Conduct, Biosafety and Intellectual Property Awareness in Scientific Practice: Demonstrate ethical scientific conduct, biosafety awareness, and understanding of intellectual property rights in research and biotechnology applications.

PO11. Social Responsibility, Environmental Stewardship and Constitutional Values: Promote biodiversity conservation, sustainable use of plant resources, and environmental awareness while upholding constitutional values and societal responsibility.

PO12. Employability, Entrepreneurship and Bio-innovation in Plant-based Sectors: Develop professional competencies and entrepreneurial skills through courses on bio-innovation, herbal resources, mushroom cultivation, nutraceuticals, and plant tissue culture for careers in research, industry, and plant-based enterprises.

Mapping of
Programme Learning Outcomes vs Course Learning Outcomes

Programme Learning Outcomes: From Foundational to Advanced Level

Programme Outcome #	Programme Learning Outcome	Learning Outcome Level
PO1	Advanced Knowledge of Plant Diversity, Structure, Function and Evolution	Foundational Knowledge Outcomes
PO2	Conceptual Integration of Classical and Modern Plant Sciences	
PO3	Critical Thinking, Scientific Reasoning and Evidence-Based Interpretation	Analytical and Cognitive Skill Outcomes
PO4	Scientific Inquiry, Experimental Design and Hypothesis Testing	
PO5	Laboratory, Field and Instrumentation Skills in Plant Sciences	Technical and Methodological Skill Outcomes
PO6	Computational, Bioinformatics and Biostatistical Skills for Biological Data Analysis	
PO7	Interdisciplinary Application of Botanical Knowledge in Environmental and Biological Sciences	Applied and Interdisciplinary Outcomes
PO8	Independent Research, Innovation and Scientific Problem Solving	Research and Scholarly Outcomes
PO9	Scientific Communication, Technical Writing and Professional Presentation Skills	
PO10	Ethical Conduct, Biosafety and Intellectual Property Awareness in Scientific Practice	Ethical, Social and Professional Outcomes
PO11	Social Responsibility, Environmental Stewardship and Constitutional Values	
PO12	Employability, Entrepreneurship and Bio-innovation in Plant-based Sectors	Career, Innovation and Entrepreneurship Outcomes

Matrix of Programme Learning Outcomes (PLOs) to Course Learning Outcomes (CLOs)

Course Code	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
SEMESTER – I												
BOT-MJR-401			■					■				
BOT-MJR-402	■	■	■				■	■	■		■	■
BOT-MJR-403	■	■	■	■	■		■	■			■	■
BOT-MJR-404	■	■	■		■				■			
BOT-MNR-405	■	■					■	■	■		■	
BOT-MNR-406	■		■									
BOT-VAC-449					■	■			■			
SEMESTER – II												
BOT-IDS-451		■					■					
BOT-MJR-452	■	■	■	■	■		■	■	■	■		■
BOT-MJR-453	■	■	■	■		■						
BOT-MJR-454	■	■	■	■	■	■	■	■	■	■	■	■
BOT-MJR-455	■		■	■								
BOT-SEC-456A	■	■	■							■	■	
BOT-SEC-456B	■					■				■	■	■
BOT-SEC-456C	■	■	■	■	■	■	■	■	■	■	■	■
BOT-SEC-456D			■	■			■	■		■	■	■
BOT-VAC-499	■		■				■				■	

Matrix of Programme Learning Outcomes (PLOs) to Course Learning Outcomes (CLOs)

Course Code	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
SEMESTER – III												
BOT-IKS-501*		■	■	■			■	■	■		■	■
BOT-MJR-502	■		■	■	■	■	■	■	■		■	■
BOT-MJR-503	■	■	■	■	■	■	■	■	■	■	■	■
BOT-MNR-504	■	■		■	■			■	■			■
BOT-MNR-505	■	■	■	■	■	■	■	■	■	■	■	■
BOT-MNR-506	■	■	■	■	■	■	■	■	■	■	■	■
BOT-EEC-507A		■	■	■	■	■	■	■	■	■	■	■
BOT-EEC-507B	■	■		■	■							■
BOT-EEC-507C			■	■	■			■	■			■
BOT-EEC-507D		■	■	■	■			■	■	■	■	■
BOT-EEC-507E	■			■	■							■
BOT-EEC-507F	■	■		■	■							■
BOT-EEC-507G		■		■	■		■			■	■	■
BOT-EEC-507H	■	■	■	■	■	■	■	■	■	■	■	■
SEMESTER -IV												
BOT-MJR-551			■	■		■		■	■	■		
BOT-GRP-599			■	■	■	■	■	■	■	■	■	■

Semester-wise Programme Structure

Semester	Course Code	Course Title	Course Type	Credit Pattern			Credit Value	Marks Distribution			Page No.
				Lecture (L)	Self-Study/ Tutorial (SS/T)	Practice/ Field (P/F)		Summative Assessment (60%)	Continuous Assessment (40%)	Total Marks	
SEM I #	BOT-MJR-401	Microbiology and Immunology	Major (Th+PR)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	13
	BOT-MJR-402	Phycology	Major (Th+PR)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	15
	BOT-MJR-403	Bryology and Pteridology	Major (Th+PR)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	17
	BOT-MJR-404	Gymnosperm, Plant Systematics and Taxonomy of Angiosperms	Major (Th+PR)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	20
	BOT-MNR-405	Mycology	Minor (Th)	2	0	0	2	30 (W)	20 (W)	50	22
	BOT-MNR-406	Cell Biology	Minor (Th)	2	0	0	2	30 (W)	20 (W)	50	23
	BOT-VAC-449	Instrumentations and Techniques in Biological Science	Value Added Course	Faculty guided VLE	--	--	--	Gradation based evaluation			24
	NCrF Level 6: UGC Course Level 400-449			**12**	**4**	**4**	**20**	**300**	**200**	**500**	

VLE: Virtual Learning Environment

Assessment Modes: W – Written; P – Practical; PPT – Power Point Presentation; A – Assignment submission

Semester	Course Code	Course Title	Course Type	Credit Pattern			Credit Value	Marks Distribution			Page No.
				Lecture (L)	Self-Study/ Tutorial (SS/T)	Practice/ Field (P/F)		Summative Assessment (60%)	Continuous Assessment (40%)	Total Marks	
SEM II #	BOT-IDS-451	Botanical Research and SDGs	Inter-disciplinary	2	2	0	4	60 (W)	40 (W)	100	26
	BOT-MJR-452	Plant Pathology and Crop Protection	Major (Th+PR)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	28
	BOT-MJR-453	Genetics	Major (Th+PR)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	30
	BOT-MJR-454	Advanced Plant Physiology	Major (Th+PR)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	32
	BOT-MJR-455	Plant Biochemistry, Metabolism and Developmental Biology	Major (Th+PR)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	34
	BOT-SEC-456 **Any one**	**456 A:** AI Applications in Plant Science **456 B:** Bioinformatics **456 C:** Forensic Botany **456 D:** Intellectual Property Rights	SEC	2	VLE	0	2	30 (W)	20 (W)	50	36 37 39 40
	BOT-VAC-499	Environmental Biology **OR** Biodiversity and Conservation	Value Added Course	Faculty guided VLE	---	---	---	Gradation based evaluation			41 42
	NCrF Level 6: UGC Course Level 450-499			**12**	**6**	**4**	**22**	**330**	**220**	**550**	

***Meant for Interdisciplinary Course for students from departments of KU including Botany. Botany students will opt for an interdisciplinary course from Botany/other PG departments of KU (mandatory).**

 # After the 1st and 2nd semesters, students may opt for the exit option. Those who exit at the end of 1st year (1st and 2nd semesters) shall be awarded a Postgraduate Diploma in Botany (as per UGC nomenclature – NHEQF Level 6).

Semester	Course Code	Course Title	Course Type	Credit Pattern			Credit Value	Marks Distribution			Page No.
				Lecture (L)	Self-Study/ Tutorial (SS/T)	Practice/ Field (P/F)		Summative Assessment (60%)	Continuous Assessment (40%)	Total Marks	
SEM III	BOT-IKS-501	Indian Knowledge System in Plant Science	IKS (Th)	2	2	0	4	60 (W)	40 (W)	100	44
	BOT-MJR-502	Ecology: Theories and Plant Systems	Major (Th+Pr)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	46
	BOT-MJR-503	Palaeobotany and Plant Evolution	Major (Th+Pr)	2	1	1	4	45 (W) 15 (P)	30 (W/PPT+A) 10 (P)	100	48
	BOT-MNR-504	Pharmacognosy	Minor (Th)	2	VLE	0	2	30 (W)	20 (W)	50	51
	BOT-MNR-505	Plant Molecular Biology	Minor (Th)	2	VLE	0	2	30 (W)	20 (W)	50	52
	BOT-MNR-506	Palynology and Its Application	Minor (Th+Pr)	1	0	1	2	30 (W)	20 (W)	50	53
	BOT-EEC-507 **(Any one)** Skill-based/ Vocational courses	**507 A:** Food Safety and Microbial Contamination Analysis **507 B:** Plant-Based Bioactive Compounds and Nutraceuticals **507 C:** Development of stress resilient crop ideotypes **507 D:** Plant Tissue Culture Techniques **507 E:** Pollination Biology and Apicultural Entrepreneurship **507 F:** Mushroom Cultivation and Entrepreneurial Technology **507 G:** Bio-innovation and Startups in Algal and Herbal Resources **507 H:** Ferns and Mosses: Care, Handling and Experimental Approach	EEC	--	2	2	4	45 (W/PPT+ Product / Business Model) 15 (W)	30 (PPT/ Report) 10 (W)	100	55 57 59 60 62 63 65 67
	NCrF Level 6.5: UGC Course Level 500-549			**11**	**6**	**5**	**22**	**330**	**220**	**550**	

Semester	Course Code	Course Title	Course Type	Credit Pattern			Credit Value	Marks Distribution			Page No.
				Lecture (L)	Self-Study/ Tutorial (SS/T)	Practice/ Field (P/F)		Summative Assessment (60%)	Continuous Assessment (40%)	Total Marks	
SEM IV	BOT-MJR-551	Research Methodology	Major (Th)	2	2	0	4	60 (W)	40 (W)	100	70
	BOT-GRP-599	~Guided Research Project	Dissertation	--	2	14	16	*300	§100	400	72
	NCrF Level 6.5: UGC Course Level 550-599			2	4	14	20	360	140	500	
Evaluation Schemes of M.Sc. Botany Curriculum in accordance with NEP2020 Guidelines											73

~ If students carry out their research project in other departments of same or different institutes, faculty member of Botany Department will act as internal supervisor, as well as internal examiner.

* Thesis Write-up: 200; Seminar presentation: 50; Viva-Voce: 50 (to be evaluated by both external and internal examiners)

§ Review of Literature (to be submitted within one month of initiation of course); Write up: 50; Presentation: 30; Interaction: 20

Grand total	**84**	**1420**	**680**	**2100**	

Credit Distribution – 84 Credits

Major (MJR) courses – **44 credits**	Minor [MNR] + EEC + SEC courses – **10 + 4 + 2 = 22 credits**	
Theory + Practical	MNR (Mandatory) **Theory + Practical**	EEC [Electives] – 4 credits and SEC [Electives] – 2 credits
Courses: 11 Theory Credits: 22 Self-Study/ Tutorial: 12 Practical Credits: 10	Courses: 05 Theory Credits: 09 Practical Course: 01 Practical Credit: 01	Courses: 02 Credits: 06
Total: 10 courses and **44 credits**	**Total:** 5 courses and **10 credits**	**Total:** 2 courses and **6 credits**
Interdisciplinary (IDS) – **4 credits**	Indian Knowledge System (IKS) – **4 credits**	Dissertation – **16 credits**
Course: 01 Credits: 04	Course: 01 Credits: 04	Course: 01 (GRP) Credits: 16
Total: 1 course and **4 credits**	**Total:** 1 course and **4 credits**	**Total:** 1 course and **16 credits**

SEMESTER I

Course Code: BOT-MJR-401	**Course Title: Microbiology and Immunology**	
Course Nature: Coursework	**Course Level: 400-449**	**NCrF credit level: 6**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory :	**45 hours; Total : 90 days; 3 hrs/ week**	
Self-study/ Tutorial :	**20 hours; Total : 90 days; 1 hr/ week**	
Practical :	**45 Hours; Total : 90 days; 3 hrs/ week**	

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain the diversity in structure and functioning of prokaryotes.
2. Describe the mechanism of disease development by pathogens.
3. Analyze the interaction of pathogen with host in relation to infectivity.
4. Demonstrate skills in controlling microbial diseases in day-to-day life.
5. Demonstrate proficiency in isolation techniques, identification and maintenance of pure cultures.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Bacterial Systematics**	Three kingdom concept of Haeckel, Five kingdom concept of Whittaker and Three domain classification of Woese, characters used in bacteriology, classification - phenetic and phylogenetic, major groups of microorganisms.	**2**
2	**Thermodynamic Principles in Microbiology**	Concept of free energy, entropy, enthalpy, energy rich bonds, chemical potential, membrane potential, diffusion potential, concept of mathematical models, application of mathematical models to microbiological processes.	**3**
3	**Bacterial Morphology**	Structure, chemistry and function of capsule, pili, flagella, cell wall, cell membrane, ribosome, chromosome and plasmid, reserved materials and cytoplasmic inclusions, endospore (structure, formation, germination).	**3**
4	**History of Development of Virology**	Nature, classification and nomenclature of viruses, structural organization and chemistry of viruses, assay of viruses, chemical and physical determination, assays of infectivity, virus diseases in plants, symptoms of diseases, general transmission of viruses, bacteriophages- isolation and demonstration, structure of adenoviruses, tobacco mosaic viruses and coliphage T4, multiplication of a virulent phage (lytic cycle), lysogeny- nature of lysogeny, vegetative cycle, lysogenic state, prophage cycle, induction of a lysogenic cell, formation of tumours, relation of viruses and plasmids in tumour formation, formation of animal tumours by DNA viruses and RNA viruses, brief idea about SARS virus, MARS virus, Zica virus, Nipah virus, Ebola virus and Hanta virus, general account of viroids, virusoids, and prions.	**15**

Unit No.	Unit	Topics	Class Hours
5	**Microbial Growth and Nutrition**	Nutritional types and requirements, types of media (natural, synthetic, semisynthetic, complex, selective), growth- phases of growth, kinetics of growth, factors influencing growth, batch culture, continuous culture, synchronous culture, diauxie, control of microorganisms: physical, chemical and chemotherapeutic agents, antibiotic resistance, control of virus using chemicals and interferon.	**5**
6	**Genetic Recombination in Bacteria**	Transformation, transduction and conjugation.	**2**
7	**Microbes in Nitrogen, Phosphorous and Sulphur Cycles**	Mechanism of biological N_2 fixation and structure and regulation of nif gene.	**3**
8	**Medical Microbiology**	Air borne diseases, water borne diseases, food borne diseases, venereal diseases, nosocomial disease, cosmetic microbiology: concept and current trends.	**3**
9	**Industrial Microbiology**	Industrial microorganisms, strain improvement, production of ethanol, penicillin, streptomycin, and vitamin B12.	**3**
10	**Fundamentals of Immunology**	Innate and acquired immunity, T-cell, B-cell, MHC, cytokines, antigen - types and characteristics: structure and functions of immunoglobins, cell mediated and humoral immunity, Ag-Ab reactions and immunological techniques, cancer immunology, transplantation immunology, vaccines and vaccination, brief account on immuno-induction, immune-suppression, immuno-tolerance, immuno-potentiation.	**6**

Practical Course Content

Practical Components	Activities/ Experiments
Plant Virology	1. Study of symptoms of diseases of economically important plants caused by virus. 2. Study of inclusion bodies in virus infected plants. 3. Study of epidermal patterns of virus infected leaves with reference to change in stomatal index. 4. Identification of some common virus vectors. 5. Biochemical tests for detection of plant viruses.
Isolation, Enumeration and Staining	6. Isolation and enumeration of bacteriophages 7. Isolation and enumeration of bacteria from air, water, soil and food samples. 8. Endospore and capsule staining of bacteria.
Soil and Agricultural Microbiology	9. Isolation and staining of Rhizobium from root nodules. 10. Enrichment and isolation of nitrogen fixing bacteria from soils.
Medical and Clinical Microbiology	11. Estimation of urine bacteria by calibrated loop -direct streak and pour plate method. 12. Isolation of enteric pathogens from stools by direct plating method.

Practical Components	Activities/ Experiments
Microbial Growth, Physiology, Biochemistry and Antibiotic Sensitivity	13. Determination of thermal death point of bacteria. 14. Study of bacterial growth and effect of inhibitor on bacterial growth. 15. Determination of antibiotic sensitivity of bacteria by disc diffusion and agar cup method. 16. Biochemical tests for characterization of microorganisms: catalase, protease, amylase, nitrate reductase, indole production. 17. Microbiological examination of milk by methylene-blue dye reduction test.

Note: Regularly checked Laboratory records, permanent slides prepared during practical classes, preserved and dried (herbarium sheets) virus infected plants specimens collected during field works should be submitted at the time of TEE.

Suggested Readings:

1. Pelczar, M. J., Chan, E. C. S and Kreig, N. R. (1993). Microbiology. Tata McGraw Hill Education Private Limited, New Delhi
2. Prescott, L. M., Harley, J.P. and Klein, D. A. (1992). Microbiology, WCB Publishers
3. Madigan, M. T. Martinko, J. M. and Parker Jack. (2000). Brock's Biology of Microorganisms, 9th edition. Prentice Hall. NJ. USA
4. Sumbali, G. and Mehrotra, R. S. (2009). Principles of Microbiology, 1stedition. Tata McGraw Hill Publishing Co. Ltd. New Delhi
5. Demain A.L, Davis J.E. and Atlas R. M. (1999). Manual of industrial microbiology and biotechnology. American society for microbiology. Washington DC
6. Khan, J.A. and Dijkstra J. (2007). Handbook of Plant Virology, Taylor and Francis
7. Bos, L. Introduction to plant virology. Oxford and IBH publication
8. Ingraham, J. L. and Ingraham, C.A. (2005). Microbiology: An Introduction. Cengage Learning Ltd.
9. Sinha S.N. (2006). Focus on college practical microbiology. Rita Book Agency, Calcutta-73
10. Talwar G.P., Gupta S.K.A handbook of practical and clinical immunology. CBS, New Delhi

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Course Code: BOT-MJR-402	**Course Title: Phycology**	
Course Nature: Coursework	**Course Level: 400-449**	**NCrF credit level: 6**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week** **Practical: 45 Hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain the origin, evolutionary trends and systematic position of major algal groups, with clarity on their phylogenetic relationships.
2. Analyse the ecological significance of algae across diverse aquatic and terrestrial ecosystems, highlighting their roles in productivity, nutrient cycling, and environmental dynamics.

3. Evaluate the biotechnological, agricultural and industrial applications of algae, including their potential in sustainable resource development.
4. Demonstrate proficiency in microscopic identification, culture techniques, and practical handling of algae for research and applied purposes.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Algal Origin and Evolution**	Origin of algae, endosymbiotic theory, primary, secondary, tertiary endosymbiosis, fossil records and evolutionary timelines.	**5**
2	**Diversity of Algal Groups I**	General characteristics and evolutionary significance of Prochlorophyta, Glaucophyta, Dinophyta, and Euglenophyta.	**6**
3	**Diversity of Algal Groups II**	Morphology and evolutionary significance of Cyanophyta, Chlorophyta, Rhodophyta and Bacillariophyceae.	**6**
4	**Ecology of Algae**	Physical and chemical characteristics of algal habitats; phytoplankton dynamics, benthic algae, algal bioindicators, symbiotic associations.	**6**
5	**Algal Environment**	Freshwater algae, marine algae, estuarine algae, algae in extreme environments, eutrophication and pollution, algal blooms.	**6**
6	**Algal Biotechnology**	Biofertilizers, algal biofuels, high-value metabolites, nutraceuticals, phyco-remediation and wastewater treatment.	**6**
7	**Algae in Climate Change and Sustainability**	Role in carbon capture and CO_2 sequestration, algae-based climate solutions, algae and UN-SDGs.	**5**
8	**Tools, Techniques and Applications in Algal Studies**	Algal culturing techniques, cultivation processes, collection and preservation methods, experimental designs in algal research.	**5**

Practical Course Content

Practical Components	Activities/ Experiments
Sample collection exercise	1. Field collection of algae from diverse freshwater/ terrestrial habitats and application of different preservation techniques. 2. Sorting of collected specimens based on morphology.
Microscopy	3. Preparation of temporary and permanent slides of algae 4. Microscopic examination of representative genera and documentation of diagnostic characters.
Culture Techniques	5. Preparation of different algal culture media (BG-11, Bold's Basal Medium, Guillard's F/2 Medium). 6. Inoculation and maintenance of algae in liquid culture. 7. Observation of growth characteristics.
Phytoplankton Analysis	8. Collection of phytoplankton using plankton net from field sites for qualitative and quantitative analysis. 9. Cell counting using haemocytometer/ Sedgwick–Rafter chamber. 10. Calculation of phytoplankton diversity indices.

Practical Components	Activities/ Experiments
Diatom Processing and Slide Preparation	11. Cleaning of diatom frustules using different methods. 12. Preparation of permanent diatom slides for Light Microscope studies. 13. Preparation of cleaned diatom stubs for SEM studies.
Field Visit and Report	14. Report on field visit for algae collection, submission of identified algal samples (at least 5 different species properly preserved and labelled)

Note: Regularly checked laboratory records, permanent slides prepared during practical classes, specimens collected during field work with detailed field diary should be submitted at the time of TEE.

Suggested Readings

1. Andersen, R. A. (Ed.). (2005). *Algal culturing techniques*. Elsevier Academic Press.
2. Barsanti, L. and Gualtieri P. (2006). Algae- Anatomy, Biochemistry and Biotechnology. Taylor and Francis
3. Bhatia, Bela and Vijayaraghavan M.R. (1997). Red Algae: Structure, Ultrastructure and Reproduction. APH Publication
4. Bold, H. C. and Wynne, M. J. (1985). Introduction to the algae: Structure and Reproduction. Prentice-Hall
5. Cole, K. M., & Sheath, R. G. (1990). *Biology of the red algae*. Cambridge University Press.
6. Dodds, W. K., & Whiles, M. R. (2010). *Freshwater ecology: Concepts and environmental applications of limnology* (2nd ed.). Academic Press.
7. Graham, Linda, Graham J.M. and Wilcox L.W. (2009). Algae. Benjamin Cummings from Pearson Education
8. Harris, G.P. (1986). Phytoplankton Ecology. Chapman and Hall
9. Lee, R.E. (2008). Phycology. Cambridge University Press
10. Ray, S. (2006). Cyanobacteria. New Age International Publishers, New Delhi
11. Reynolds, C. S. (2006). *The ecology of phytoplankton*. Cambridge University Press.
12. Richmond, A., & Hu, Q. (Eds.). (2013). *Handbook of microalgal culture: Applied phycology and biotechnology* (2nd ed.). Wiley-Blackwell.
13. Round, F. E., Crawford, R. M., & Mann, D. G. (1990). *The diatoms: Biology and morphology of the genera*. Cambridge University Press.
14. Stein, J. R. (Ed.). (1973). *Handbook of phycological methods: Culture methods and growth measurements*. Cambridge University Press.
15. van Den Hoek, C., Mann D.G. and Jahns H.M. (2009). Algae – An Introduction to Phycology. CUP
16. Vijayaraghavan, M.R. and Kumari S. (1995). The Chlorophyta: Structure, Ultra-structure and Reproduction. Bishen Singh Mahendra Pal Singh.

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Course Code: BOT-MJR-403	**Course Title: Bryology and Pteridology**	
Course Nature: Coursework	**Course Level: 400-449**	**NCrF credit level: 6**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week** **Practical: 45 Hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain the biology and systematics of bryophytes and pteridophytes.
2. Describe and elucidate the diversity, evolution, and conservation of the organism.
3. Analyse the economic prospect of the organism.
4. Elaborate research progress and present scenario in India and abroad.

Theory Course Content

Unit No.	Unit	Topic	Class Hours
BRYOPHYTES			
1	**Systematics and Evolution**	Major lineages of bryophytes (liverworts, hornworts and mosses), interrelationship with other groups and evolutionary trend, fossil bryophytes, classification criteria, molecular systematics, chemosystematics, classification system.	**5**
2	**Morpho-anatomy and Cytology**	Morphology, anatomy, ontogenetic development, and chromosome study.	**5**
3	**Ecology, Distribution and Conservation**	Ecological significance, diversity and distribution pattern, floristics, physiological ecology, biochemical and molecular mechanism of desiccation tolerance, species and speciation, indicator species, conservation needs and strategies.	**5**
4	**Research Developments and Opportunities**	Research in India *vis-à-vis* the global centre, contribution of pioneer workers and research progress, mosses and liverworts as model organisms for the development of cell and molecular biology.	**5**
PTERIDOPHYTES			
5	**Systematics and Evolution**	Major lineages of pteridophytes, interrelationship with other groups, evolutionary trends and land migration, classification criteria, molecular taxonomy, chemosystematics, classification system.	**10**
6	**Morpho-anatomy, Cytology, Palynology and Physiology**	Morphology, anatomy, and ontogenetic development (sporophytic phase), mating system, chromosome study and speciation, spore characters, gametophyte development, and antheridogen system.	**5**
7	**Ecology, Economy, Distribution, and Conservation**	Ecological significance, diversity and distribution pattern, floristics, conservation approach, economic prospects.	**5**
8	**Research Developments and Opportunities**	Major research hub in India vis-à-vis the globe, the contribution of pioneer workers, and recent development.	**5**

Practical Course Content

Practical Components	Activities/ Experiments
Morpho-Anatomical Studies	1. Workout and identification of members of the 3 lineages: Marchantiophyta, Bryophyta and Anthocerotophyta. 2. Workout of supplied pteridophytic taxa based on morpho-anatomy, analysis of systematic position and identification up to genus level.
Microscopic Examination, Using Keys Manual	3. Identification of diagnostic features from supplied bryophytic specimens, permanent slides. 4. Microscopic staining techniques for pteridophytic tissues
Field Collection and Survey Techniques	5. Collection of bryophytes from different localities through local field tours, followed by preservation and identification. 6. Field tour and collection of pteridophytes, including methods of dry and wet preservation and herbarium preparation.
Specimen Processing and Preservation	7. Dry and wet preservation of collected bryophyte and pteridophyte specimens. 8. Preparation of herbarium (pteridophytes) using standard techniques.
Field-Based Mini Project	9. Exercise in field investigation, ecological observations, specimen handling, documentation and report preparation.

Note: Regularly checked laboratory records, permanent slides prepared during practical classes, specimens collected during field work should be submitted at the time of TEE.

Suggested Readings

1. Vanderpoorten, A. and Goffinet, B. (2009). Introduction to Bryophytes. Cambridge University Press, Cambridge. ISBN 978-0-521-70073-3
2. 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
3. Rashid A. (1998). An introduction to Bryophyta. Vikas Publishing House Pvt. Ltd. First edition.
4. Rashid A. (1999). An introduction to Pteridophyta. Vikas Publishing House Pvt. Ltd. 2nd revised ed.
5. Gifford M.E. and Foster A.S. 1988 Morphology and Evolution of Vascular Plants. W H. Freeman and Comp.
6. Willis, K.J., and McElwain, J. C. (2002). The Evolution of Plants. Oxford University Press, New York.
7. Sen K. (2024). Exploring the Local Ferns and Cultivated Varieties of West Bengal (Excluding the Himalayan Range).

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Course Code: BOT-MJR-404	Course Title: Gymnosperm, Plant Systematics and Taxonomy of Angiosperms	
Course Nature: Coursework	Course Level: 400-449	NCrF credit level: 6
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week Practical: 45 Hours; Total : 90 days; 3 hrs/ week		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain the systems of classification of flowering plants, their origin, diversification, and the advanced principles of taxonomy, including identification, nomenclature and classification.
2. Analyse evolutionary processes and patterns in major angiosperm families and in gymnosperms, including speciation, reproductive biology, adaptation, convergence and biogeography.
3. Evaluate the roles of data resources used in taxonomy, botanical gardens, and herbaria in taxonomy and phylogenetics, integrating approaches such as phenetics, cladistics, morphology and molecular data.
4. Demonstrate proficiency in systematic survey of plant families and local flora and apply taxonomic and phylogenetic principles to interpret relationships among major plant groups.
5. Critically assess patterns of diversification and evolution in gymnosperms.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
GYMNOSPERMS			
1	**Origin, Evolution and Classification**	Overview of gymnosperm characteristics; evolutionary trends in seed habit; brief study of important fossil groups- Cycadofilicales, Bennettitales, Cordaitales, and Pentoxylales as precursors to living gymnosperms; comparative classification and phylogenetic relationships among Cycadales, Ginkgoales, Coniferales, and Gnetales with reference to molecular evidence and evolutionary significance.	**5**
2	**Morphology, Anatomy and Reproduction**	Comparative morphology and anatomical adaptations of vegetative organs in selected genera; features of secondary growth and wood structure; organization of male and female reproductive structures; gametophyte development, fertilization, and embryogeny with emphasis on evolutionary modifications and diversity among major groups.	**5**
3	**Physiology and Ecology**	Photosynthesis and water relations in gymnosperms; ecological and physiological adaptations to drought and cold; role of gymnosperms in forest ecosystems and carbon sequestration.	**2**
4	**Conservation and Economic Importance**	Threats to gymnosperm diversity and conservation approaches (*in situ* and *ex situ*); basic applications of tissue culture and molecular tools in propagation and conservation; economic importance with reference to timber, resin, and medicinal uses.	**3**

Unit No.	Unit	Topics	Class Hours
PLANT SYSTEMATICS AND TAXONOMY OF ANGIOSPERMS			
5	**Introduction to Taxonomy and Identification**	Taxonomy and systematics; taxonomic keys; phases of taxonomy; importance and objectives of taxonomy; Taxonomic literature: Definition with examples of classics, flora and manual, revision, index, icons, catalogues, glossary and dictionary, revision and monograph, e-taxonomy; Significance of herbaria and botanic garden.	**5**
6	**Classification systems and Biosystematics**	Classification of Cronquist (1988), Takhtajan (2009) up to Subclass/ Super orders; Angiosperm Phylogeny Group (APG IV, 2016); Biosystematics: Definition, methods, categories, relationships with classical taxonomy	**4**
7	**Taxonomic Groups**	Characteristics, phylogeny and evolutionary trends in Magnoliidae, Caryophyllidae, Asteridae, Alismatidae and Liliidae (*sensu* Cronquist, 1988).	**5**
8	**Plant Nomenclature**	Changes (additions and alteration) in latest Code; Principles, Nomenclatural types, Rules of Priority and its limitations, Effective and Valid publications, names of new taxa (species), new combinations; Retention and Rejection of names; Brief idea about BioCode and PhyloCode.	**6**
9	**Phenetics and Cladistics**	Numerical taxonomy: Principles, methods, application, merits and demerits; Cladistics: Principles, methods, merits and demerits.	**4**
10	**Data sources of Taxonomy**	Embryology, Phytochemistry, Anatomy and ultrastructure; Molecular Systematics: nuclear r-DNA, chloroplast and mitochondrial DNA; DNA Barcoding.	**6**

Practical Course Content

Practical Components	Activities/ Experiments
Taxonomic Observation and Description	1. Drawing and description of specimens from representative, locally available angiosperm families.
Identification Using Keys and Floras	2. Identification of families using Keys from Plant Identification- James Cullen (2006). 3. Identification of genera and species using local and regional floras.
Key Construction and Systematic Skills	4. Preparation of artificial indented/bracketed keys at family, generic and species levels using locally available and worked-out plants.
Gymnosperm Morphology and Anatomy	5. Morphological and anatomical study of representative gymnosperms. 6. Cone and seed dissection; pollen and embryo study.
Herbarium Techniques and Submission	7. Preparation and submission of at least 25 herbarium specimens of common wild plants.
Field Study and Project Work	8. Two compulsory local field excursions for familiarization with local flora. 9. Mini-project or seminar on a gymnosperm species or a conservation-related topic.

Note: Regularly checked laboratory records, specimens collected during field works and permanent slides prepared during practical classes should be submitted in a standard manner along with Field Note Books at the time of TEE.

Suggested Readings

1. Grant W.F., Plant Biosystematics, Academic Press, London.
2. Davis, P. H. and Heywood, V. H. 1963. Principles of Angiosperm Taxonomy. Princeton, NJ: Van Nostrand.
3. Johnes, S. B. and Luchsinger, A. E. 1987. Plant Systematics. McGraw-Hill. London.
4. Judd, W. S., Campbell, C. S., Kellogg, E. A., Stevens, P. F., Donoghue, M. J. 2008. Plant Systematics–Phylogenetic Approach. Sinauer Associates, Inc., Sunderland, Massachusetts USA.
5. Lawrence, G. H. M. 1964. Taxonomy of Vascular Plants. Oxford and IBH Publishers, Calcutta.
6. Naik, V. N. 1984. Taxonomy of Angiosperms. Tata McGraw-Hill Publishing Company Limited, New Delhi.
7. Radford, A. E. 1986. Fundamentals of Plant Systematics. Harper and Row, London.
8. Simpson, M. G. 2010. Plant Systematics. Elsevier Academic Press, Amsterdam.
9. Singh, G. 2012. Plant Systematics – Theory and Practice. Oxford and IBH Publishing Co. Pvt. Ltd.
10. Sivarajan, V. V. 1991. Introduction to the Principles of Plant Taxonomy. Oxford and IBH Pub. Co. Pvt. Ltd..
11. Stace, C. A. 1989. Plant Taxonomy and Biosystematics. Arnold Publishers, United Kingdom.
12. Stuessy, T. F. 2008. Plant Taxonomy – The Systematic Evaluation of Comparative Data. Columbia, University press, New York.
13. Bhatnagar, S.P. and Moitra, A. (1996). Gymnosperms. New Age International P Ltd. Publishers, New Delhi
14. Taylor E.L., Krings M, and Taylor T.N. 2009. Paleobotany: The biology and evolution of fossil plants
15. Fahn A (1982). Plant Anatomy. Pergamon press
16. Dickison W.C. 2000. Integrative Plant Anatomy. Harcourt Academic Press. ISBN-13:978-0-12-215170-5

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Course Code: BOT-MNR-405	**Course Title: Mycology**	
Course Nature: Coursework	**Course Level: 400-449**	**NCrF credit level: 6**
Credit Pattern: Theory:	**2 credits**	
Class Hours: Theory :	**30 hours; Total : 90 days; 2 hrs/ week**	

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Understand phylogenetic position of fungi and interrelationship among different fungal groups
2. Know about cellular and reproductive behavior of fungi
3. Understand different applied aspects of fungi for preparation of food and medicine, role in agriculture, bioremediation and ecological significance as saprotrophs

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**An Introduction to Kingdom Mycetae**	Distinctive features of fungi to form a separate kingdom, important criteria used for classification of fungi, structure of *rRNA* gene and its application for identification, evolutionary relationships of fungi with other organisms.	**3**

Unit No.	Unit	Topics	Class Hours
2	**Structural Features of Fungal Cell**	Components of fungal cell wall and their specific functions, cell membrane, cell organelles, nucleus and its division, extra-chromosomal genetic materials.	**3**
3	**Genetics of Fungi**	Heterothallism, sexual and non-sexual variation in fungi.	**3**
4	**Salient Features of Different Fungal Groups and Allies**	Salient features of Basidiomycota, Ascomycota, Zygomycota, Chytridiomycota, Oomycota and Myxomycota.	**12**
5	**Ecological Significance**	Role of fungi as saprotrophs: wood decay, white fungi and brown rot fungi.	**2**
6	**Industrial and Agricultural Benefits**	Application of fungi in food industry, myco-medicines, role of mycorrhiza as biofertilizer, mycoremediation, biosensor.	**4**
7	**Medical Mycology**	Fungi as human pathogens with special emphasis to virulence mechanism, allergens, mycotoxins.	**3**

Suggested Readings

1. Alexopoulos, C.J., Mims, C.W., Blackwell, M. (1996). Introductory Mycology, John Wiley and Sons (Asia) Singapore, 4th edition.
2. Deacon, J. (2006). Fungal Biology, 4th Edition, Blackwell Publishing
3. Moore-Landecker, E. (1996) Fundamentals of the Fungi, 4th Edition, Prentice Hall
4. Sethi, I.K. and Walia, S.K. (2011). Text book of Fungi and Their Allies, Macmillan Publishers India Ltd.
5. Webster, J. and Weber, R. (2007). Introduction to Fungi, Cambridge University Press, Cambridge, 3rd edition.
6. Related articles from scientific journals

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Course Code: BOT-MNR-406	**Course Title: Cell Biology**	
Course Nature: Coursework	**Course Level: 400-449**	**NCrF credit level: 6**
Credit Pattern: Theory:	**2 credits**	
Class Hours: Theory :	**30 hours; Total : 90 days; 2 hrs/ week**	

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Understand the role of proteins in controlling cell cycle.
2. Know about membrane transport of small molecules, intracellular compartments and protein sorting, vesicular trafficking and cell signalling.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Cell Cycle Regulation**	Cell cycle proteins, role of RB, E_2F and p^{53} in tumour suppression.	**5**
2	**Membrane Transport of Small Molecules**	Principles of membrane transport, membrane transport proteins, active and passive membrane transport, ionophores.	**5**
3	**Intracellular Compartments and Protein Sorting**	Compartmentalization of higher cells, signal peptides and signal patches, transport of proteins into nucleus, mitochondria and chloroplasts.	**5**
4	**Vesicular Traffic in the Secretory and Endocytic Pathways**	Transport of proteins from E.R. through the Golgi apparatus, role of mannose 6-phosphate receptor in lysosomal enzyme sorting, transport from the plasma membrane via endosomes- endocytosis, transport from the *trans* Golgi network to the cell surface- exocytosis.	**8**
5	**Cell Signalling**	Principles of cell signalling, cell surface and intracellular receptor proteins; signalling via G-protein linked cell surface receptors, inositol phospholipid pathway, calmodulin.	**7**

Suggested Readings

1. Molecular Biology of the Cell, Alberts, Bruce; Johnson, Alexander; Lewis, Julian; Raff, Martin; Roberts, Keith; Walter, Peter New York and London: Garland Science.
2. Molecular Cell Biology- Lodish H, Berk A, Kaiser C.A., Krieger M., Scott M.P., Bretscher A., Ploegh H. and Matsudaira P. (W.H. Freeman and Co.).
3. The Cell: A Molecular Approach by Geoffrey M. Cooper, Robert E. Hausman. Sinauer Associates Inc.

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Course Code: BOT-VAC-449	**Course Title: Instrumentations and Techniques in Biological Science**	
Course Nature: Coursework	**Course Level: 400-449**	**NCrF credit level: 6**
Credit Pattern: Theory:	**2 credits**	
Class Hours: Theory :	**30 hours; Total : 90 days; 2 hrs/ week**	

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Understand principles and applications of instruments used in plant sciences.
2. Develop hands-on familiarity with analytical, physiological and molecular instruments.
3. Interpret experimental data generated using modern botanical instrumentation.
4. Use with precision and precaution instruments for measurement of scientific data.

Theory Course Content

Unit No.	Unit	Topic	Class Hours
1	**Microscopy and Imaging Techniques**	Light microscopy: bright field, phase contrast, dark field, fluorescence microscopy and confocal microscopy (principles and applications), electron microscopy: SEM and TEM (overview), image acquisition and analysis in plant studies.	**4**
2	**Spectroscopic and Analytical Techniques**	UV–Visible spectrophotometry: principles and applications, colorimetry and fluorimetry infrared spectroscopy (FTIR) – basics, Atomic Absorption Spectroscopy (AAS) - overview, Nanodrop spectroscopy.	**4**
3	**Chromatographic Techniques**	Principles of chromatography, paper and thin layer chromatography (TLC), column chromatography, HPLC – basic working and applications, gas chromatography (GC) – overview.	**4**
4	**Electrophoretic Techniques**	Basic principles (separation by charge/size), types (gel, paper, capillary, 2D, IEF), key techniques (Agarose, PAGE, SDS-PAGE), reagents, equipment, and troubleshooting applications in DNA, protein analysis.	**4**
5	**Polymerase Chain Reaction and Sequencing Techniques**	Fundamental principle: Components (template DNA, primers, DNA polymerase, dNTPs, buffer), step-by-step processes: (Denaturation, Annealing, Extension), Types: (RT-PCR, qPCR, Digital PCR), applications.	**4**
6	**Environmental Monitoring Instrumentation**	Soil analysis instruments (pH, EC, moisture meters), weather monitoring instruments (rain gauge, anemometer, hygrometer), remote sensing and GIS – introduction, environmental sensors for pollution monitoring, drone, data loggers and field instruments.	**5**
7	**Common Supporting Instrumentation**	Analytical balance, BOD incubator, growth chamber, microtome, tissue processor, incubator, autoclave, laminar air flow.	**3**
8	**Immunodetection**	ELISA: types and principles.	**2**

Suggested Readings

1. Sadasivam and Manickam, *Biochemical Methods*
2. Plummer, *An Introduction to Practical Biochemistry*
3. Green, M.R. and Sambrook, J. (2012). Molecular Cloning: A Laboratory Manual. Fourth Edition. Cold Spring Harbor Laboratory Press. ISBN 978-1-936113-42-2
4. Wilson, K. and Walker, J. (2013). *Principles and Techniques of Biochemistry and Molecular Biology*. Cambridge University Press.

SEMESTER II

Course Code: BOT-IDS-451	**Course Title: Botanical Research and Sustainable Development Goals**	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain the biochemical nature and uses of phytopharmaceuticals.
2. Describe plant stress, types, and its effects in crop production.
3. Analyze pollen morphology and plant–pollinator interactions to evaluate honey authenticity, pollinator health, and their relevance to sustainable agriculture and livelihoods.
4. Explain application of beneficial soil microflora as biofertilizer and their relevance to sustainable agriculture and livelihood.
5. Know about medicinal importance of mushroom for health benefits.
6. Explain how botanical research contributes to climate mitigation, ecosystem resilience, and environmental monitoring.
7. Validate how botanical research supports transparent environmental governance, biodiversity protection, and sustainable resource management.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Treatment of Waste Water Through Microbiological Techniques**	Definition of waste water- sewage and industrial effluent, cause of water contamination, treatment of waste water and potable water. *Linkage with SDG: Clean Water and Sanitation (SDG 6)*	**5**
2	**Plant and Medicines**	Introduction, source and medicinal uses of the following plant-derived pharmaceutical compounds - (artemisinin, aspirin, atropine, campothecin, cannabadiol, ephedrine, digoxin, diosgenin, galanthamine, L-dopa, morphine, codeine, quinine, colchicine, vincristine, vinblastine, podophyllotoxin, taxol), importance of phytopharmaceuticals, classification of plant secondary metabolites, exploration of secondary metabolites in therapeutics. *Linkage with SDG: Good Health and Well-being (SDG 3)*	**6**
3	**Plant Stress Types, Interactions and Crop Production**	Stress in plant: types, it's effect on crop production, stress avoidance, stress hormones, stress mitigating methods, factors regulating plant growth and development, methods of mitigation of stress, plant stress and crop productivity, stress resistance, and developing novel plant-based products. *Linkages with SDG: Zero Hunger (SDG 2), Good Health and Well-being (SDG 3)*	**6**

Unit No.	Unit	Topics	Class Hours
4	**Genetically Modified Crops for Sustainable Agriculture and Food Security**	Recombinant DNA technology and its use in crop improvement: Genetically modified (GM) crops, pros and cons of GM foods, commercially approved GM crops, antisense RNA technology -FLAVR SAVR, Bt cotton, Golden rice etc. *Linkage with SDGs: Zero Hunger (SDG 2), Responsible Consumption and Production (SDG 12)*	**6**
5	**Palynology, Pollination and Apiculture**	Morphology of pollen and evolutionary significance, basics of pollen identification and melissopalynology, plant–pollinator interactions and crop pollination, pollinator decline and sustainable agriculture, honey authentication and floral source mapping, scientific beekeeping and value-added honey production. *Linkage with SDGs: No Poverty (SDG 1), Zero Hunger (SDG 2), Good Health and Well-being (SDG 3), Life on Land (SDG 15)*	**6**
6	**Biofertilizers in Solving Food Security Problems**	Biofertilizers: types, Plant Growth Promoting Rhizobacteria (PGPR): role in plant growth promotion, Mycorrhiza: application in agriculture. *Linkage with SDGs: No Poverty (SDG 1), Zero Hunger (SDG 2), Biodiversity (SDG15)*	**3**
7	**Mushroom as a Source of Medicines**	Anti-cancerous, anti-diabetic, anti-oxidant, anti-microbial activities. *Linkage with SDG: Good Health and Well-Being (SDG 3)*	**3**
8	**Botanical Research for Climate Action**	Role of algae and phytoplankton in global primary productivity and carbon fixation, Nature-based climate solutions: forest and mangrove ecosystems. *Linkage with SDG: Climate Action (SDG 13)*	**2**
9	**Biodiversity Governance and Environmental Justice**	Biodiversity documentation and monitoring for ecosystem protection, community participation in plant resource management, ethical and institutional frameworks for sustainable biodiversity governance. *Linkage with SDGs: Peace, Justice and Strong Institutions (SDG 16)*	**3**
10	**Sourcing bryophytes and pteridophytes for medicinal use**	Investigating the medicinal potential of bryophytes and pteridophytes for drug discovery and sustainable health care. *Linkage with SDG: Good Health and Well-Being (SDG 3)*	**5**

Suggested Readings

1. United Nations (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*.
2. Food and Agriculture Organization (2017). *The future of food and agriculture: Trends and challenges*.
3. Intergovernmental Panel on Climate Change (2023). *Sixth Assessment Report (AR6)*.
4. Convention on Biological Diversity (2022). *Kunming–Montreal Global Biodiversity Framework*.
5. World Health Organization (2019). *WHO global report on traditional and complementary medicine*
6. Relevant recent publications on the above topics shall be discussed during curriculum transaction.

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Course Code: BOT-MJR-452	Course Title: Plant Pathology and Crop Protection	
Course Nature: Coursework	Course Level: 450-499	NCrF credit level: 6
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week Practical : 45 Hours; Total : 90 days; 3 hrs/ week		

Course Learning Outcomes

After completion of the course the learners will be able to:

1. Explain plant pathogen interactions, how does pathogen cause infection and how plant defend against pathogen.
2. Know about the gene responsible for resistance of the plant.
3. Understand different disease control strategies and specify which strategy will be appropriate for a particular disease.
4. Explain several techniques for disease forecasting and diagnosis.
5. Develop skill for extraction of protein and phenol from plant parts, measurement of pathogen's virulence factors such as the cell-wall-degrading enzymes, estimation of toxins, fungicide sensitivity and biocontrol activity.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**An Introduction to Plant Pathology**	Scope as an interdisciplinary science, disease: definition, types, components of disease development.	1
2	**Survival and Spread of Pathogen Propagules**	Inoculum: types, production, liberation and dispersal, inoculum potential and affecting factors, sources of survival, spread of pathogen propagules.	3
3	**Plant-Pathogen Interaction**	Recognition, signal transduction, compatible interaction, adhesion, different modes of entry into plant tissue, chemical weapons: cell-wall-degrading-enzymes, toxins, plant growth regulators, effectors, evasion of host defense, incompatible interaction: plant innate immunity (PTI and ETI), oxidative burst, ion efflux, Nitric Oxide, pre-existing structural and biochemical defense, induced structural and biochemical defense, systemic acquired resistance, induced systemic resistance, communal resistance.	12
4	**Genetics of Pathogenicity**	Gene for gene hypothesis, types of resistance; horizontal and vertical resistance, avirulence gene, resistance gene, concept of NLR/ resistosome.	4
5	**Physiological and Molecular Changes in Diseased Plants**	Photosynthesis, respiration, translocation of water and nutrients, protein and nucleic acid changes in diseased plants.	2

Unit No.	Unit	Topics	Class Hours
6	**Epidemiology**	Disease pyramid, measurement and stimulation of plant disease epidemics, forecasting, remote sensing, change of pathogen behavior with climate change.	**5**
7	**Principles and Strategies of Plant Disease Control**	Exclusion, eradication, protection and therapy, cultural and biological control, plant quarantine, integrated pest management, fungicides: types, application, mode of action, antibiotics in plant disease control, fungicide resistance.	**10**
8	**Symptomology, Etiology and Management of Selective Diseases**	Blast of rice, whip smut of sugarcane, linseed rust, downy mildew of grapes, bacterial wilt of banana, potato mosaic, club root of crucifers, root knot of tomato.	**8**

Practical Course Content

Practical Components	Activities / Experiments
Instrument Handling	1. Culture media preparation, sterilization, incubation.
Collection and Identification	2. Field collection of infected plant samples and identification of diseases by observing symptoms. 3. Histopathological study under light microscope.
Pathological Techniques	4. Isolation of pathogen from infected plant. 5. Preparation of pure culture and sub-culturing. 6. Inoculation of tuber, leaf, fruit, seedling and disease scoring. 7. Demonstration of Koch's postulates.
Fungicides Assay	8. Mycelia growth inhibition and determination of ED50 value. 9. Spore germination inhibition and determination of EC50 value.
Antifungal Bio-products	10. Extraction and demonstration of phenolic compound of onion. 11. Demonstration of bio-control activity by antagonist.
Infection induced Plant Metabolite Change	12. Determination of phenol and protein contents from healthy and diseased tissues.
Virulence Component of Pathogen	13. Estimation of cell-wall-degrading enzymes.
Field Visit and Report	14. Field note book containing colour photograph of pathological specimens mentioning name of disease, host and causal agent, date and place of collection should be submitted at the time of term-end examination. 15. Herbarium specimens (at least 10) of diseased plants collected from the locality or at the time of field work to be submitted at the term-end examination.

Note: Regularly checked laboratory records, permanent slides prepared during practical classes, specimens collected during field visit should be submitted at the time of TEE

Suggested Readings:

1. Agrios, G.N. (1997). Plant Pathology, 4th edition, Academic Press, U.K.
2. Burchett, S. and Burchett, S. (2018). Plant Pathology, Garland Science
3. Chaube, H.S., Pundhir, V.S. (2005). Crop Diseases and their Management, Prentice Hall India Eastern Economy Edition
4. Dickinson, M. (2003) Molecular Plant Pathology, Bios Scientific Publishers
5. Mehrotra, R.S. and Agarwal, A. (2013). Fundamentals of Plant Pathology, McGrow Hill Education
6. Singh, R.P. and Singh U.S. (2018) Molecular methods in Plant Pathology, CRC Press
7. Related articles from scientific journals

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Course Code: BOT-MJR-453	**Course Title: Genetics**	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week** **Practical: 45 Hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Understand the Mendelian and Post-Mendelian concept of heredity.
2. Acquire knowledge of epigenetics and understand underlying mechanisms.
3. Comprehend the concept of RNAi by small regulatory RNAs, proteome, protein separation and identification techniques, and post-translational modifications of proteins.
4. Develop an understanding of genome editing techniques, self-incompatibility and male sterility, the genetics of disease resistance, heritability, and biostatistics.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Classical Genetics**	Mendelian and Post-Mendelian concepts of heredity, linkage and crossing over, transposable elements, population genetics, sex determination in plants, dosage compensation.	**5**
2	**Epigenetics**	Introduction, DNA methylation, histone modifications, epialleles.	**3**
3	**Genes Directing Flower Development**	ABC model and floral organ identity gene mutations in *Arabidopsis*, floral quartet model of floral organ specification, modifications of ABC model.	**3**
4	**RNA Biology**	RNA editing, gene silencing through antisense RNA technology and Ribozymes, RNA interference (RNAi) by small regulatory RNAs, different types of small non-coding RNAs, their biogenesis and functions in posttranscriptional gene silencing, applications of RNAi in crop quality improvement.	**10**

Unit No.	Unit	Topics	Class Hours
5	**Genomics**	Concept of genome, approaches to analyze differential gene expression- ESTs, microarrays and their applications, reverse genetics, gene tagging, gene trapping, gene silencing and gene knockout, genome editing technologies and their applications in crop improvement.	**6**
6	**Proteomics**	Concept of proteome, structural, functional and differential proteomics, principle of 2D gel electrophoresis (2-DE), advantages and limitations of 2-DE, protein fingerprinting, gel free proteomics (iTRAQ), mass spectrometry (MALDI-TOF MS), post-translational modifications of proteins, applications of proteomics in agriculture.	**6**
7	**Self-Incompatibility and Male Sterility**	Types, genetic and molecular basis, transgenic approach; utilization in crop improvement.	**3**
8	**Genetics of Disease Resistance**	Pathogenicity *vs*. Virulence; physiological races and differential hosts, models for plant pathogen recognition Flor's hypothesis; vertical and horizontal resistance.	**3**
9	**Heritability**	Understanding, components of phenotypic variance, broad-sense and narrow-sense heritability, applications.	**2**
10	**Biostatistics**	$\chi 2$ test (detection of segregation ratio and linkage, test of independence), t-test (student and paired), analysis of variance (ANOVA), correlation and regression.	**4**

Practical Course Content

Practical Components	Activities/ Experiments
Isolation and PCR Amplification of Genomic DNA	1. Plant genomic DNA extraction by CTAB method and estimation of DNA concentration and purity using spectrophotometry.
	2. Visualization of plant genomic DNA by agarose gel electrophoresis.
	3. DNA amplification by polymerase chain reaction.
Plant RNA Extraction and Gene Expression Study	4. Plant RNA extraction and estimation.
	5. Formaldehyde gel electrophoresis of total RNA.
	6. cDNA preparation.
	7. Gene expression study using reverse transcription polymerase chain reaction (RT-PCR).
Changes of Nucleolar Frequency: Microscopic Study	8. Study of nucleolus using *Hematoxylin* and determination of nucleolar frequency.
Assessment of Genetic Variation Through Allele Frequency Estimation	9. Determination ABO blood group and calculation of allele frequency in human population.
Localization of DNA by Light Microscopy	10. *In situ* localization of DNA by Feulgen staining.

Suggested Readings:

1. *i*Genetics- A Molecular Approach- Peter J. Russell (Pearson Int. Edition)
2. Concepts of Genetics- Klug W.S., Cummings M.R., Spencer C.A. and Palladino M.A. (Pearson Int. Edition).
3. Genes XII- Lewin Benjamin (Jones and Bartlett publishers)
4. Molecular Cell Biology- Lodish H, Berk A, Kaiser C.A., Krieger M., Scott M.P., Bretscher A., Ploegh H. andMatsudaira P. (W.H. Freeman and Co.)
5. Molecular Biology of the Cell, Alberts, Bruce; Johnson, Alexander; Lewis, Julian; Raff, Martin; Roberts, Keith; Walter, Peter New York and London: Garland Science.
6. Principles of Genetics- Snustad D.P. and Simmons M.J. (John Wiley and sons Inc.)
7. Principles of Genetics- Robert H. Tamarin (Tata McGraw-Hill)
8. An Introduction to Genetic Analysis- Anthony J.F. Griffiths, Susan R. Wessler, Sean B. Carroll, John Doebley (WH Freeman)

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Course Code: BOT-MJR-454	**Course Title: Advanced Plant Physiology**	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week** **Practical: 45 Hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

After completion of the course the learners will be able to:

1. Comprehend the intricate network of vital functions and metabolic pathways that govern plant life, including photosynthesis, respiration, and nutrient uptake.
2. Discern the fundamental relationship between structure and function across all levels of biological organization in plants, from the molecular to the cellular and tissue levels.
3. Analyze the dynamic interplay of internal and external factors that regulate plant growth, development, and adaptation to diverse environmental conditions.
4. Evaluate the biotechnological applications of plant physiology, exploring how knowledge of plant processes can be harnessed to improve crop yields, enhance stress resistance, and develop novel plant-based products.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Plant Water Relationship**	Water in plant life and in soil, chemical properties of water, water potential and its components, major factors contributing water potential, water transport through xylem, mechanisms of water uptake and movement.	**6**

Unit No.	Unit	Topics	Class Hours
2	**Cell Membrane and Life Processes**	Cell wall structure, biogenesis, growth and properties of cell wall, cell membrane.	**4**
3	**Phloem Transport and Nutrient Assimilation**	Transport processes, solute transport across membranes, phloem translocation, assimilation of nutrients, energetics of nutrient assimilation.	**6**
4	**Photosynthesis, Carbon Concentration Mechanism**	Photosynthesis, light reaction, organization of light absorption system, molecular analysis of PS-II structures and function, structure and function of RUBISCO, different carbon concentrating mechanisms, photorespiration.	**8**
5	**Biophysical Chemistry**	Principles of biophysical chemistry, pH, buffer, reaction kinetics, thermodynamics, law of mass action, acid base reactions, bond energy, energy rich compounds, redox potential, free energy.	**4**
6	**Enzyme Kinetics**	Catalytic reactions and regulatory properties of enzymes, types of inhibitions, allosterism, iso-enzymes, ribozyme and abzyme, vitamins as coenzyme.	**4**
7	**Early Growth in Plants**	Seed germination behavior and seedling growth.	**2**
8	**Abiotic Stress: Molecular Responses and Adaptive Mechanisms**	Stress diversity, tolerance and avoidance, various types of abiotic stresses, stress phytohormones, molecular mechanism of stress amelioration, alteration of gene expression and its regulation due to environmental stress, development of molecular marker for physiological traits and transgenic plants to stress tolerance.	**8**
9	**Signal Transduction in Plants**	Ca^{2+} and ABA signaling in plants, immunoassay of plant growth regulators.	**3**

Practical Course Content

Practical Components	Activities / Experiments
Photobiological Process	1. Estimation of pigments: total chlorophyll and carotenoids
	2. Determination of rate of oxygen evolution from bicarbonate source of carbon under light.
	3. Assessment of photosynthetic electron reduction under light.
	4. Assessment of real time fluorescence from field grown plants.
Transport of Water	5. Induction of stomatal closure and loss of water from illuminated plants.
	6. Determination of water use efficiency and stomatal frequency from water stressed plants.
Plant Water Rrelation	7. Determination of water potential of dissected plants parts.
	8. Determination of osmotic potential from field grown plant.
Determination of Stress Markers	9. Determination of stress metabolites (proline, glycine betaine) from dehydrated leaves.
	10. Assessment of reactive oxygen species (superoxide, hydrogen peroxide) by spectrophotometric methods.
	11. Detection of stress enzymes (catalase, peroxidase, superoxide dismutase)

Suggested Readings

1. Taiz L., Zeiger, E, Moller, I. M. and Murphy, M. (2015) Plant Physiology and Development, 6th edition, Sinauer Associates, USA.
2. Taiz L. and Zeiger, E. (2010) Plant Physiology, 5thedition, Sinauer Associates, USA.
3. Jones R., Ougham H., Thomas H. and Waaland S. (2012) The Molecular Life of Plants, Wiley-Blackwell,
4. Buchanan B. B., Gruissem, W and Jones R. J. (2015) Biochemistry and Molecular Biology of Plants, American Society of Plant Physiologists, MD, USA.
5. Hopkins W. G. and Huner N. PA. (2008) Introduction to Plant Physiology, 4th ed., John Wiley and Sons Ltd.
6. Nelson D. L. and Cox M. M. (2021) Lehninger Principles of Biochemistry, 8th edition, W.H.Freeman and Company, New York, USA.
7. Berg J. M., Stryer, L., Tymoczko J. and Gatto G. (2019) Biochemistry, 9th edition, Worth Publishers, USA.
8. Dey P.M. and Harborne J.B. (1997) *Plant Biochemistry*, Academic press.
9. Voet, D., Voet, J. G., and Pratt, C. W. (2016). *Fundamentals of Biochemistry: Life at the Molecular Level*. John Wiley and Sons.
10. Gilbert, S.F. and Barresi, M.J.F. (2017), *Developmental Biology*, 11th edition. American Jour. of Medicine.
11. Leyser, O. and Day, S. (2009). *Mechanisms in plant development*. John Wiley and Sons.

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Course Code: BOT-MJR-455	**Course Title: Plant Biochemistry, Metabolism and Developmental Biology**	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week** **Practical: 45 Hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Understand the plant metabolic and developmental processes by examining the structure, function, and regulation of primary and secondary metabolites, key energy and nutrient assimilation pathways, and phytohormone signalling.
2. Clarify the molecular and physiological mechanisms behind plant development -from cell polarity and meristem function to organogenesis, floral induction, and senescence - supported by hands-on training in biochemical and developmental assays.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Primary Plant Metabolites in Metabolism**	Structure and properties of carbohydrates, lipids, amino acids, proteins, nucleic acids.	**2**

Unit No.	Unit	Topics	Class Hours
2	**Energy-Yielding Metabolism**	Paths of energy synthesis through glycolysis, citric acid cycle, plant mitochondrial electron transport chain, alternative oxidase, PPP cycle, regulation of respiratory pathways, lipid metabolism, fatty acid biosynthesis and oxidation.	**3**
3	**Nucleotide Metabolism**	Biosynthesis of purine and pyrimidine nucleotides.	**3**
4	**Nutrient Metabolism**	Non-symbiotic and symbiotic nitrogen fixation, chemoattractant during symbiosis, role of lectins, *nod* genes, *nif* genes, structure and function of nitrogenase, leghemoglobin, nodulins, nitrate reduction, pathways of ammonia assimilation, biosynthesis of proteinogenic amino acids and their degradation, the urea cycle, uptake, transport, and assimilation of sulphate and phosphate.	**15**
5	**Metabolism and Signalling of Phytohormones**	Chemistry, biosynthesis, physiological effects and signal transduction pathways of IAA, gibberellins, cytokinins, ethylene, abscisic acid, brassinosteroids, polyamines and jasmonates.	**5**
6	**Secondary Metabolites**	Distinction between primary and secondary metabolites, categories of secondary metabolites emphasizing phenolics, terpenoids and alkaloids in metabolic processes.	**2**
7	**Cell Polarity and Meristem Function**	Developmental processes in *Dictyostelium* and *Acetabularia*, polarity in higher plants, form and function of the root apical meristem (RAM) and the shoot apical meristem (SAM), differentiation of root, stem, leaf, and axillary buds, development of root hair and stomata.	**3**
8	**Floral Induction and Development**	Transition from vegetative to floral meristem, environmental and internal inductive pathways, molecular mechanisms of floral development, and floral organ differentiation.	**3**
9	**Sensory Photobiology**	Light control on plant development, structure and function of plant photoreceptors.	**3**
10	**Senescence in Plants**	Types of senescence, metabolic changes associated with senescence and its regulation, role of hormones and genetic determinants.	**6**

Practical Course Content

Practical Components	Activities/ Experiments
Plant Biochemistry	1. Estimation of sulphur. 2. Estimation of phosphorus content by Fiske-Subbarow method. 3. Estimation of reducing sugar. 4. Quantitative estimation of total soluble sugar by Anthrone method. 5. Quantitative estimation of amino acids and proteins by colorimetric method. 6. Paper chromatography of amino acids and sugars. 7. Thin-layer chromatography of amino acids and sugars.
Plant Metabolism	8. Effect of uncoupler on the rate of respiration.

Practical Components	Activities/ Experiments
Plant Developmental Biology	9. Induction of α-amylase synthesis in aleurone cells of rice grains by GA_3. 10. Bioassay of IAA, gibberellins, and cytokinins.

Suggested Readings:

1. Nelson D. L. and Cox M. M. (2021) Lehninger Principles of Biochemistry (8th edition), Macmillan Publishers Ltd., London, UK
2. Taiz L., Zeiger, E, Moller, I. M. and Murphy, M. (2015) Plant Physiology and Development, 6th edition, Sinauer Associates, USA.
3. Jones, R. L, Ougham, H., Thomas, H. and Waaland, S. (2012) The Molecular Life of Plants. Wiley Blackwell and American Society of Plant Biologists, USA.
4. Dey P.M. and Harborne J.B. (1997) Plant Biochemistry, Academic press.
5. Voet, D., Voet, J. G., and Pratt, C. W. (2016). Fundamentals of Biochemistry: Life at the Molecular Level. John Wiley and Sons.
6. Hopkins, W. G. and Huner, N. P. A. (2008). Introduction to Plant Physiology. John Wiley, UK.
7. Buchanan, B. B., Gruissem, W. and Jones, R. L. (2015) Biochemistry and Molecular Biology of Plants. John Wiley and Sons and American Society of Plant Biologists, USA.
8. Nelson D. L. and Cox, M. M. (2008). Principles of Biochemistry. W H Freeman and Co., USA.
9. Berg J. M., Stryer, L., Tymoczko J. and Gatto G. (2019) Biochemistry, 9th edition, Worth Publishers, USA.
10. Gilbert, S.F. and Barresi, M.J.F. (2017), Developmental Biology, 11th edition. American Journal of Medicine.
11. Leyser, O. and Day, S. (2009). Mechanisms in plant development. John Wiley and Sons.
12. Howell, S.H. (1998). Molecular genetics of plant development. Cambridge University Press.

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Course Code: BOT-SEC-456	Course Titles: (Any One) **456 A: AI applications in Plant Science** 456 B: Bioinformatics 456 C: Forensic Botany 456 D: Intellectual Property Rights	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory : 1 credit + SST/ Tutorial : 1 credit		
Class Hours: Theory : 30 hours; Total : 90 days; 2 hrs/ week		

Course Learning Outcomes: AI applications in Plant Science 456A

Upon successful completion of this course, students will be able to:

1. Known different systems related to AI
2. Understand application of AI in different aspects of plant science with their challenges
3. Develop skill to use AI for crop improvement, data prediction for climate change

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**AI System**	Deep Neural Networks (DNNs), Convolution Neural Networks (CNNs), Artificial Neural Networks (ANNs).	2
2	**Working Principle (Machine Learning)**	Data collection, pre-processing, segmentation, feature extraction, classification.	2
3	**Optimization of Experimental Parameters, Correlation Analysis**	Central Composite Design (CCD), Response Surface Modeling (RSM), Principal Component Analysis (PCA).	2
4	**AI in Biotechnology**	Gene function prediction, protein modeling, virtual compound screening, metagenomic profiling.	4
5	**AI in Plant Breeding and Crop Improvement**	Plant phenotyping, generation of germplasm bank, multi-omics data integration, identification of marker gene, transposon detection.	5
6	**AI in Plant Pathology**	Plant disease diagnosis *via* image recognition, plant disease forecasting, computer stimulation, remote sensing, robotics in agriculture.	5
7	**AI in Ecology and Environmental Sciences**	Wild-life monitoring, biodiversity mapping, water quality indexing, pollution analysis.	4
8	**AI in Pollen Grain Analysis**	Decoding intricate pollen fingerprint, allergen source identification, application in forensic science.	4
9.	**Challenges**	Data quality and availability, data integration, model interpretability, biological complexity, ethical issues.	2

Suggested readings:

1. AI in Plant Science and Precision Agriculture; Edited By Jen-Tsung Chen, CRC Press
2. AI Technologies for Crop Breeding, Edited by Jen-Tsung Chen, Academic Press
3. Relevant scientific articles

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Course Code: **BOT-SEC-456**	**Course Titles: (Any One)** 456 A: AI applications in Plant Science **456 B: Bioinformatics** 456 C: Forensic Botany 456 D: Intellectual Property Rights	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory : 1 credit + SST/ Tutorial : 1 credit		
Class Hours: Theory : 30 hours; Total : 90 days; 2 hrs/ week		

Course Learning Outcomes: Bioinformatics 456B

Upon successful completion of this course, students will be able to:

1. Apply bioinformatics tools and computational approaches to retrieve, analyze, and interpret biological data from major databases such as NCBI and UniProt.
2. Achieve proficiency in sequence analysis, structural prediction, and genome data exploration using platforms like Ensembl and UCSC Genome Browser.
3. Develop skills in handling next-generation sequencing (NGS) data, molecular dynamics simulations using GROMACS, and structure-based drug design and molecular docking, enabling them to address complex biological problems through computational methods.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Biological Databases**	NCBI-GenBank, UniProt, DDBJ, EMBL, PDB, NCBI different modules, ORF-finder, taxonomy browser, BOLD, PubMed.	3
2	**Sequence Aanalysis**	Introduction to sequence analysis, local and global alignment, pairwise and multiple alignment, substitution matrix (introduction to PAM, BLOSUM), BLAST, FASTA.	6
3	**Structure-Prediction**	Structure classification of proteins (SCOP, CATH).	2
4	**Patterns, Motifs and Profiles in Sequences**	Derived databases of patterns, motifs and profiles e.g. Prosite, Blocks, Prints-S, Pfam.	3
5	**Overview of Tertiary Structure Prediction methods**	Protein structure prediction by comparative modeling approaches (homology modeling and fold recognition), ab-initio structure prediction methods, etc.	8
6	**Introduction to Various Databases**	Genome browsers and associated tools, ENSEMBL, GeneCards, UCSC genome browser and their application.	5
7	**Molecular Docking**	Protein-protein, protein-ligand docking, scoring methods.	3

Suggested readings:

1. Textbook of Computational Biology and Bioinformatics, Christina Marshall, Syrawood Publishing House
2. Fundamentals of Bioinformatics and Computational Biology: Methods and Exercises in MATLAB, Gautam B. Singh, Springer.
3. Related scientific articles

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Course Code: BOT-SEC-456	Course Titles: (Any One) 456 A: AI applications in Plant Science 456 B: Bioinformatics **456 C: Forensic Botany** 456 D: Intellectual Property Rights	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory : 1 credit + SST/ Tutorial : 1 credit		
Class Hours: Theory : 30 hours; Total : 90 days; 2 hrs/ week		

Course Learning Outcomes: Forensic Botany 456C

Upon successful completion of this course, students will be able to:

1. Explain the scope, principles, and historical development of forensic botany.
2. Evaluate different types of botanical evidence and their role in criminal investigations.
3. Integrate knowledge from palynology, plant anatomy, ecology, limnology, and molecular biology in forensic analysis.
4. Interpret analytical findings from pollen, diatoms, anatomical structures, and plant DNA.
5. Assess the contribution of botany in drug enforcement and legal case resolution.

Theory Course Content: Forensic Botany

Unit No.	Unit Title	Topics	Class Hours
1	**Introduction to Forensic Botany**	Definition, scope and history of forensic botany, importance of plant evidence in criminal investigations, role of forensic botanists in legal system.	**2**
2	**Botanical Evidence in Criminal Investigation**	Types of botanical evidence (pollen, spores, seeds, wood, leaves, fibers, algae), source and transfer of plant materials, recognition, collection, preservation and documentation, chain of custody, interpretation and evidentiary value in court.	**8**
3	**Branches of Botany in Forensic Study**	Forensic palynology, forensic limnology (diatom analysis in drowning cases), forensic plant anatomy, forensic plant ecology (habitat reconstruction), forensic plant molecular biology (DNA barcoding, genetic fingerprinting).	**10**
4	**Analysis of Botanical Samples**	Microscopic analysis of pollen grains, anatomical examination of plant tissues, diatom analysis, DNA extraction and molecular identification, interpretation of laboratory results.	**6**
5	**Drug Enforcement and Botanical Contributions**	Identification of narcotic and psychotropic plants, detection of plant-based drugs, botanical expertise in illegal cultivation, role in wildlife and forest crime investigations, brief review of classic forensic botany case studies.	**4**

Suggested Readings: Forensic Botany

1. Forensic Botany: Principles and Applications to Criminal Casework – H.M. Coyle. CRC Press.
2. Forensic palynology: Why do it and how it works–D.C. Mildenhall, P.E.J. Wiltshire, V.M. Bryant. Editorial of Forensic Science International 163 (2006) 163–172.
3. Forensic Science: From the Crime Scene to the Crime Lab – R. Saferstein. Pearson.
4. Forensic Science Handbook – R. Saferstein and Adam B. Hall. CRC Press.

Course Code: **BOT-SEC-456**	**Course Titles: (Any One)** 456 A: AI applications in Plant Science 456 B: Bioinformatics 456 C: Forensic Botany **456 D: Intellectual Property Rights**	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory : 1 credit + SST/ Tutorial : 1 credit		
Class Hours: Theory : 30 hours; Total : 90 days; 2 hrs/ week		

Course Learning Outcomes: Intellectual Property Rights 456D

Upon successful completion of this course, students will be able to:

1. Explain the basic concepts and significance of Intellectual Property Rights in the context of innovation, research, and knowledge economy.
2. Identify different types of intellectual property such as patents, copyrights, trademarks, and geographical indications.
3. Understand the legal and institutional framework of IPR in India, including major national and international agreements.
4. Recognize the procedures involved in protection and management of intellectual property, particularly patent filing and copyright protection.
5. Apply basic principles of IPR in academic research, entrepreneurship, and technology transfer.

Theory Course Content: Intellectual Property Rights

Unit No.	Unit Title	Topics	Class Hours
1	**Introduction to Intellectual Property**	Concept and meaning of intellectual property, evolution and importance of IPR in knowledge economy, need for protection of intellectual creations, role of IPR in innovation, research, and economic development.	**6**
2	**Types of Intellectual Property Rights**	Overview of major forms of intellectual property, copyright and related rights, patents: concept, criteria for patentability, duration, geographical indications, protection of plant varieties and traditional knowledge.	**8**
3	**IPR Framework in India and International Agreements**	IPR laws and administrative structure in India, key provisions of the Indian Patent Act, Copyright Act, and Trademark Act, role of national IP offices and regulatory authorities, international frameworks such as TRIPS and WIPO conventions, India's participation in global IPR governance.	**6**
4	**Patent Filing and IPR Management**	Process of patent application and examination, patent search and documentation, technology transfer and commercialization, licensing, royalties, and technology management, IPR issues in academic research and innovation.	**6**
5	**Emerging Issues in Intellectual Property**	IPR in plant science research, traditional knowledge and biodiversity protection, ethical and legal challenges in IPR, open access, open innovation, and digital copyright, IPR and sustainable development.	**4**

Suggested Readings:

1. Pandey, N. and Dharni, K. (2014). Intellectual Property Rights. PHI Learning Pvt. Ltd., New Delhi
2. Ganguli, P. (2001). *Intellectual Property Rights: Unleashing the Knowledge Economy.* McGraw Hill.
3. Narayanan, P. (2017). *Intellectual Property Law.* Eastern Law House.
4. Cornish, W., Llewelyn, D., and Aplin, T. (2019). *Intellectual Property: Patents, Copyright, Trade Marks and Allied Rights.* Sweet and Maxwell.
5. WIPO. (World Intellectual Property Organization). *Understanding Intellectual Property.* WIPO Publication.
6. Government of India. *Intellectual Property Rights Policy and Patent Office Guidelines.*
7. Bently, L., Sherman, B. (2014). *Intellectual Property Law.* Oxford University Press.

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Course Code: BOT-VAC-499	**Course Title: (any one)** **1. Environmental Biology** 2. Biodiversity and Conservation	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory:	**2 credits**	
Class Hours: Theory :	**30 hours; Total : 90 days; 2 hrs/ week**	

Course Learning Outcomes: Environmental Biology

Upon successful completion of this course, students will be able to:

- Understand mechanisms by which organisms interact with other organisms and with their physical environment.
- Describe biotic and abiotic factors that influence the dynamics of populations.
- Appreciate the inter-relationship between organism in population and communities.
- Understand principles of toxicology and the harmful effects of toxic metals on humans and environment.
- Realize the role of various International Organisations for the protection and safeguard of environment.

Theory Course Content: Environmental Biology

Unit No.	Unit Title	Topics	Class Hours
1	**Natural Resources**	Brief overview, degradation and conservation,	**3**
2	**Environmental Pollution**	Air, water, soil: types of pollutants, sources, effects and remedial measures, electronic waste: source, types, components of e-waste, recycling of e-waste, impact of e-waste on environment and their management, ecotoxicology: principles, mechanisms, types and effects, biomonitoring.	**15**
3	**Global Environmental Change**	Green house effects, global warming, causes and effects, Ozone depletion, Intergovernmental Panel on Climate Change (IPCC).	**6**

Unit No.	Unit Title	Topics	Class Hours
3	**Environmental Impact Assessment**	Principles and theories.	**2**
4	**Environmental Law and Policies**	International and national laws and policies.	**2**
5	**Sustainable Development**	Concept, national sustainable development strategies.	**2**

Suggested Readings: Environmental Biology

1.Eldon, D., Enger, Bradley, Smith, F. (1995). Environmental Science. W C Brown Publications.

2. Grant, W. E. and Swannack, T. M. (2008). Ecological Modelling. Blackwell.

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Course Code: BOT-VAC-499	**Course Title: (any one)** 1. Environmental Biology **2. Biodiversity and Conservation**	
Course Nature: Coursework	**Course Level: 450-499**	**NCrF credit level: 6**
Credit Pattern: Theory:	**2 credits**	
Class Hours: Theory :	**30 hours; Total : 90 days; 2 hrs/ week**	

Course Learning Outcomes: Biodiversity and Conservation

Upon successful completion of this course, students will be able to:

1. Explain the concept, levels, and significance of biodiversity in ecological and evolutionary contexts.
2. Analyze patterns of biodiversity distribution and identify major biodiversity hotspots and ecosystems.
3. Evaluate major threats to biodiversity, including habitat loss, climate change, invasive species, and overexploitation.
4. Understand principles and strategies of biodiversity conservation, including protected areas and sustainable management.
5. Interpret the role of national and international conservation frameworks in biodiversity protection and sustainable development.

Theory Course Content: Biodiversity and Conservation

Unit No.	Unit Title	Topics	Class Hours
1	**Concept and Levels of Biodiversity**	Definition and concept of biodiversity, levels of biodiversity: genetic, species, and ecosystem diversity, importance and values of biodiversity (ecological, economic, cultural), methods for measuring biodiversity (species richness, diversity indices), biodiversity and ecosystem services.	**6**

Unit No.	Unit Title	Topics	Class Hours
2	**Patterns and Distribution of Biodiversity**	Global patterns of biodiversity distribution, latitudinal gradients and ecological determinants of biodiversity, concept of biodiversity hotspots, major terrestrial and aquatic ecosystems, biodiversity of the Indian subcontinent.	**6**
3	**Threats to Biodiversity**	Habitat loss and fragmentation, climate change and biodiversity responses, invasive species and biological pollution, overexploitation of biological resources, pollution and ecosystem degradation.	**6**
4	**Conservation Strategies and Management**	Principles of biodiversity conservation, *in-situ* conservation (national parks, wildlife sanctuaries, biosphere reserves, sacred groves), *ex-situ* conservation (botanical gardens, seed banks, gene banks, cryoconservation), community-based conservation and sustainable resource management, ecological restoration and conservation planning.	**6**
5	**Biodiversity Policy and Global Initiatives**	Biodiversity conservation laws and policies in India, Convention on Biological Diversity and international conservation frameworks, Nagoya Protocol, Montreal Protocol, access and benefit sharing, role of indigenous knowledge in conservation, biodiversity and sustainable development, PBR (People's Biodiversity Register).	**6**

Suggested Readings: Biodiversity and Conservation

1. Primack, R. B. (2014). *Essentials of Conservation Biology.* Sinauer Associates.
2. Hunter, M. L. (2002). *Fundamentals of Conservation Biology.* Blackwell Science.
3. Gaston, K. J., and Spicer, J. I. (2013). *Biodiversity: An Introduction.* Wiley-Blackwell.
4. Krishnamurthy, K. V. (2003). *An Advanced Textbook of Biodiversity: Principles and Practice.* Oxford and IBH.
5. Singh, J. S., Singh, S. P., and Gupta, S. R. (2017). *Ecology, Environmental Science and Conservation.* S. Chand.
6. Ministry of Environment, Forest and Climate Change (India). Biodiversity policies and reports.

SEMESTER III

Course Code: BOT-IKS-501	**Course Title: Indian Knowledge System in Plant Science**	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Trace the evolution of plant science in India, from early references in Vedic and Ayurvedic literature to the development of modern botanical research.
2. Understand plant classification and nomenclature within Indian Knowledge Systems, including Sanskrit texts and regional folk taxonomies.
3. Recognize the scope and significance of ethnobotanical knowledge, particularly in the cultural, plant wealth and ecological context of Bengal and eastern India.
4. Appreciate ecological ideas embedded in traditional Indian thought and their relevance to contemporary approaches in plant conservation.
5. Examine indigenous agricultural knowledge and plant resource management practices, including traditional seed conservation and agroecological systems of Bengal.
6. Evaluate the contribution of Indian Knowledge Systems and Traditional Knowledge to biodiversity conservation, sustainability, and knowledge protection frameworks.
7. Explore the integration of traditional plant knowledge with modern plant sciences, especially in taxonomy, ecology, ethnopharmacology, and conservation.

Theory Course Content

Unit No.	Unit Title	Topics	Class Hours
1	**Early Foundations of Plant Knowledge in India**	Plant knowledge in the Vedic and early philosophical texts, botanical ideas in classical ayurvedic literature, early observations on plant growth, health and cultivation in traditional texts, conceptual understanding of plant life in classical Indian thought, agricultural practices in classical Indian thought	**6**
2	**Classical Textual Traditions in Indian Plant Science**	Botanical knowledge in Charaka Samhita and Sushruta Samhita, Parashara's Vrikshayurveda and early agricultural–botanical knowledge, the Nighantu tradition and early documentation of medicinal plants, concept of Ayurveda and its current status, role of sanskrit literature in preserving plant knowledge.	**6**
3	**Emergence of Modern Botanical Science in India**	Early European botanical explorations in India (16th–18th centuries), contributions of Portuguese, Dutch, Danish and British naturalists, development of botanical exploration and plant documentation, early botanical writings on Indian flora.	**5**

Unit No.	Unit Title	Topics	Class Hours
4	**Institutional Development of Botany in India**	Establishment of botanical gardens and herbaria in colonial India, growth of systematic botany during the 19th and early 20th centuries, role of botanical institutions and surveys, development of botanical research in independent India.	**5**
5	**Plant Classification and Nomenclature in Traditional Knowledge Systems**	Traditional plant classification in sanskrit texts, folk and indigenous plant classification practices, sanskrit plant nomenclature and regional plant names, linking vernacular plant names with modern scientific binomials.	**5**
6	**Ethnobotany and Cultural Plant Traditions of Bengal**	Scope and approaches of ethnobotany, plants in rituals, festivals and folk traditions of Bengal, sacred plants and their cultural symbolism, ethnobotanical knowledge among rural and tribal communities of eastern India.	**5**
7	**Traditional Ecological Knowledge and Conservation**	Ecological perspectives in Indian philosophical traditions, sacred groves and community-protected landscapes, indigenous forest management and plant conservation practices, role of traditional ecological knowledge in biodiversity conservation.	**6**
8	**Indigenous Agriculture and Integration with Modern Plant Science**	Traditional crop diversity and indigenous seed conservation, agroecological practices: mixed cropping, crop rotation and organic soil management, traditional irrigation and plant resource management systems, integration of traditional plant knowledge in modern botanical research and conservation.	**7**

Suggested Readings

1. Jain, S.K. (2016). *Ethnobotany in India*. Deep Publications, New Delhi.
2. Jain, S.K. (1991). *Dictionary of Indian Folk Medicine and Ethnobotany*. Deep Publications, New Delhi.
3. Cotton, C.M. (1996). *Ethnobotany: Principles and Applications*. John Wiley and Sons, Chichester.
4. Schultes, R.E., and Reis, S.V. (1995). *Ethnobotany: Evolution of a Discipline*. Chapman and Hall, London.
5. Sadhale, N. (1996). *Surapala's Vrikshayurveda (The Science of Plant Life by Surapala)*. Asian Agri-History Foundation, Secunderabad.
6. Dash, B. (2006). *Charaka Samhita*. Chowkhamba Sanskrit Series Office, Varanasi.
7. Desmond, R. (1992). *The European Discovery of the Indian Flora*. Oxford University Press, Oxford.
8. Prain, D. (1903; reprint editions). *Bengal Plants*. Botanical Survey of India, Kolkata.
9. Gadgil, M., and Guha, R. (1992). *This Fissured Land: An Ecological History of India*. Oxford University Press, New Delhi.
10. Ramakrishnan, P.S. (2001). *Ecology and Sustainable Development*. National Book Trust, New Delhi.
11. Sacred Groves of West Bengal. West Bengal Biodiversity Board, Government of West Bengal, Kolkata.
12. Relevant Scientific articles

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Course Code: BOT-MJR-502	Course Title: Ecology: Theories and Plant Systems	
Course Nature: Coursework	Course Level: 500-549	NCrF credit level: 6.5
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week Practical: 45 Hours; Total : 90 days; 3 hrs/ week		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain and critically evaluate key ecological theories, including their historical development and relevance to contemporary ecological science.
2. Analyze the structure and function of plant systems within various ecosystem contexts across spatial and temporal scales.
3. Apply systems thinking and modelling tools (e.g., conceptual models, energy flow diagrams, succession models) to study ecological interactions involving plants.
4. Interpret ecosystem energetics and nutrient cycling in plant-based systems using quantitative and conceptual approaches.
5. Design and conduct field-based experiments that investigate ecological hypotheses related to plant communities and ecosystems.
6. Synthesize ecological knowledge with global frameworks such as the Sustainable Development Goals (SDGs), ecosystem restoration strategies, and climate resilience planning.
7. Communicate scientific findings effectively through written reports, visualizations, and presentations rooted in ecological reasoning and evidence.

Theory Course Content

Unit No.	Unit	Topic	Class Hours
1	**Foundations of Ecological Thought**	History of ecological perspectives - from natural history to systems ecology, evolution of ecological concepts, ecological paradigms over time.	5
2	**Ecological Theories and Dynamics**	Niche concepts, ecological succession models, island biogeography theory, metapopulation and source-sink dynamics, chaos theory and self-organization in ecosystems.	5
3	**Population Ecology**	Characteristics of populations, (density, dispersion, age structure), population growth curves (exponential, logistic), population regulation, life history strategies (r- and K-selection), population interactions and regulation.	6
4	**Functional Traits and Plant Strategies**	Plant functional traits, Competitor - Stress tolerator - Ruderal (CSR) framework and Grime's model, resource acquisition strategies, resource use efficiency and trade-offs.	5
5	**Community Ecology and Plant Interactions**	Species coexistence, competition, facilitation, allelopathy, plant diversity - productivity relationships, ecosystem services provided by plant communities.	6

Unit No.	Unit	Topic	Class Hours
6	**Plant Ecophysiology**	Eco-physiological responses to variations, drought, flood, temperature, CO_2, and salinity, adaptive strategies and mitigation *wrt.* changing climate.	**5**
7	**Ecosystem Processes and Modelling**	Ecosystem energetics, productivity, energy flow, and trophic structure, nutrient cycling and ecological stoichiometry, systems ecology, modelling stocks and flows, feedback loops, ecosystem resilience and restoration.	**6**
8	**Landscape Ecology and Global Perspectives**	Spatial patterns and scale in ecological systems, basic principles of landscape ecology, applications of GIS and remote sensing in vegetation studies, interpretation of NDVI and landscape fragmentation.	**7**

Practical Course Content

Practical Components	Activities / Experiments
Field Ecology and Sampling Techniques	1. Familiarization with ecological field equipment: GPS, soil and water thermometer, different probes and lux meter. 2. Soil and water parameter testing. 3. Quadrat sampling to estimate plant density, frequency and abundance in a natural plant community. 4. Line and belt transect methods for analysing vegetation structure and species distribution patterns.
Population Ecology Analysis	5. Construction and interpretation of population growth curves using field or simulated datasets. 6. Preparation of life tables and survivorship curves for plant populations.
Plant Functional Traits and Strategies	7. Measurement of plant functional traits such as leaf area, specific leaf area (SLA), leaf dry matter content and plant height. 8. Comparative assessment of plant adaptive strategies across contrasting habitats.
Community Ecology and Vegetation Analysis	9. Estimation of species richness and calculation of diversity indices (Shannon, Simpson) and evenness in plant communities. 10. Observation and documentation of plant–plant interactions such as competition or facilitation in field conditions.
Ecosystem Processes and Productivity	11. Estimation of primary productivity in plant communities using biomass sampling methods. 12. Study of litter fall and decomposition dynamics using litter bag techniques.
Biodiversity Economics Exercises	13. Valuation of plant resources of different categories and ecosystems applying different valuation methods.
Field-Based Component	14. Students must undertake a compulsory field excursion to a nearby ecosystem (e.g., wetland/ forest/ estuarine/ marine) to apply ecological sampling and analytical techniques. A comprehensive field report, including methodology, data analysis, and ecological interpretation, must be submitted as part of the practical evaluation.

Suggested Readings

1. Begon, M., Townsend, C.R., and Harper, J.L. (2006). Ecology: From Individuals to Ecosystems. Blackwell Publishing.
2. Ehleringer, J.R., & Monson, R.K. (2025). Plant Ecology in a Changing World. CRC Press.
3. Fitter, A.H., & Hay, R.K.M. (2002). Environmental Physiology of Plants (3rd ed.). Academic Press.
4. Grime, J.P. (2001). Plant Strategies, Vegetation Processes, and Ecosystem Properties (2nd ed.). Wiley.
5. Gurevitch, J., Scheiner, S. M., & Fox, G. A. (2006). The ecology of plants (2nd ed.). Sinauer Associates.
6. Harper, J.L. (1977). Population Biology of Plants. Academic Press.
7. Huston, M.A. (1994). Biological Diversity: The Coexistence of Species on Changing Landscapes. Cambridge University Press.
8. Kent, M. (2012). Vegetation Description and Data Analysis: A Practical Approach (2nd ed.). Wiley-Blackwell.
9. Larcher, W. (2003). Physiological Plant Ecology (4th ed.). Springer.
10. Levin, S.A. (Ed.). (2009). The Princeton Guide to Ecology. Princeton University Press.
11. Loreau, M. (2010). From Populations to Ecosystems: Theoretical Foundations for a New Ecological Synthesis. Princeton University Press.
12. Ricklefs, R.E., and Relyea, R. (2014). Ecology: The Economy of Nature. W.H. Freeman and Company.
13. Smith, T.M., and Smith, R.L. (2015). Elements of Ecology. Pearson Education.
14. Molles, M.C. (2019). Ecology: Concepts and Applications. McGraw-Hill Education.
15. Krebs, C.J. (2016). Ecology: The Experimental Analysis of Distribution and Abundance. Pearson.
16. Odum, E.P., and Barrett, G.W. (2005). Fundamentals of Ecology. Cengage Learning.
17. Ricklefs, R.E., and Miller, G.L. (2000). *Ecology*. W.H. Freeman and Company, New York.
18. Schulze, E.-D., Beck, E., & Müller-Hohenstein, K. (2005). Plant Ecology. Springer.
19. Scheiner, S.M., & Willig, M.R. (Eds.). (2011). The Theory of Ecology. University of Chicago Press.
20. Tilman, D. (1982). Resource Competition and Community Structure. Princeton University Press.

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Course Code: BOT-MJR-503	**Course Title: Palaeobotany and Plant Evolution**	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 1 credit + Practical: 1 credit		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 20 hours; Total : 90 days; 1 hr/ week** **Practical: 45 Hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain fossilization, geological time scale, and stratigraphic principles.
2. Analyze plant fossil records to trace the evolution of major plant groups.
3. Apply evolutionary theories, genetic principles, and molecular evolution to plant evolution.
4. Correlate plant fossil distribution with plate tectonics, Gondwana history, and palaeogeography.
5. Use palaeobotanical and palynological data to reconstruct palaeoenvironment and palaeoclimate.
6. Demonstrate laboratory and analytical skills in fossil identification, microfossil extraction, stratigraphy, and quantitative evolutionary analysis.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Fundamentals of Palaeobotany and Fossilization**	Definition and scope of palaeobotany, preservation of plants as fossils, taphonomy, environments of fossilization, modes of preservation, types of plant fossils, systematics, reconstruction and nomenclature, major rock types and rock cycle, fossiliferous rocks, elements of stratigraphy: stratigraphic units, facies concept, geological time scale: relative *vs* numerical age, physical and biological principles of dating.	**6**
2	**Origin of Earth, Early Life and Cellular Evolution**	Origin of earth and earliest atmosphere, theories of origin of life, abiotic synthesis of organic molecules, first cell and anaerobic metabolism, evolution of prokaryotes, origin of eukaryotic cells, photosynthesis and oxygen revolution, fossil evidence of early life (stromatolites, microfossils), early diversification - algae and fungi.	**6**
3	**Colonization of Land and Early Vascular Plants**	Geologic time and palaeo-environmental context, transition from aquatic to terrestrial habitat, vegetative and reproductive adaptations, transitional fossil plants, early non-vascular land plants (bryophytes), early vascular plants (pteridophytes), arborescent pteridophytes, Progymnosperms- advancement in adaptive features for land dwelling.	**6**
4	**Evolution of Seed Plants and Angiosperms**	Transition from isospory to heterospory, origin of ovule, hydrasperman reproduction, early gymnosperms, origin and evolution of flowering plants, derived angiosperm characteristics, fossil evidences of early angiosperms, place of origin and radiation, phylogeny and diversification trends.	**6**
5	**Evolutionary Theories and Genetic Basis of Evolution**	Emergence of evolutionary thought, concepts of variation, adaptation, struggle, fitness, natural selection, neo-Darwinism, genetic variation and its origin, Mendelian genetics, linkage and recombination, epistasis and gene–environment interaction, population genetics (Hardy–Weinberg equilibrium), molecular evolution and molecular clocks, speciation concepts.	**6**
6	**Plate Tectonics, Gondwana and Fossil Correlation**	Geological structures- stress, strain, folds and faults, continental drift theory, plate tectonics, break-up history of major continents, plant fossils as evidence of continental drift, concept, limit and extension of Gondwana, rise and decline of Glossopteris flora, Climatic interpretations.	**6**
7	**Plant Fossils as Palaeoenvironmental and Climate Proxies**	Palaeogeography and palaeoclimate, leaf physiognomy, NLR (nearest living relative) and coexistence approach, CLAMP analysis, stomatal density and index, dendrochronology, role of plant fossils in predicting future climate change, mass extinction and diversification events.	**5**

Unit No.	Unit	Topics	Class Hours
8	**Applied Palaeobotany, Microfossils and Energy Resources**	Microfossils and palaeoecological significance- spore, pollen grains, microforaminifera, dinoflagellates, diatoms, radiolaria, and ostracods, coal formation- peat to anthracite, constitution of coal, coalfields and coal seams, petroleum origin, migration and accumulation, oil shales, ancient DNA and palaeogenomics, fossil biomolecules and stable carbon isotopes.	**4**

Practical Course Content

Title of Practical	Activities / Experiments
Identification of Fossiliferous rocks, fossil types, and modes of preservation	1. Identification and description of fossiliferous rocks, understanding and interpretation of fossil types and modes of preservation.
Systematic Study of Representative Fossils	2. Morphological description, systematic placement and evolutionary interpretation.
Fossil Preparation Techniques	3. Demonstration of peel technique and preparation/ observation of fossil thin sections, hands-on demonstration for maceration of peat, lignite and coal samples and slide preparation.
Palaeopalynology and Quantitative Analysis	4. Extraction of microfossils from peat, lignite and coal, qualitative identification, frequency calculation. 5. Preparation of pollen diagrams, interpretation of stratigraphic age and depositional environment.
Stratigraphy and Geological Interpretation	6. Preparation of simplified stratigraphic columns using plant fossil assemblages, correlation of strata using fossil data.
Climate Proxy Analysis	7. Leaf physiognomy analysis, stomatal index calculation, palaeo-climate interpretation using fossil plant data.
Evolutionary and Biogeographic Mapping Exercise	8. Simple phylogenetic interpretation. 9. Mapping exercise on continental drift and plant fossil distribution (Gondwana correlation).
Field-Based Component	10. Field visit/ Fossil Museum report with proper documentation and interpretation.

Submission of practical record; viva based on fossil identification, palaeopalynology, stratigraphy and evolutionary interpretation.

Suggested Readings

1. T.N. Taylor, E.L. Taylor and M. Krings (2009). Palaeobotany: The Biology and Evolution of Fossil Plants – Elsevier.
2. W.N. Stewart and G.W. Rothwell (1993). Palaeobotany and the Evolution of Plants –Cambridge University Press.
3. C.J. Cleal and B.A. Thomas (1999). Plant Fossils: The History of Land Vegetation. Boydell Press.
4. S.V. Meyen (1987). Fundamentals of Palaeobotany. Chapman and Hall.
5. K.J. Willis and J.C. McElwain (2002). The Evolution of Plants. Oxford University Press.
6. Brasier, M. D. (1980). *Microfossils*. London, UK: George Allen & Unwin.

7. Traverse A. (1988). Paleopalynology. Springer.
8. P.D. Moore, J.A. Webb and M.E. Collinson (1991). Pollen Analysis. Blackwell.
9. T.P. Jones and N.P. Rowe (1999). Fossil Plants and Spores: Modern Techniques. Geological Society, London.
10. Duff, P. McL. D. (Ed.). (1992). Holmes' principles of physical geology (4th ed.). London, UK: Chapman & Hall.
11. R. Kumar (2011). Fundamentals of Historical Geology and Stratigraphy of India. New Age International.
12. M. Ridley (2003). Evolution. Blackwell.
13. D.J. Futuyma (1998). Evolutionary Biology. Sinauer Associates.
14. K.J. Niklas (1999). The Evolutionary Biology of Plants. University of Chicago Press.
15. K.R. Surange, R.N. Lakhanpal and D.C. Bharadwaj (1974). Aspects and Appraisal of Indian Palaeobotany. Birbal Sahni Institute.

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Course Code: BOT-MNR-504	**Course Title: Pharmacognosy**	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Theory:	**2 credits**	
Class Hours: Theory :	**30 hours; Total : 90 days; 2 hrs/ week**	

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Understand the safe use of herbal drugs.
2. Recognize risks of possible drug adulteration and how to detect them.
3. Apply their knowledge to connect ethnobotany, medicinal chemistry, and pharmacotherapeutics.
4. Support drug discovery using natural products.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Definition and Scope of Pharmacognosy**	Utility of pharmacopeia, brief idea about traditional Indian medicine systems.	**2**
2	**Classification of Crude Drugs**	Morphological, pharmacological, and chemical classification.	**3**
3	**Drug Adulteration**	Types of adulterants, detection of adulterants (common examples).	**3**
4	**Ethnobotany**	Scope, relevance of ethnobotany to pharmacology.	**2**
5	**Pharmacological Characteristics of Ethnomedicinally Important Plants**	*Andrographis paniculata* (Burm.f.) Nees, *Bacopa monnieri* (L.) Wettst., *Boerhavia repens* L., *Centella asiatica* (L.) Urb., *Dioscorea alata* L., *Hemidesmus indicus* (L.) R.Br. ex Schult., *Hygrophila auriculata*	**10**

Unit No.	Unit	Topics	Class Hours
		(Schumach.) Heine, *Justicia adhatoda* L. (*Adhatoda vasica* Nees), *Paederia foetida* L., *Phyllanthus emblica* L. (*Emblica officinalis* Gaertn.), *Piper longum* L., *Plumbago zeylanica* L., *Terminalia bellirica* (Gaertn.) Roxb., *Terminalia chebula* Retz., *Tinospora sinensis* (Lour.) Merr.	
6	**Natural Products as Phytomedicine**	Alkaloids, phenolics, and terpenes, essential plant-derived pharmaceutical products, future prospects of phytopharmaceuticals.	**4**
7	**Metabolic Phytochemistry**	Basic secondary metabolic pathways-phenylpropanoid, shikimate/chorismate, terpenoid, and tropane alkaloids.	**4**
8	**Techniques**	Contemporary techniques of phytochemical analyses.	**2**

Suggested Readings

1. Evans W. (2009) Trease and Evans's Pharmacognosy, 16th edition, Saunders Ltd.
2. Kokate C. K., Purohit A. P. and Gokhale S. B. (2008) Pharmacognosy, Nirali Prakashan
3. Heinrich M., Barnes J., Prieto Garcia J. M., Gibbons S. and Williamson E.M. (2018) 3rd edition, Fundamentals of Pharmacognosy and Phytotherapy, Elsevier.
4. Wallis T. (1967) Text Book of Pharmacognosy, J and A Churchill, London
5. Harborne, J.B. (1998) Phytochemical Methods, Chapman and Hall.
6. Dewick P.M. (2009) Medicinal Natural Products: A biosynthetic approach, 3rd edition, John Wiley and Sons Ltd.

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Course Code: BOT-MNR-505	**Course Title: Plant Molecular Biology**	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Theory:	**2 credits**	
Class Hours: Theory :	**30 hours; Total : 90 days; 2 hrs/ week**	

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Understanding Plant genome organization (nuclear, chloroplast, mitochondrial DNA).
2. Studies the techniques of gene expression mechanisms controlling response of plants to stress
3. Understanding the key regulation of gene expression through promoters, transcription factors, signalling pathways
4. Deciphering molecular basis of stress tolerance at the genomic level and epigenomic interaction

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Plant Genome Organization and Gene Regulation**	Structure of plant genome, reporter gene, terminator gene, regulation of promoter activities, inducible promoters.	**4**
2	**Promoter**	Types, synthetic promoters, electrophoretic mobility assay.	**4**
3	**Gene Cloning and Vectors**	Cloning techniques, DNA transformation, RNase protection assay, Selection of recombinants, Binary vectors, agro-vectors, construction of Ti plasmid, plant transformation, selection	**10**
4	**Probe Preparation**	Probe preparation, autoradiographic technique	**3**
5	**Gene Expression Techniques**	Southern, northern, and western hybridization, gel mobility shift assay,	**3**
6	**DNA Sequencing**	Chemical and enzymatic methods, automated DNA sequencing.	**3**
7	**Application of plant molecular biology**	Development of transgenics, pest and herbicide resistance, marker assisted selection, *in vivo* hybridization of genes.	**3**

Suggested Readings

1. Grierson, D. and Covey, S. N. *Plant Molecular Biology*. Springer, 2nd ed., 1991.A concise textbook focusing on gene expression, molecular processes in plants, genomics, and genetic engineering.
2. Lea, P. J. and Leegood, R. C. (Eds.) Plant Biochemistry and Molecular Biology. Wiley-Blackwell, 2nd ed., 1998.
3. Alberts, B., et al. *Molecular Biology of the Cell*. Garland Science (W.W. Norton), 6th or 7th ed., latest. Essential for understanding cellular and molecular mechanisms that are foundational to plant molecular studies.
4. lark, M. S. (Ed.) *Plant Molecular Biology — A Laboratory Manual*. Springer, 1997. A manual with detailed molecular biology techniques useful for experiments in plant systems.
5. Buchanan, B. B., Gruissem, W. and Jones, R. L. (Eds.) *Biochemistry and Molecular Biology of Plants*. Wiley, 2nd ed., 2015.
6. McLennan, A., Bates, A. D., Turner, P., and White, M. (2012). *BIOS Instant Notes in Molecular Biology* (4th ed.). Taylor and Francis. ISBN: 9780415684163.

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Course Code: BOT-MNR-506	**Course Title: Palynology and Its Application**	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Theory: 1 credit; Practical: 1 credit		
Class Hours: Theory : 15 hours; Total : 90 days; 1 hr/ week **Practical : 24 hours; Total : 90 days; 2 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain spore and pollen morphological features using standard terminology and NPC system.
2. Describe pollen wall stratification, development, and chemical composition.
3. Evaluate adaptive significance of pollen traits in different ecological contexts.
4. Assess pollen viability and storage methods for research applications.
5. Interpret applied uses of palynology in taxonomy, ecology, forensic science, and environmental reconstruction.

Theory Course Content

Unit No.	Unit	Topics	Class Hours
1	**Spore–Pollen Morphology and Aperture Systems**	Morphological units- polarity, symmetry, shape, size, aperture types- NPC system for numerical expression, evolution of aperture types, taxonomic significance of pollen characters.	**4**
2	**Pollen Wall Structure and Development**	Sporoderm stratification (exine, intine), sexine and nexine, sculpturing patterns, LO-analysis, sporopollenin, pollen wall development, ubisch bodies, perine, pollen-kitt, pollen connecting threads, functional significance.	**4**
3	**Pollen Adaptation, Viability and Storage**	Pollen adaptations in different pollination types, ecological significance of wall modification, harmomegathic mechanism, pollen viability estimation, factors affecting viability, short- and long-term storage and applications.	**3**
4	**Pollen Limitation, Natural Traps and Applications**	Pollen limitation and plant diversification, natural pollen/ spore traps and environmental reconstruction, branches of palynology, applied palynology (taxonomic, phylogenetic, melissopalynology, medical, forensic, entomopalynology, copropalynology).	**4**

Practical Course Content

Title of Practical	Activities / Experiments
Study of Pollen Morphology	1. Microscopic observation of pollen/spore slides, identification of polarity, symmetry, shape, size and aperture types, comparison of different pollen types.
NPC System and Aperture Coding	2. Numerical expression of apertural characters using NPC system, interpretation of aperture evolution trends.
Pollen Viability Testing	3. Viability estimation using staining methods (Acetocarmine/ TTC), calculation of percentage viability, interpretation of factors affecting viability.
Pollen Storage Techniques	4. Demonstration of short-term and long-term storage methods, discussion on gene banks and breeding applications.
Applied Palynology Exercise	5. Case-based exercise in applied palynology on any selected aspect, including melissopalynology (honey pollen identification), entomopalynology, forensic palynology (sample interpretation), and environmental applications.

Note: Submission of practical record, viva based on morphology, wall structure, viability and applied aspects. Regularly checked laboratory records, permanent slides prepared during practical classes should be submitted at the time of TEE.

Suggested Readings

1. Alfred Traverse (2007). Paleopalynology (2nd ed.). Springer.
2. Peter D. Moore, James A. Webb, & Margaret E. Collinson (1991). Pollen analysis (2nd ed.). Blackwell Scientific Publications.
3. Gunnar Erdtman (1969). Handbook of palynology: Morphology, taxonomy, ecology. Munksgaard, Copenhagen.
4. Gunnar Erdtman (1952). Pollen morphology and plant taxonomy: Angiosperms. Almqvist & Wiksell.
5. Knut Fægri & Johs Iversen (1989). Textbook of pollen analysis (4th ed.). John Wiley & Sons.
6. Willem Punt, Stephen Blackmore, Stig Nilsson, & Annie Le Thomas (2007). *Glossary of pollen and spore terminology*. LPP Foundation.

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Course Code: BOT-EEC-507 **Any one to be selected from 507A-507E**	**Course Titles:** **507A: Food safety and microbial contamination analysis** 507B: Plant-based bioactive compounds and nutraceuticals 507C: Development of stress resilient crop ideotypes 507D: Plant tissue culture techniques 507E: Pollination biology and apicultural entrepreneurship 507F: Mushroom cultivation and entrepreneurial technology 507G: Bio-innovation and startups in algal and herbal resources 507H: Ferns and Mosses: care, handling and experimental approach	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Self Study/Tutorial: 2 credits + Practical: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

- Explain key concepts of food safety and contamination
- Identify major foodborne microbes and contamination routes
- Perform basic microbiological tests for food quality assessment
- Apply food safety standards and hygiene practices in food handling.

Course Content for Self-Study/ Tutorial

Unit	Topics
Fundamentals of Food Safety	Concept and importance of food safety, types of food hazards: biological, chemical, physical. Food spoilage and foodborne diseases.
Microbial Contamination in Foods	Sources of contamination (air, water, handlers, equipment), types of microorganisms in food (bacteria, fungi, viruses), factors affecting microbial growth (temperature, pH, moisture).

Unit	Topics
Foodborne Pathogens and Control	Major pathogens (*Salmonella, E. coli, Listeria, Staphylococcus*), food preservation methods (heat, cold, drying, preservatives), hygiene and sanitation practices.
Food Safety Management and Analysis	HACCP, GMP, GHP principles, food safety standards (FSSAI), basic microbiological testing methods (sampling, culture techniques)

Practical Course Content

Practical Components	Activities
Microbial Analysis Techniques	1. Detection and enumeration of indicator and index organisms for foodborne pathogenesis (total Enterobacteriaceae, total coliforms, faecal coliforms, *Escherichia coli*, and aerobic spore formers). 2. Mushroom production. 3. Determination of the role of yeasts in bread making. Determination of the role of moulds in tempe making.
Detection and Hygiene Assessment	4. Detection of common pathogens using selective media. 5. Enumeration and identification of *Staphylococcus aureus* in chicken salads. 6. Enumeration and identification of *Listeria monocytogenes* on Ready-to-Eat (RTE) sausage. 7. Isolation and Identification of *Salmonella* and *Campylobacter* spp. on chicken. 8. Swab test for surface and hand hygiene
Food Safety, Application and Field Study	9. Preparation of simple HACCP plan. 10. Visit to food industry / lab and report preparation.

Suggested Readings

1. Food Safety and Standards Act 2006, Rules 2011, Regulations, 2011, 10th Edition, ILBCO India, Indian Law Book Company, 2013.
2. Early, R. (1995): Guide to Quality Management Systems for the Food Industry, Blackie, Academic and Professional, London.
3. Gould, W.A and Gould, R.W. (1998). Total Quality Assurance for the Food Industries, CTI Publications Inc. Baltimore.
4. Pomeraz, Y. and MeLoari, C.E. (1996): Food Analyasis: Theory and Practice, CBS publishers and Distributor, New Delhi.
5. Bryan, F.L. (1992): Hazard Analysis Critical Control Point Evaluations A Guide to Identifying Hazards and Assessing Risks Associated with Food Preparation and Storage. World Health Organisation, Geneva.
6. Kirk, R.S and Sawyer, R. (1991): Pearson's Composition and Analysis of Foods, Longman Scientific and Technical. 9th Edition, England.
7. FAO (1980): Manuals of Food Quality Control. 2-Additives Contaminants Techniques, Rome. 8. FSSAI, FSIS, EU and FAO website for updates

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Course Code: BOT-EEC-507 **Any one to be selected from 507A-507E**	**Course Titles:** 507A: Food safety and microbial contamination analysis **507B: Plant-based bioactive compounds and nutraceuticals** 507C: Development of stress resilient crop ideotypes 507D: Plant tissue culture techniques 507E: Pollination biology and apicultural entrepreneurship 507F: Mushroom cultivation and entrepreneurial technology 507G: Bio-innovation and startups in algal and herbal resources 507H: Ferns and Mosses: care, handling and experimental approach	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Self Study/Tutorial: 2 credits + Practical: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Classify key plant-based bioactive compounds such as polyphenols, alkaloids, terpenoids, and glucosinolates based on their structural features.
2. Identify plant-based macronutrients, micronutrients, and phytonutrients, and link them to their biological roles and health benefits.
3. Use of analytical techniques (HPLC, GC-MS, LC-MS, FTIR) for extracting, purifying, and characterizing bioactive compounds.
4. Assess the nutraceutical potential of plant-based foods for enhancing cognitive function, immune health, and metabolic regulation.
5. Analyze the physiological roles of phytonutrients such as flavonoids, carotenoids, PUFA, and organosulfur compounds from specific plant sources, and understand the types and effects of anti-nutritional factors in food, as well as their roles.

Course Content for Self-Study/ Tutorial

Unit	Topics
Plant-Based Bioactive Compounds	Diversity of plant-based bioactive compounds, classification of major groups based on their structure of polyphenols, alkaloids, terpenoids, and glucosinolates, plant-derived compounds from cereals, nuts, vegetables, herb, spices, fruits, and seeds with principal bioactivities such as antioxidant, anti-inflammatory, antimicrobial, and chemo-preventive effects; extraction and purification using HPLC, GC-MS, LC-MS, and FTIR.
Plant-Derived Nutrients and Functional Health Applications	Macronutrients and micronutrients of plant origin - structure, biological functions, and recommended dietary allowances (RDA), nutraceutical applications of plant-derived compounds in promoting, enhancing cognitive performance, strengthening immune function, and regulating metabolic processes, formulation and utilization of functional plant foods and botanical dietary supplements in preventive and therapeutic applications.

Unit	Topics
Phytonutrient Diversity and Nutraceutical Roles	Diversity, sources and physiological roles of key plant phytonutrients including isoprenoids, isoflavones, flavonoids, carotenoids, tocotrienols, polyunsaturated fatty acids, sphingolipids, lecithin, choline, and terpenoids, evidence-based health benefits of specific plant sources such as common beans (polyphenols, fiber), *Capsicum annum* (capsaicinoids, carotenoids), mustards (glucosinolates), ginseng root (ginsenosides), garlic (organo-sulfur compounds), grapes (resveratrol, proanthocyanidins), citrus fruits (hesperidin, naringenin), traditional spices (curcuminoids, essential oils), moringa leaves, flaxseed, chia seed as nutraceuticals, anti-nutritional factors in foods- understanding anti-nutritional factors (ANFs) and their dual role as nutraceuticals, types (protease inhibitors, amylase inhibitors, phytates, oxalates, tannins, saponins, lectins, cyanogenic glycosides.

Practical/ Field/ Skill Training Course Content

Practical Components	Activities
Plant Based Bioactive compounds	1. Qualitative tests for alkaloids, phenolics, flavonoids, saponins, glycosides, and terpenoids. 2. Identification of phenolics by Thin Layer Chromatography (TLC). 3. DPPH radical scavenging assay (antioxidant activity), TAA of plant extract by UV-Vis spectrophotometry.
Phytonutrient Diversity and Nutraceutical Roles	4. Morphological identification of nutraceutically important plants (*Phyllanthus emblica*, *Curcuma longa*, *Azadirachta indica*, *Aloe vera*, *Moringa oleifera*).
Field Study and Project Work	5. Dissertation on bioactive properties of selected nutraceutical plants. 6. Report from a field visit: food technology lab, nutraceutical manufacturing plant, herbal processing unit, functional food company, Start-up Incubator etc.

Note: Regularly checked laboratory records should be submitted at the time of TEE.

Suggested Readings

1. Vattem, Dhiraj A. and Vatsala Maitin. 2016. Functional Foods, Nutraceuticals and Natural Products, Concepts and Applications. USA: DEStech Publications, Inc.
2. Boye, Joyce I. 2015. Nutraceutical and Functional Food Processing Technology. New Jersey: Wiley-Blackwell.
3. Iwu, Maurice M. 2017. Food as Medicine: Functional Food Plants of Africa. US: CRC Press.
4. Cho, S. S. and M. L. Dreher. 2001. Handbook of Dietary Fiber. New York: Marcel Dekker Inc.
5. Wildman, R.E. C. 2000. Handbook of Nutraceuticals and Functional Foods. Boca Raton: CRC Press.
6. Aluko, Rotimi E. 2012. Functional Foods and Nutraceuticals. Germany: Springer.
7. C Galanakis. 2017. Nutraceutical and Functional Food Components: Effects of Innovative Processing Techniques. Academic Press.
8. Dey P.M. and Harborne J.B. (1997). Plant Biochemistry. Academic press.
9. J Gilbert. 2014. Bioactive Compounds in Foods. Wiley India.
10. S Riar et al., 2015. Functional Foods and Nutraceuticals: Sources and Their Developmental Techniques. New India publishing agency.

Course Code: BOT-EEC-507 **Any one to be selected from 507A-507E**	**Course Titles:** 507A: Food safety and microbial contamination analysis 507B: Plant-based bioactive compounds and nutraceuticals **507C: Development of stress resilient crop ideotypes** 507D: Plant tissue culture techniques 507E: Pollination biology and apicultural entrepreneurship 507F: Mushroom cultivation and entrepreneurial technology 507G: Bio-innovation and startups in algal and herbal resources 507H: Ferns and Mosses: care, handling and experimental approach	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Self Study/Tutorial: 2 credits + Practical: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain mechanisms and role of plant stresses.
2. Analyze plant-stressor interactions and conservation issues.
3. Demonstrate basic skills analysing plant yield production.
4. Evaluate economic potential agriculture entrepreneurship.
5. Develop a basic business model for agriculture ventures

Course Content for Self-Study/ Tutorial

Unit	Topics
Fundamentals of Plant Stress Physiology	1. Types of stress (biotic, abiotic), physiological adaptation mechanisms.
Water Relations in Plants	2. Water potential concept and plant tolerance. 3. Breeding for salinity, high temperature and oxidative stress tolerance.
Energy Acquisition	4. Crop ideotypes for better harvest index, leaf area, solar energy utilization, photoperiod sensitivity, fertilizers responsiveness, micro nutrients, post-harvest shelf life.
Selection Criteria	5. Net assimilation rate, improved water use efficiency, root architecture, partitioning of dry mass, allocation of reduced carbon, harvest index.

Practical/ Field/ Skill Training Course Content

Practical Components	Activities
Study of Stress Physiology	1. Observation of stressed and healthy plants and comparison between them.
Analysis of Stressed Plants	2. Study of stressed plants collected from field.
Stressed Plant Handling Equipment	3. Demonstration of stress types, yield, condition.
Plant Inspection and Management	4. Identification of stress types, quantification of loss, management practices to overcome the loss.

Practical Components	Activities
Field visit and Survey	5. Field visit to document ideotypes in respect to crop productivity, visit to agricultural farms and institutes.
Entrepreneurship Module	6. Preparation of a mini business plan related to the skill learnt.

Suggested Readings

1. Taiz L., Zeiger, E, Moller, I. M. and Murphy, M. (2015) Plant Physiology and Development, 6th edition, Sinauer Associates, USA.
2. Taiz L. and Zeiger, E. (2010) Plant Physiology, 5thedition, Sinauer Associates, USA.
3. Jones R., Ougham H., Thomas H. and Waaland S. (2012) The Molecular Life of Plants, Wiley- Blackwell, USA.
4. Buchanan B. B., Gruissem, W and Jones R. J. (2000) Biochemistry and Molecular Biology of Plants, American Society of Plant Physiologists, MD, USA.
5. Hopkins W. G. and Huner N. PA. (2008) Introduction to Plant Physiology, 4th edition, John Wiley andamp; Sons Ltd.
6. Nelson D. L. and Cox M. M. (2008) Lehninger Principles of Biochemistry, 5th edition, W.H.Freeman and Company, New York, USA.
7. Berg J. M., Stryer, L., Tymoczko J. and Gatto G. (2019) Biochemistry, 9th edition, Worth Publishers, USA.

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Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Self Study/Tutorial: 2 credits + Practical: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Gain knowledge about the principles and techniques of plant tissue culture.
2. Understand the role of *SERK* and *LEC* genes in somatic embryogenesis.
3. Develop an understanding of micropropagation protocol and genetic fidelity assessment using DNA markers.
4. Comprehend the concept of developing haploid plants.

Course Content for Self-Study/ Tutorial

Unit	Topics
Organogenesis	Developmental sequences, mechanism of action of phytohormones, control of *in vitro* organogenesis by cyclin-dependent kinase activity.
Somatic Embryogenesis	Gene expression and signal transduction during embryogeneis- Role of SERK and LEC genes, brassinosteroid (BR) signalling.
***In vitro* Genetic Variation**	Somaclonal and gametoclonal variation, isolation and characterization of somaclones, molecular basis of somaclonal variation, advantages of somaclonal variation over induced mutations, applications in crop improvement, *In vitro* mutagenesis.
Micropropagation	Overview, stages of micropropagation, advantages and limitations, horticultural uses, production of virus-free plants, molecular and immunological techniques of plant virus detection, genetic fidelity assessment using DNA markers.
Haploid Plant Culture	Production of haploid plants, hybrid sorting, doubled haploid (DH) development, aapplication of DHs in plant breeding.

Practical/ Field/ Skill Training Course Content

Practical Components	Activities
***In vitro* propagation of plants**	1. Media preparation.
	2. Callus culture technique.
	3. Seed culture technique.
	4. Embryo culture technique.
	5. Micropropagation using nodal explant.

Suggested Readings

1. Bhojwani, S.S. and Razdan, M.K. (1996). Plant Tissue Culture: Theory and Practice (a revised edition). Elsevier Science Publishers, New York, USA.
2. Karl-Hermann Neumann, Ashwani Kumar, Jafargholi Imani. Plant Cell and Tissue Culture - A Tool in Biotechnology. Springer-Verlag Berlin and Heidelberg GmbH and Co. K. ISBN: 9783540938828.
3. Collins, H.A. and Edwards, S. (1998). Plant Cell Culture, Bios Scientific Publishers, Oxford, UK.
4. George E.F., Hall M.A. and Klerk J.D. Plant Propagation by Tissue Culture (3rd Ed.), Springer.
5. Vasil, I.K. and Thorpe, T.A. (1994). Plant Cell and Tissue Culture, Kluwer Academic Press, The Netherlands.
6. Bhojwani, S.S. (1990). Plant Tissue Culture: Applications and Limitations, Elsevier Science Publisher, New York, USA.
7. Khasim, S.M. (2002). Botanical Microtechnique: Principles and Practice, Capital Publishing Company, New Delhi.

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Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
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Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain mechanisms and ecological significance of pollination.
2. Analyze plant–pollinator interactions and conservation issues.
3. Demonstrate basic skills in hive management and honey processing.
4. Evaluate economic potential of apiculture-based entrepreneurship.
5. Develop a basic business model for apicultural ventures.

Course Content for Self-Study/ Tutorial

Unit	Topics
Fundamentals of Pollination Biology	Types of pollination (self, cross), pollination syndromes, floral adaptations, co-evolution of plants and pollinators, pollen–pistil interaction.
Pollinators and Ecosystem Services	Insect pollinators (honeybees, solitary bees, butterflies), non-insect pollinators (birds, bats), pollinator diversity and decline, conservation strategies, role in crop productivity.
Introduction to Apiculture	Species of honeybees, biology and social organization of bees, beekeeping equipment, hive management, seasonal management practices.
Apicultural Entrepreneurship	Honey production and processing, bee products (wax, propolis, royal jelly, pollen), value addition and marketing, government schemes and subsidies, business planning and start-up models.

Practical/ Field/ Skill Training Course Content

Title	Activities
Study of Floral Biology	1. Observation of floral structure and pollination mechanisms in selected plants.
Pollinator Diversity Survey	2. Field visit to document pollinator species and their visitation patterns.
Pollen Analysis	3. Study of pollen load in bees (basic melissopalynology demonstration).
Beekeeping Equipment Handling	4. Demonstration of hive types, frames, smoker, protective gear.
Hive Inspection and Colony Management	5. Identification of queen, worker, drone; brood pattern study.

Title	Activities
Honey Extraction and Processing	6. Demonstration of honey extraction, filtration, storage.
Value-Added Products	7. Preparation/demonstration of beeswax candles, pollen products, propolis collection.
Entrepreneurship Module	8. Preparation of a mini business plan for small-scale apiculture unit.
Field Visit	9. Visit to apiary / agricultural farm / honey processing unit.
Record and Viva Voce	10. Submission of practical record and oral examination.

Suggested Readings

1. Pollination Biology and Ecology – Blake Hughes (Ed.), Syrawood Publishing House
2. Pollination and Floral Ecology – Patricia Willmer, Princton University Press
3. The Hive and the Honey Bee – Joe M Graham, Dadant Publicaiton
4. The ABC and XYZ of Bee Culture – A I Root and E R Root, Kessinger Publishing
5. Bees and Beekeeping: Science, Practice and World Resources – E. Crane, Comstock Pub. Associates.
6. National Beekeeping and Honey Mission (NBHM), Ministry of Agriculture and Farmers Welfare, Government of India – Training Manuals and Scheme Guidelines.

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Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Know several steps for cultivation of edible mushrooms
2. Experience hand-on-training for preparation of spawn, cultivation techniques etc.
3. Understand the problems associated with mushroom cultivation and about their remedies.

Course Content for Self-Study/ Tutorial

Unit	Topics
Edible mushrooms	Identification and nutrition value.
Mushroom farm	Infrastructure and equipment.
Spawn	Types, preparation, techniques of spawning.
Compost	Types, preparation and composting.
Cultivation of edible mushrooms	Button mushroom, oyster mushroom, paddy straw mushroom.
Management of mushroom crop	Fungal diseases, bacterial diseases, virus diseases, pests.
Mushroom processing	Short-term and long-term preservation, food items.
Techniques for improvement of mushroom crops	Introduction, selection, hybridization, mutagenesis, protoplast fusion, genetic engineering.
Cost-benefit ratio analysis for mushroom cultivation	Economics of production of spawn, button mushroom, oyster mushroom, paddy straw mushroom.

Practical/ Field/ Skill Training Course Content

Title	Activities
Spawn technology	1. Demonstration of preparation mushroom tissue culture, preparation of spawn, techniques of spawning.
Cultivation technology	2. Hand-on-training cum demonstration for cultivation procedure of oyster mushroom.
Farm visit	3. Visit to mushroom farms.
Market-demand survey	4. Survey work on demand of mushroom crops on local markets.

Suggested Readings

1. Archya, K., Roy, A., Sarkar, J. (2020). Mushroom cultivation technology, Techno World.
2. Datta B. (2024). Mushroom Cultivation, Global Net Publication
3. Eiri Staff (2007). Hand Book of Mushroom Cultivation, Processing and Packaging, Engineers India Research Institute
4. Mishra SR (2014). Techniques of Mushroom Cultivation, Discovery Publishing Pvt Ltd
5. Suman BC and Sharma VP (2021). Mushroom Cultivation in India, Daya Publishing House

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Course Code: BOT-EEC-507 **Any one to be selected from 507A-507E**	**Course Titles:** 507A: Food safety and microbial contamination analysis 507B: Plant-based bioactive compounds and nutraceuticals 507C: Development of stress resilient crop ideotypes 507D: Plant tissue culture techniques 507E: Pollination biology and apicultural entrepreneurship 507F: Mushroom cultivation and entrepreneurial technology **507G: Bio-innovation and startups in algal and herbal resources** 507H: Ferns and Mosses: care, handling and experimental approach	
Course Nature: Coursework	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Self Study/Tutorial: 2 credits + Practical: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Explain the diversity, bioactive potential and economic importance of algal and plant resources.
2. Analyze scope of bio-innovations in algae and plant systems for application in food, nutraceutical, therapeutic and environmental sectors.
3. Demonstrate knowledge of cultivation, harvesting, and processing techniques for algal and medicinal plant resources.
4. Apply appropriate extraction, value addition, and product development strategies for algal and herbal products.
5. Interpret the role of intellectual property rights (IPR) and patents in bioresource-based innovations and enterprises.
6. Evaluate entrepreneurial opportunities in algae- and plant-based bio-industries.
7. Deliver an innovative product using algal/ herbal resource OR
   Design sustainable and economically viable bio-enterprise models aligned with circular bioeconomy principles of BioE3 Policy.

Course Content for Self-Study/ Tutorial

Unit	Topics
Fundamentals of algal and herbal resources	Diversity of algae and medicinal plants-based market products, key bioactive compounds (pigments, polysaccharides, alkaloids, phenolics) and their functional roles, nutraceutical, therapeutic, food and cosmeceutical applications, relevance of IKS, traditional knowledge, and ethnobotany.
Bio-innovations in algal and plant systems	Innovative applications of algae (biofuel, wastewater treatment, carbon sequestration, nutraceuticals, cosmeceuticals, food) and plants (phytopharmaceuticals, functional foods), biotechnological interventions (strain improvement, optimized cultivation systems, and translational/innovative applications), value addition and product development, relevance to sustainability, circular bioeconomy and SDGs.

Unit	Topics
Cultivation and Processing Techniques	Algal culture systems (open ponds, photobioreactors) and cultivation of medicinal plants, optimization and scaling-up of biomass production, harvesting and post-harvest management, extraction and processing techniques (solvent extraction, distillation, and emerging green methods), basic approaches in quality control, standardization, and storage of algal and plant-derived products.
Value Addition and Product Development	Value addition of algal products (agar, carrageenan, pigments, nutraceuticals) and herbal products (extracts, oils, powders, standardized formulations), packaging, branding, and shelf-life evaluation, regulatory compliance and quality standards (AYUSH, FSSAI), basics of intellectual property rights (IPR), patents, and bioresource-based innovations.
Entrepreneurship and Startup Development	Business opportunities in algal and herbal sectors, startup ecosystem in India, including incubation support and technology transfer, policy support and funding mechanisms (Startup India, MSME, Ministry of AYUSH), market analysis and feasibility assessment, strategies for commercialization and scaling, case studies of successful bio-based enterprises.

Practical/ Field/ Skill Training Course Content

Title	Activities
Resource Identification and Documentation	1. Collection and identification of algae and medicinal plants, preparation of herbarium of plants and algae, preservation of algae as wet specimens, ethnobotanical documentation.
Cultivation Techniques of algae and herbal resources	2. Algal culture (basic media preparation, batch culture models), nursery and propagation techniques for medicinal plants.
Biomass Harvesting and Post-harvest Management	3. Harvesting methods (filtration/centrifugation), drying, storage, and preservation techniques for algal and plant materials.
Extraction and Processing Methods	4. Solvent extraction and distillation, filtration and concentration.
Value Addition and Product Development	5. Preparation of simple algal/ herbal products (extracts, powders, formulations), basic packaging and labelling.
Quality Control and Analytical Techniques	6. Preliminary phytochemical screening, pigment estimation, nutritive value assessment and shelf-life assessment.
Entrepreneurship Module	7. Preparation of a mini business plan for algal/ herbal startup.
Field Visit	8. Visit to herbal garden, algal culture unit, AYUSH unit, or small-scale bio-enterprise.
Case Study Analysis	9. Study of successful startups in algal/ herbal sectors.

Title	Activities
Project work	10. Development of a prototype/ product concept, related market survey, submission of final project report and presentation of a startup pitch.

Suggested Readings

1. Borowitzka, M. A., and Moheimani, N. R. (Eds.). (2013). *Algae for biofuels and energy*. Springer.
2. Ravishankar, G. A. and Ambati, R. R. (Eds.). (2020). *Handbook of algal technologies and phytochemicals: Volume I – Food, health and nutraceutical applications*. CRC Press. ISBN: 9780367149796
3. Richmond, A. and Hu, Q. – *Handbook of Microalgal Culture: Applied Phycology and Biotechnology*, Wiley-Blackwell
4. Peter, K. V. (Ed.). (2012). *Handbook of herbs and spices* (2nd ed.). Woodhead Publishing.
5. Barsanti, L. and Gualtieri, P. – *Algae: Anatomy, Biochemistry, and Biotechnology*, CRC Press
6. Kokate, C. K., Purohit, A. P. and Gokhale, S. B. – *Pharmacognosy*, Nirali Prakashan
7. Koul, O., and Wahab, S. (Eds.). (2004). *Medicinal plants: Cultivation and their uses*. Springer.
8. Jain, S. K. (1995). *A manual of ethnobotany* (2nd ed.). Scientific Publishers.
9. Harborne, J. B. – *Phytochemical Methods*, Springer
10. Govil, J. N. (Ed.) – *Recent Progress in Medicinal Plants*, Studium Press
11. Thangadurai, D., Sangeetha, J., and Prasad, R. (Eds.). (2020). *Algal genetic resources: Cosmeceuticals, nutraceuticals and pharmaceuticals from algae*. CRC Press.
12. Warren, D. M., Slikkerveer, L. J., and Brokensha, D. (Eds.). (1995). *The cultural dimension of development: Indigenous knowledge systems*. Intermediate Technology Publications.
13. Shimasaki, C. (2014). *Biotechnology entrepreneurship: Starting, managing, and leading biotech companies*. Academic Press.
14. Osterwalder, A., and Pigneur, Y. (2010). *Business model generation: A handbook for visionaries, game changers, and challengers*. Wiley.
15. Ministry of AYUSH, Government of India – Guidelines and Training Manuals
16. Startup India Initiative – Government of India (Policies and Funding Support Documents)

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Course Code: BOT-EEC-507 **Any one to be selected from 507A-507E**	**Course Titles:** 507A: Food safety and microbial contamination analysis 507B: Plant-based bioactive compounds and nutraceuticals 507C: Development of stress resilient crop ideotypes 507D: Plant tissue culture techniques 507E: Pollination biology and apicultural entrepreneurship 507F: Mushroom cultivation and entrepreneurial technology 507G: Bio-innovation and startups in algal and herbal resources **507H: Ferns and Mosses: care, handling and experimental approach**	
Course Nature: Research **Skill based**	**Course Level: 500-549**	**NCrF credit level: 6.5**
Credit Pattern: Self Study/Tutorial: 2 credits + Practical: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week **Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Identify the mosses and ferns using the flora, manual, and keys.
2. Able to analyze the uses of ferns and mosses in air pollution control and monitoring.
3. Cultivation and gardening technique.
4. Phytochemical diversity and extraction.
5. Aesthetic value of ferns and mosses.
6. Nutritional values of these unexplored bioresources.
7. Physiological response and water conduction mechanism.

Course Content for Self-Study/ Tutorial

Unit	Topics
Know ferns and mosses	Fern world: brief introduction, moss world: brief introduction, identification manual, digital herbarium, expert consultation.
Environmental monitoring	Fern and moss in air pollution control, biomonitoring and quality control, fern as an insect repellent.
Entrepreneurship and startups with ferns and mosses	Nursery building and gardening, moss bed preparation, fern block preparation.
Phytochemistry and anatomy	Microchemistry and anatomy.
Nutritional utility	Nutritional values- food and fodder*, Azolla, Marsilea*, uses of mosses.
Ferns and aesthetics	Aesthetics, decor your environment.
Phytochemical diversity	Terpenoid, flavonoid, alkaloid diversity and other small phenolic molecules in ferns and mosses, fatty acid and derivative compounds.
Physiology and water relation	Ferns and mosses as desiccation tolerant, water transport, hydraulic conductance.

Practical/ Field/ Skill Training Course Content

Title	Activities
Identification and work out	1. Collection and identification of bryophytes and pteridophytes; uses of manual, flora and keys.
Air pollution monitoring	2. Air quality control experiment, fern spore as bioindicators
Desiccation-tolerant experiment	3. Fern gametophyte and liverwort to perform desiccation tolerance
Gametophyte culture and moss culture	4. *In vitro* culture, uses of different media, and moss culture in bioreactor
Phytochemical extraction	5. Uses of different solvents in phytochemical extraction
Hydraulic conductance	6. Measurement of hydraulic conductance
Field Visit	7. Short-term field trip to explore regional flora and collect specimens for herbarium preparation

Suggested Readings

1. Dyer A.F. 1979. Experimental Biology of Ferns. Academic press. ISBN: 0-12-226350-2 2. 2.
2. Tryon A. F and Lugardon B 1990. Spores of the pteridophyta: Surface, Wall Structure, and Diversity Based on electron microscope studies. Springer –verlag. ISBN: 0-387-97218-8.
3. Ogura Y. 1972. Comparative anatomy of vegetative organs of the pteridophytes. Second revised edition ISBN: 3-443 14006 8.
4. Kramer K.U. and Green P.S. (Eds) The families and genera of vascular plants: Pteridophytes and Gymnosperms. Springer –verlag
5. Gifford M.E. and Foster A.S. 1988 Morphology and Evolution of Vascular Plants. W H Freeman and Company
6. Stewart W. N and Rothwell G.W. Palaeobotany and the evolution of plants. Cambridge University Press. Second Edition
7. Willis, K.J., and McElwain J.C. 2002. The Evolution of Plants. Oxford University Press, New York.
8. Taylor E.L., Krings M, and Taylor T.N. 2009. Palaeobotany: The biology and evolution of fossil plants
9. Ranker T.A. and Haufler C.H. 2008. Biology and evolution of ferns and Lycophytes. Cambridge University Press. ISBN: 978-1-4410-7161-6 2.
10. Fernandez H, Kumar A, Revilla M. A. 2010. Working with ferns: Issues and Applications. Springer. ISBN: 978-0-521-87411-3

SEMESTER IV

Course Code: BOT-MJR-551	Course Title: Research Methodology	
Course Nature: Research – Guided Project	Course Level: 550-599	NCrF credit level: 6.5
Credit Pattern: Theory: 2 credits + Self Study/Tutorial: 2 credits		
Class Hours: Theory : 45 hours; Total : 90 days; 3 hrs/ week Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Demonstrate understanding of scientific research processes and interdisciplinary approaches in plant sciences.
2. Conceptualize research problems rooted in classical botany while integrating ecological, molecular, and socio-environmental perspectives.
3. Design robust and reproducible studies and execute experiments across field, herbarium, laboratory, and computational domains using appropriate methodologies and sampling techniques.
4. Apply quantitative and inferential tools to analyse datasets across botany and allied fields such as microbiology, phytochemistry, plant stress biology, molecular biology, genetics, plant pathology, palaeobotany, ecology, and conservation.
5. Synthesize and critique global scientific literature, identifying gaps to develop structured research proposals.
6. Develop fundable research proposals aligned with national priorities (e.g., biodiversity, climate resilience, sustainable development).
7. Communicate scientific findings effectively in internationally accepted formats (papers, datasets, policy briefs).
8. Ensure research integrity, apply ethical principles and compliances, data transparency, intellectual property management, and adherence to plagiarism standards in research practices.

Theory and Self Study/ Tutorial Course Content

Unit No.	Unit	Topics	Class Hours
1	**Foundations of Plant Science Research**	Nature and scope of research, scientific inquiry in plant sciences, types of research (basic, applied, interdisciplinary), identification of research problems in plant science investigations, developing research questions, scope of interdisciplinary and multidisciplinary approaches.	5
2	**Literature Review, Knowledge Synthesis and Research Planning**	Types of scientific literature- primary, secondary, grey literature, floras, monographs, use of online database, methods of systematic review of related studies - meaning, nature, steps and importance, identification of research gaps, citation management tools, research proposal writing.	5

Unit No.	Unit	Topics	Class Hours
3	**Experimental Design in Plant Science Research**	Hypothesis formulation, designing research in diverse domains, principles of experimental design- control, replication, randomization, validity and reliability, sampling strategies- stratified, random, systematic, spatial and temporal considerations, research approaches- field-based, laboratory-based, database/ computational studies, reproducibility and scientific rigor- repeatability, protocol standardization and documentation.	**7**
4	**Data Integrity, Instrument Validation and Scientific Record-Keeping**	Good laboratory practices and good field practices, calibration and validation of instruments- accuracy, precision, error estimation, recording scientific observations- field notebooks, herbarium labels, metadata standards, digital data management: data sheets, repositories, FAIR data principles, detecting data fabrication, falsification, and selective reporting.	**7**
5	**Quantitative Methods and Biostatistics**	Data types in plant science research (morphological, ecological, molecular), descriptive statistics- mean, variance, standard deviation, data visualization- graphs, ecological curves, diversity indices, probability and biological distributions- hypothesis testing- parametric tests (t-test, ANOVA), non-parametric tests, ecological and biodiversity indices- species richness and diversity indices, use of statistical software.	**10**
6	**Scientific Writing and Publication**	Components of research report and scientific papers, taxonomic descriptions and ecological reports, referencing styles and formatting, selecting journals and avoiding predatory publishers, preparation of tables, and illustrations, submission process of peer review journal and other reputed journals, writing for diverse outputs- research papers, policy briefs, technical reports, science communication for broader audiences.	**6**
7	**Research Ethics, IPR and Plagiarism**	Ethics in scientific research, plagiarism and plagiarism detection tools, intellectual property rights (IPR), animal ethics, human ethics, patents and plant variety protection, environmental and biosafety regulations in plant research.	**5**

Suggested Readings

1. Creswell, J. W., and Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed method approaches (5th ed.). SAGE Publications.
2. Kothari, C. R., and Garg, G. (2019). Research methodology: Methods and techniques (4th ed.). New Age International.
3. Alley, M. (2018). The craft of scientific writing (4th ed.). Springer.

4. Hofmann, A. H. (2019). Scientific writing and communication: Papers, proposals, and presentations (3rd ed.). Oxford University Press.
5. Zar, J. H. (2010). Biostatistical analysis (5th ed.). Pearson Education.
6. Montgomery, D. C. (2017). Design and analysis of experiments (9th ed.). Wiley.
7. National Academies of Sciences, Engineering, and Medicine. (2009). On being a scientist: A guide to responsible conduct in research (3rd ed.). National Academies Press.
8. Day, R. A., and Gastel, B. (2012). How to write and publish a scientific paper (7th ed.). Cambridge University Press.

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Course Code: BOT-GRP-599	**Course Title: Guided Research Projects**	
Course Nature: Coursework	**Course Level: 550-599**	**NCrF credit level: 6.5**
Credit Pattern: Self Study/Tutorial:2 credits + Practical/ Field (Dissertation): 16credits		
Class Hours: Self-study/ Tutorial : 45 hours; Total : 90 days; 3 hrs/ week **Dissertation : 360 hours; Total : 90 days; 24 hrs/ week**		

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Critically evaluate existing research studies to identify gaps and emerging trends in the field of research in plant sciences and its allied academic spheres.
2. Apply ethical research practices- issues of plagiarism avoidance, data integrity, authorship norms, biosafety, and environmental responsibility.
3. Formulate scientifically valid research problems, hypotheses, and objectives relevant to regional and global plant science issues.
4. Design robust research methodologies and justify the selection of sample and tools based on theoretical and practical considerations.
5. Apply suitable statistical and computational tools (descriptive statistics, inferential tests, multivariate analysis, bioinformatics where applicable) for rigorous data analysis.
6. Interpret and synthesize findings in relation to theoretical frameworks and existing body of knowledge in plant sciences and finally draw meaningful conclusions and scientific implications.
7. Communicate research effectively through oral presentations, power-points, and *viva voce*, demonstrating critical defence of methods and conclusions.
8. Demonstrate independent research competence, time management, and problem-solving skills.

Theory and Self Study/ Tutorial Course Content

The student shall undertake the dissertation work in terms of the specialized research area opted and the research programme allotted to him/ her by the concerned mentor. The broad course of content realization in the dissertation shall be under two broad heads:

1. Research planning and proposal development.
2. Research execution and report writing in dissertation format.

Evaluation Schemes of M.Sc. Botany Curriculum in accordance with NEP2020 Guidelines

Course Category	Semester and Courses	Evaluation Pattern	Summative Assessment (SA)	Continuous / Formative Assessment (CA)	Practical / Other Component
Major (MJR)	Sem I: 401–404 Sem II: 452–455 Sem III: 502–503	40% CA + 60% SA	**45 marks** **(2 hrs)** 10×1 (2) = 10 5×5 (7) = 25 2×5 (7) = 10	**30 marks** **(1.5 hrs)** **(**for class test**)** **Seminar:** 20 (15+5 viva) **Assignment:** 10 **Class Test:** 30 5×2 = 10 2×5 = 10 1×10 = 10	**25 marks** **(2 hrs)** **Term End Exam:** 20 **CA:** 5
Minor / SEC (MNR/SEC)	Sem I: 405–406 Sem II: 456 Sem III: 504–505	40% CA + 60% SA	**30 marks** **(1.5 hrs)** 5×4 (6) = 20 2×5 (7) = 10	**20 marks** **(1 hr)** 2×5 (7) = 10 1×10 (12) = 10	—
	Sem III: 506	25% CA + 75% SA	**30 marks** **(1.5 hrs)** 5×4 (6) = 20 2×5 (7) = 10	**10 marks** **(0.5 hr)** 5×1 (2) = 5 1×5 (7) = 5	**10 marks** **CA:** 10
VAC	Sem I: 449 Sem II: 499	Gradation Based	—	—	—
IDS / IKS / MJR	Sem II: 451 Sem III: 501 Sem IV: 551	40% CA + 60% SA	**60 marks** **(2.5 hrs)** 5×8 (10) = 40 2×10 (12) = 20	**40 marks** **(1 hr)** 2×16 (20) = 32 1×8 (10) = 8	—
EEC (Entrepreneur ship)	Sem III: 507	40% CA + 60% SA	**15 marks** **(1 hr)** 5×1 (2) = 5 1×10 (14) = 10	**10 marks** **(0.5 hr)** **Class Test** 5×1 = 5 1×5 = 5	**45 + 25 marks** **Product/Report:** 45 **Seminar:** 20 (15+5 viva) **CA:** 5
Project / Dissertation (GRP)	Sem IV: 599	25% CA + 75% SA	**300 marks** Thesis: 200 Seminar: 50 Viva: 50	**100 marks** Literature of review (to be submitted within one month) Write up: 50 Presentation: 30 Interaction: 20	—

Key Notes

- ***CA = Continuous Assessment, SA = Summative Assessment***
- *Most courses follow **40% (CA) + 60% (SA)** structure, except BOT-MNR-506 (Sem III) and BOT-GRP-599 (Sem IV) which follow **25% (CA) + 75% (SA)** structure*
- *Practical-based and project-based courses include **additional evaluation components***
- *VAC courses follow **gradation (non-marks-based) system***