SIKKIM UNIVERSITY

(A Central University Established by an Act of Parliament of India, 2007)

LEARNING OUTCOME - BASED CURRICULUM

M.Sc. BOTANY PROGRAMME

(With effect from Academic Session 2023-24)

DEPARTMENT OF BOTANY

SIKKIM UNIVERISTY

6TH MILE, TADONG - 737102

GANGTOK, SIKKIM, INDIA

VICE-CHANCELLOR'S MESSAGE

Sikkim University stands at the forefront of embracing the transformative National Education Policy (NEP) 2020. In alignment with NEP 2020's vision and the guidelines of the Learning Outcomes-based Curriculum Framework (LOCF) mandated by the UGC, we have undertaken a comprehensive revision of our curriculum across all departments. This initiative ensures a holistic educational experience that transcends traditional knowledge delivery, emphasizing the practical application of knowledge in real-world scenarios.The shift towards LOCF marks a pivotal change from teacher-centric to learner-centric education, fostering a more active and participatory approach to learning. Our updated curriculum clearly defines Graduate Attributes, Programme Learning Outcomes (PLOs), and Course Learning Outcomes (CLOs), setting clear objectives for our students to achieve. This revision is designed to enable a teaching-learning environment that supports the attainment of these outcomes, with integrated assessment methods to monitor and encourage student progress comprehensively.

A key innovation in our curriculum is the mandatory integration of Massive Open Online Courses (MOOCs) through the SWAYAM platform, enhancing accessibility and the breadth of learning opportunities for students. Our approach encourages multidisciplinary studies through the curriculum while allowing for specialization. The curriculum embodies the policy's core principle of flexibility by enabling mobility for students, thereby allowing the exit and entry of students in the program.

I extend my heartfelt gratitude to our faculty, the Head of the Department, the Curriculum Development Committee members, the NEP coordinators, and the dedicated NEP Committee of Sikkim University for their relentless dedication to updating our curriculum. I appreciate Prof. Yodida Bhutia, the Chairperson, and all dedicated NEP Committee members for their thorough review and integration of LOCF and NEP components into our curriculum.

To our students, I convey my best wishes as we embark on this journey with our updated and inclusive curriculum, aiming not only to enrich their academic knowledge but also to nurture their personal growth, critical thinking, and ability to adapt and innovate in an ever-changing world.

Best wishes,

Prof. Avinash Khare
Vice Chancellor
Sikkim University

DEPARTMENT OF BOTANY
SIKKIM UNIVERSITY, GANGTOK

M.Sc. PROGRAMME IN BOTANY

PREAMBLE

The M.Sc Botany programme is designed taking into consideration that students from various universities with different training at the Under Graduate level may join and therefore the basics and advanced topics in botany are comprehensively framed. Also, the recent developments in the field of botany are integrated in each core course and electives. All major disciplines in the field of botany like systematics, diversity studies, plant biotechnology and genetic engineering, ecology, developmental biology, physiology and biochemistry, economic botany, plant response to pathogens and methods in plant biology are offered as core course along with basic courses like cell and molecular biology and genetics. In the past 30 years, remarkable progress has taken place in understanding plant biology at the molecular level and therefore it is imperative that students are exposed to the tools of modern biology to address specific questions in botany. Keeping this in mind, there is greater emphasis in the syllabus to impart latest knowledge through courses like Omics in Plant Science, Plant Biotechnology and Genetic engineering. In addition, skill-based courses in plant science will give opportunities for the students to enhance their skills.

POSTGRADUATE ATTRIBUTES

The attributes of a student of M.Sc Botany includes disciplinary knowledge and understanding of plant science and generic skills that she/he should acquire, demonstrate, and apply in real-life situations to solve problems. Some of the attributes of a post-graduate student are as follows:

PGA1: Knowledge and understanding
The graduates will acquire advanced knowledge of botany with a critical understanding of the emerging developments and issues relating to their field of specialization.

PGA2: Research aptitude
The graduates will get advanced knowledge and understanding of the research principles, methods, and techniques applicable to the study of plants from various points of view. At the same time, students will advance their cognitive and technical skills to evaluate research findings and designing and conducting relevant research in plant systems.

PGA3: General, technical, and professional skills
The graduates will acquire the advanced cognitive and technical skills to perform and accomplish complex tasks where knowledge of plants is involved.

PGA4: Critical thinking and problem-solving skills
The graduates will apply the acquired advanced theoretical and/or technical knowledge of various aspects of botany to inquire into a range of cognitive and practical skills to identify and analyze problems and issues of real-life situations. Even they will acquire knowledge and will be trained enough to apply their advanced knowledge to carry out research and investigate evidence-based solutions to complex and unpredictable problems.

PGA5: Communication Skills:
The graduates will be able to discuss and demonstrate concepts of botany to peers as well as with the public. They will be skilled enough to make judgment across a range of issues of botany with professionals.

PGA6: Digital literacy
The graduates will be able to use digital resources to explore the knowledge of botany and develop/improve the digital knowledge.

PGA7: Constitutional, humanistic, ethical, and moral values
The graduates will be able to demonstrate the willingness and ability to embrace and practice constitutional, humanistic, ethical, and moral values in their life. They will get enough exposure to the subject that they will adopt objective and unbiased actions in all aspects of work related to botany and professional practice and contribute to actions to address environmental protection and sustainable development issues. The graduates will learn ethical and moral issues and their practice to work in a multicultural environment with brotherhood. The graduates will learn to avoid unethical practices such as fabrication, falsification or misrepresentation of data or committing plagiarism.

PGA8: Employability and job-ready skills, and entrepreneurship skills and capabilities/qualities and mindset
During this Post Graduate programme, the graduates will acquire the knowledge and skill sets required to generate new job opportunities in the field of botany and in other sectors by highlighting the role of botany by using an interdisciplinary approach and serving society.

PGA9: Teamwork and leadership
The lab work and field exercises will make the graduates more comfortable with teamwork and leadership to take up new projects to explore the potential of Botany with new strategic approaches.

PROGRAMME LEARNING OUTCOME
M.Sc botany programme is designed to:

PLO1: Generate postgraduates with sound theoretical knowledge and practical skills in basic and applied botany

PLO2: Provide post graduates with necessary scientific skills and problem-solving ability that enable them to take up innovative research in the field of botany.

PLO3: Generate post graduates with the ability to synthesize scientifically based opinion in the field of botany and communicate the same to the general public.

PLO4: Demonstrate adequate skills to contribute towards the conservation of the local flora and traditional knowledge, and conduct cutting edge studies in plant ecology, taxonomy, physiology & biochemistry, microbiology, molecular biology and plant biotechnology.

STRUCTURE OF THE POST GRADUATE PROGRAMME OFFERED BY THE DEPARTMENT

Course category	No. of courses	Credits per course	Total credits
Core theory	06	04	24
Core practical	02	06	12
Open course	01	4	04
Elective theory (any three)	25	04	12
Elective practical (any two)	12	04	08
Skill enhancement course (any three)	10	02	06
Value added courses	02	4+2	06
Research course	01	08	08
TOTAL	**59**		**80**

DEPARTMENT OF BOTANY
SIKKIM UNIVERSITY, GANGTOK

COURSE STRUCTURE OF M.Sc. BOTANY

COURSES OFFERED BY THE DEPARTMENT					
Code	**Course Title**				
		Lecture	**Tutorial**	**Practical**	**Credits**
SEMESTER-I					
Value added course					
BOT-V-501	Indian contributions to Botany	4	0	0	4
Core Courses					
BOT-C-502	Cryptogams and Phanerogams	4	0	0	4
BOT-C-503	Structural, Reproductive and Evolutionary Biology of Plants	4	0	0	4
BOT-P-504	Cryptogams, Anatomy, Embryology and Phanerogams Lab	0	3	3	6
Skill enhancement course					
BOT-S-505	Techniques in Field Botany	1	0	1	2
Total Credits					**20**
SEMESTER-II					
Core Courses					
BOT-C-551	Microbiology and Plant Pathology	4	0	0	4
BOT-C-552	Plant Physiology and Biochemistry	4	0	0	4
BOT-P-553	Plant physiology, Biochemistry, Molecular Biology and Microbiology Lab	0	3	3	6
Open Course					
BOT-O-554	Plants and Human welfare	4	0	0	4
Skill enhancement course					
BOT-S-555	Analytical Techniques in Biological Sciences	1	0	1	2
Total Credits					**20**
SEMESTER-III					
Core Course					
BOT-C-601	Ecology and Phytogeography	4	0	0	4
BOT-C-602	Cytogenetics and Plant Breeding	4	0	0	4
Value added course					
BOT-V-603	Cyber Security and Privacy (MOOC) from NPTEL)	2	0	0	2
Elective Theory-I (To choose any one course from 604 to 609)					
BOT-E-604	Advanced Microbiology	4	0	0	
BOT-E-605	Plant Systematics	4	0	0	
BOT-E-606	Plant Metabolism	4	0	0	

BOT-E-607	Gene Expression and Regulation	4	0	0	4
BOT-E-608	Essentials of Ecology	4	0	0	
BOT-E-609	Ethnobotany and Herbal Medicine	4	0	0	
Elective Practical-I (To choose any practical course from 610 to 615)					
BOT-P-610	Microbiology Lab	0	2	2	4
BOT-P-611	Plant Taxonomy Lab	0	2	2	
BOT-P-612	Plant Physiology Lab	0	2	2	
BOT-P-613	Molecular Biology and Genetic Engineering Lab	0	2	2	
BOT-P-614	Ecology Lab	0	2	2	
BOT-P-615	Herbal Medicine Analysis Lab	0	2	2	
Skill enhancement course					
BOT-S-616	Research Methodology	1	1	0	2
Total Credits					**20**

SEMESTER-IV					
Elective Theory-2 (To choose any one course from 651 to 656)					
BOT-E-651	Fundamentals of Plant Pathology	4	0	0	4
BOT-E-652	Systematic Evidences	4	0	0	
BOT-E-653	Advanced Plant Physiology	4	0	0	
BOT-E-654	Genomics and Proteomics	4	0	0	
BOT-E-655	Advanced Ecology	4	0	0	
BOT-E-656	Ethnobotany and Ethnopharmacology	4	0	0	
Elective Theory-3 (To choose any one course from 657 to 661					
BOT-E-657	Plant Diseases and Management Practices	4	0	0	4
BOT-E-658	Conservation and Sustainability	4	0	0	
BOT-E-659	Advances in Plant Biochemistry	4	0	0	
BOT-E-660	Methods in Plant Biotechnology	4	0	0	
BOT-E-661	Pharmacognosy and Phytochemistry	4	0	0	
Elective Practical-2 (To choose any practical course from 662 to 667)					
BOT-P-662	Plant Pathology Lab	0	2	2	4
BOT-P-663	Plant Systematic Lab	0	2	2	
BOT-P-664	Plant Biochemistry Lab	0	2	2	
BOT-P-665	Plant Tissue Culture Lab	0	2	2	
BOT-P-666	Environment Biology Lab	0	2	2	
BOT-P-667	Natural Products Anal. Lab	0	2	2	
Dissertation					
BOT-R-668		0	4	4	8

Total Credits	**20**
PROGRAM STATISTICS	
TOTAL NUMBER OF CORE COURSES	06
TOTAL NUMBER OF PRACICUM COURSES	14
TOTAL NUMBER OF ELECTIVE COURSES	17
TOTAL NUMBER OF ELECTIVE COURSES (THROUGH MOOC PLATFORM)	08
TOTAL NUMBER OF OPEN COURSES	01
TOTAL NUMBER OF SKILL ENHANCEMENT COURSES	03
TOTAL NUMBER OF SKILL ENHANCEMENT COURSES (THROUGH MOOC PLATFORM)	07
TOTAL NUMBER OF VALUE ADDED COURSES	02
TPTAL NUMBER OF RESEARCH COURSE	01
Total Courses (A total 20 courses should be selected)	59*
TOTAL CREDITS	**80**

*A candidate is required to complete a total of 20 courses to get 2yr. MSc Botany Degree

Instructions for selecting the courses:

1. Core courses are compulsory for all the students of M.Sc. Botany.
2. University Department offers three Ability/Skill enhancement courses in I, II and III semester (one from the department, and two from the MOOCs) of which a student can choose a maximum of **ONE** course in each semester.
3. There will be a basket of ten elective theory courses (Elective Theory-I) in semester III (sixr from the department and four from the MOOCs) of which a student can choose a maximum of **ONE** course.
4. There will be a basket of another nine elective theory courses (Elective Theory-3) in semester IV (five from the department and four from the MOOCs) of which a student can choose a maximum of **ONE** course.
5. At any given point of time, the maximum number of credits that a student can earn from the MOOCs courses shall not exceed 20% (16 credits) of out the total 80 credits.
6. Dissertation is compulsory to all the students for obtaining M.Sc degree.

SAWYAM COURSE OPTIONS

MOOCs Skill Enhancement Courses (2 Credits)

Sem.	Course Code	Course Title	Course Coordinator(s)	Source
I	BOTM-S-506	1. Basic crop production practices	Prof J R Yadav, Dr. Shrawan Kumar Shukla Dr. Vinod Kumar, IIT, Kanpur	NPTEL
	BOTM-S-507	2. Organic farming for sustainable agricultural production	Prof Diilip Kumar Swain IIT, Kharagpur	NPTEL
II	BOTM-S-556	1. Experimental Biotechnology	Prof. Vishal Trivedi, IIT, Guwahati	NPTEL
	BOTM-S-557	2. Analytical Technologies in Biotechnology	Dr. Ashwani K. Sharma	NPTEL
	BOTM-S-558	3. Bioinformatics: Algorithms and Applications	Prof. M Michael Gromiha, IIT Madras	NPTEL
III	BOTM-S-617	1. Biostatistics and Design of Experiments	Prof. Mukesh Doble, IIT, Madras	NPTEL
	BOTM-S-618	2. Data Analysis for Biologists	Prof Biplab Bose, IIT, Guwahati	NPTEL

MOOCs Elective-1 Theory Courses (4 Credits)

III	BOTM-E-620	1. RNA Biology	Prof. Rajesh Ramachandra, IISER, Mohali	NPTEL
	BOTM-E-621	2. Plant Developmental Biology	Sri Ram Yadav, IIT Roorkee	NPTEL
	BOTM-E-622	3. Remote Sensing and GIS	Prof. Rishikesh Bharti, IIT Guwahati	NPTEL
	BOTM-E-623	4. Biological Sciences & Bioengineering	Prof. Sanjeeva Shrivastava, IIT Bangalore	NPTEL

MOOCs Elective-3 Theory Courses (4 Credits)

IV	BOTM-E-669	1. Plant Cell Processing	Prof. Smita Srivastava, IIT, Madras	NPTEL
	BOTM-E-670	2. Essentials of Biomolecules: Nucleic acids and Peptides	Prof. L.M. Kundu, IIT, Guwahati	NPTEL
	BOTM-E-671	3. Natural Resource Management	Prof. Sudip Mitra, IIT Guwahati	NPTEL
	BOTM-E-672	4. Environmental Biotechnology	Prof. Pinaki Sar, IIT, Kharagpur	NPTEL

EVALUATION PLAN

Evaluation of Theory Courses:

Assessment	Formative				Summative	
Type of Test	Written, quiz, class test, online test, seminar, home assignment, term paper, group discussion				Written	
Nomenclature	1st Sessioinal test	2nd Sessional test	3rd Sessional test	Marks in Formative (sum of 2 best tests)	End Term Examination	Total
Marks	25	25	25	50	50	**100**

Evaluation of Practical Courses:

Assessment	Formative	Summative	
Type of Test	Seminar, poster, class test, online test, review paper, report, demonstration, viva	Thesis, seminar, viva -voce	
Nomenclature	Internal practical exams	End Term Exam	Total
***Marks**	50	50	**100**

*The above score holds good when the Practical paper is a 4 credit course; in case of 6 credit practical, both the internal and end term practical exam marks increases correspondingly

Evaluation of Ability / Skill Enhancement Courses:

Assessment	Formative	Summative	
Type of Test	Class test, online test, review paper, report, demonstration, viva, written test	Thesis, seminar, viva -voce	
Nomenclature	Mid-term /Internal Examinations	End Term Exam	Total
Marks	25	25	**50**

Evaluation of Dissertation Course:

Assessment	Formative	Summative
Type of Test	Practical examinations, viva-voce	Practical examinations, viva-voce
Nomenclature	Progress report	End Term Exam
Marks		**200**

SEMESTER-I		
Core Theory: Course Level-500 Total Marks: 100 L+T+P: 4+0+0=4 Credits Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr.		
BOT-V-501	**INDIAN CONTRIBUTIONS TO BOTANY**	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Learn the different uses of plants in ancient India. CLO2. Learn the uses of plant for medicinal, household, nutritional purposes CLO3. Know important plants of commerce and trade also for product development CLO4. Know about important imminent botanists of India	
Unit	**Topics**	**Hrs**
I	**Knowledge of Plants in ancient India:** Description of plants in Vedic period; Indian plants in ancient languages- Pali, Brahmi and Sanskrit literatures (hymns, verses) and monuments. Nature and Human Integration in ancient India. Plants used in ancient Indian ceremonies and rituals, *vrikshayurveda*.	15
II	**Plants and Traditional Healthcare System in India:** Traditional healthcare system in India – Ayurveda, Yoga, Naturopathy, Unani, Siddha, Homeopathy and Sowa rigpa. Indigenous healthcare system of the Eastern Himalaya. Basic principles of Ayurveda - Charaka Samhita and Sushruta Samhita. Use of plants in common herbal preparations – *Chewanpras, trifala*; ethnopharmacological relevance of Indian pharmacopeia.	15
III	**Indian plants in ancient trade and commerce:** Spices of India – ajwain, black pepper, chillipapper, c ardamom, clove, cumin, ginger, *Trigonella*). Fruits of India (Aam, Amruth, Baer, Chalta, Citrus). Medicinal plants of India- *Aconitum*, *Andrographis paniculata* (Kalmegh), Kutki, *Neem, Tulsi, Pudina, Cassia tora, Pipla.* Aromatic, cosmetic and dye yielding plants of India- *Aquilaria khasiana* (Agarwood), *Bixa orellana*(Lipstick tree)*, Curcuma longa* (Haldi*), Indigofera tinctoria* (Indigo)*, Santalum album* (Chandan). Fiber yielding plants of India- cotton, coconut, jute.	15
IV	**Contribution of Indian Scientists in Botany:** Contributions of Acharya J.C. Bose, Professor P. Maheshwari, K.C.Mehta, Professor MandayamOsuri Parthasarathy Iyenger, Professor Shiv Ram Kashyap, Professor R.Mishra, Professor Janaki Ammal, Professor M.S.Swaminathan, Dr.S.K.Jain, Professor Birbal Sahni, Professor Govindjee, Dr. P. Pushpangathan and Professor Ajit Verma.	15
SUGGESTED TEACHING LEARNING STRATEGIES • Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis • Quiz, group discussions, Case studies, and Group Projects • Guided readings and discussions in the class/lab/field and out of the class/field/lab. • Individual and group presentations by students on selected topics. • Attending various seminars/online events/presentations etc.		

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment,
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Chaturvedi GN, Tiwari SK, Rai NP. Medicinal use of opium and Cannabis in medieval India. *Indian Journal of History of Science*. 16 (1): 31-35 (1981).
2. Devpujari A. *Botany in Sanskrit literature*. Sanskrit Bharati, New Delhi, (2000).
3. Dharmapal. *Indian Science and technology in 18th century.* India Press (2000).
4. Paria ND, Das Manishi Nath, Sen Sharma Priyadarshan. *History of Science in India*. Vol-IV, Part-I Plant Science.National Academy of Sciences, India (NASI) and The Ramakrishna Mission Institute of Culture, Kolkata (2014). ISBN 978-93-81325-44
5. Pujari RM, Kolhe Pradeep, Kumar NR. *Pride of India: A Glimpse into India's Scientific Heritage.* Samskrita Bharati Publication.(2006) ISBN-10 : 8187276274, ISBN-13 : 978-8187276272
6. Sabareesh PA. *A brief history of science in India*. Garuda Publications, New Delhi (2023).
7. Sharma PV. *Essentials of Ayurveda- Text and Translation of So dasangahrdayam.* Motilal Banarsidass Publishers Private Limited, Delhi (1998).ISBN: 978-81-208-1517-9
8. Singh BP, Srivastava U. *Plant Genetic Resources in Indian perspective (Theory & Practices).* Directorate of Information & Publications of Agriculture, Indian Council of Agriculture Research, New Delhi (2004). ISBN: 81-7164-017-6
9. Tiwari M. *Ayurveda-A Life of Balance*. Motilal Banarsidass Publishers Private Limited, Delhi (1995). ISBN: 978-81-208-2076-2

Core Theory; Course Level:500		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Prac tical: 0 hr.		
BOT-C-502	**CRYPTOGAMS AND PHANEROGAMS**	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Understand important cryptogams and phanerogams. CLO2. Describe the geological period and fossil species of prehistoric periods. CLO3. Analyze the basic evolutionary affinity of plant groups. CLO4. Apply knowledge of important plants in daily life.	
Unit	**Topics**	**Hrs**
I	**Phycology and Bryology:** General account of algae, classification, thallus organization and reproduction in algae, economic importance of algae. General characteristics, classification, morphology, anatomy and reproduction of bryophytes; General characteristics of the three classes (Hepaticopsida,Anthocerotopsida and Bryopsida).Ecological and economic importance of bryophytes.	15
II	**Pteridology and Paleobotany:** General characteristics and classification of pteridophytes. Morphology, anatomy and reproduction in ferns. Telome concept, stelar evolution, heterospory and seed habit in pteridophytes; economic importance of pteridophytes. Paleobotany: types of fossils and fossilization process; study of fossil pteridophytes and gymnosperms: Rhynia, Calamites, Lepidodendron, Pteridospermales, Cycadeodiales and Glossopteris	15
III	**Gymnology:** General characteristics of gymnosperms; classification of gymnosperms. Comparative study on vegetative, anatomical and reproductive structures of Cycadophyta, Coniferophyta and Gnetophyta. Evolutionary trends and phylogenetic relationship among various groups of gymnosperms. Economic importance of gymnosperms.	15
IV	**Angiosperms:** History of developments in taxonomy: merits and demerits of major systems of classification. Angiosperm Phylogeny Group (APG) system of classification (APG III and IV); biosystematics; concepts and components; Aims of systematics; direct and indirect methods of plant identification; practice of taxonomic key; diversity and taxonomic studies of flowering plants of North-Eastern India with special reference to primitive and advanced taxa.	15

SUGGESTED TEACHING LEARNING STRATEGIES

• Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
• Quiz, group discussions, Case studies, and Group Projects
• Guided readings and discussions in the class/lab/field and out of the class/field/lab.
• Individual and group presentations by students on selected topics.
• Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Arnold AC. *An Introduction to Paleobotany*. Agrobios (India), Jodhpur-342002 (2014).
2. Bhatnagar SP, Moitra A. *Gymnosperms*, New Age Int. Pvt. Ltd., New Delhi (1996).
3. Kholia BS. *Ferns and Fern-allies of Sikkim* (Part-1 & 2), Sikkim State Biodiversity Board & Botanical Survey of India (2010 & 2014).
4. Mishra SR. *Text Book of Paleobotany.* Discovery Publishing House Pvt.Ltd., New Delhi-110002 (2010).
5. Morris J. *An Introduction to the Algae*. Cambridge University Press, U.K (1986).
6. Parihar NS. *Bryophytes*. Central Book Depot, Allahabad (1991).
7. Ralph P. *Mosses, Liverworts and Hornworts-A field guide to common bryophytes of the Northeast.* Comstock Publishing Associates-A Division of Cornell University Press, Ithaca and London (2016).
8. Singh, DK, Singh SK, Singh Devendra .*Liverworts and Hornworts of India*. Botanical Survey of India, Ministry of Environment, Forests and Climate Change, CGO Complex, 3rd MSO Building, Block-F, Saltlake, Kolkata-700064 (2016).
9. Sporne KR. *The Morphology of Pteridophytes*. B.I. Publ. Pvt. Ltd (1991).
10. Trivedi AN. *Advances in Pteridology.*S.Chand& Company Pvt.Ltd. New Delhi (2002).

Core Theory; Course Level:500		
Total Marks: 100	L+T+P: 4+0+0=4 Credits Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr.	
BOT-C: 503	**STRUCTURAL, REPRODUCTIVE AND EVOLUTIONARY BIOLOGY OF PLANTS**	
Course Learning Outcome	After the completion of the course, the students will be able to…. 1. Describe the events of plant growth and development, and the mechanisms associated. 2. Explain the structure of reproductive structures and their role in sexual reproduction and plant improvement. 3. Identify the tissue/cell types present in various plant parts and their role in plant life. 4. Illustrate evolutionary trends and events with reference to plants.	
Unit	**Topics**	**Hrs**
I	**General features of plant growth and development:** Introduction to plant growth and development; Germination and vegetative growth; Reproductive phase; senescence and death; measurement of plant growth; Types, Phases and characteristics of growth; Growth rates; Differentiation, dedifferentiation, redifferentiation; Plasticity concept. Root Development: Organization of root apical meristem (RAM); Shoot Development: Organization of shoot apical meristem (SAM); tissue differentiation in the shoot; Theories of RAM, SAM. Flower Development: Physiology of flowering, florigen concept and photoperiodism.	15
II	**Development of reproductive structures:** Male Gametophyte: Structure of anther, microsporogenesis, tapetum; pollen development male sterility; sperm dimorphism; pollen germination; pollen tube growth and guidance. Female Gametophyte: Ovule types; megasporogenesis; organization of embryo sac; structure of embryo sac cells. Pollen-pistil interaction, self-incompatibility and fertilization; Structure of the pistil; pollen-stigma interactions, double fertilization; Post fertilization; Seed Development and fruit growth: Endosperm development; embryogenesis; embryo; polyembryony; apomixes; embryo. Fruit development and growth.	15
III	**Anatomy:** Anatomy and systematics; secondary growth and nodal anatomy, the node-internode transition, formation of leaf and branch traces. Wood histology, growth rings, tracheids, vessels and wood rays, longitudinal parenchyma and its arrangement, grain and texture, knots, formation of resin cavities and tyloses. Anatomy of floral axis and the whorls, the leaf, origin of carpel, types and distribution of laticifers and lenticels, anatomy in relation to their physiological roles. Applications (in brief) of anatomical studies in systematics, climate studies, pharmacology, forensic sciences.	15

IV	**Evolutionary Biology of Plants:** Green plants (viridiplantae) evolution, non-land plant green plants, alternation of generations, embryophytes, diversity of nonvascular land plants (*Liverworts, Mosses, Hornworts, Polysporangiophytes*). Vascular plant apomorphies, vascular plant diversity (Rhyniophytes, Lycopodiaceae, Isoetaceae, Selaginellaceae, Equisetaceae, Ophioglossaceae, Psilotaceae, Marattiaceae, Osmundaceae, Cyatheaceae, Polypodiaceae); Evolution of lignophytes, spermatophytes; diversity of woody and seed plants (*Archaeopteris*, seed ferns, gymnosperms); Angiosperm apomorphies, angiosperm evolutions.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Johri BM. *Embryology of Angiosperms*. Springer-Verlag, Berlin Heidelberg (1984).
2. Donald EF. *Plant Growth and Development*—A Molecular Approach. Harcourt Brace & Company, U.S.A (1994).
3. Howell SH. *Molecular Genetics of Plant Development*. Cambridge University Press, UK (1998).
4. Carlquist S. *Comparative Wood Anatomy*, Springer-Verlag, Germany (2001).
5. Cutter EG. *Plant Anatomy*, Part I & II, Edward Arnold, United Kingdom (1978).
6. Cutter EG. *Plant anatomy*: Experiment and Interpretation, Part II, Organs Edward Arnold, London (1971)..
7. Fahn A. *Plant Anatomy*. 3rdedn. Pergamon Press, Oxford (1982).
8. Esau K. *Anatomy of Seed Plants*, 2ndedn. John Wiley and Sons, New York (1977).
9. Burleigh JG, Bansal MS, EulensteiO,Hartmann AW, Vision TJ. *Genome-scale phylogenetics:* Inferring the plant tree of life from 18,896 gene trees. Syst. Biol. 60:117-125 (2011)..
10. Bierhorst DW. *Morphology of Vascular Plants*. Macmillan, New York (1971).
11. Johnson LAS, and Wilson KL.*Stangeriaceae*. In: Kramer KU, GreenPS (eds.), T*he Families and Genera of Vascular Plants. I. Pteridophytes and Gymnosperms.*pp. 370-371. Springer-Verlag, Berlin (1990d).

Core Practical; Course Level:500	
Total Marks: 150	L+T+P: 0+3+3=6 Credits
Lecture: 0 hrs. + Tutorial: 45 hrs. + Practical: 90 hr.	
BOT-P-504	**CRYPTOGAMS, ANATOMY, EMBRYOLOGY AND PHANEROGAMS LAB**
Course Learning Outcome	After the completion of the course, the students will be able to… CLO1. Integrate the practical knowledge of lower plants. CLO2. Describe anatomical features of selected angiosperms, gymnosperms and pteridophytes. CLO3. Explain embryological aspects of plants

Laboratory Experiments

1. Vegetative and reproductive structure study of the representative members of algae: *Nostoc, Vallisneria, Trentipolia, Chara, Oedogonium,Polysiphonia*.
2. Morphological and anatomical study of the representative members of bryophytes: *Marchantia, Lunularia, Plagiochasma, Metzgeria, Sphagnum, Anthoceros, Notothylas, Pogonatum, Funaria, Bryum, Fissidens*.
3. Morphological, anatomical and reproductive structures of representative members of Pteridophytes – *Lycopodium, Selaginella, Equisetum, Gleichenia, Cyathea, Pteris, Polystichum, Diplazium.*
4. Study of paleobotany through fossil specimens
5. Dissection of flowering plants for taxonomic works
6. Observation of trichomes of various plant organs.
7. Observation of anatomical (through C.S., RLS & TLS) structure of gymnosperms – *Cycas, Pinus, Cupressus, Juniperus,Cryptomeria, Taxus*
8. Anatomical study of monocotyledon and dicotyledon root, stem and leaf and anomalous secondary growth in dicot stems.
9. Anatomical basis of identification of C3 & C4 sub types in grasses.
10. Anatomy of lenticels and periderm in plants.
11. Study of stomata types.
12. Anatomical study of different types of ovule from angiosperms.

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Bendre AM, Kumar A. *A textbook of practical botany I and II*. Rastogi publication Meerut, UP, India (2009).
2. Davis GL.*Systematic Embryology of the Angiosperms*. John Wiley and Sons, New York (1996).
3. Johri BM. *Embryology of angiosperms.* Springer-Verlag, Berlin, New York (1984).
4. Johri BM, Ambegaokar KB, Srivastava PS. *Comparative embryology of angiosperms*. Springer-Verlag, Berlin, New York (1992).
5. Maheswari P.*An Introduction to the embryology of Angiosperms.* McGraw-Hill, New York (1950).
6. Parihar NS. *Bryophytes.* Central Book Depot, Allahabad (1991).
7. Santra SC, Chatterjee TP, Das AP. *College Botany Practical. Vol.II.* New Central Book Agency (P) Ltd, 8/1 Chintamoni Das Lane, Kolkata 700-009 (2004).
8. Sinha RK. *Practical Taxonomy of Angiosperms*. IK International Publishing House Pvt.Ltd (2010).
9. Sporne, K.R. *The Morphology of Pteridophytes*. B.I. Publ. Pvt. Ltd (1991)
10.

Skill Enhancement Course; Course Level:500		
Total Marks: 50	L+T+P: 1+0+1=2 Credits	
Lecture: 15 hrs. + Tutorial: 0 hr. + Practical : 30 hrs.		
BOT-S-505	**TECHNIQUES IN FIELD BOTANY**	
Course Learning Outcome	After the completion of the course, the students will be able to… CLO1. Demonstrate important equipment used for the study of cryptogams and phanerogams in the field as well as in the laboratory. CLO2. Analyze the basic evolutionary affinity and their taxonomic hierarchy CLO3. Apply the techniques required for botanical research and post research management.	
Unit	**Topics**	**Hrs**
I	**Field techniques procedures:** Basics of plant morphology, botanical terminology and vocabulary. Handling of field equipment – GPS, cameras and photography-microphotography, telephotography, wide angle photography. He rbarium methods- selection of plants for herbarium and museum specimens. Preservation, pressing and post collection care in the field, field notebook and field number. Preparation of preservatives for plant specimens. Basic requirements for botanical expedition. Planning for the fieldwork/botanical expedition. SWOT analysis, field force analysis and field techniques for collection of botanical information (PRA, APPA, SSI).	15
II	**Herbarium methods:** Pressing, drying, mounting, labeling (Identification) and nomenclature of the specimen, preservation and care. Use of flora and websites for authentication of botanical names. Herbarium accession number, scanning methods of herbarium, digital database preparation. Arrangement of herbarium according to the accepted system of classification. Analysis of the collected specimens. Presentation of the outcome of field visit/botanical expedition and submission of the field visit/expedition report.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Chettri A, Rai SK. *Wild Medicinal Plants of Sikkim.* (Edited by J.H.Franklin Benjamin and RajibGogoi). State Medicinal Plants Board, Non-Timber Forest Produce Sector, Forest & Environment Department, Government of Sikkim. ISBN: 978-8196062200 (2023).
2. GogoiR, Sherpa N, Benjamin JHF, Agrawala DK, Rai SK, Dash SS. *Flora of Sikkim-A Pictorial Guide. Botanical Survey of India*. Botanical Survey of India, Ministry of Environment, Forest and Climate Change, CGO Complex, 3rd MSO Building, Wing-F, 5th& 6th Floor, DF Block, Sector-1, Salt Lake City, Kolkata-700064 (2021).
3. Jain SK, Rao RR. *A handbook of Field and Herbarium Methods.* Today and Tomorrow's Printers and Publishers, New Delhi (1976).
4. Kehimkar I.*Common Indian Wild Flowers.* Oxford University Press, Walton Street, Oxford OX2 6 DP (2000). .
5. KholiaBS. *Ferns and Fern-allies of Sikkim (Part - 1),* Sikkim State Biodiversity Board & Botanical Survey of India (2010)..
6. Kholia BS. *Ferns and Fern-allies of Sikkim (Part- 2),* Sikkim State Biodiversity Board & Botanical Survey of India (2014)..
7. Polunin O, Stainton A. *Flowers of the Himalaya*. Oxford University Press, Walton Street, Oxford OX2 6 DP (1990).
8. Rana TS, NairKN, Upreti DK. *Plant Taxonomy and Biosystematics*. New India Publishing Agency, 101, Vikas Surya Plaza, CU Block, LSC Market, Pitam Pura, New delhi – 110034. ISBN: 978-93-83305-41-4 (2014).
9. Stainton Adam.*Flowers of the Himalaya-A Supplement.* Oxford University Press, Great Clarendon Street, Oxford OX2 6DP. ISBN: 019 5644158 (1997).
10. Singh SK, Agrawala DK, Jalal JS, Dash SS, M AA, Singh P.*Orchids of India-A Pictorial Guide*. Botanical Survey of India, Ministry of Environment, Forest and Climate Change, CGO Complex, 3rd MSO Building, Wing-F, 5th& 6th Floor, DF Block, Sector-1, Salt Lake City, Kolkata-700064 (2019).

	SEMESTER-II	
	Core Theory; Course Level: 500	
Total Marks: 100	L+T+P: 4+0+0=4 Credits Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr.	
BOT-C-551	**MICROBIOLOGY AND PLANT PATHOLOGY**	
Course Learning Outcome	After the completion of course, the students will be able to… CLO1: Describe the history of microbiology and plant pathology. CLO2: Explain various methods used in microbiology and plant pathology including biosafety measures. CLO3: Discuss the taxonomy and applications of fungi and lichens CLO4: Analyze various plant disease, causal organisms and remedies.	
Unit	**Topics**	**Hrs**
I	**Historical perspectives and microbial taxonomy:** Discovery of microbial world; landmark discoveries relevant to different eras; controversies over spontaneous generation; major characteristics of microorganisms; role of microorganisms in agriculture, pharmaceutical and industries; Classification, nomenclature and identification of microorganisms; Classification of microorganisms on the basis of risk.	15
II	**Methods in microbiology:** Theory and practice of sterilization; Control of microorganisms: physical and chemical method. Plasma sterilization, Principles, functioning and types of Biosafety cabinets. Pure culture techniques; culture media; culture methods; Maintenance and preservation of pure culture; Enrichment culture techniques for isolation of microorganism.	15
III	**Fungi and Lichens:** Classification of fungi (GC Ainsworth, Alexopoulos, AFTOL, Kirk et al., 2008). Life cycles of important phytopathogenic fungi. Economic mycology, edible fungi and entomogenous fungi. Mycorrhizal associations: type, morphology, functions and chemical composition. Lichens: Thallus structure, reproduction and economic importance.	
IV	**Plant pathology:** Historical and developmental aspects of Plant pathology. Outline of classification of plant diseases. Pathogenesis: penetration; development inside the host tissue. Defense mechanisms of plants against infection: Preexisting and postinfectionstructural defenses, Biochemical defense, hypersensitive reaction, SAR, and the role of phytoalexins and other phenolic compounds. Plant/microbes/pests interaction. Study of some important diseases of the following crops: Rice, Wheat, Potato, sugarcane, and Tea.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Dubey RC, MaheshwariDK. A Text book of Microbiology, S.C.Chand and Company, Ltd. Ramnagar, New Delhi (2002).
2. Sullia SB, ShantharamS. General Microbiology. Oxford and IBH publishing Co.Pvt.Ltd. New Delhi (1998).
3. Sharma PD. Microbiology and Plant Pathology. Rastogi publications. Meerut, India.
4. Ananthnarayan, R and Jayaram Panikar,C.K. 1986. Text book of Microbiology. Orient Longman ltd. New Delhi (1999).
5. Brook TD, Smith DW, Madigan MT. Biology of Microorganisms, 4th ed. Eaglewood Cliffts. N.J.Prentice- Hall. New Delhi (1984).
6. Claus WG.Understanding microbes. A laboratory text book for Microbiology. W.H.Freeman and Company. New York (1989).
7. Ketchum PA.Microbiology, concepts and applications. John Wiley and Sons. New York (1988).
8. Stainer, Roger Y, Ingrahan JL, Wheelis ML, Painter PR. Microbial World 5th edition. Prentice-Hall India, Pvt. Ltd. New Delhi (1990).
9. Schlegel HG.General Microbiology. Cambridge University Press. London, 587pp (1986).
10. Prescott H, Klein S. Microbiology., VII EditionMcGraw-Hill International Edition, (2008).

Core Theory; Course Level:500

Total Marks: 100 L+T+P: 4+0+0=4 Credits

Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr

BOT-C-552	**PLANT PHYSIOLOGY AND BIOCHEMISTRY**	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Describe various aspects of plant-water relations CLO2. Define the structure, properties and significance of biomolecules CLO3. Describe and explain the major metabolic pathways and their significance	
Unit	**Topics**	**Hrs**
I	**Water relations and Mineral nutrition:** Physico-chemical properties of water, water potential and its components, apparent free space, bulk movement of water, SPAC, Passive and active solute transport, An overview of the functions of macro- and micro-nutrients.	15
II	**Photosynthesis and Respiration:** Photosynthetic apparatus, pigments and light harvesting complexes, photo-oxidation of water, mechanism of electron transport and photophosphorylation. Carbon assimilation: Calvin cycle, C_4 cycle, CAM pathway. Photorespiration and its significance. Overview of plant respiration, glycolysis, TCA cycle, electron transport and ATP synthesis, alternative oxidase system.	15
III	**Proteins and Carbohydrates:** Proteins: Classification of amino acids, Different levels of protein structure, Structure-function relationship. Protein folding Carbohydrates: Monosaccharides, disaccharides, polysaccharides, Glycoproteins. Glycolipids	15
IV	**Lipids and Nucleic acids:** Lipids: Classification and functions of lipids and fatty acids Nucleic acids:Nucleosides and nucleotides, Structure of DNA and RNA and types of RNA,. History of DNA double helix discovery	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Campbell MK, Farrell SO. *Biochemistry*. 7th Reprint, Cengage Learning Publisher (2011).
2. Conn EE, Stumpf PK. *Outlines of Biochemistry*. John Wiley and Sons, New Delhi (2009).
2. Berg JM, Tymoczko JL, Stryer L. *Biochemistry.* 9th edition. WH Freeman (2019).
3. Fisher J, Arnold.*BIOS Instant notes in chemistry for Biologists.* Garland Science publications (2003).
4. Dey PM, HarborneJB. *Plant Biochemistry*. Elsevier publications(1997).
5. Zubay G. *Biochemistry*. Brown (William C.) Co ,U.S. (1997).
6. Buchanan BB, Gruissem W, Jones RL. *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists. Maryland, USA (2015).
7. Taiz L,Zieger E.*Plant Physiology.* 5th Edition. Sinauer Associates Inc. Publishers, Massachusetts, USA. (2010).
8. Hopkins WG, Huner NPA. *Introduction to Plant Physiology*. 4th edition. John Wiley & Sons (2008).
9. Marschner P. *Marschners' Mineral Nutrition of Higher Plants.* Academic Press (2012).

Core Practical; Course Level:500	
Total Marks: 100	L+T+P: 0+3+3=6 Credits
Lecture: 0 hr. + Tutorial: 45 hr. + Practical : 90 hrs	
BOT-P-553	**PLANT PHYSIOLOGY, BIOCHEMISTRY, MOLECULAR BIOLOGY AND MICROBIOLOGY LAB**
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Perform experiments related to certain physiological aspects such as determination of water potential, pigment contents, seed viability etc. CLO2. Perform experiments related to determination of certain biochemical components, enzyme assays. CLO3. Describe the rules and procedures to be observed in a laboratory CLO4. Describe the equipment and apparatus used in microbiology practical exercises

Laboratory Experiments

1. Determination of water potential of plant tissue.
2. Estimation of total chlorophyll contents of leaves of different chronological ages.
3. Determination of seed viability by Tetrazolium [TZ] test.
4. Determination of peroxidase activity from plant sample.
5. Isolation of DNA from leaf tissues.
6. Isolation of RNA from leaf tissues.
7. Purity checking and quantification of nucleic acids.
8. Agarose gel electrophoresis for separation of DNA.
9. SDS-PAGE for separation of proteins in a mixture.
10. Microbiology Laboratory: Basic rules and requirements.
11. Preparation of media, sterilization.
12. Slant stab and media plate preparation.
13. Cultivation and isolation of microorganisms from plant samples.
14. Cultivation and isolation of microorganisms from soil samples.
15. Cultivation and isolation of microorganisms from food samples.
16. Pure culture technique by streak and pour plate method.
17. Isolation of pathogens from diseased tissues.
18. Methods of culture preservation and maintenance: Lyophilization, storage in liquid nitrogen, storage at -70^{o}C, storage in minerals, maintenance by sub-culturing.

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Onslow MR.*Practical Plant Biochemistry*.Legare Street Press (2022).
2. Gupta NK, Sangha MK, Bala M, Gupta S.*Practicals in Plant Physiology and Biochemistry.* Scientific Publishers (India) (2016).
3. Choudhury MA, Gupta KK. *Practical Plant Physiology*. New Central Book Agency, (2009).
4. Kochhar SL, Gujral SK. *Comprehensive Practical Plant Physiology*. Laxmi Publications (2011).
5. Srivastava GC. *Modern methods in Plant Physiology.* 1st edition. NIPA, New Delhi (2010).
6. Bhattacharya A. *Methods and techniques in Plant Physiology*. NIPA, (2015).
7. Glick BR, Thompson JE. *Methods in Plant Molecular Biology and Biotechnology*. CRC Press, 1st Edition. (1993)
8. Zurbriggen MD. *Plant Synthetic Biology: Methods and Protocols: 2379 (Methods in Molecular Biology)*. Springer-Verlag New York Inc.; 1st ed. (2022)
9. Ingle KP, Moharil MP, Padole DA. *Molecular Methods in Plant Biology: A Comprehensive Book on Biotechnicological Aspects*. I K International Publishing House Pvt. Ltd. (2020).
10. Dubey RC, Maheshwari DK. *Practical Microbiology*. Rajendra Printers Pvt. Ltd. 7361, Ram Nagar, New Delhi- 110055 (2002).
11. Kumar BS, Zothansanga D,Senbagham N, Senthil Kumar G., Gurusubramanian. *Practical Microbiology, A Laboratory Manual.*Panima Publishing Corporation, New Delhi (2018)

Open Theory; Course Level:500		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-O-554	**PLANTS AND HUMAN WELFARE**	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Describe the importance of traditional knowledge and associated laws and regulations CLO2. Explain plants of economic importance CLO3. Use medicinal plants for different purposes CLO4. Understand the intellectual property rights associated to traditional knowledge	
Unit	**Topics**	**Hrs**
I	**Traditional Knowledge:** Characteristics and aspects of traditional knowledge. Trad itional knowledge of different indigenous communities of Sikkim and North Eastern states of India on agriculture, healthcare and shelter. Documentation of traditional knowledge- methods and indices. National and international initiatives for the protection of traditional knowledge; National Biodiversity Authority (NBA); State Biodiversity Board (SBB), Biodiversity Management Committee (BMC), People's Biodiversity Register (PBR), Nagoya protocol.	15
II	**Economic Botany:** Diversity and distribution of food, vegetables, fruits and spices of Himalaya and the North Eastern regions; industrial plants and plant products- fiber yielding, essential oils, medicines and beverages; value addition and product development of some economically important plants.	15
III	**Herbal Medicine:** Medicinal plants scenario in India. Diagnostic features, bioactive molecules and therapeutic value of some common important medicinal plants; standardization of herbal drugs; commercial cultivation of medicinal plants.	15
IV	**Biopiracy and Intellectual Property Rights:** Copyrights, design, layout design of semiconductor integrated circuit, patent, trade mark, trade secret. Criteria for patenting inventions, Patent (Amendment) Act (2005. Geographical indication (GI), protection of plant variety and farmers rights (PPVFR), TRIPS and patent law, Trad itional Knowledge, Digital Library (TKDL), National Innovation Foundation (NIF).	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Ganguli P.*Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill (2001).
2. Krishnamurthy KV. *An Advanced Text Book on Biodiversity: Principles and Practice*. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi (2003).
3. Pandey BP. *Economic Botany- Revised edition*. S. Chand & Company Private Limited, Ram Nagar, New Delhi 110055 (2014). ISBN: 81-219-0341-6
4. Reddy R, Surekha S, Krishna M, Reddy MK. *Biodiversity, Traditional Knowledge, Intellectual Property Rights*. Scientific Publishers, Jodhpur-342001 (2016).
5. Rathore NS, Mathur, Mathur SM, Anshul PR. *Intellectual Property Rights*. New India Publishing Agency, Pitam Pura, New Delhi-110034 (2013).
6. Saha R.(Ed.). *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publishing House, New Delhi (2006).
7. Ramesh U. *Basics of Economic Botany*. Anmol Publications Pvt. Ltd, New Delhi – 110002 (2009).
8. Vardhana R. *Economic Botany*. Sarup Book Publishers Pvt. Ltd, New Delhi - 110002(2009). ISBN:978-81-7625-983-5

Skill Enhancement Course; Course Level:500

Total Marks: 2 L+T+P: 1+0+1=2 Credits

Lecture: 15 hrs. + Tutorial: 0 hr. + Pr actical: 30 hrs.

BOT-S-555	**ANALYTICAL TECHNIQUES IN BIOLOGICAL SCIENCES**	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Handle different types (expressions) of solutions and buffer systems used in diverse biological analyses. CLO2. Have an understanding of the principles underlying the commonly used analytical techniques in biological sciences. CLO3. Have an elaborate idea about different components of instrumentation associated with the commonly used analytical techniques in biological sciences CLO4. Have an idea about diverse applications of the commonly used analytical techniques in biological sciences.	
Unit	**Topics**	**Hrs**
I	Good Laboratory Practices, solutions types and preparation methods, pH, buffers; Principles, Instrumentation and applications of (i) Microscopy, (ii) Spectrophotometry, (iii) Chromatography	15
II	Principles, Instrumentation and applications of (i) Electrophoresis, (ii) Centrifugation.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Currell G. *Analytical Instrumentation – Performance Characteristics and Quality*. John Wiley & Sons, Ltd, West Sussex PO19 1 UD, England. ISBN: 0 471 99900 8 (HB), 0 47 99901 6 (SB) (2000)

2. Dewalia CN. *Analytical Instrumentation*. Chinttan Publications, 4/8, Anandnagar, Paud Road, Kothrud, Pune-411038. ISBN: 81-89194-18-6. (2015).

3. Freifelder D. *Physical Biochemistry.* WH Freeman and Company (1982).

4. Havlicek V, Spizek J. *Natural Product Analysis- Instrumentation, Methods and Applications*. John Wiley & Sons, Inc, Hoboken, New Jersey. ISBN: 978-1-118-46661-2 (Hardback) (2014).

5. Harborne JB. *Phytochemical Methods- A guide to modern techniques of plant analysis*. Springer (India) Private Limited, 17 BarakhambaRoad,New Delhi-110001. ISBN: 978-81-8128-310-8 (1998).

6. Plummer DT. *An Introduction to Practical Biochemistry*. Tata McGraw Hill (2007).

7. Sawhney SK, Singh R. *Introductory Practical Biochemistry*. 2nd Ed., Narosa publishing house New Delhi (2011).

8. Talluri S. *Bioanalytical Techniques.*I.K.International Publishing House Pvt. Ltd,New Delhi-110016. ISBN: 978-93-81141-70-0 (2012).

9. Upadhyay A, Upadhyay K, Nath N. *Biophysical Chemistry (Principles and Techniques).* Himalaya Publishing House Pvt. Ltd, Mumbai. (2010).

10. Wilson K, Walker J. *Principles and Techniques of Biochemistry and Molecular Biology.* 6th Ed., Cambridge University Press, New Delhi (2008).

	SEMESTER III	
Core Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr	
BOT-C-601	**ECOLOGY AND PHYTOGEOGRAPHY**	
Course Learning Outcome	After the course, the student will be able to CLO1. Describe the concepts of Ecology and relate them with the different life processes CLO2. Illustrate the importance of biodiversity conservation CLO3. Distinguish the different phytogeographic regions of India CLO4. Identify environmental problems and relate them with geomatics tool.	
Unit	**Topics**	**Hrs**
I	**Introduction to plant ecology:** Introduction to ecology; Structure and function, Population Ecology: Growth forms and regulation, Species interaction, ecological niche, keystone species, ecotypes, biogeochemical cycles, Succession, Energy flow models, Food chain and Food web, biosphere, biomes and impact of climate on biomes.	15
II	**Plant Biodiversity:** Biodiversity levels, global hotspots of biodiversity, biodiversity hotspots of India. Important biological resources of the Himalaya and North Eastern states of India. Biodiversity indices, assessment and monitoring; biodiversity conservation, international convention for biodiversity conservation, Biodiversity Act of India. Causes of biodiversity loss, threats to biodiversity (IUCN categories), invasive species.	15
III	**Phytogeography:** Principles, concepts and types of phytogeography; Phytogeographical regions of the world, Phytogeographical regions of India; Vegetation types of India, vegetation types of Eastern Himalaya, Vegetation types of Sikkim-Darjeeling Himalayan region. Plant explorers in Sikkim-Darjeeling Himalayan region; Theories of endemism, factors for endemism, endemic plants of India, Eastern Himalaya and Sikkim.	15
IV	**Environmental science:** Introduction to environmental science and sustainability, environmental laws and problems. Environmental risk assessment and management. Environmental Pollution, Introduction to remote sensing and GIS; remote sensing satellites; data analysis and image processing; application of remote sensing; tools of GIS, Application of GIS in ecology and Environmental Science	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1.Ambasht RS, Ambasht NK. *Text Book of Plant Ecology* (15th Edn.). CBS Publishers and Distributors, New Delhi (2008).

2.Kormondy EJ. *Concepts of Ecology* (4th Edn.). Prentice-Hall of India Pvt. Ltd. (1996).

3. Krebs CJ. *Ecology: The Experimental Analysis of Distribution and Abundance*. Harper and Row, New York (1985).

4. Odum EP, Barrett GW. *Fundamentals of Ecology* (5th Edn.) Thompson (2005).

5. Singh JS, Singh, SP, Gupta SR. *Ecology, Environmental Science and Conservation*. S. Chand & Company Pvt. Ltd. New Delhi (2014).

6.Burough PA, McDonnell R. *Principles of Geographical Information Systems*. Oxford University Press, NY (1998).

7.Campbell JB. *Introduction to Remote Sensing*. (2nd Ed), Taylor and Francis (1996).

8.Christopher J. *Geographical Information Systems and Computer Cartography*. Longman (1997).

9.Reeves, Robert G. *Manual of Remote Sensing* (Vols. I & II). American Society of Photogrammetry and Remote Sensing, USA (1999).

10. Singh RB. *Phytogeography and Biodiversity*. Rawat Publications, Jaipur-302004 (2009).

Core Theory; Course Level:600

Total Marks: 100 L+T+P: 4+0+0=4 Credits

Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr

BOT-C-602	**CYTOGENETICS AND PLANT BREEDING**	
Course Learning Outcome	After the completion of the course, students will be able to….. 1. Enumerate the components of cell biology, genetics, and plant breeding. 2. Describe structure and functions of cell organelle, genes, and related biomolecules. 3. Explain molecular genetics with mechanisms of replication, transcription, and translation. 4. Design experiments to understand inheritance pattern of traits and their applications in plant improvement.	
Unit	**Topics**	**Hrs**
I	**Cell Biology:** Ultrastructure of plant cell organelles- cell wall, cell membrane, endoplasmic reticulum, Golgi body, mitochondria, chloroplast, ribosomes, vacuole, spherosomes, nucleus, nucleolus; cell cycle. Cytoskeleton and molecular organization of a plant cell.	15
II	**Classical Genetics:** Classical theories, dominance, codominance and incomplete dominance, gene interaction and epistasis, concept of gene and cistron, cis-trans complementation experiment, gene concept.	15
III	**Molecular Genetics:** Central dogma, structure, composition and functions of DNA and RNA. Eukaryotic and prokaryotic gene architecture, replication of DNA in prokaryotes; Transcription and Translation.	15
IV	**Plant Breeding:** Importance and applications of plant breeding, genetic variability, selection, hybridization, self and cross pollination, domestication, apomixis, test cross and back cross, heterosis breeding, wide hybridization, gene-environment interactions and molecular breeding.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Alberts B. *Molecular Biology of the Cell*, 6th edition. Garland Science (2014).
2. Griffiths AJF, W essler SR, Carroll SB, Doebley J. *Introduction to Genetic Analysis*, 11th edition. W.H. Freeman & Worth Publishers (2015).
3. Hartwell L, Goldberg ML, Fischer J, Hood L. *Genetics: From Genes to Genomes*, 6th edition. McGraw-Hill Education (2017).
4. Hartl Daniel L,CochraneBruce J. *Genetics: Analysis of Genes and Genomes* 9th edition. Jones & Bartlett Learning (2017).
5. Karp Gerald, Iwasa Janet, Marshall Wallace. *Karp's Cell Biology*, 8th edition. Wiley (2018). ISBN: 978-1119454175.
6. Klug WS, Cummings MR, Spencer CA, Palladino MA, Darrell Killian. *Concepts of Genetics*, 12th edition. Pearson (2019).
7. Krebs JE, Goldstein ES, Kilpatrick ST. *Lewin's GENES XII*. Jones and Bartlett Publishers, Inc.(2017).
8. Lodish H, Berk A, Kaiser CA, Krieger M, Bretscher A. *Molecular Cell Biology*, 8th edition. W H Freeman &Co.(2016).
9. Pierce BA. *Genetics: A Conceptual Approach* 6th edition. W. H. Freeman (2016).
10. SnustadPD,Simmons MJ. *Principles of Genetics*, 7th edition. John Wiley & Sons, Inc.(2015).
11. Watson JD, Tania AB , Stephen PB, Alexander G, Michael L, Richard L. *Molecular Biology of the Gene*, 7th edition. Pearson Education (2017).
12. Singh BD, Shekhawat, NS. *Plant Breeding in the 21st Century*, 1st edition.Scientific Publishers (2019). ISBN: 978-9389061277

Open Theory; Course Level:600

Total Marks: 50 L+T+P: 2+0+0=2 Credits

Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr

BOT-V-603	**Cyber Security and Privacy (MOOC-NPTEL)** Prof. Saji K Mathew, IIT Madras	
Course Learning Outcome	CLO1. Students will understand the basics of security management, information security and related risk management. CLO2. Students will be able to recognize cyber security regulations, Cyber security and privacy in the Indian context, evolution and issues. CLO3. Students will be able to appraise choices on security and privacy.	
Unit	**Topics**	**Hrs**
I	Foundations, cyber security, information security and related concepts, Principles of information security management, Confidentiality, Integrity, Availability and related concepts. Security management, Governance, Risk and Compliance (GRC), Contingency planning, incidence response, disaster recovery and business continuity. Understanding security policy, security behaviour, Risk management: Risk identification, threat modeling, strategies.	15
II	Control strategies and protection mechanisms (Guest lecture), Cryptography for security. Regulatory landscape: EU's GDPR and its implications and other privacy and cyber security regulations, Cyber security and privacy in the Indian context, evolution and issues. Information security and privacy, Regulatory landscape: Fair information practices, US regulatory frameworks. Economics of privacy, privacy calculus and trade-offs, privacy paradox, managing stakeholders, making choices on security and privacy	15

SUGGESTED TEACHING LEARNING STRATEGIES

•Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis

• Quiz, group discussions, Case studies, and Group Projects

• Guided readings and discussions in the class/lab/field and out of the class/field/lab.

• Individual and group presentations by students on selected topics.

• Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Whitman ME, MattordHJ. *Principles of Information Security*, 6th edition, Cengage Learning, N. Delhi (2018)..
2. Darktrace,"Technology" https://www.darktrace.com/en/technology/#machine-learning, accessed November 2018.
3. Paul VK. *Is cyber security about more than protection?* EY Global Information Security Survey (2018-2019).
4. Johnston AC, Warkentin M. *Fear appeals and information security behaviors:* An empirical study. *MIS Quarterly* (2010).
5. Arce I, et al. *Avoiding the top 10 software security design flaws.* IEEE Computer Society Center for Secure Design (CSD) (2014).
6. Smith HJ, Dine T, Xu H. *Information privacy research: an interdisciplinary review*. *MIS Quarterly* (2011).
7. Subramanian R. *Security, privacy and politics in India*: a historical review. J*ournal of Information Systems Security (JISSec)* (2010).
8. Acquisti A, John LK,Loewenstein G. *What is privacy worth*? *The Journal of Legal Studies* (2013).
9. Xu H., Luo X.R., Carroll J.M., Rosson M.B. T *he personalization privacy paradox*: An exploratory study of decision-making process for location-aware marketing. *Decision Support Systems* (2011).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-604	**Advanced Microbiology**	
Course Learning Outcome	After the completion of the course, the student will be able to… CLO1. Analyze and classify microbes CLO2. Understand the basic concepts of host-parasite interaction, virus replication, genome organization,isolation, and detection. CLO3. Understand bacterial biology and its applications in various industries	
Unit	**Topics**	**Hrs**
I	**Microbes in General and Virology:** Analysis of phenetic, genetic, and phylogenetic features; Bergey's system of classification; Salient features of major groups /division. Bacterial growth; measurement. Host – pathogen interactions, genetics of bacterial virulence, acquired immunity. **Virology**: Virus Classification, Isolation, purification, detection, identification, and economic importance. Bacteriophages: classification, properties. Study of some important plant viruses.	15
II	**Microbial Genetics:** Plasmid; types and functions. Bacterial recombination; conjugation, transformation, transfection, and transduction. Transposons: molecular mechanism of transposition in bacteria- its type, detection, and regulation. Gene regulation: Operon model- regulation and attenuation (lac, trp and ara), Quorum Sensing, CRISPR-CAS; its action and application.	15
III	**Bacterial physiology:** Bacterial photosynthesis anoxygenic and oxygenic pathways; formation of various complexes and reaction centers Chemosynthesis and its mechanism. Fermentation process; lactic acid, propanoicacid, and butanol. Nitrogen Metabolism; its process and gene's involved. Amino acid metabolism with reference to some of the important amino acids.	15
IV	**Applied Microbiology:** Recent developments in industrial microbiology: Sources of industrially important microbes, strain development.Fermenters, and process optimization. Microbes in food manufacture (yeast, lactobacillus,etc.) and food spoilage (*Clostridium, Escherichia, bacillus*etc). Microbial production of pesticides- degradation of xenobiotics, and bioremediations.Antibiotics; types and modes of action; beneficial and harmful aspects.	15

SUGGESTED TEACHING LEARNING STRATEGIES

• Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
• Quiz, group discussions, Case studies, and Group Projects
• Guided readings and discussions in the class/lab/field and out of the class/field/lab.
• Individual and group presentations by students on selected topics.
• Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Stephen K. Tyring. *Antiviral Agents, Vaccines, and Immunotherapies*. Publisher: Marcel Dekker(2004).
2. Dube R, Mukerji KG. Microbial Technology A. P. H. Publishing corporation, New Delhi (2001).
3. Jay JM.*Modern food Microbiology*, CBS Publishers and Distributors, New York. (1987).
4. Frazier WC,Westhoff DC. *Food Microbiology* Tata Mc Graw- hill Publishing Company Ltd. New Delhi (1995).
5. Gadd G, Sariaslani S. *Advances in Applied Microbiology*, Elsevier.(2020).
6. Dale JW, Simon P. .*Molecular Genetics of Bacteria.* John Wiley & Sons, New York(2004).
7. Jayaraman J, Verma JP. *Fundamentals of Plant Bacteriology*. Kalyani Publ., Ludhia. (2002).
8. Ketchum PA. 1988. Microbiology, concepts and applications. John Wiley and Sons. New York.
9. Stainer R, Ingrahan Y, John L. Wheelis ML, Painter PR. Microbial World 5th edition. Prentice-Hall India, Pvt. Ltd. New Delhi (1990).
10. Schlegel HG.General Microbiology. Cambridge University Press. London, 587pp. (1986).
11. Prescott, Harley and Klein's, VII Edition. Microbiology. McGraw-Hill International Edition (2008).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-605	**PLANT SYSTEMATICS**	
Course Learning Outcome	After the completion of course, students will be able to.. CLO1. Describe the modern trends in classification and phylogeny CLO2. Explain diverse approaches employed in biosystematic studies. CLO3. Understand the types of variations, evolutionary mechanisms and phylogeny of angiosperms.	
Unit	**Topics**	**Hrs**
I	**Elements of classification:** Systems of Angiosperm Classification: Phenetic versus phylogenetic systems. Principles of Taxometrics. Cladistics in taxonomy- Phylogenetic terms; plesiomorphic and apomorphic characters; homology and analogy; parallelism and convergence; monophyly, paraphyly, polyphyly; phylogenetic diagram; phylogenetic data analysis.	15
II	**Approaches in plant systematics:** Difference in Systematics and Taxonomy; Principles and procedures of plant systematics; Plant speciation: Allopathic, abrupt, sympatric, hybrid, apomictic speciation, Isolating mechanisms; Biosystematics: Steps in biosystematics, categories, importance of Biosystematic studies.	15
III	**Variation and evolution:** Types of variation; variance analysis; reproductive system-types; outbreeding; Hybridization-introgressive hybridization; recognition of hybrids; stabilization of hybrids; outbreeders with internal barriers; inbreeding. Evolution-mutation; random genetic drift; natural selection; Darwinian fitness and fitness coefficient; molecular evolution.	15
IV	**Phylogeny of angiosperms:** Origin of angiosperms; age of angiosperm; molecular dating. Are angiosperms monophyletic or polyphyletic; possible ancestor and theories; origin of monocot. Basal living angiosperms; Evolutionary trends- evolution of inferior ovary.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Angiosperm Phylogeny Group. *An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants*: APG II. Botanical Journal of the Linnaean Society 141: 399-436 (2003).
2. Cracknell AP, Hayes L .*Introduction to Remote Sensing*. CRC Press, Boca Raton, USA (Special Indian Edition) (2009).
3. Crawford DJ. *Plant Molecular Systematics*. Cambridge University Press, Cambridge, UK (2003).
4. Cronquist A. *An integrated system of classification of flowering plants.* Columbia (1981).
5. Jain SK. *Manual of Ethnobotany*. Scientific Publisher; Second edition (1995).
6. Judd WS, Campbell CS, Kellogg EA, Stevens PA, Donoghue MJ. *Plant Systematics*: A Phylogenetic Approach. Sinauer Associaes, Inc., Massachusetts (2002).
7. Nei M, Kumar S.*Molecular Evolution and Phylogenetics.* Oxford University Press, New York (2000).
8. Raven PH, Begr LR, Hassenzahl DM. *Environment*. 6th edition. John Wiley & Sons, Inc., New York (2008).
9. Semple C, Steel MA. *Phylogenetics.* Oxford University Press, Oxford (2003)..
10. Simpson MG.*Plant Systematics*. Elsevier, Amsterdam (2006)..

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-606	**PLANT METABOLISM**	
Course Learning Outcome	After the course, the student will be able to: CLO1. Describe and explain certain key plant metabolic pathways and their inter relationships. CLO2. Describe in detail the biosynthesis of different macromolecules from their precursors. CLO3. Explain the mechanisms of gene expression and its regulations.	
Unit	**Topics**	**Hrs**
I	**Nitrogen and sulphur metabolism:** Nitrogen Metabolism: Biological nitrogen fixation, nodule formation and nod factors, mechanism of nitrate uptake and reduction, ammonium assimilation, biosynthesis of amino acids, Urea cycle. Sulfur metabolism: Sulfate uptake, transport and assimilation, Glutathione biosynthesis and functions	15
II	**Fat metabolism:** Fatty acid biosynthesis and oxidation, Glyoxylate cycle, Ketone bodies	15
III	**Protein synthesis:** Transcription unit – start site, upstream promoter regions, terminator; Structure and function of RNA polymerases, Sigma factors; Mechanism of transcription-initiation, elongation and termination – Rho-dependent and independent termination. Transcriptional factors– general features, motifs - zinc fingers, leucine zippers, helix-turn helix, homeodomains; Translation machinery – ribosomes; charging of tRNA molecules and formation of aminoacyl-tRNA; mechanism - initiation, elongation, Differences in translation between *E. coli* and eukaryotes	15
IV	**RNA editing, RNA interference and Regulation of gene expression** Post-transcriptional modifications: Splicing, 5' cap formation, 3' polyadenylation; RNA editing. RNA interference (RNAi)- mechanism and significance. Operon concept – inducible and repressible operons. E.g., lac, trp, and his operons; Bacterial small RNA (sRNA) and its role in regulation of gene expression.	15

SUGGESTED TEACHING LEARNING STRATEGIES

• Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
• Quiz, group discussions, Case studies, and Group Projects
• Guided readings and discussions in the class/lab/field and out of the class/field/lab.
• Individual and group presentations by students on selected topics.
• Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Taiz L, Zeiger E. *Plant Physiology*. Sinauer Associates, Inc. Publishers. Sunder land, USA (2018).
2. Lodish H, Berk A, Zipursky SL, Matsudaira P, Baltimore D, Darnell J.*Molecular Cell Biology* (IV Edition). W. H. Freeman and Company, New York, USA (2000).
3. Nelson D, Cox M. *Lehninger Principles of Biochemistry*. 8th Edition, W.H.Freeman and Company. New York (2021).
4. Nobel PS. *Physiochemical and Environmental Plant Physiology* (Second Edition). Academic Press, San Diego, USA (1999).
5. Bowsher C. *Plant Biochemistry* 2nd edition. Garland Science, UK (2021).
6. Berg JM, Tymoczko JL, Stryrer L. *Biochemistry*. 5th Ed. Wlt. Freeman and Company, New York. (2002)
7. Buchanan BB, Gruissem W, Jones RL. *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists Maryland, USA (2015).
8. Heldt HW, Piechulla B. *Plant Biochemistry*. Academic Press, California (2021).
9. Hopkins WG. *Introduction to Plant Physiology*. John Wiley and Sons, Inc., New York, USA (1995).
10. Williams JP, Khan MU, Lem NW. *Physiology, Biochemistry and Molecular Biology of Plant Lipids.*Springer (2010).
11. Ahmad A, Abrol YP. *Sulphur metabolism in plants*. Springer-Verlag (2013).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-607	**GENE EXPRESSION AND REGULATION**	
Course Learning Outcome	After successful completion of the course students will be CLO1. Able to classify different types of RNA, TFs and other regulatory sequences associated with transcription in prokaryotes and eukaryotes. CLO2. Relate genetic code, anticodons, and other essential components of translation in cells. CLO3. Explain the gene regulation mechanism in prokaryotes and eukaryotes. CLO4. Compare the prokaryotic and eukaryotic gene regulation and their application in various fields of life sciences.	
Unit	**Topics**	**Hrs**
I	**Transcription:** Classes of RNA molecules, Transcription factors, activators and repressors, transcription in prokaryotes- initiation, elongation and termination, Transcription in Eukaryotes. Promoters, hypersensitive sites, Upstream activation sites and enhancers, Capping and polyadenylation, Splicing mechanisms, rRNA precursors, small RNAs, Micro RNAs, RNA editing, RNA transport, exon shuffling	15
II	**Translation:** The Genetic Code, the decoding System, Codon Anticodon interaction, special properties of the prokaryotic Initiator tRNAfMet, Transfer RNA genes, Protein Synthesis in prokaryotes and eukaryotes, Inhibitors and Modifiers of protein synthesis. Post-translational modifications.	15
III	**Gene regulation in Prokaryotes**: General aspects of Regulation, transcriptional regulation - inducible and repressible, positive regulation and negative; Operon concept – Lactose, Tryptophan, and galactose operon, Regulation of Translation, Regulation of the synthesis of Ribosomes, Unregulated changes in gene expression, Feedback Inhibition. RNA interference, mRNA half-life, riboswitches, ribozymes	15
IV	**Gene regulation in Eukaryotes:** Regulatory strategies in Eukaryotes, Gene alteration (Gene loss, Gene amplification, Gene rearrangements), Regulation mediated through TFs, Regulation of enhancer activity, role of chromatin changes in regulating gene expression, RNA processing, RNA splicing, RNA degradation and RNA interference, Regulation of gene expression in plant cells by light. Transcriptional Control by hormones and signaling factors, Translational control.	15

SUGGESTED TEACHING LEARNING STRATEGIES

• Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
• Quiz, group discussions, Case studies, and Group Projects
• Guided readings and discussions in the class/lab/field and out of the class/field/lab.
• Individual and group presentations by students on selected topics.
• Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Lehninger, Nelson and Micheal Cox (2017). Principles of Biochemistry 7 th Edition. W. H. Freeman and Macmillan Learning, New York
2. Lewin B. Micheal Stone (2008). Genes IX. Jones and Barlett Publishers Ltd.
3. Russell P. iGenetics: A Molecular Approach 3rd Edition. Pearson Publishers (2016).
4. Benjamin Pierce . Genetics: A conceptual Approach 5th Edition. W. H. Freeman And Company (2013).
5. Cooper G. The Cell: A Molecular Approach 8th Edition. Oxford University Press (2018).
6. Brown TA. Gene Cloning and DNA Analysis: An Introduction. 8th Edition. Wiley and Sons, (2021).
7. Walker JM,RapleyR. Molecular Biology and Biotechnology 6th Edition. RSC Publishing, (2015).
8. Watson JD, BakerTaniaABaker TA. Stephen B, Alexander G, Levine M, Losic R. (2016). Molecular Biology of the gene 7th edition Pearson Publishers (2016).
9. Lodish H, Berk A, Zipursky SL, Matsudaira P, Baltimore D, Darnell J. Molecular Cell biology: 9th Edition. W.H.Freeman& Co. (2021).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-608	**ESSENTIALS OF ECOLOGY**	
Course Learning Outcome	After the course, the student will be able to CLO1. Describe population and community ecology dynamics CLO2. Differentiate the concepts of population and community ecology CLO3. Illustrate the structure and function of ecosystem CLO4. Articulate the different systems of the Earth	
Unit		**Hrs**
I	**Population Ecology:** Characteristics of populations, Population growth, Population regulation, r and k Selection strategies, species interaction types, Lotka-Voltera Model of competition, Theory of resource capture and sharing, Herbivores counter measures, Model of predator prey dynamics	15
II	**Community Ecology:** Community concepts and nature (unit theory and continuum view), structure and attributes, Keystone species, Ecological succession, mechanism and theories of succession, Climax concept, Species diversity, Ecological Niche, Vegetation sampling approaches.	15
III	**Ecosystem structure, function and management:** Ecosystem structure and function, Primary production and its measurements and regulating factors, plant biomass and turnover, Litterfall and litter decomposition, Nutrient cycling, food chain, food web, energy flow models, Sustainable development, Sustainability indicators, Ecological economics, Ecosystem services	15
IV	**Earth's system**: Major rock and ore forming minerals, Impact of mining, Soil formation (weathering and erosion), type and profile, Soil properties (Physical, chemical and biological), Disasters (Earthquake, landslides, floods) and their impact on environment, Ground and surface water, composition of the atmosphere and thermal stratification, Climate, classification, and its relationship with landscape and biomes	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Begon M, Harper JL,Townsend, CR. Ecology: Individuals, Populations and Communities. Blackwell Scientific Publications (2006).
2. Chapman JLK, Reiss MJ. Ecology: Principles and Applications. Cambridge University Press (1997).
3. Dash MC, Dash SP. Fundamentals of Ecology (3rd edn.). Tata McGraw -Hill Publishing Co., New Delhi (2009).
4. Kormondy EJ. Concepts of Ecology (4th edn.). Prentice Hall of India, New Delhi (1996).
5. Narwal SS, Patrick T. Allelopathy in Agriculture and Forestry. Scientific Publishers, Jodhpur (1994).
6. NaskarK, Manadal R. Ecology and Biodiversity of Indian Mangroves. Daya Books, Delhi (1999).
7. OdumEP, Barrett GW. Fundamentals of Ecology. (5th Edn.) Belmont, CA (2005).
8. Putman RJ. Community Ecology. Chapman and Hall, New York (1993).
9. Silverton JW. Introduction to Plant Population. Longman (1982).
10. Singh JS, Singh SP, Gupta SR. Ecology, Environmental Science and Conservation. S.C. Chand & Company Pvt. Ltd., New Delhi (2014).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-609	**ETHNOBOTANY AND HERBAL MEDICINE**	
Course Learning Outcome	After the completion of the course, the student will be able to…. CLO1. Describe the range of plants used for indigenous culture and herbal medicine CLO2. Explain the phytochemicals involved in the medicinal properties of different plant species. CLO3. Understand the importance of bio-resources of Eastern Himalaya.	
Unit	**Topics**	**Hrs**
I	**Ethnobotany:** Concept, history, evolution and scope; the relevance of ethnobotany in the present context; methods of ethnobotanical studies, areas of ethnobotanical studies, plants associated to indigenous culture in India.	15
II	**Herbal Medicine:** Medicinal plant research scenario in India; Diagnostic features, bioactive molecules and therapeutic value of some common medicinal plants; Standardization of herbal drugs; Commercial cultivation of medicinal plants; Conservation of medicinal plants; Neutraceuticals and medicinal food	15
III	**Chemistry and Pharmacology of Herbal Drugs:** Classification of active plant constituents with source and phytotherapeutic properties; Routes of drug administration; Absorption, metabolism and fate of drugs; Mechanism of drug action; Drug tolerance. Metabolic pathways of some important secondary metabolites.	15
IV	**Eastern Himalayan Bioresources:** Definition and demarcation of the Eastern Himalaya. Geographical background of Eastern Himalaya. Classification Bio-resources of Eastern Himalaya: medicinal plants, aromatic plants, wild edible plants, dye yielding plants, fiber yielding plants, spices and condiments, masticatories, ethno-veterinary plants; important Non-Timber Forest Products (NTFP's) of Eastern Himalaya.	15

SUGGESTED TEACHING LEARNING STRATEGIES

• Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
• Quiz, group discussions, Case studies, and Group Projects
• Guided readings and discussions in the class/lab/field and out of the class/field/lab.
• Individual and group presentations by students on selected topics.
• Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Cotton CM. *Ethnobotany – Principles and applications*. John Wiley and Sons – Chichester (1997).
2. Anthony C. *Applied Ethnobotany - People, Wild Plants use & Conservation.* Earthscan Publications Ltd. London & Sterling, VA (2001).
3. Das AP, Pandey AK. *Advances in Ethnobotany*. Bishen Singh and Mahendra Pal Singh, Dehradun (2007).
4. Dhar U. *Himalayan Biodiversity: Conservation Strategies.*GyanodayaPrakashan(1993).
5. Christopher G. *Ethnobotany*. Apple Academics Press Inc. 3333 MistwellCrescent,Oakville, ON L6L 0A2. (2012).
6. Jain SK. *Manual of Ethnobotany* (2nd Revised edition).Scientific Publishers (India). Jodhpur-342001 (1995)
7. Pusphanganthan*et al*. *Conservation and Ecological Economics of Biodiversity*. (1997).
8. Simpson BB, Conner-Ogorzaly M. *Economic Botany: plants of our world*. Mc Graw Hill (1986).
9. Subba TB, Ghosh GC. *Anthropology of North-East India*. Orient Longman Limited, New Delhi (2003).
10. Albuquerque UP, Cruz da Cunha LVF, Paiva de Lucena RF, Alues RRN (Eds.). *Methods and Techniques in Ethnobiology and Ethnoecology.* Humara Press, Springer, New York. ISBN: 978-1-4614-8635-0. (2014).

Elective Practical; Course Level:600

Total Marks: 100 L+T+P: 0+2+2=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hr

BOT-P-610	**MICROBIOLOGY LAB**
Course Learning Outcome	After the course, the student will be able to CLO1. Isolate and culture bacteria from nature, and to discern important microscopic characteristics of microbes. CLO2. Identify bacteria using biochemical tests CLO3. Isolate DNA from microbes CLO4. Use fermentation technology

Laboratory Experiments

1. Microscopy and Micrometry, dimensions of microbes using ocular- and stage-micrometer.
2. Differential staining of bacteria using Gram-stain; Endospore staining using Malachite Green
3. Isolation of bacteria from soil through serial dilution.
4. Study of bacterial growth curve and determination of generation time.
5. To determine the effect of pH and temperature on microbial growth
6. Detection of plant viruses from infected leaf tissues using ELISA and Western Blot. (Demo)
7. Determination of gas, acid production by the bacteria during fermentation.
8. Determination of hydrolysis starch, fat, protein.
9. Antibiotic susceptibility test
10. Isolation and estimation of DNA from bacteria.

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Okafor N, Okeke BC. . *Modern Industrial Microbiology and Biotechnology*, 2nd Edition, CRC Press, Boca Raton(2018).
2. Aneja KR. *Laboratory Manual of Microbiology and Biotechnology*, Medtech, New Delhi(2016).
3. Noordam D. Identification of Plant Viruses, Methods and Experiments. Oxford & IBH, Ne (1973).
4. Norris JR, Ribbons DW. Methods in Microbiology. Academic Press, London, (1970).
5. Forster D, Taylor SC. Plant Virology Protocols: From Virus Isolation to Transgenic Resistance. Methods in Molecular Biology. Humana Press, Totowa, New Jersey (1998).
6. Matthews REF. Diagnosis of Plant Virus Diseases. CRC Press, Florida, (1993).
7. Garrity GM, Krieg NR, Brenner DJ. 2006. Bergeyís Manual of Systematic Bacteriology: The Proteobacteria. Vol. II. Springer Verlag, New York (2006).

Elective Practical; Course Level:600	
Total Marks: 100	L+T+P: 0+2+2=4 Credits
Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hr	
BOT-P-611	**PLANT TAXONOMY LAB**
Course Learning Outcome	After the completion of the course, the students will be able to…. CLO1. Integrate practical ideas about different families of plants. CLO2. Formulate experimental protocols associated with morphological attributes of plants. CLO3. Demonstrate the phylogenetic analysis and mapping.

Laboratory Experiments

1. Live plants/ Herbarium specimens of the following families will be provided in the class for description and identification (classification based on APG II, 2003):
2. Specimens collection and handling
3. Taxonomic literatures – Check lists, Floras, Keys, Monographs and Laboratory identification manuals.
4. Preparation of artificial keys.
5. Understanding of phylogenetic classifications.
6. Basal Angiosperm and Magnoliids: Nymphaeaceae, Magnoliaceae
7. Basal Monocots: Araceae, Alismataceae
8. Petaloid monocots: Liliaceae, Smilacaceae, Alliaceae, Orchidaceae
9. Commelinids: Commelinaceae, Poaceae, Cyperaceae
10. Basal Eudicots and Caryophyllids: Ranunculaceae, Caryophyllaceae
11. Rosids: Euphorbiaceae, Rosaceae, Fabaceae, Cucurbitaceae
12. Asterids: Solanaceae, Lamiaceae, Apiaceae, Asteraceae
13. Hand drawing of the botanical specimens and vocabulary
14. Handling of stereo zoom microscope for taxonomic studies
15. Geoinformatics and map reading
16. Preparation of database (digital) of the local/regional plants (bryophytes, pteridophytes, gymnosperms, angiosperms- dicot, monocot)
17. Preparation of the taxonomic keys of the laboratory worked out plants
18. Cladogram construction and analysis of the laboratory worked out plants
19. Botanical tour to the selected areas – minimum two (field and institutional visit) and preparation of the visit reports

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Angiosperm Phylogeny Group. *An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants*: APG II. Botanical Journal of the Linnaean Society 141: 399-436 (2003)..
2. Cracknell AP, Hayes L. *Introduction to Remote Sensing*. CRC Press, Boca Raton, USA (Special Indian Edition) (2009).
3. Cronquist A. *An integrated system of classification of flowering plants*. Columbia (1981).
4. Ghoshal S. *Taxonomy-Principle and Problems*. Techno World.90/6 A, M.G.Road, Kolkata-700007. ISBN:978-93-88347-54-9 (2020).
5. Judd WS, Campbell CS, Kellogg EA, Stevens PA and Donoghue MJ. *Plant Systematics: A Phylogenetic Approach*. Sinauer Associates, Inc., Massachusetts (2002).
6. Nei M, Kumar S. *Molecular Evolution and Phylogenetics*. Oxford University Press, New York (2000).
7. Rana TS, Nair KN, Upreti DK. *Plant Taxonomy and Biosystematics-Classical & Modern Methods.* New India Publishing Agency, New Delhi-1100034 (2014).
8. Santra SC, Chatterjee TP, DasAP. *College Botany - Practical*. Vol.II. New Central Book Agency (P) Ltd, 8/1 Chintamoni Das Lane, KolkT 700-009 (2004).
9. Semple C, Steel MA. *Phylogenetics*. Oxford University Press, Oxford (2003).
10. Sinha RK. *Practical Taxonomy of Angiosperms*. IK International Publishing House Pvt.Ltd (2010).

Elective Practical; Course Level:600

Total Marks: 100 L+T+P: 0+2+2=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hr

BOT-P-612	**PLANT PHYSIOLOGY LAB**
Course Learning Outcome	After the completion of the course, the students will be able to… CLO1. Have a practical idea about different analytical techniques. CLO2. Describe and explain the experimental protocols associated with quantification of different metabolites. CLO3. Demonstrate certain enzyme assays and free radical scavenging properties of plant samples.

Laboratory Experiments

1. Extraction and estimation of total free amino acids from plant sample
2. Determination of the absorption spectrum of chlorophylls
3. Colorimetric estimation of IAA
4. Determination of catalase activity from plant sample
5. Determination of α- amylase activity in germinating seeds
6. Estimation of alkaloids from plant sample
7. Determination of flavonoids from plant sample
8. Determination of DPPH radical scavenging activity of methanolic plant extracts
9. Determination of rate of transpiration
10. Estimation of reducing sugar by dinitrosalicylic acid method

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Choudhury MA, Gupta KK. *Practical Plant Physiology*. New Central Book Agency (2009).
2. Kochhar SL, Gujral SK. *Comprehensive Practical Plant Physiology*. Laxmi Publications (2011).
3. Inam A, Sahay S, Akhtar A. *Experiments in Plant Physiology, Biochemistry & Ecology*. Narendra Publishing House (2022).
4. Larcher W. *Physiological Plant Ecology*, Springer (2003).
5. Plummer D. *An introduction to Practical Biochemistry.* MCGraw Hill Education (2017).
6. Sadasivam S. *Biochemical Methods*.New Age International Pvt Ltd Publishers (2018).
7. Scopes RK.*Protein purification: Principles and Practice*. Springer (2010).
8. Wilson K, Walker J. *Principles and Techniques of Practical Biochemistry and Molecular Biology.* Cambridge University Press (2000).
9. Katoch R. *Analytical Techniques in Biochemistry and Molecular Biology.* Springer (2011).
10. Farell SO, Taylor L. *Experiments in Biochemistry: A Hands-on Approach.* Brooks/Cole (2005).

Elective Practical; Course Level:600

Total Marks: 100 L+T+P: 0+2+2=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hr

BOT-P-613	**MOLECULAR BIOLOGY AND GENETIC ENGINEERING LAB**
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Isolate genomic DNA and use the electrophoresis technique. CLO2. Prepare competent cells, use restriction enzymes, clone the genes, and use PCR and RT PCR thermal cyclers for various experiments. CLO3. Observe, record, interpret, and report the outcome of the experiments in scientific language.

1. Isolation of plasmid DNA from bacterial culture and separation on Agarose gel electrophoresis.
2. Isolation of total RNA from plant cells and separation of RNA by formaldehyde/agarose gel electrophoresis.
3. Western blotting techniques for protein expression studies
4. Preparation of Competent cells
5. Restriction digestion of plasmid- single and double digestion- determination of molecular weight- physical mapping.
6. Cloning of gene of interest in appropriate vector- insertional inactivation/ Blue white selection
7. Isolation of plasmid from the recombinant clone, restriction digestion and agarose gel electrophoresis- confirmation of size by insert
8. IPTG induction of expression of cloned gene in E coli: SDS-PAGE.
9. PCR amplification of DNA, RAPD/ISSR, gel electrophoresis- analysis of fragments
10. cDNA synthesis, isolation of target cDNA using degenerate primers
11. Gene expression analysis using SYBR green assay.

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Muller JH. A short course in bacterial genetics: a laboratory manual and handbook for E coli and related bacteria, Cold Spring Harbor Laboratory Press, USA (1992).
2. Muller JH. Experiments in molecular genetics. Cold Spring Harbor Laboratory Press, USA, (1972).
3. Sambrook J, Fritsch EF, Maniatis T. Molecular cloning: a lab manual, 2nd edition-, Cold Spring Harbor Laboratory Press, USA, (1989).

Elective Practical; Course Level:600

Total Marks: 100 L+T+P: 0+2+2=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hr

BOT-P-614	**ECOLOGY LAB**
Course Learning Outcome	After the completion of the course, the student will be able to… CLO1. Generate quantitative vegetation data from the field CLO2. Test the plant diversity of an area CLO3. Identify plant communities of an area CLO4. Monitor the plant functional attributes of an area

Laboratory Experiments

1. To evaluate the importance value Index (IVI) of different species.
2. Determination of leaf area Index (LAI)
3. Determination of minimum size of quadrat by species area curve
4. Determination of Water holding capacity of soil
5. To study frequency of tree species and to compare the frequency distribution with Raunkiaer's standard frequency diagram.
6. Determination of plant biomass by harvest method in grassland
7. To calculate the concentration of dominance (cd) of different species.
8. To study plant species diversity of an area.
9. To determine forest floor litter mass and categorized it into different components.
10. Studies of physico - chemical properties of soil-Texture (b) Porosity (c) Water holding capacity (d) organic matter content
11. Study of soil profile in a forest.
12. Study of clump characteristics of bamboo

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Maiti SK. Handbook of methods in environmental studies Soil, air and water analysis APD Publishers, Jaipur (2003).
2. Banik RL. A Manual for Vegetative Propagation of Bamboos. Technical Report No. 6, International Network for Bamboo and Rattan Noida (1995).
3. Bisht NS, Ahlawat AS. Seed Technology. Information Bulletin no.7. State Forest Research Institute (SFRI), Arunachal Pradesh (1999).
4. FSI State of Forest Report. Forest Survey of India, Dehradun (2013).
5. Husch B, Beers TW, Kershaw JA. Forest Mensuration (4th Edn.) John Wiley and Sons, Inc New York (2003).
6. Jha LK, Sen-Sharma PK. Forest Entomology. Ashish Publishing House, New Delhi (1994).
7. Joseph G. Fundamentals of Remote Sensing (2nd Edn.) University Press (2005).
8. Lillesand TM, Kiefer RW. Chipman JW. Remote Sensing and Image Interpretation (5th Edn.). Wiley India (2004).
9. Misra R. Ecology Workbook (Reprint Edn.). Scientific Publishers, Jodhpur (2012).
10. Mueller-Dombois D. Ellenberg H. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York (1974).

Elective Practical; Course Level:600

Total Marks: 100 L+T+P: 4+0+0=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hr

BOT-E-615	**HERBAL MEDICINE ANALYSIS LAB**
Course Learning Outcome	After the completion of the course, the students will be able to… CLO1. Illustrate the classification of crude drugs CLO2. Demonstrate the use of different analytical instruments. CLO3. Determine the qualitative and quantitative properties of herbal drugs.

Laboratory Experiments

1. Study of powdered drugs – physical, chemical and microscopic examinations.
2. Quantitative microscopy of leaf drug – stomatal frequency and stomatal index,
3. Determination of palisade ratio, vein islet number and vein islet termination number.
4. Qualitative determination of alkaloids, tannins, steroids and saponins from medicinal plants
5. Determination of water soluble and water insoluble ash from crude drugs.
6. Determination of foaming index from crude drugs
7. Determination of titratable organic acid from leaves and fruits
8. Determination of ascorbic acid from plant sample
9. Estimation of phytic acid
10. Determination of total phenol content from powdered drugs.
11. Determination of free radical scavenging activity of methanolic extracts of powdered drugs.
12. Quantitative estimation of total flavonoids content of drugs.

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Bajracharya D. *Experiments in Plant Physiology*.Narosa Publishing House, New Delhi (1998).
2. Bhattacharya A and Vijay Laxmi. *Methods and techniques in plant physiology*, New India Publishing Agency, New Delhi (2015).
3. Evans WC. *Trease and Evans Pharmacognosy*, Saunders Elsevier, Edinburgh (2009).
4. Harborne JB. *Phytochemical Methods- A guide to modern techniques of plant analysis*. Springer (India) Private Limited, 17 BarakhambaRoad,New Delhi-110001. ISBN: 978-81-8128-310-8 (1998).
5. Mandal SC, Mandal V and Das AK. *Essentials of Botanical Extraction.* Academic Press, London (2015).
6. Pawar HA. *A Practical book on Pharmacognosy and Phytochemistry* (Vol. I & II). Everest Publishing House, Appa Balwant Chowk, Pune-411030. M.S (2018).
7. Shah B, Seth AK. *Text Book of Pharmacognosy and Phytochemistry* (Vol. I, II & III). Reed Elsevier India Private Limited (2010).

Skill Enhancement Course; Course Level:600

Total Marks: 50 L+T+P: 1+1+0=2 Credits

Lecture: 15 hrs. + Tutorial: 15 hrs. + Practical: 0 hr.

BOT-S-616	**RESEARCH METHODOLOGY**	
Course Learning Outcome	After successful completion of the course, the students will be able to.. CLO1. Enumerate different types of scientific articles and components of articles. CLO2. Find appropriate journals for the research articles and enlist the quality parameters of the publications CLO3. Describe the IPR related to scientific writings. CLO4. Create scientific articles/projects using scientific writing skills	
Unit	**Topics**	**Hrs**
I	**Scientific writings:** Introduction, online sources of literature, Type of scientific articles (Letter, perspectives, news, correspondence, short note, research article, review article), Scientific format of a paper (Title, authors and affiliations, Highlights, Graphical abstract, abstract, keywords, Introduction, Materials and Methods, Results, Discussion, summary/conclusion, acknowledgment, authors contribution, Conflict of interest, Supplementary materials, References), Various referencing styles, citation styles. Concept notes, research projects, scientific content, and blogs.	15
II	**Publication of the articles:** Finding the appropriate journals, Journal Impact Factors, ABDC Ranking of journals, Clarivate, Scopus, Web of Science, Google Scholar, H index, I10 index, UGC CARE list, IPR with special reference to copyrights and ethical issues related to scientific writing: Introduction to IPR, Types of IPRs. Plagiarism, tools of plagiarism, paraphrasing.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Shoja M, Arynchyna A, Loukas M, D'Antoni AV, Sandra M. BuergerMK, Karl MR, Tub bs S. A Guide to the Scientific Career: Virtues, Communication, Research and Academic Writing. Editor(s):; First published:18 October 2019; Print ISBN:9781118907429 John Wiley & Sons. (2019).
2. Ahuja VK, Law relating to Intellectual Property rights, 2 nd Edition,LexisNexis (2013).
3. Margreth B. Intellectual Property, New York Aspen publishers (2009).
4. Tewari R, Bhardwaj M. Intellectual property Rights A primer for academia, Publication Bureau Panjab University Chandigarh.ISBN: 81-85322-92-9 Edition: 2021 Printer: Jatinder Moudgil Manager Press Panjab University, Chandigarh-160014, India (E Book by DST)
5. Iphofen R. Handbook of research ethics and scientific integrity. Cham: Springer (22020).
6. Sharma OP. 2008. Journal impact factors-essential primary quality indicators-surely not so!! Response. Current Science, 94(4), pp.426-426 (2008).
7. PaoML. On the relationship of funding and research publications. Scientometrics, 20(1), pp.257-281 (1991).
8. Anonymous. Academic Integrity and research quality, University Grants Commission, Bahadur Shah Zafar Marg, New Delhi- 110002 (2021).
9. CSIR Guidelines for ethics in research and in governance, CSIR, New Delhi (2019).
10. Muralidhar K, Ghosh A,Singhvi AK. Ethics in Science Education, Research and Governance; Indian National Science Academy: New Delhi, India, (2019).

SEMESTER-IV		
Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-651	**FUNDAMENTALS OF PLANT PATHOLOGY**	
Course Learning Outcome	After the course, the student will be able to: CLO1. Understand general characteristics of plant pathogenic organisms, including fungi, bacteria, viruses, nematodes, and mycoplasma. CLO2. Learn about the interaction between plant and pathogen in relation to the environment and the mechanisms of disease development by pathogens. CLO3. Basic concepts of molecular diagnostics and molecular basis of innate immunity CLO4.Will also be able to diagnose plant disease for proper recommendation of control measures.	
Unit	**Topics**	**Hrs**
I	**Plant pathogen interactions:** Pathogen diversity and mechanisms of disease induction by fungi, bacteria, mycoplasma, and viruses. Role of enzymes, toxin, and growth regulators in pathogenesis. Defense strategies- oxidative burst; Phenolics, Phytoalexins, PR proteins, Elicitors, defense enzymes. Plant-virus interactions (potyviruses), Plant-bacterial (Erwinia sp. and potatoes); Plant-fungus (Magnaporthe sp. and rice); Plant-nematode (Meloidogyne sp. and tomatoes); Plant-Insect interactions. Induced responses to herbivory.	15
II	**Molecular Plant Pathology:** Concepts of compatibility and specificity, gene for gene relationship. Methods of selection of resistant genotypes. Plant immune system; molecular basis of host pathogen interaction. Signaling mechanism behind the development of localized and systemic acquired resistance in plants.	15
III	**Disease detection and diagnosis:** Early detection of plant pathogens in soil, water, and plant tissues using immunodiagnostics. Immunofluorescence microscopy, in situ localization by techniques such as FISH and GISH. Bar coding as a tool for molecular identification of fungi. Serological and molecular techniques for detection of plant pathogens.	15

IV	**Sustainable Agriculture**: Microbes in agriculture- Rhizosphere,Phyllosphere, Mycorrhizae, Actinorrhizae, Tripartite associations, concepts of Biofertilizers, biopesticides, Plant growth promoting rhizobacteria (PGPRs)- Production of ammonia, IAA, siderophores, HCN, antibiotics, antifungal metabolites. Trends and future possibilities of biological control; Mass production of quality biocontrol agents- techniques, formulations, economics, field release/application and evaluation. Concepts of organic farming, natural farming and conventional farming.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Agrios GN. *Plant Pathology,* Academic Press, 5th edition. (2005)
2. Mehrotra RS. *Plant pathology.* Tata Mc Graw- Hill. Publishing Company, New Delhi. 3rd edition (2017).
3. Bilgrami KS, Dubey HC. *Text Book of modern Plant pathology,* Vikas, New Delhi, (1980).
4. Wood RKS. *Physiological Plant Pathology* Blackwell Scientific Publications, (1967).
5. Webster J. *Introduction to Fungi*. Cambridge University Press. New York.(1985).
6. Baker F, Cook RJ. *Biologist Control of Plant Pathogens*. W. H. Freeman & Co. San Francisco (1974).
7. Singh RS. *Plant Pathogens and The Fungi.* Oxford & IBH, New Delhi (1982).
8. Chet I. *Biotechnology in Plant Disease Control*. John Wiley & Sons, New York (1993)

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits Lecture: 60 hrs. + Tutorial: 0 hr. + Practical: 0 hr	
BOT-E-652	**SYSTEMATIC EVIDENCES**	
Course Learning Outcome	After completing the course, the students will be able To: CLO1. Describe and explain systematic evidence from chemical and cytological studies of plants. CLO2. Compile evidence from palynology and numerical study of plants. CLO3. Illustrate the systematic evidence from embryology, anatomy, and molecular studies.	
Unit	**Topics**	**Hrs**
I	**Chemo and cytotaxonomy:** Cytotaxonomy: Chromosome number, basic chromosome number, polyploidy, aneuploidy, chromosome morphology, karyotype, chromosome banding, meiotic analysis, scope and limitations. Chemotaxonomy: Origin of chemotaxonomy, classes of compounds and their biological significance, stages in chemotaxonomic investigations; techniques, use of chemical criteria in plant taxonomy.	15
II	**Numerical taxonomy and palynology:** Numerical Taxonomy: Principles, construction of taxonomic groups, OUTs, unit characters, character coding, measurement of resemblances, cluster analysis, phenons and ranks, discrimination, nomenclature and numerical taxonomy, merits and demerits. Palyotaxonomy: Pollen Morphology-Polarity, symmetry, NPC of pollen, exine stratification, excrescences, L/O pattern, palynogram; pollen characters of taxonomic importance.	15
III	**Embryology and anatomy:** Embryology in relation to taxonomy: Embryological characters of taxonomic importance, utilization of embryological data in solving taxonomic problems. Anatomy in relation to taxonomy: Vegetative, wood and floral anatomy, anatomical characters of taxonomic importance, use of anatomical data in understanding interrelationship and evolution of angiosperms and solving taxonomic problems.	15
IV	**Molecular taxonomy:** Introduction to molecular systematics; Generating molecular data, types of molecular data, conserved genes for taxonomic analyses – Nuclear, Plastid and mitochondrial genes; molecular characters; homoplasy, phylogeny reconstruction, methods of estimating genetic diversity using molecular data and its modifications. Applications of molecular systematics in plant taxonomy.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Angiosperm Phylogeny Group. *An update of the Angiosperm Phylogeny Grou*p (2003).
2. Crawford DJ. *Plant Molecular Systematics.* Cambridge University Press, Cambridge, UK (2003).
3. Judd WS, CampbellCS, Kellogg EA, Stevens PF, Donoghue MJ.*Plant Systematics:* A phylogenetic Approach. Sinauer Associates, Inc., Massachusetts (2002).
4. Nei M, Kumar S.*Molecular Evolution and Phylogenetics.* Oxford University Press, New York (2000).
5. Semple C, Steel MA. *Phylogenetics.* Oxford University Press, Oxford (2003).
6. MichaelGS..*Plant Systematics.*Elsevier Academic Press, Burlington, MA (2006).
7. Singh G.*Plant Systematics,* (2 ed.)Ox. & IBH Publ. Co, Pvt. Ltd., New Delhi (2004).
8. Hillis DM, MortizC. Mable BK. (eds.). Mol. *Systematics*, Sinaver Associates, Sunderland, USA (1996).
9. Judd WS, Cmpbell CS, Kollogg EA, Stevens PF,Donoghue MJ. *Plant. Systematics.* Sinauer Associates, INC, Publishers, Sunderland, Massachusetts, USA (2008).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-653	**ADVANCED PLANT PHYSIOLOGY**	
Course Learning Outcome	After the completion of course, the student will be able to.. CLO1. Describe and explain different metabolic and mechanistic aspects of major phytohormones and molecules involved in sensory photobiology. CLO2. Describe and explain the plant responses and mechanisms of tolerance to common abiotic stress. CLO3. Describe and explain the physiology of flowering, fruit development and seed germination.	
Unit	**Topics**	**Hrs**
I	**Physiology and biochemistry of phytohormones:** Structure, biosynthesis, metabolism, transport, functions and mechanism of action of: Auxins, Gibberellins, Cytokinins, Ethylene, Abscisic acid, Brassinosteroids, Salicyclic and Jasmonic acid. Peptide and other novel hormones of plants	15
II	**Sensory photobiology:** Structure, function and mechanism of action of phytochromes,cryptochromes and phototropins; photobiology of light-induced responses, stomatal movements	15
III	**Stress physiology:** **C**oncept of biological stress,plant responses and mechanisms of tolerance of various abiotic stresses: water deficit stress, salinity stress, heavy metal toxicity, freezing and heat stress, oxidative stress.	15
IV	**Reproductive physiology:** Flowering process: Photoperiodism, endogenous clock and its regulation, floral induction and development. Role of vernalization. Fruit biology: Stages of fruit development and their regulation, biochemical and related events during fruit ripening in climacteric and non-climacteric fruits. Seed biology: Hormonal regulation of seed development, metabolic events associated with seed maturation, factors regulating seed dormancy, metabolism of germinating seeds.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Taiz L, Zeiger E. *Plant Physiology.* Sinauer Associates, Inc. Publishers. Sunderland, USA (2018).
2. Nobel PS. *Physiochemical and Environmental Plant Physiology*. (Second Edition) Academic Press, San Diego, USA (1999).
3. Bowsher C.*Plant Biochemistry* 2nd edition, Garland Science, UK (2021).
4. Buchanan BB, Gruissem W, Jones RL. *Biochemistry and Molecular Biology of Plants.* American Society of Plant Physiologists Maryland, USA (2015).
5. Heldt HW, Piechulla B. *Plant Biochemistry*. Academic Press, California (2021).
6. Hopkins WG. *Introduction to Plant Physiology*. John Wiley and Sons, Inc., New York, USA (1995)
7. Willey N. *Environmental Plant Physiology*. Garland Science, Taylor and Francis, London (2016).
8. Hopkins WG.*Introduction to Plant Physiology.* John Wiley & Sons. Inc. New York (1999).
9. Fitter AH, Hay RKM.*Environmental Physiology of plants.* Academic Press (2012).
10. Davies PJ. *Plant Hormones: Biosynthesis, Signal Transduction, Action*. 3rd Edition, Kluwer Academic Publisher, Dordrecht, The Netherlands (2004).
11. Ainsworth C. *Flowering and its Manipulation*. Annual Plant Reviews, Vol. 20. Blackwell Publishing, Oxford, U.K. (2006).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-654	**GENOMICS AND PROTEOMICS**	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. To describe the genome organization and will be able to analyze the genome. CLO2. To understand and compare the genome sequencing techniques and their applications CLO3. To discuss function of genes and use various techniques to evaluate function of genes CLO4.To identify/distinguish the protein-protein interaction and will be able to use this knowledge to solve issues of plant metabolism	
Unit	**Topics**	**Hrs**
I	**Genome Organization:** Important features of bacterial and eukaryotic genome organization. Organellar genome: Mitochondria and Chloroplast genome. C-Value Paradox. Plant Genome Analysis: Classes of molecular markers & applications, genetic and physical mapping.	15
II	**Genome Sequencing:** Strategies for genome sequencing: Chain termination method, automated sequencing, pyrosequencing. Sequence assembly: Next Generation Sequencing (NGS) methods, data analysis, bioinformatics tools. Plant genome project and its applications. Applications of DNA sequencing to crop improvement.	15
III	**Functional Genomics:** Determination of the functions of genes: gene inactivation (knock-out, anti-sense and RNA interference) and gene over expression. Approaches to analyze global gene expression: transcriptome, Serial Analysis of Gene Expression (SAGE), Expressed Sequence Tags (ESTs), Massively Parallel Signature Sequencing (MPSS), microarray and its applications, gene tagging, Metagenomics. Genome editing-CRISPR-cas9 system.	15
IV	**Proteomics:** Introduction and scope of proteomics; Protein extraction, separation, detection and quantification methods. Protein sequencing and modification. Protein-protein interaction (Two hybrid interaction screening); Protein engineering; Protein chips and functional proteomics. Application of proteomics to plant sciences; Proteome database; Proteomics industry.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Town C. *Functional Genomics*. Springer Dordrecht (2002).
2. Primrose SB and Twyman R. *Principles of Gene Manipulation and Genomics*, 7th Edition, Wiley Blackman (2006).
3. Pevsner J. *Bioinformatics and Functional Genomics*, 3rd Edition, Wiley Blackwell(2015).
4. Meroni G., Petrera F. *Functional Genomics*. InTech Open publisher (2012)
5. Lesk AM. *Introduction to Genomics*. Oxford University press. Oxford, UK (2017).
6. Green MR, Sambrook J. *Molecular Cloning, A Laboratory Manual*. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, USA (2014).
7. Twyman R. *Principles of Proteomics*. Garland Science, Taylor & Francis Group, LLC, New York, USA (2013).
8. Liebler DC. *Introduction to Proteomics*- Humana Press, New York, USA (2002).
9. Brown TA. *Genome 4.* Garland Science, India (2017).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-655	**ADVANCED ECOLOGY**	
Course Learning Outcome	After the course, the student will be able to CLO1. Identify the reasons for climate change and its possible solutions. CLO2. Describe the different types of pollution and their effects on human health CLO3. Demonstrate the importance of natural resources and the need to conserve them. CLO4. Differentiate the different nutrient cycles	
Unit	**Topics**	**Hrs**
I	**Global Environmental Change:** Ozone layer depletion: causes, consequences and mitigation, Climate change: Drivers of climate change, greenhouse gas effects, Sources of greenhouse gases, Implications and mitigation, Effect of CO_2 fertilization, Eutrophication, acid rain and atmospheric deposition of nutrient and trace elements.	15
II	**Environmental Pollution:** Air, water, Soil and Noise Pollution: Types, Sources, Types of pollutants and their effect on human health Thermal water pollution, effect of heavy metals and pesticides, weedicides, chemical fertilizers on ecosystems, Radioactive pollution: Sources and health hazards, Solid waste: Sources and Effects, Ecotoxicants: Bioaccumulation, biotransformation	15
II	**Natural Resources Management:** Resources: Types, Degradation and conservation, Renewable and alternative sources of Energy Sources: Solar energy, Wind energy, water energy, Ocean energy, Geothermal energy, Bio energy: Biomass, Biodiesel Water resources management: Threats to surface water, Rain water harvesting, ground water recharge, Dams. Water quality, effluent and sewage treatment, Impact of human on natural resources and its management: Land Resources, Water resources, Energy Resources, and Mineral Resources.	15
IV	**Nutrient cycling and biogeochemical cycling:** Nutrient cycling models, Nutrients inputs and outputs to ecosystem, Storage and accumulation of nutrients in plants, Intersystem and Intrasystem nutrient cycling, Biogeochemical cycling - C, N, P and S cycle.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Burrough PA, Mc.Donnell RA. Principles of Geographical Information Systems. (2nd edn.) Oxford University Press (1998).

2. Gangstad EO. Natural Resource Management of Water and Land. Van Nostrand Reinhold, NewYork (1990).

3. Jensen JR. Introductory Digital Image Processing: A Remote Sensing Perspective (2nd Edn.). Prentice Hill Inc (2005).

4. Joseph G. Fundamentals of Remote Sensing (2nd Edn.). University Press (2005).

5. Lillesand TM, Kiefer RW, Chipman JW. Remote Sensing and Image Interpretation. (5th Edn.) Wiley India (2004).

6. Mather AS, Chapman K. Environmental Resources. Prentice Hall India (1996).

7. Ramade F. Ecology of Natural Resources. John Wiley and Sons (1983).

8. Rathore NS, Mathur AN, Kothari S. Alternate Sources of Energy. ICAR, New Delhi (2007).

9. Pawar SH, Ekal LA. Advances in Renewable Energy Technologies. Narosa Publishing House Pvt. Ltd., New Delhi (2003).

10. Tiwari, G.N. and Ghosal, M.K. (2005) Renewable Energy Resources: Basic Principles and Applications. Narosa Publishing House Pvt. Ltd., New Delhi (2005).

Elective Theory; Course Level:600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr	
BOT-E-656	**ETHNOBOTANY AND ETHNOPHARMACOLOGY**	
Course Learning Outcome	After the completion of the course, the student will be able to… 1. Understand the diverse uses of plants among the ethnic communities of North East India. 2. Demonstrate the useful plants for the welfare of human society 3. Illustrate different phytochemical present in medicinal plants and their functions.	
Unit	**Topics**	**Hrs**
I	**Himalayan Ethnobotany:** Evolution of ethnobotany as an interdisciplinary science; Indigenous knowledge and traditional practices of some Himalayan communities; Taxonomic epidermal characters and pharmacognostical studies to check adulteration. Problems and prospects of value addition applicable to plant resources. Scope for development of plant resources.	15
II	**Ethnobotany of North East India:** Major ethnic groups in North East India, their social institutions, livelihood, cultural and religious practices, Shamanism and other belief systems, sacred groove and methods of biological resource conservation. Current status of Ethnobiology, biodiversity and traditional knowledge.	15
III	**Ethnopharmacology:** Role of Ethnobotany in drug discovery. Ayurvedic drug preparation and drug adulteration. Chemical composition of few medicinal and aromatic plants, extraction and uses pertaining to typical Indian formulation of drugs. Ethnopharmacological validation of traditional medicine; approaches to drug discovery from ethnobotanical leads.	15
IV	**Natural Products from Plants:** Definition, importance and systematics and characterization of natural products. Phenolic acids, alkaloids, glycosides, terpenoids, flavonoids, steroids, tannins in plants kingdom. Function of secondary metabolites for plant defense and protection	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Cotton CM. *Ethnobotany – Principles and applications*. John Wiley and Sons, Chichester (1997).
2. Cunningham Anthony. *Applied Ethnobotany - People, Wild Plants use & Conservation.* Earthscan Publications Ltd. London & Sterling, VA (2001).
3. Das TS. *Tribal life of North - Eastern India*. Gian Publishing House (1986).
4. Das AP,PandeyAK. *Advances in Ethnobotany.* Bishen Singh and Mahendra Pal Singh, Dehradun (2007).
5. Dhar U. *Himalayan Biodiversity: Conservation Strategies*. GyanodayaPrakashan(1993).
6. Green Christopher. *Ethnobotany*. Apple Academics Press Inc. 3333 MistwellCrescent,Oakville, ON L6L 0A2. (2012).
7. Jain SK. *Manual of Ethnobotany*. Scientific Publishers, Jodhpur (1995).
8. Jain SK. *Contributions of Indian Ethnobotany*. Scientific publishers, Jodhpur(1990).
9. Shah Biren, Seth AK. *Text Book of Pharmacognosy and Phytochemistry* (Vol.I, II & III). Reed Elsevier India Private Limited (2010).
10. Subba TB, Ghosh GC. *Anthropology of North-East India*. Orient Longman Limited, New Delhi (2003).

SEMESTER-IV		
Elective Theory; Course Level: 600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-657	**PLANT DISEASES AND MANAGEMENT PRACTICES**	
Course Learning Outcome	After the completion of the course, the students will be able to.. CLO1. Explain basic concepts of plant disease epidemiology and disease management practices. CLO2. Enhance their knowledge on improving the crop for disease resistance through genetic engineering and transgenic approaches. CLO3. Understand general characteristics of plant pathogenic organisms and diseases caused by them.	
Unit	**Topics**	**Hrs**
I	**Plant disease epidemiology**: Growth, reproduction, survival, and dispersal of important plant pathogens, role of the environment and host nutrition on disease development. Computer simulation of epidemics, Disease forecasting, and its importance. Methods used in disease forecasting. Emerging issues in plant pathology; climate change and plant disease.	15
II	**Strategies fordisease management:** Basics of disease management principles. Chemical protection; nature, properties, and mode of action of antifungal, antibacterial, and antiviral chemicals; Health and environmental hazards, residual effects; and safety measures. IPM. Concepts of biofertilizers, biopesticides, andtheir modes of action to induce systemic resistance.	15
III	**Agriculture biotechnology:** Types of resistance, Molecular breeding for disease resistance, biotechnological approaches for the transfer of R- genes into susceptible plants (Rice and wheat). Testing for host resistance to diseases. Recent developments in virus management: Transgenics through RNAi and VIGS; Tissue culture-mediated and in planta transformation. Nanotechnology in agriculture.	15
IV	**Study of Plant Diseases:** Symptoms, disease cycle, and control measures of: Black wart disease of potato, Club root of crucifers, Smut of maize, Downy mildew of grapes, Powdery mildew of wheat, Apple scab, Fusarium wilt of tomatoes, Rhizome rot of ginger, Red rot of sugarcane, Brown leaf spot and blast of rice, Bacterial blight of wheat, Citrus canker, Tobacco mosaic virus, Tomato spotted wilt virus, Chirkey and foorkey of large cardamom, Root knot of vegetables, Blister blight of tea.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Subba Rao NS. *Advances in Agricultural Microbiology,* 2nd Edition, Medtech, New Delhi (2018).
2. Karban R, Baldwin IT *Induced responses to herbivory*,Chicago University Press (1997).
3. Hull R. *Plant Virology - The Principles,* Edward Arnold London (2002).
4. Gibbs A, Harrison B.*Plant Virology,* 4th Ed. Academic Press, New York (1976)
5. Noordam D. *Identification of Plant Viruses, Methods, and Experiments* . Oxford & IBH, New Delhi (1973).
6. Mehrotra RS, Aggarwal A. *Plant Pathology* . 2nd Ed. Oxford & IBH, New Delhi (2003)
7. Singh RS. *Introduction to Principles of Plant Pathology* . Oxford & IBH, New Delhi (2002)
8. Disease and Insect Resistance in Plants Singh DP, Singh A. Oxford,and IBH, New Delhi (2007).
9. Upadhyay RK, Mukherjee KG, Toxins *in Plant Disease Development and Evolving Biotechnology.* Oxford & IBH, New Delhi (1997).
10. Trigiano RN, Windham MT, W indham AS. *Plant Pathology- Concepts and LaboratoryExercises*, CRC Press, Florida (2004).

Elective Theory; Course Level: 600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-658	**CONSERVATION AND SUSTAINABILITY**	
Course Learning Outcome	After the course, the student will be able to CLO1. Describe the different levels of biodiversity and different conservation methods. CLO2. Illustrate the importance of environmental impact assessment. CLO3. Identify the principles of Sustainable development goals of United Nations.	
Unit	**Topics**	**Hrs**
I	**Biodiversity conservation:** Introduction and levels of biodiversity; diversity gradient, methods to monitor biodiversity, biodiversity hotspots; biodiversity and ecosystem services, Biodiversity threats- natural and anthropogenic, species extinction, habitat loss and over exploitation of resources, invasive species. Biodiversity conservation-*in-situ* and *ex-situ*, sacred grooves, JFM, Concept of Lead Botanical Gardens and Biodiversity Parks, role of Botanical Gardens in plant conservation; IUCN threat categorization, extinction of species; International efforts to conserve biodiversity.	15
II	**Environmental Impact Assessment, monitoring and restoration:** Environmental impact assessment-purpose, aims, principles, EIA guidelines, process and report, Ambient air monitoring; Methods of collection and analyses of gaseous and particulate pollutants,Methods of collection of water and soil samples and analyses of physico-chemical characteristics. Bio-monitoring and bio-indication, Ecosystem degradation, Causes, and remedies. Ecotoxicants: Bioaccumulation, biotransformation, concept and strategies of ecorestoration; Biological and biotechnological tools of ecorestoration.	15
III	**Microbial ecology:** Microbes: Types, Plant microbe interaction, Biofuels, Role of microbes in environmental processes: decomposition, nutrient cycling and return, nitrogen fixation, enhancement of soil fertility, bioremediation and microbes, case studies of microbial bioremediation	15
IV	**Sustainable development and ecological economics:** Definition and dimensions of sustainability; ecological footprint and carrying capacity.Threats to sustainable development; indicators of sustainability; environmental sustainability index; ecological footprints; ecological economics; characteristics and role of government and NGOs in sustainable development. Sustainable development goals (SDG's), Payment for ecosystem services (PES), Carbon trade.	15

Suggested Readings:

1. Maiti SK. Handbook of methods in environmental studies Soil, air and water analysis APD Publishers, Jaipur (2003).
2. Banik RL. A Manual for Vegetative Propagation of Bamboos. Technical Report No. 6, International Network for Bamboo and Rattan Noida (1995).
3. Bisht NS, Ahlawat AS. Seed Technology. Information Bulletin no.7. State Forest Research Institute (SFRI), Arunachal Pradesh (1999).
4. Singh UV, Ahlawat AS. Bisht NS. Nursery Techniques for Local Tree Species. Information Bulletin no.11. State Forest Research Institute (SFRI), Arunachal Pradesh (2003).
5. FSI State of Forest Report. Forest Survey of India, Dehradun (2013).
6. Husch B, Beers TW. Kershaw JA. Forest Mensuration (4th Edn.) John Wiley and Sons, Inc New York (2003).
7. Joseph G. Fundamentals of Remote Sensing (2nd Edn.) University Press (2005).
8. Lillesand TM, Kiefer RW, Chipman JW. Remote Sensing and Image Interpretation (5th Edn.). Wiley India (2004).
9. Misra R. Ecology Workbook (Reprint Edn.). Scientific Publishers, Jodhpur (2012).
10. Mueller-Dombois D, Ellenberg H. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York (1974).

Elective Theory; Course Level: 600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-659	**ADVANCES IN PLANT BIOCHEMISTRY**	
Course Learning Outcome	After the course, the student will be able to: CLO1. Describe and explain diverse aspects of protein chemistry/metabolism and enzymology. CLO2. Describe and explain the biosynthetic pathways and functional significance of different secondary metabolites in plant biology. CLO3. Explain the inter relationship between primary and secondary metabolism	
Unit	**Topics**	**Hrs**
I	**Proteins and Enzymes:** Protein targeting, Protein degradation, Protein purification, Protein-DNA interactions, Evolution of biocatalytic reactions; Classification and nomenclature of enzymes, significance of ribozymes; abzymes; artificial enzymes; enzyme technology; regulation of enzyme action	15
II	**Secondary metabolism:** Introduction to secondary metabolites: Structure, biosynthesis and functions of phenolics, alkaloids, terpenoids, flavonoids, lignans, lignins, Tannins. Plant responses to herbivory: constitutive defense mechanisms; induced phytochemical responses; biochemical mechanisms of allelopathty.	15
III	**Signal transduction:** Signal Transduction: Overview, second messengers, receptors and G-proteins, phospholipid signaling, role of cyclic nucleotides, calcium-calmodulin cascade, diversity in protein kinases and phosphatases, sucrose sensing mechanism	15
IV	**PCD and senescence:** Programmed cell death (PCD): Concept of PCD and its types in plants during vegetative and reproductive stages. Developmental and stress-induced PCD. Aerenchyma formation and HR; Reactive oxygen species and PCD; Apoptosis and PCD. Plant senescence and its characteristics. Leaf and flower senescence. Metabolic changes associated with senescence and its regulations	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Bowsher C. *Plant Biochemistry*. 2nd edition, Garland Science, UK (2021).
2. Buchanan BB, Gruissem W, Jones RL. *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists Maryland, USA (2015).
3. Heldt HW, Piechulla B. *Plant Biochemistry*. Academic Press, California. (2021).
4. Hopkins WG. *Introduction to Plant Physiology*. John Wiley and Sons, Inc., New York, USA (1995).
5. Nelson D, Cox M. *Lehninger Principles of Biochemistry*. 8th Edition, W.H. Freeman and Company. New York. (2021).
6. Berg JM, Tymoczko JL, Stryrer L. *Biochemistry*. 5th Ed. Wlt. Freeman and Company, New York. (2002).
7. Zubay G. *Biochemistry*. Brown (William C.) Co, USA (1997).
8. Nooden LD, Leopold AC. *Senescence and Ageing of Plants*. Academic Press Inc. (1988).
9. Aducci P. *Signal Transduction in Plants (Molecular and Cell Biology Updates)*. Birkhäuser (2011).
10. Oelmuller R, Maheswari SC, SoporySK. *Signal Transduction in Plants: Current Advances*. Springer-Verlag New York Inc (2012)
11. Mérillon JM (Editor), Ramawat KG. Co-Evolution of Secondary Metabolites (Reference Series in Phytochemistry). Springer; 1st ed. (2020).

Elective Theory; Course Level: 600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits	
Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr		
BOT-E-660	**METHODS IN PLANT BIOTECHNOLOGY**	
Course Learning Outcome	After successful completion of the course students will be able to.. CLO1. Define terminologies used in plant biotechnology and will understand the process of plant tissue culture and genetic engineering. CLO2. Differentiate various tools/techniques used in plant tissue culture and genetic engineering and will be able to select the appropriate one for their endeavors. CLO3. Discuss and disseminate the knowledge of modern techniques of *in vitro* plant utilization/improvement to public	
Unit		**Hrs**
I	**Plant tissue culture:** Laboratory organization, Methods of sterilization, media composition and preparation, culture initiation. Callus induction and establishment, Cell suspension culture, Somatic embryogenesis, Soma clonal variation and applications.	15
II	**Micropropagation:** Production of virus free plantlets, haploid production, protoplast culture and fusion, biotransformation of plant cells, hairy root culture. Production of secondary metabolites using cell and tissue culture. Molecular farming and immuno-protective drugs.	15
III	**Introduction to Gene cloning**: Gene cloning vectors - Plasmids, Phages, Cosmids, Transposons, Primary vectors and plasmids - expression vectors. Enzymes in genetic engineering, applications ofPCR, genomic and cDNA libraries in gene cloning.	15
IV	**Gene transfer in plants**: Gene transfer methods, Ti plasmid, Ti plasmid mediated transfer. Gene transfer via. calcium phosphate, PEG, DEAE, liposomes, microinjection, microprojectile, and electroporation. Selection of clones, marker and reporter genes in screening methods. Methods in recombinants screening.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Nicholl DST. 2008. *An Introduction to Genetic Engineering*. Cambridge Univ. press, USA (2008).
2. Verma PS, Agarwal VK. *Genetic Engineering*. S Chand & Company Ltd. New Delhi (2009).
3. Kurnaz IA. *Techniques in Genetic Engineering*. CRC Press. Taylor & Francis Gp. USA (2015).
4. Brown TA. *Gene Cloning and DNA analysis* (2nd Edition), John Wiley & Sons Inc., UK (2016).
5. Setlow JK. *Genetic Engineering: Principles & Methods*. Springer, Germany (2010).
6. Razdan MK, Bhojwani SS. *Plant Tissue Culture: Theory and Practice.*Revised edition, Elsevier Science (1996).
7. Purohit SD. *Introduction to plant cell, tissue and organ culture*. Prentice Hall India Learning Private Limited, India (2012).
8. Dodds JH, Roberrtis LN. *Experiments in plant tissue culture*, Cambridge University Press New York (1985).
9. Singh BD. Biotechnology: Expanding horizons. Kalyani Publisher (2020).
10. George EF, Paul DS. *Plant propagation by tissue culture*. Exegetics Ltd. (1984).

Elective Theory; Course Level: 600		
Total Marks: 100	L+T+P: 4+0+0=4 Credits Lecture: 60 hrs. + Tutorial: 0 hr. + Practical : 0 hr	
BOT-E-661	**PHARMACOGNOSY AND PHYTOCHEMISTRY**	
Course Learning Outcome	After the completion of this course, the students will be able to… CLO1. Understand the phytochemical properties of medicinal plants and their scope CLO2. Demonstrate different types of plant based crude drugs and statutory regulations CLO3. Illustrate different methods of phytochemical extraction and their applications.	
Unit	**Topics**	**Hrs**
I	**Fundamentals of Pharmacognosy:** Definition, scope and applications in herbal medicine. Classification and identification of drugs: Need for classification of drugs; classical (taxonomic, morphological, organoleptic, therapeutic); microscopy and modern (biogenetic) criteria for classification of powdered drugs, methods for documentation of raw drugs. Drug evaluation.	15
II	**Drug Adulteration:** Types, methods of evaluation - biological, anatomical, physical, Phytochemical investigation. Global trend in herbal market. Status of Indian medicinal plant trade, medicinal plants prohibited from export. WHO regulation of herbal medicine. CHMP/ CVMP guidelines of the European Medicines Agency Inspections	15
III	**Phytochemical Extraction:** Introduction, definition, factors influencing the choice of extraction. Principles of extraction methods, types of extraction. Extraction of Plant drugs by Microwave assisted techniques and their merits and demerits. Selection of Solvents for extraction. Methods of isolation, purification and characterization of some natural products: Podophyllin, Ginsenosides, Curcumin, Cordycepin, Lemongrass oil, Emetine, Artimisinin, Quinine etc.	15
IV	**Bioactive Secondary Metabolites:** *Steroids*: Occurrence and distribution in plants, saponins, sapogenins and steroids; Isolation, and biosynthesis of bioactive steroids such as cholesterol, diosgenin, estrone, estrodiol, etc.; *Terpenoids*: Occurrence and distribution in plants, essential oils, aroma chemicals, mono and sesquiterpenoids, their use in flavour and perfumery industry, diterpenes, triterpenes, isolation and characterization of terpenes, their synthesis; *Alkaloids*: occurrence and distribution in plants, bioactive alkaloids-isolation and structure elucidation of alkaloids such as atropine, quinine, papaverine, thebaine, vincristine, etc.;	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Dennis DT, Turpin DH, Lefebvre (Layzell DD, D.B.-eds). *Plant Metabolism* (Second Edition) Longman, Essex, England (1997).
2. Dey PM,Horborne JB. *Plant Biochemistry*. Acadamic Press, London (1997).
3. Harborne JB. *Phytochemical Methods- A guide to modern techniques of plant analysis*. Springer (India) Private Limited, 17 Barakhamba Road, New Delhi-110001 (1998).
4. Leninger AC. *Principles of Biochemistry*. CBS Publishers and Distributors (Indian Reprint) (1987).
5. Sadasivam S, Manickam A. *BioChemical methods* (2nd edition). New Age International Pvt. Ltd. New Delhi (2004).
6. Shah BN,Seth AK. *Text Book of Pharmacognosy and Phytochemistry*. Reed Elsevier India Limited (2010).
7. Verma SK, Verma Mohit. *A.T.B of Plant Physiology, Biochemistry and Biotechnology*.S.Chand Publications (2007).

Elective Practical; Course Level: 600

Total Marks: 100 L+T+P: 0+2+2=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical: 60 hrs

BOT-P-662	**PLANT PATHOLOGY LAB**
Course Learning Outcome	After the course, the student will be able to CLO1. Gain necessary skills to isolate and handle fungi from nature, and to discern important microscopic characteristics of fungi. CLO2. Characterization of pathogens through morphological and molecular means and protocols. CLO3. Detects enhanced resistance by biochemical assays.

Laboratory Experiments

1. Media preparation and sterilization.
2. Isolation, identification, and enumeration of AM fungal spores from soil.
2. Symptomatology and histopathology of locally available disease-plants and identification of the pathogenic organisms.
3. Identification of fungal cultures: *Colletotrichum, Curvularia, Alternaria, Pestalotiopsis, Trichoderma, Fusarium, Dreschlera.*
4. Isolation of fungal pathogens from diseased tissues.
5. Study of Koch's postulates and pathogenicitytests in whole plants/cut shoots/ leaves.
6. Biochemical markers of enhanced resistance (i) Estimation of total phenols and O-didhydroxyphenols (ii) Estimation of activity of Phenylalanine ammonia lyase in healthy and diseased leaves
7. SDS-PAGE analysis of defense proteins
8. Isolation and estimation of DNA from fungal pathogens
9. Field visit to study diseases on crop plants.
10. Collection and submission of plant disease samples (Minimum 10)

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Mukerji KG, Tewari JP, Arora DK, Saxena G. *Recent Developments in Biocontrol of Plant* Diseases. Aditya Books, New Delhi (1992).
2. Verma JP, Varma A, Kumar D. (Eds). *Detection of Plant Pathogens and their Management*. Angkor Publ., New Delhi (1995).
3. Mehrotra RS, AnejaKR. *.An Introduction to Mycology*. New Age International Publisher (1999).
4. Harris KF, Maramarosh K. *Vectors of Plant Pathogens*. Academic Press, London.(eds.)(1980).
5. Fox RTV. *Principles of Diagnostic Techniques in Plant Pathology*. CABI Wallington (1993).
6. Gurr SJ, McPhersen MJ, Bowlos DJ. *Molecular Plant Pathology - A Practical Approach.* Vols. I & II, Oxford Univ. Press, Oxford (1992).

Elective Practical; Course Level: 600

Total Marks: 100 L+T+P: 0+2+2=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hrs

BOT-P-663	**PLANT SYSTEMATICS LAB**
Course Learning Outcome	After successful completion of this course students will be able to… CLO1. Carry out experiment on chemotaxonomy, palynotaxonomy and cytology CLO2. Carry out experiments on morphometric attributes. CLO3. Integrate the training of molecular taxonomy in systematic classification

Laboratory Experiment

1. Gain a basic understanding of botanical vocabulary and terminology.
2. Preparation of artificial keys.
3. Understanding of phylogenetic classifications.
4. Chemotaxonomy – Flower pigment analysis of plants from Caryophyllales and Curvembryae.
5. Palynotaxonomy – Study of pollen characters of taxonomic significance.
6. Cytotaxonomy – Study of intergeneric / interspecific karyotypic differences.
7. Numerical taxonomy-study attributes, coding, statistical analysis
8. Peruse journal articles in plant systematics, e.g., American Journal of Botany, Systematic Botany, or International Journal of Plant Sciences, and note those that describe plant embryological features in relation to systematic studies. Identify all embryological characters and character states described.
9. Molecular Taxonomy: Specimen collection, Isolation of DNA, DNA-purification, quantification.
10. Peruse five articles in a systematics journal and tabulate the different types of research questions that are addressed.

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Angiosperm Phylogeny Group. *An update of the Angiosperm Phylogeny Group.* Classification for the orders and families of flowering plants: APG II. Botanical Journal of the Linnaean Society 141: 399-436 (2003).
2. Crawford DJ. *Plant Molecular Systematics*. Cambridge University Press, Cambridge, UK (2003).
3. Cronquist A. An integrated system of classification of flowering plants. Columbia University Press, New York (1981). .
4. Judd WS, Campbell CS, Kellogg EA,Stevens PF, Donoghue MJ. *Plant Systematics*: A phylogenetic Approach. Sinauer Associates, Inc., Massachusetts (2002).
5. Maheshwari JK. *The Flora of Delhi,* CSIR, New Delhi (1963).
6. Nei M,Kumar S. *Molecular Evolution and Phylogenetics.* Oxford University Press, New York (2000).
7. Radford AE, DickisonWC, Massey JR, Bell CR. *Vascular Plant Systematics*. Harper and Row, New York (1974).
8. Semple C, Steel MA. *Phylogenetics*. Oxford University Press, Oxford (2003).
9. Michael GS. *Plant Systematics.* Elsevier Academic Press, Burlington, MA (2006).

Elective Practical; Course Level: 600	**L+T+P: 0+2+2=4**
Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hrs	
BOT-P-664	**PLANT BIOCHEMISTRY LAB**
Course Learning Outcome	After the completion of the course, the students will be able to… 1. Have a practical idea about different analytical techniques. 2. Use various experimental protocols for quantification of different metabolites. 3. Perform enzyme assay and analysis.

Laboratory Experiments

1. Estimation of total proteins based on Lowry's and Bradford's method.
2. Determination of the effect of pH on enzyme activity.
3. Estimation of ascorbic acid [Colorimetric / volumetric]
4. Estimation of riboflavin.
5. Estimation of total Phenolics using Folin – Ciocalteau reagent.
6. Estimation of DNA by diphenylamine method

Determination of proline in normal and stressed plants

7. Estimation of free amino acids from plant sample
8. Estimation of carbohydrate by Anthrone reagent
9. Estimation of inorganic phosphate from plant sample

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment,
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Kochhar SL, Gujral SK. *Comprehensive Practical Plant Physiology*. Laxmi Publications (2011).
2. Inam A, Sahay S, Akhtar A. *Experiments in Plant Physiology, Biochemistry & Ecology*. Narendra Publishing House (2022).
3. Larcher W. *Physiological Plant Ecology*. Springer (2003).
4. Plummer D. *An Introduction to Practical Biochemistry*. MCGraw Hill Education (2017).
5. Sadasivam S. *Biochemical Methods*.New Age International Pvt Ltd Publishers (2018).
6. Scopes RK. *Protein Purification: Principles and Practice*. Springer (2010).
7. Wilson K, Walker J. *Principles and Techniques of Practical Biochemistry and Molecular Biology*. Cambridge University Press (2000).
8. Katoch R. *Analytical Techniques in Biochemistry and Molecular Biology.* Springer (2011).
9. Farell SO, Taylor L. *Experiments in Biochemistry: A Hands-on Approach*. Brooks/Cole (2005).
10. Choudhury MA, Gupta KK. *Practical Plant Physiology*. New Central Book Agency (2009).

Elective Practical; Course Level: 600

Total Marks: 100 L+T+P: 0+2+2=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical: 60 hrs

BOT-P-665	**PLANT TISSUE CULTURE LAB**
Course Learning Outcome	After successful completion of the course, the students will be able to…. 1. Visualize plant tissue culture lab and its requirements. 2. Handle various tools/equipments used in plant tissue culture lab 3. Prepare various solutions and media used in plant tissue culture 4. Record observations, analyze and interpret the results based on standard scientific practices

Laboratory Experiments

1. Requirement for Plant tissue culture works: Work station, equipment and culture conditions.
2. Preparation of MS media stock solution and hormones.
3. Media Preparation & Sterilization.
4. Preparation of explants & callus induction techniques.
5. Micropropagation through axillary bud culture.
6. Induction of Somatic embryogenesis.
7. Anther/ovary culture
8. Isolation of protoplasts.
9. Suspension culture.
10. Preparation of synthetic seeds.
11. Hardening /Acclimatization.

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment,
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. KrishnamurthyKV.*Methods in plant histochemistry*. Viswanathan printers and publishers, Chennai, (1988).
2. LindsleyK. *Plant tissue culture manual*. Kluwer Academic publishers (1992).
3. Purvis CJ, Collen D,Walls D. *Laboratory technique in Botany*. Orient Longman, Singapore (1966).
4. ReinertJ, Yeoman MM. *Plant cell and Tissue culture- Laboratory manual*, Springer Science and business media (2012).
5. Patki LR, Bhalchandra BL. *An introduction to Mictotechnique*. S. Chand & Co, New Delhi (1983).
6. Giri CC, Giri A. Plant BiotechnologyPractical Manual. I.K. International Publishing House Pvt. Limited(2013).
7. Thorpe TA. *Plant tissue culture methods and application in agriculture*. Elsevier, London (1981).

Elective Practical; Course Level: 600

Total Marks: 100 L+T+P: 0+2+2=4 Credits

Lecture: 0 hr. + Tutorial: 30 hrs. + Practical: 60 hrs

BOT-P-666	**ENVIRONMENTAL BIOLOGY LAB**
Course Learning Outcome	After the course, the student will be able to CLO1. Allocate biomass allocation pattern of a grassland. CLO2. Analyze the physical and chemical properties of water and soil samples CLO3. Use GPS to collect the geolocation and altitude of the study site CLO4. Interpret satellite images visually

Laboratory Experiments

1. To estimate the biomass allocation pattern in grassland community.
2. Determination of Dissolved oxygen by Winkler method.
3. Study of phytoplankton in an aquatic ecosystem.
4. Documentation of endangered, endemic and exotic species in PAN (Protected Area Network)
5. Determination of litter accumulation in forest stand.
6. Determination of p^H of soil and water by using p^H meter.
7. Study of root nodules of leguminous and non-leguminous species.
8. Estimation of NO_3 from water and waste water.
9. Drafting/ Preparation of EIA report
10. Study of girth increment in tree species
11. Data collection using Global positioning system (GPS)
12. Land use/ land cover delineation from satellite imagery using visual interpretation

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment,
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. SreemahadevanPR, Pillai A. comprehensive laboratory manual for Environmental Sciences and Engineering. New Age International Publishers (2009)..

2. Trivedi RK, Goel PK. Chemical and Biological methods for water pollution studies. Environmental Publications Publishers (2006)

3. Maiti SK. Handbook of methods in environmental Studies: Volume 2 (Air, Noise and overburden Analysis). ABD Publishers, New Delhi (2003).

4. Anonymous. Standard methods for examination of water and wastewater, American Public Health Association (2011).

5. Trivedi RK, Chemical and biological methods for water pollution studies

6. Bryan FJ. Manly. Statistics for Environmental Science and Management. CRC Press (2009).

Elective Practical; Course Level: 600

Total Marks: 100 L+T+P: 4+0+0=4 Credits

Lecture: 0 hr. + Tutorial: 30 hr. + Practical : 60 hrs

BOT-P-667	**NATURAL PRODUCTS ANALYSIS LAB**
Course Learning Outcome	After the completion of the course, the students will be able to… CLO1. Understand the protocols to quantify different secondary metabolites. CLO2. Illustrate different medicinal plants having important phytochemicals and their properties CLO3. Demonstrate different analytical techniques employed to medicinal plants.

Laboratory Experiments

1. Determination of tannins.
2. Determination of flavonoids.
3. Pharmacological screening of Anti-diabetic Agents.
4. Determination of anti-oxidant activity from local plants.
5. Screening of Crude Drugs for Anti-microbial activity.
6. Phytochemical screening methods: Paper Chromatography, TLC, HPLC, Spectrometry.
7. Estimation of Alkaloids from local plants.
8. Identification of amino acids by Paper Chromatography.
9. Identification and Estimation of Lipids
10. Qualitative determination of Phenols from local plants.
11. Determination of adulteration in crude drugs.
12. Determination of extractive value of crude drugs.

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Farell SO, Taylor L. (2005). Experiments in Biochemistry: A Hands-on Approach. Brooks/Cole
2. Harborne JB. (1983). Phyto chemical methods. Chapman and Hall. London.
3. Harborne JB (1998). Phytochemical Methods- A guide to modern techniques of plant analysis. Springer (India) Private Limited, 17 BarakhambaRoad,New Delhi-110001. ISBN: 978-81-8128-310-8
4. Kokate CK, Purohit AP, Gokhale SB. Pharmacognosy NivaliPrakashan Publication.
5. Leninger AC. (1987). Principles of Biochemistry, CBS Publishers and Distributors (Indian Reprint).
6. MillerLP (1973). Phyto chemistry. 1-3 volumes Van Nostrand, Reinhold Co.
7. Plummer D. (2017). An introduction to practical biochemistry. McGraw Hill Education.
8. SadasivamS. (2018). Biochemical methods, New Age International Pvt Ltd Publishers.
9. Shah, Biren N, Seth AK. (2010). Text Book of Pharmacognosy and Phytochemistry. Reed Elsevier India Limited.
10. Trease GE. Evans WC. (1983).Pharmacognosy. 12 Edition. Bailliere, Tindall, East Bourne, U.K.

MOOC COURSES

	DEPARTMENT OF BOTANY SIKKIM UNIVERSITY, GANGTOK	
	Skill Enhancement Course (Theory) COURSE LEVEL 500; Credits=2	
	SEMESTER-I, 2 Credits	
BOTM-S-506	**BASIC CROP PRODUCTION PRACTICES** (Prof J R Yadav, Dr. Shrawan Kumar Shukla; Dr. Vinod Kumar, IIT, Kanpur)	
Course Learning Outcome	After successful completion of this paper students will be able to CLO1. Students will be able to know about agricultural practices. CLO2. Understand the basic practices of crop production. CLO3. Students will be able to know about the importance of rotation of crops.	
Unit	**Topics**	**Hrs**
I	**Irrigation in crop production:** Crops and their classification, Definition of crop, classification of crops, importance of Vegetable, Importance of vegetables and their classification, Irrigation management, system of irrigation, method of irrigation and critical period of water requirement. Crop rotation, concept of crop rotation. Paddy, Sorghum, Pearl millet and Maize crop production. Paddy crop variety, field preparation, seed and sowing/transplanting, manure and fertilizer, irrigation, weed control, disease control, insect control, harvesting and yield. Sorghum crop variety, field preparation, seed and sowing, manure and fertilizer, irrigation, weed control, disease control, insect control, harvesting and yield.	15
II	**Common crop production practices:** Oilseed crops production practices: Groundnut, Sesame, Soybean and Sunflower crop production. Groundnut crop variety, field preparation, seed and sowing, manure and fertilizer, irrigation, weed control, disease control, insect control, harvesting and yield. Soybean crop variety, field preparation, seed and sowing, manure and fertilizer, irrigation, weed control, disease control, insect control, harvesting and yield. Sunflower crop variety, field preparation, seed and sowing, manure and fertilizer, irriga tion, weed control, disease control, insect control, harvesting and yield. Mango, Guava, Banana and Papaya crop production. Mango crop variety, field preparation, seed and sowing/transplanting, manure and fertilizer, irrigation, weed control, disease contr ol, insect control, harvesting and yield.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment,
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Amani I, Fischer RA, Reynolds MP.Canopy temperature depression association with yield of irrigated spring wheat cultivars in a hot climate. Journal of Agronomy and Crop Science 176, 119-129 (1996).
2. Araus JL, Reynolds MP, Acevedo E. Leaf posture, grain yield, growth, leaf structure, and carbon isotope discrimination in wheat. Crop Science 33, 1273-1279 (1993) (1993).
3. Ayeneh A, Van Ginkel M, Reynolds MP,. Ammar K. Comparison of leaf, spike, peduncle and canopy temperature depression in wheat under heat stress. Field Crops Research 79, 173-184 (2002).
4. Bagci SA, Ekiz H, Yilmaz A,CakmakI. Effects of zinc deficiency and drought on grain yield of field-grown wheat cultivars in Central Anatolia. Journal of Agronomy and Crop Science 193, 198-206 (2007).
5. Banziger M, Setimela PS, Hodson D, Vivek B.Breeding for improved abiotic stress tolerance in maize adapted to southern Africa. Agricultural Water Management 80, 212-224 (2006).
6. Barnabas B, Jager K, Feher A. The effect of drought and heat stress on reproductive processes in cereals. Plant, Cell and Environment 31, 11-38 (2008).
7. Boer MP, Wright D, Feng L, Podlich DW, Luo L, Cooper M , Van Eeuwijk FA. A mixed-model quantitative trait loci (QTL) analysis for multiple-environment trial data using environmental covariables for QTL-by-environment interactions, with an example in maize. Genetics 177, 1801-1813 (2007).
8. Borrell AK, Hammer GL Nitrogen dynamics and the physiological basis of stay-green in sorghum. Crop Science 40, 12951307 (2000).

BOTM-S-507	**ORGANIC FARMING FOR SUSTAINABLE AGRICULTURE PRODUCTION** Prof Diilip Kumar Swain, IIT, Kharagpur (Source: NPTEL) Course level 500; credits=2	
Course Learning Outcome	After successful completion of this course, the students will be able to… CLO1. Understand the basic principles of organic farming. CLO2. Apply the techniques acquired for the organic farming practices. CLO3. Manage the basic requirements for organic farming like organic manure, seeds and crops, and produce the organic certified produces/products. CLO4. Manage the economic aspects of the organic produces/products	
Unit	**Topics**	**Hrs**
I	Organic farming- Introduction, status, components, concept and principles. SWOT Analysis of Organic farming, sustainable agriculture, key indicators of sustainable agriculture. Organic farming and climate change. Principles of compost production, vermicompost production technology, enriched vermicompost production technology, vermicompost quality and marketing. Introduction to pest and disease management, pest and disease management in organic farming, level C pest and disease management.	15
II	Introduction to organic crop management, organic vegetable crop management, organic crop management-cereals, organic field crop management-pulses and oil seed crop, organic plantation crop management, organic meat production. Introduction on transition to organic crop production, crop planning and rotation design in organic system. Integrated farming system and urban agriculture. Quality organic food, natural sources of antioxidants for health defense, antioxidant capacity of fruits and vegetables, organic food and human health. Organic standard, organic certification process, operational structure and organic certification, marketing of organic products.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Bhutia DT. Sikkim Organic Mission. *Sikkim Organic Mission.* Food Security & Agriculture Development Department and Horticulture & Cash Crops Development Department, Government of Sikkim (2015).
2. Dabbert S, Haring AM,Zanoli R. *Organic Farming: Policies and Prospects*. Zed Books Ltd., 7 Cynthia Street,London, N19JF, UK. ISBN:1 -84-277-326-7 (2004).
3. Dahama AK. *Organic Farming for Sustainable Agriculture*. Agrobios (India), Agro House, Jodhpur-342002. ISBN: 978-81-7754-058-1 (1997).
4. Gehlot D. *Organic Farming: Components and Management*. Agrobios (India), Agro House, Behind Nasrani Cinema, Chopasani Road, Jodhpur-342002. ISBN: 978-817754-400-8, 81-7754-400-4 (2010).
5. Ghosh GK.*Bio-Pesticide and Integrated Pest Management*. A.P.H Publishing corporation, Ansari Road, Darya Ganj, New Delhi-110002. ISBN: 81-7648-135-1
6. Gupta RD, Gupta SK, BhardwajSD.*Agrotechniques and Uses of Medicinal Plants*. Associated Publishing Company, New Delhi-110002. ISBN:978-81-85211-96-1 (2016).
7. Palaniappan SP, Annadurai K. *Organic Farming-Theory & Practice*. Scientific Publishers (India), P.O.Box-91, Judhpur-342001. ISBN: 978-81-7233-538-0 (HB), 978-81-7233-537-3 (2010).
8. ParthasarathyVA, KandiannanK Srinivasan V. *Organic Spices* (Eds.). New India Publishing Agency, Pitam Pura, New Delhi-110088. ISBN:81-89422-84-7, 978-89422-84-3 (2008).
9. Reddy PP. *Organic Farming for Sustainable Horticulture*. Scientific Publishers (India), 5-A, Pali Road,P.O.Box-91, Jodhpur-342001. ISBN: 978-81-7233-640-0 (2010).
10. Thapa U,TriathyP. *Organic farming in India-Problems & Prospects*. Agrotech Publishing Academy, Udaipur-313002. ISBN: 81-8321-033-3 (2006).
11. VarmudyV. Marketing of Spices. Daya Publishing House, Delhi-110035. ISBN: 81-7035-242-8 (2001)

	Skill enhancement course (theory)
	SEMESTER-II **COURSE LEVEL 500; CREDITS =2**
BOTM-S-556	**EXPERIMENTAL BIOTECHNOLOGY** Prof. Vishal Trivedi, IIT, Guwahati
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Identify and use various instruments and tools for the analysis of cells/biological molecules. CLO2. Describe principles, instrumentations, applications, advantages, and limitations of various bioanalytical tools and techniques. CLO3. Compare various similar techniques and will be able to understand the importance of one technique over another.

Unit	Topics	Hrs
I	Solution and Buffer Preparation, Basics of Chromatography, Ion-exchange chromatography, Hydrophobic Interaction Chromatography, Gel Filtration Chromatography, and Affinity chromatography, Antigen body introduction, Antigen-antibody interaction, Immunoassay	15
II	Basics of Electrophoresis, Horizontal Gel Electrophoresis, and Different Varients of Gel Electrophoresis, Polymerase chain reaction and its variants, blotting techniques, Sequencing techniques, Microscopy, Cell biology experiments and Designing experiment.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment,
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings

1. Wilson K, Walker J. *Principles and techniques of biochemistry and molecular biology.* 6th Ed., Cambridge University press, New Delhi (2008).
2. Sawhney SK, Singh R. *Introductory practical biochemistry*. 2nd Ed., Narosa publishing house New Delhi (2011).
3. Upadhyay A, Upadhyay K, Nath N. *Biophysical Chemistry (Principles and Techniques).* Himalaya Publishing House Pvt. Ltd, Mumbai (2010).
4. Freifelder D. *Physical Biochemistry*. WH Freeman and Company (1982).
5. Plummer DT. *An Introduction to Practical Biochemistry*. Tata McGraw Hill (2007).
6. Schmauder H-P, Schweizer M, Schweizer LM (Eds.). *Methods in Biotechnology*. Taylor & Francis Publishers (2002).
7. Skoog DA, Leary JJ. *Principles of Instrumental Analysis*. 4th Ed. Saunders College Publishing (1992).
8. Kothari CR. *Research methodology: Methods and Techniques*, 3rd Ed., New age International, (2014).
9. Kumar R. *Research methodology a step-by-step guide for beginners.* Sage Publications, London (2011).
10. Thomas CG. Research methodology and scientific writing, Ane books, Delhi (2015).

BOTM-S-557	**ANALYTICAL TECHNOLOGIES IN BIOTECHNOLOGY** Dr. Ashwani K. Sharma, IIT, Department of Biotechnology, Roorke COURSE LEVEL 500 ; CREDITS =2	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Describe different types of microscopy and their applications. CLO2. Describe principles, instrumentation and applications of different types of chromatography, electrophoresis, centrifugation and spectroscopy. CLO3. Describe diverse aspects of polymerase chain reaction (PCR) and ELISA.	
Unit	**Topics**	**Hrs**
I	**Microscopy:** Basic concepts, Dark-field and phase contrast microscopy, Differential interference contrast and polarization, Fluorescence and confocal microscopy, Transmission electron microscopy, scanning electron microscopy; Chromatographic methods: Introduction and Basic concepts, Low-pressure liquid chromatography (LPLC) and high performance liquid chromatography (HPLC), Ion-exchange chromatography, Gel-filtration chromatography, Affinity chromatography, Gas-liquid chromatography; Electrophoresis: Basic concepts in electrophoresis, Horizontal and vertical gel electrophoresis, Native gel electrophoresis and SDS-PAGE, Isoelectric focusing (IEF), 2-D gel electrophoresis and protein detection methods, Electrophoresis of nucleic acids, Immunoelectrophoresis and capillary electrophoresis.	15
II	**Centrifugation techniques:** Introduction and basic concepts, Types of centrifuges and analytical ultracentrifugation method, Separation methods in preparative ultracentrifuges, Types and care of rotors; Spectroscopic techniques: Introduction and basic concepts, UV-Visible spectroscopy, Infrared and fluorescence spectroscopy, Atomic spectroscopy and mass spectrometry; Polymerase chain reaction (PCR), DNA sequencing methods, Enzyme linked immunosorbent assay (ELISA)	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Wilson K, Walker J. *Principles and techniques of biochemistry and molecular biology*. 6th EdCambridge University press, New Delhi (2008).
2. Sawhney SK, Singh R. *Introductory practical biochemistry*, 2nd EdNarosa publishing house New Delhi (2011).
3. Upadhyay A, Upadhyay K, Nath N. *Biophysical Chemistry (Principles and Techniques).* Himalaya Publishing House Pvt. Ltd, Mumbai (2010).
4. Freifelder D. Physical Biochemistry. WH Freeman and Company (1982). .
5. Plummer DT. *An Introduction to Practical Biochemistry*. Tata McGraw Hill (2007). .
6. Schmauder HP, Schweizer M, Schweizer LM. *Methods in Biotechnology*, (eds), Taylor & Francis Publishers (2002).
7. Skoog, DA, Leary JJ. P*rinciples of Instrumental Analysis.* 4th Edition. Saunders College Publishing (1992).
8. Wiley J, Sandman K, Wood D. *Prescott's Microbiology (11th Ed.)*. McGraw Hill (2019).

	(Skill enhancement course theory)
	Semester II COURSE LEVEL 500, CREDITS=2
BOTM-S-558	**BIOINFORMATICS: ALGORITHMS AND APPLICATIONS** (MOOC-NPTEL), IIT Madras Prof. M. Michael Gromiha
Course Learning Outcome	At the end of the course, students will be able to.. 1. Focus on DNA and protein sequence databases and analysis, secondary structure and 3D structural analysis. 2. Know the applications such as prediction of protein structure, folding rates, stability upon mutation, and intermolecular interactions. 3. Garner computer-aided drug design using docking and QSAR studies.

Unit	Topics	Hrs
I	**Bioinformatics and Protein structure:** Concepts and importance of Bioinformatics, Complexities in biological, systems, DNA sequence analysis, Sequence based parameters, Database, Database categories, Protein structure and function, Protein structure and function II, Protein sequence databases, Protein sequence databases II, pairwise alignment, pairwise alignment II, uniprot Demo, Sequence alignment.	15
II	**Sequence alignment and phylogenetics:** Sequence alignment II, Sequence alignment: Online resources, Sequence alignment: Online resources II, conservation score, Conservation score II, Blast Demo. Phylogenetic trees, Phylogenetic trees II, Protein sequence analysis, Protein sequence analysis II, Hydrophobicity profiles, Patterns and PSSM profiles, Protein structure analysis – IV, Protein structure prediction – I, Protein structure prediction – II, Protein stability – I, Protein stability – II, Computer aided drug design – II, Development of algorithms – II, Applications of bioinformatics – I, II	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Gromiha MM. *Protein Bioinformatics:* From Sequence to Function, Academic Press, (2010).
2. Krane DE, Raymer ML. *Fundamental concepts of bioinformatics*, Pearson Education Inc. (2006).
2. Marx V. *Biology: the big challenges of big data*. Nature, 498, 255-260 (2013).
3. International Human Genome Sequencing Consortium. *Initial sequencing and analysis of the human genome*. Nature, 409, 860-921 (2001).
4. Goodman A. et al. *Ten simple rules for the care and feeding of scientific data.* PLoS Comp. Biol., 10(4):e1003542 (2014).
5. Masum H., et al. *Ten simple rules for cultivating open science and collaborative R&D*. PLoS Comp. Biol., 9(9):e1003244 (2013).
6. Michener WK. *Ten simple rules for creating a good data management plan*. PLoS Comp. Biol., 11(10):e1004525 (2015).
7. Brazma A. et al. *Minimum information about a microarray experiment (MIAME)-toward standards for microarray data.* Nature Genetics, 29, 365-371 (2001).
8. Stevens R, Rector A, Hull D. *What is an ontology?*. Ontogenesis (2010).
9. Kazic T. *Ten simple rules for experiments' provenance.*PLoS Comp. Biol., 11(10):e1004384 (2015).

	Skill enhancement course (theory)	
	Semester III	
BOTM-S-617	**BIOSTATISTICS AND DESIGN OF EXPERIMENTS** Dr. Mukesh Doble, IIT, Madras COURSE LEVEL 600; CREDITS=2	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Describe various experimental design strategies and data types/distribution. CLO2. Describe various statistical tests. CLO3. Apply ANOVA for various experimental data sets.	
Unit	**Topics**	**Hrs**
I	Introduction, Experimental design strategy, Data types/Binomial Distribution, Poisson Distribution, Normal Distribution, Standardized Normal Distribution/ t distribution, t distribution/confidence interval; Statistical tests, t-tests, F-tests, ANOVA	15
II	Normality test/Odds ratio, Chi square distribution/test, Weibull distribution, Nonparametric tests/Homogeneity of variance/Beta distribution Exponential/Hypergeometric distributions, Hypergeometric/Log normal distributions; Design of Experiments (DOE) – Introduction, Factorial design, Full Factorial design, Fractional Factorial design; Other designs: Second order designs, Regression Analysis Control Charts.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings

1. Gomez AA, GomezKA. *Statistical procedures for agricultural research* (2nd ed.). Wiley (1984)
2. Hampton RE, Havel JE. *Introductory Biological Statistics* (3rd Ed.). Waveland Press Inc. (2018).
3. Le CT, Eberly LE. *Introductory Biostatistics*. Wiley (2016).
4. ForthoferRN et al. *Biostatistics* (2nd Ed.). Elsevier (2007).
5. Panse VG, Sukhatme PV. *Statistical Methods for Agricultural Workers* (2nd Ed.). ICAR (1967).
6. Glass DJ. *Experimental design for biologists* (2nd Ed.). CSHL Press (2014).
7. Montgomery DC. *Design and analysis of experiments* (10th Ed.). John Wiley (2019).
8. GP Quinn. *Experimental Design and Data Analysis for Biologists.* Cambridge University Press (2023).
9. Heath D. *An Introduction to Experimental Design and Statistics for Biology* (1st Ed.). Routledge (1995).

BOTM-S-618	**DATA ANALYSIS FOR BIOLOGISTS** Prof. Biplab Bose, IIT, Guwahati COURSE LEVEL 600, CREDITS=2	
Course Learning Outcome	After the course, the student will be able to… CLO1. Describe about probability distribution CLO2. Identify the difference between different statistical operations and learn how to analyze them with R CLO3. Analyze statistical data using R	
Unit	**Topics**	**Hrs**
I	Probability and its types, Statistics using R, concepts of statistical tests. Concepts of Vector and matrix and its operations, Eigen values and vector, Linear system of Equations, getting acquaintance with R, Algebraic and logical operations with R, Statistics with R, t test and ANOVA.	15
II	Scatter plot, Line and bar plot. Histogram, Box plot. Heat map, Volcano plot, ggplots 1 and 2, Correlations, Linear regression and Multiple linear regression with R, Nonlinear regression, Clustering and classification, Measures of clustering, K means clustering, Decision tree, Support vector machines. Higher dimensional data analysis in Biology, Principal component analysis.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
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ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. WhitlockMC, Schluter D. *The Analysis of Biological Data* (2nd edition). Freeman, W. H. & Company, (2014).
2. Yang ZR. *Machine Learning Approaches to Bioinformatics*. World Scientific, (2010).
3. Moses A. Statistical Modelling and Machine Learning for Molecular Biology. Chapman and Hall/CRC, (2016).
4. Hartvigsen G. *A Primer in Biological Data Analysis and Visualization Using R*, (1st Edition). Columbia University Press, (2014).
5. Stewart J, Day T.*Biocalculus*: Calculus for Life Sciences. Cengage Learning, (2015)
6. James G et al. An introduction to statistical learning with application in R. Vol. 112. New York: springer, (2013).

	MOOC Elective-I Theory Course (4 credits)	
	SEMESTER-III	
BOTM-E-620	**RNA BIOLOGY** Prof. Rajesh Ramachandra, IISER, Mohali COURSE LEVEL 600, CREDITS=4	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Explain diverse aspects of RNA structure, functions, and replication. CLO2. Describe the RNA processing and life cycle. CLO3. Describe the mechanisms of RNA decay, non-coding RNAs and lncRNA-induced Cancer. CLO4. Describe telomeres in the context of aging and cancers. CLO5. Explain the role of RNA in translation.	
Unit	**Topics**	**Hrs**
I	Introduction to RNA Biology and RNA World-The Beginning, Evidences, Origin of Monomers, Shift to DNA, RNA Self Replication, Origin of RNA Enzymes; RNA as Enzymes: The Ribozymes, Structure and Functions, The Present and Future; RNA Transcription: The Central Dogma; Initial Steps, Different Stages, Termination and RNA Modification, Different Polymerases.	**15**
II	RNA Processing and Life Cycle: RNA Maturation and RNPs, RNA Splicing, Post Transcriptional Processing; Alternative RNA Processing and Editing, Implications of Introns, Splicing and Pathology, RNA Editing in Detail, Relevance of RNA Editing, Relevance in Immunology; RNA Splicing, Export and Stability: Relevance of Introns, Introns in RNA Splicing, Different Spliceosomes, SMN Complex.	**15**
III	snRNA, rRNA, miRNA, siRNA Processing, Export and Function: Introns and Link to Splicing, RNA Helicases, Nucleo Cytoplasmic Transport, Nucleoporins and miRNAs, RNA Export Mechanisms, RNA Quality Control; Mechanisms of RNA Decay and Non Coding RNAs: Decay Pathways, mRNA Surveillance, Mechanisms of RNA Decay, Autoregulation of RNAs, Introduction to Non-Coding RNAs; Dosage Compensation and X-Inactivation: SRP and Different Modes of Compensation, Dosage Compensation of X, Omprinted vs Random X Inactivation, Molecular Basis of X-Inactivation, ES Cells and X-Inactivation.	**15**
IV	Dosage Compensation, Xist and ncRNA in Imprinting: The Roles of YY1, shRNAs and Gene Expression, Mechanism of RNAi in Action, Genomic Imprinting in Action, Different ncRNAs and their Roles, lncRNA-Induced Cancer, Xist and Cancer; Telomere, Telomerase and Impact on Genomes: The Importance of Telomeres, Telomerase and Aging, Telomere Length as Marker of Aging, Telomeres and Cancer, Cell Cycle Arrest, Maintenance and Manipulation of Telomeres; Epitranscriptome and Protein Synthesis: Important RNA Modifications, Readers, Writes and Erasers, Biological Implications of RNA Modifications, Roles of RNAs in Translation, Mechanism of Translation.	**15**

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment,
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Atkins J F. et al (ed.), *RNA Worlds: From Life's Origins to Diversity in Gene Regulation*.CSHL press (2011).
2. Meister G (ed.), *RNA Biology: An Introduction*. Wiley press (2011).
3. Elliott D, Ladomery M. (ed.), *Molecular Biology of RNA*. Oxford University Press (2011).
4. Darnell J. (ed.), *RNA: Life's Indispensable Molecule*.CSHL press (2011).
5. Morillon A. *Long non-coding RNA: The dark side of the genome*. Elsevier (2018).
6. Clark DP et al. *Molecular Biology*. AP Cell (2018).
7. Doran G. *Essentials of Molecular Biology*. Callisto Reference (2018).
8. Freifelder D. *Molecular Biology*. Narosa Publ. House.
9. Twyman RM, Primrose SB. *Principles of gene manipulation and genomics*. John Wiley & Sons (2006).

BOTM-E-621	**PLANT DEVELOPMENTAL BIOLOGY** Sri Ram Yadav, IIT, Roorkee COURSE LEVEL 600, CREDITS=4	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Have an idea regarding the development of the different parts of plants. CLO2. Differentiate between the development of vegetative and reproductive parts. CLO3. Compare the development of various plants in different stages of development.	
Unit	**Topics**	**Hrs**
I	Life Cycle of an Angiosperm Characteristics of plant growth and development-I Characteristics of plant growth and development-II	15
II	Root Development, Vascular Root development Root branching: Lateral Root Development	15
III	Shoot Development: SAM Maintenance Shoot Development: Organogenesis Shoot Development: Leaf Development	15
IV	Shoot development: flowering Cell-cell communication: Leaf development Techniques Used in Lab	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Leyser O, Day S. *Mechanisms in plant development*. John Wiley & Sons (2009).
2. Howell SH. *Molecular genetics of plant development*. Cambridge University Press. (1998).
3. Taiz L, Zeiger E. *Plant Physiology.* Sinauer Associates. 5th Eds (2010).
4. Raven PH, Evert RF, Eichhorn SE. *Biology of plants*. Macmillan. 8th Eds) (2005.
5. Buchanan BB, Gruissem W, Jones RL. *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists. Maryland, USA (2015).
6. Hopkins WG,Huner NPA. *Introduction to Plant Physiology*. 4th edition. John Wiley & Sons, (2008).
7. Nobel PS. *Physiochemical and Environmental Plant Physiology* (Second Edition) Academic Press, San Diego, USA (1999).
8. Heldt HW, Piechulla B.*Plant Biochemistry.* Academic Press, California, (2021).
9. Hopkins WG. *Introduction to Plant Physiology.* John Wiley and Sons, Inc., New York, USA, (1995).
10. LarcherW. P *hysiological plant ecology.* Springer, (2003).

BOTM-E-622	**REMOTE SENSING AND GIS** Prof. Rishikesh Bharti, IIT Guwahati COURSE LEVEL 600, CREDITS=4	
Course Learning Outcome	After the completion of this course, the students will be able to… CLO1. Use satellite images and field data and GIS in their future research work. CLO2. Understand basics of remote sensing. CLO3. Practice satellite image corrections and processing.	
Unit	**Topics**	**Hrs**
I	Remote Sensing Data and Corrections: Overview and Introduction, Basics of Remote Sensing, Error corrections in satellite image	15
II	Satellite image corrections: Error Identification and Correction - I Error Identification and Correction - II Error Identification and Correction - III	15
III	Digital image processing I: DIP-I DIP-II DIP-III Digital image processing II: DIP-IV Image Classification-I Image Classification-II	15
IV	GIS-II and Application GIS-II Applications of Remote Sensing & GIS-I Applications of Remote Sensing & GIS-II	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
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ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Lillesand TM, Kiefer RW.*Remote sensing and Image Interpretation,* John Wiley (1987)..
2. Jensen JR. *Introductory digital image processing from a remote sensing perspective*, Prentice Hall series in geographic information science (2015).
3. Schowengerdt RA.*Remote Sensing:* Models and Methods for Image Processing, Academic Press (2007)..
4. Campbell JB. *Introduction to Remote Sensing*, Taylor & Francis, London (1996).
5. Jensen JR.*Remote Sensing of the Environment and Earth Resource Perspective,* Pearson Education, Delhi (2003).
6. Joseph G. *Fundamentals of Remote Sensing*, University press (2003).
7. Gupta RP.*Remote Sensing Geology*, Springer (2005).
8. Van-dr-Meer F, De Jong S .*Imaging spectrometry:* Basic principles and prospective applications (The Netherlands: Springer Publishers), p451 (2006).
9. Rencz AN.*Remote Sensing for the Earth Sciences*, Manual of Remote Sensing, 3, ASPRS, pp703 (2008).
10. De-Jong, StevenM, Van der Meer FD.*Remote Sensing Image Analysis:* Including the Spatial Domain: Including the Spatial Domain, 5, Springer, pp359 (2004).

BOTM-E-623	**BIOLOGICAL SCIENCES & BIOENGINEERING** (Prof. Sanjeeva Shrivastava, IIT Bangalore) COURSE LEVEL 600, CREDITS=4	
Course Learning Outcome	After the completion of this course, the students will be able to….. CLO1. Understand the basics of biological concepts. CLO2. Motivate themselves why understanding biology is crucial for several applications.	
Unit	**Topics**	**Hrs**
I	**Nucleic acid and tools in biotechnology:** Biology for engineers: Part-I, Why biology for engineers: Part-II, Life processes & Cell, Cell and its properties, Clinician's Perspective-I, Nucleic Acid & Central Dogma, DNA Tools: Gene Cloning, DNA Tools: Gene Cloning-II, DNA Tools & Biotechnology, DNA Tools & Biotechnology-II, DNA Tools & Biotechnology-III, DNA Tools & Biotechnology-IV, DNA Tools & Biotechnology-V, DNA Tools & Biotechnology-VI, Clinician's Perspective-II	15
II	**Cytogenetics:** Genetics-I, Genetics-II, Genetics-III, Genetics-IV, Clinician's Perspective-III, Chromosomal basis of inheritance, Linkage, chromosomal disorders, Classical Genetics Experiments, Bacteria and Viruses, Clinician's Perspective-IV	15
III	**Amino acids and Proteins:** Cell cycle disregulation and Cancer, Developmental Biology, Principles and application of Animal Cloning, Evolution, Clinician's Perspective-V, Amino acids & proteins, Proteins & Proteomics, Techniques to Study Protein & Proteome-I	15
IV	**Bioinformatics tools:** Techniques to Study Protein & Proteome-II, Bioinformatics-I, Techniques to Study Protein & Proteome-III, Protein Interactions & Microarrays, Protein interactions & Systems biology, Bioinformatics-II, Ethics in Research and Publications	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Ahern K. Biochemistry and Molecular Biology, The Great Courses, The Teaching Company, 2019.
2. AudesirkT,Audesirk G. Biology, Life on Earth, 5th Ed., Prentice-Hall, 1999.
3. CrichtonRR. Biological Inorganic Chemistry, Elsevier (2008).
4. Denton M. The Miracle of the Cell, Discovery Institute (2020).
5. EngerED, RossFC. Concepts in Biology, 10th Ed., McGraw -Hill (2003.
6. GrauerK. A Practical Guide to ECG Interpretation, Mosby Year Book, (1992).
7. Hickman CP, RobertsLS, Larson A. Integrated Principles of Zoology, 9th. Ed., Wm C. Brown, 1995.

	MOOC Elective-III Theory Course (4 credits)	
	SEMESTER-IV	
BOTM-E-669	**PLANT CELL BIOPROCESSING** By Dr. Smita Srivastava, IIT Madras COURSE LEVEL 600, CREDITS =4	
Course Learning Outcome	After completing the course, the students will be able to… CLO1. Describe how to establish aseptic cultures of plant cell/ tissue/organs. CLO2. Explain the concept of micropropagation, its applications, and its limitations. CLO3. Deliberate on techniques used for in vitro production of secondary metabolites.	
Unit	**Topics**	**Hrs**
I	Introduction to plant cells and In-vitro forms of plant tissue cultures for commercial applications and Culture initiation	15
II	Somatic embryogenesis and culture preservation; Secondary metabolism in plant cells: Its role and commercial applications and Secondary metabolism in plant cells; Strategies to enhance yield and productivity of plant secondary metabolites in in vitro cell/tissue cultures	15
III	Strategies to enhance yield and productivity of plant secondary metabolites under in vitro cell/tissue cultures; Biotransformation and Immobilization of plant cell cultures and Genetic transformations in plant cells	15
IV	Scale-up considerations in plant cell/tissue cultures and case studies on in vitro production of high-value plant secondary metabolites for commercial applications: A Combinatorial/ Integrated approach for synergistic effect on production rates.	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Neumann KH, Kumar A,Imani J. 2009. *Plant cell and tissue culture: a tool in biotechnology* (Vol. 12). Berlin: Springer (2009
2. Gupta SD, Ibaraki Y. (eds) *Plant tissue culture engineering* (Vol. 6). Netherlands: springer (2006).
3. Zhong JJ et al. *Plant cells*. Springer Berlin, Heidelberg (2001).
4. Gamborg OL, Phillips GC (eds). *Plant Cell, Tissue and Organ Culture*. Springer Berlin, Heidelberg (2013).
5. Razdan MK, Bhojwani SS. *Plant Tissue Culture: Theory and Practice.*Revised edition, Elsevier Science (1996).
6. Ramawat KG. *Biotechnology*: Secondary Metabolites, 2nd Ed., CRC Press (2007).
7. Veeresham C. *Medicinal Plant Biotechnology*, 1st Ed., CBC Publishers and Distributors, NewDelhi (2011).
8. Shuler M, Kargi F, DeLisa M. (eds), *Bioprocess Engineering: Basic concepts. Pearsons.* (2017).
9. Lee JM. (ed) Biochemical Engineering. pp: 118-123 Prentice Hall, (1992)

BOTM-E-670	**ESSENTIALS OF BIOMOLECULES: NUCLEIC ACIDS AND PEPTIDES** Prof. Lal Mohan Kundu, IIT, Guwahati COURSE LEVEL 600, CREDITS=4	
Course Learning Outcome	After the completion of the course, the students will be able to… CLO1. Understand the self-synthesis of DNA molecules CLO2. Differentiate various tools, enzymes and strategies applied to sequences the DNA sample. CLO3. Demonstrate the use of DNA sequences for protein synthesis using bioinformatics tools.	
Unit	**Topics**	**Hrs**
I	Importance of Biomolecules, DNA double helix: Chemical parameters DNA and Proteins, Synthesis of nucleotides	15
II	DNA replication, DNA damage, mutation and cancer DNA to proteins: transcription, translation and genetic code	15
III	Protein sequencing using Sanger's and Edman's degradation methods Mass spectroscopy and other sequencing methods for large proteins Solution phase and solid phase peptide synthesis, Peptide based therapeutics	15
IV	Purification and Characterization techniques of biomolecules Molecular probes: PNA and LNA-I Carbohydrate chemistry: Introduction, synthesis of sugars and carbohydrates, Carbohydrate based polymers as biomolecular probes and therapeutics;	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
- Attending various seminars/online events/presentations etc.

ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Miller A, Tanner J. Essentials of Chemical Biology. John Wiley & Sons, Chichester (2008)
2. Berg T.Stryer Biochemistry, W. H. Freeman & Co. New York (2019).
3. Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff Keith Roberts, and PeterWalter.Molecular Biology of The Cell. W. W. Norton and Company, (2022).
4. Watson JD, Baker TA, Bell SP, Gann A, Levine M, Losi c R. Molecular Biology of The Gene.

BOTM-E-671	**NATURAL RESOURCES MANAGEMENT** By Prof. Sudip Mitra, IIT Guwahati COURSE LEVEL 600, CREDITS=4	
Course Learning Outcome	After successful completion of this paper students will be able to CLO1. Understand the basics of Natural Resource Bases. CLO2. Utilize the patterns for Resource Management CLO3. Handle the assessment tools and technologies in Resource Management	
Unit	**Topics**	**Hrs**
I	Introduction to Natural Resource Bases; Resource Management Paradigms; Approaches to NRM	15
II	Biodiversity and conservation of natural resources; Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA)	15
III	Technologies for integrated NRM; PRA techniques within INRM; Ranking techniques; community based NRM; watershed management; National water policy; Land use management for flood risk reduction	15
IV	Precision Farming & Protected Cultivation; Environmental Impact Assessment; Climate change; vulnerability; adaptation	15

SUGGESTED TEACHING LEARNING STRATEGIES

- Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
- Quiz, group discussions, Case studies, and Group Projects
- Guided readings and discussions in the class/lab/field and out of the class/field/lab.
- Individual and group presentations by students on selected topics.
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ASSESSMENT FRAMEWORK

Assessment	Written mode	Oral Mode	Integrated mode
Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Lynch DR. *Sustainable Natural Resource Management: For Scientists and Engineers, Publisher:* Cambridge University Press, (2009).
2. Dash MC. *Concepts of Environmental Management for Sustainable Developmen*t Publisher: I K International Publishing House Pvt. Ltd., (2013).
3. ShivakotiG, Pradhan U,Helmi H (eds).*Redefining Diversity and Dynamics of Natural Resources Management in Asia, Volume*. 1st Edition, Sustainable Natural Resources Management in Dynamic Asia, Editors: ISBN: 9780128054543, Elsevier, (2016).
4. Rogers P, Jalal KF, Boyd J. *An Introduction to Sustainable Development.* Publisher: Routledge; 1 edition, ISBN-10:1844075206, (2007).
5. EldredgeN. *Systematics, Ecology and Biodiversity Crisis.* Cambridge University Press, New York (1992).
6. Ellis EC.*Sustaining biodiversity and people in the world's anthropogenic biomes.* Current Opinion in Environmental Sustainability, 5:368–372 (2013).
7. SinghJS, Singh SP, Gupta SR. Ecology,Environment and ResourceConservation.Anamaya Publ.,NewDelhi.pp688 (2006).
8. Lovejoy TE, Hannah LJ.*Climate ChangeBiodiversity;*YaleUniversityPress,pp418 (2006).
9. Anonymous.*Global Environmental Change:* Research Pathways for the Next Decad e, National Research Council, (1999)
10. Anonymous.Our Common Journey: *A Transition Toward Sustainability*, National Researc hcouncil, (1999)

BOTM-E-672	**ENVIRONMENTAL BIOTECHNOLOGY** **Prof. Pinaki Sar, IIT, Kharagpur** COURSE LEVEL 600, CREDITS=4	
Course Learning Outcome	After the completion of the course, the student will be able to… CLO1. Describe the role of microbes in the environment CLO2. Illustrate the different bioremediation approaches CLO3. Identify organisms involved in the bioengineering and biotechnology	
Unit	**Topics**	**Hrs**
I	Introduction to Environmental Biotechnology Definitions, Microorganisms & Environmental Biotechnology Global crisis challenge environmental science and biotechnology, Microbial ecology (Part I): Principles and concepts, habitats and species. species diversity and abundance in Microbial Habitats and their controls Microbial ecology (Part II): Microbial Ecosystems and Biogeochemical cycling Microbial ecology (Part III): Microbial Ecology and environmental biotechnology	15
II	Microbiology of Environmental bioengineering systems (Part I): Goals, Microorganisms involved in bioengineering and biotechnology Microbiology of Environmental bioengineering systems (Part II): Eukaryotic micro and macro-organisms involved in bioengineering, microbial biomass, Growth medium, storage compounds and classification of microorganisms based on carbon source for growth Microbiology of Environmental bioengineering systems (Part III): Transformation of microbial cells into specialized cells Cell cycles	15
III	Physiological Ecology and Resource Exploitation by Microorganisms, Biodegradation: Concepts, Requirement, role of biodegradation, Availability of nutrients Adequate pH and buffering capacity Adequate temperature Absence of toxic or inhibitory substances Common biotransformation reactions	15
IV	Bioremediation: Concepts, principles, requirements, merits and limitations, goals, progress and challenges, pregenomic approaches, heavy metals, metalloids, Bioleaching, biological nitrogen and phosphorus removal, Microbially enhanced oil recovery Emerging Areas: Pollutants, Microbial carbon capture, Bioenergy, Radioactive bioremediation, Acid mine drainage bioremediation	15

SUGGESTED TEACHING LEARNING STRATEGIES

• Lecture-cum discussion, library readings, Critical Discussion, Reflective Writing Comparative analysis
• Quiz, group discussions, Case studies, and Group Projects
• Guided readings and discussions in the class/lab/field and out of the class/field/lab.
• Individual and group presentations by students on selected topics.
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Formative Marks: 50	Descriptive test, Objective test, Assignment, Online test, report, case study	Viva-voce and Group discussion	Seminar, presentation, lab exercise, Field assignment
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Madigan M et al. Brock Biology of Microorganisms, Pearson Press.
2. PrescottH, Wiley KJM, Shrewood LM, Woolverton CJ, Microbiology, McGrawHill Education
3. Madsen EL. Microorganisms and their roles in fundamental biogeochemical cycles, Current Opinion in Biotechnology, 22: 456-464 (2011).
4. Rittmann BE. Microbial ecology to manage processes in environmental biotechnology, , TRENDS in Biotechnology, 24: 261-266 (2006).
5. Rittmann BE. A Vista for microbial ecology and environmental biotechnology, Bruce E Rittman et al, Environmental Science and Technology, 40: 1096-1103 (2006).