

**FOUR YEAR UNDER GRADUATE (FYUG) PROGRAMME**

**UNDER NATIONAL EDUCATION POLICY 2020**

**BOTANY**



**NORTH-EASTERN HILL UNIVERSITY**

**SHILLONG**

## **Preface:**

The four-year undergraduate program (FYUP) in Botany offers a comprehensive curriculum covering a wide array of topics essential for understanding plant biology and its interdisciplinary applications. Students begin with fundamental courses on plant diversity, delving into the biology of the different taxonomic groups which will form the basis of understanding the ensuing aspects of plant biology laid out in the curriculum. The course content encompasses fundamental concepts in plant anatomy, morphology, physiology, and ecology, equipping students with a strong foundation in Plant Sciences. Through hands-on laboratory experiments and fieldwork, students will gain understanding into the practical aspects of plant biology such as ecology, taxonomy, genetics, development and biotechnology. With a carefully modulated blend of theoretical learning and hands-on practical exposure, graduates of the FYUP will be equipped to emerge as skilled plant biologists prepared to address the different challenges of plant ecology, agriculture, environmental sustainability, and biotechnological innovations.

## **Programme Outcomes (POs):**

1. Students will gain an understanding of the biology of different plant taxonomic groups and their major classification systems.
2. Students will be acquainted with the economic importance of selected plants, their parts used, their characteristics, cultivation methods and processing.
3. Students will gain fundamental understanding of the biology of bacteria, viruses and fungi and their applications.
4. Students will gain awareness of plant biodiversity richness, its value and strategies for conservation and sustainable utilisation of biodiversity wealth.
5. Students will be introduced to principles of plant function, such as physiology, metabolism, biochemistry, and growth and development.
6. The course will familiarise students of the complex interrelationship between plants and environment; plant community patterns and processes, and ecosystem functions.
7. Students will gain comprehensive understanding of cell biology, molecular biology, genetics and plant breeding.
8. Students will be acquainted with biotechnological interventions in plant biology and gain understanding of the applications of plant biotechnology.
9. Students will acquire knowledge of biofertilizers, their types and the different methods of preparation.
10. Students will be able to conduct research in the field of Plant Sciences and demonstrate integrity, objectivity, and accountability in research, management and decision-making.

## 1<sup>st</sup> Semester

Course Code	Course Title	Credits			Total Contact Hours
		Theory	Practical	Total	
BOT-100	Plant Diversity I: Algae, Bryophytes and Pteridophytes (Major)	3	1	4	75
BOT-100	(Minor)	3	1	4	75
MDC-110----119	Any of the available course as notified by the University from time to time.	3	-	3	45
AEC-120----129	Any of the available course as notified by the University from time to time	3	-	3	45
SEC-130---139	Any of the available course as notified by the University from time to time	3	-	3	45
VAC-140	Environmental Sciences	3	-	3	45
<b>Total</b>		<b>18</b>	<b>2</b>	<b>20</b>	<b>330</b>

## 2<sup>nd</sup> Semester

Course Code	Course Title	Credits			Total Contact Hours
		Theory	Practical	Total	
BOT-150	Plant Diversity II: Gymnosperms and Paleobotany, Angiosperm Morphology, Plant Anatomy (Major)	3	1	4	75
BOT-150	(Minor)	3	1	4	75
MDC-160---169	Any of the available course as notified by the University from time to time	3	-	3	45
AEC-170---179	Any of the available course as notified by the University from time to time	3	-	3	45
SEC-180---189	Any of the available course as notified by the University from time to time	3	-	3	45
VAC-190---199	Any of the available course as notified by the University from time to time	3	-	3	45
<b>Total</b>		<b>18</b>	<b>2</b>	<b>20</b>	<b>330</b>

BOT – Botany; MDC – Multi Disciplinary Course; AEC – Ability Enhancement Course; SEC – Skill Enhancement Course; VAC – Value Added Course; VTC – Vocational Education and Training Course

### 3<sup>rd</sup> Semester

Course Code	Course Title	Credits			Total Contact Hours
		Theory	Practical	Total	
BOT-200	Economic Botany and Ethnobotany and Phytogeography (Major)	3	1	4	75
BOT-201	Angiosperm Taxonomy (Major)	3	1	4	75
MDC-210---219	Any of the available course as notified by the University from time to time	3	-	3	45
AEC-220---229	Any of the available course as notified by the University from time to time	2	-	2	30
SEC-230---239	Any of the available course as notified by the University from time to time	3	-	3	45
VTC-240---249	Any of the available course as notified by the University from time to time	1	3	4	105
<b>Total</b>		<b>15</b>	<b>5</b>	<b>20</b>	<b>375</b>

### 4<sup>th</sup> Semester

Course Code	Course Title	Credits			Total Contact Hours
		Theory	Practical	Total	
BOT-250	Mycology and Plant Pathology (Major)	3	1	4	75
BOT-251	Microbiology (Major)	3	1	4	75
BOT-252	Reproductive Biology of Angiosperms (Major)	3	1	4	75
BOT-253	Biodiversity and Conservation Biology (Major)	3	1	4	75
VTC-260---269	Any of the available course as notified by the University from time to time	1	3	4	105
<b>Total</b>		<b>13</b>	<b>7</b>	<b>20</b>	<b>405</b>

**5<sup>th</sup> Semester**

Course Code	Course Title	Credits			Total Contact Hours
		Theory	Practical	Total	
BOT-300	Plant Physiology (Major)	3	1	4	75
BOT-301	Plant Biochemistry (Major)	3	1	4	75
BOT-302	Plant Ecology (Major)	3	1	4	75
BOT-302	Angiosperm Taxonomy, Ecology and Economic Botany (Minor)	3	1	4	75
BOT-303	Internship	-	4	4	120
<b>Total</b>		<b>12</b>	<b>8</b>	<b>20</b>	<b>420</b>

**6<sup>th</sup> Semester**

Course Code	Course Title	Credits			Total Contact Hours
		Theory	Practical	Total	
BOT-350	Genetics and Plant Breeding (Major)	3	1	4	75
BOT-351	Molecular Biology (Major)	3	1	4	75
BOT-352	Plant Stress biology (Major)	3	1	4	75
BOT-353	Plant Biotechnology (Major)	3	1	4	75
VTC-360---369	Any of the available course as notified by the University from time to time	1	3	4	105
<b>Total</b>		<b>13</b>	<b>7</b>	<b>20</b>	<b>405</b>

## 6. BOTANY

The Botany curriculum provides students with a comprehensive understanding of plants, incorporating subject knowledge, technical skills, and interdisciplinary components. It equips them with cutting-edge technologies used in plant science research and emphasizes the social and environmental importance of plants. Students gain awareness of plants' role in maintaining ecological balance, conserving biodiversity, and mitigating environmental challenges. The curriculum also highlights the economic relevance of plants in sectors like agriculture, horticulture, and pharmaceuticals. By integrating these elements, the curriculum prepares students as well-rounded professionals capable of addressing complex challenges, contributing to scientific advancements, and making informed decisions for the benefit of society, the environment, and the economy.

**Programme Outcomes (POs):** Expected outcome of the programme:

1. Gain comprehensive understanding of different branches of Botany: Systematics, evolution, ecology, developmental biology, physiology, biochemistry, plant interactions, morphology, anatomy, reproduction, genetics, and molecular biology.
2. Acquire competence in analytical and technical skills relevant to plant sciences.
3. Develop abilities in plant identification, experimental design, database utilization, and statistical analysis.
4. Conduct short research projects using various tools and techniques in plant sciences, fostering a scientific and research-oriented mindset.

### **BOT-100: PLANT DIVERSITY–I:ALGAE, BRYOPHYTES AND PTERIDOPHYTES**

**(Contact Hours: 75, Credits: 4)**

#### **Course Objectives (Cos):**

This paper aims to provide students with a comprehensive understanding of the lower groups of plants, enabling them to grasp the interrelationships and evolutionary affinities among these plant groups. Additionally, it will equip students with proficiency in experimental techniques for analyzing and studying these plant groups.

#### **Learning Outcomes (LOs):**

After the completion of the course, the students will be able to:

1. Acquire knowledge regarding the classification, diversity, and life cycles of various groups of algae, including their economic significance.
2. Develop a critical understanding of the morphology, anatomy, reproduction, and life cycles of bryophytes.
3. Gain a critical understanding of the morphology, anatomy, reproduction, and life cycles of pteridophytes.

4. Understand the ecological and economic uses of archegoniate plants.
5. Demonstrate proficiency in employing experimental techniques and methods for the appropriate analysis of algae, bryophytes, and pteridophytes.

### **Unit – I: Algae**

1. Salient features of algae and Classification by Fritsch (1935) with characteristic features of each class.
2. Range of thallus and reproductive structures in algae.
3. Life cycles of *Chara*, *Oedogonium*, and *Polysiphonia*.
4. Economic importance of algae.

### **Unit – II: Bryophytes** Salient features of bryophytes and classification by Proskauer (1957).

1. Origin and range of gametophytic structures in Bryophytes.
2. Life cycle of *Marchantia*, *Anthoceros* and *Funaria*.
3. Economic importance of Bryophytes.

### **Unit- III: Pteridophytes**

1. Salient features of pteridophytes and classification by Smith (1955).
2. Types of stelar structures in Pteridophytes.
3. Life cycle of *Lycopodium* and *Selaginella*.
4. Economic importance of Pteridophytes.

### **Unit - IV: Practical**

1. Study of vegetative and reproductive parts with the help of temporary preparations of all genera prescribed in Paper BOT-100-T.
2. Dissection, sectioning, drawing, description and identification of the specimens covered in the preparations.
3. Spotting: Includes those specimens not covered in experiments 1 and 2.
4. Field visit to nearby areas to observe different groups of plants prescribed in the theory syllabus.

### **Suggested Readings:**

1. Bold, H.C. and Wynne, M.J. (1978). Introduction to Algae: Structure and Reproduction. Prentice Hall, New Jersey.
2. Bux, F. and Chisti, Y. (2018). Algae Biotechnology: Products and Processes. Springer, International Publishing, Cham.
3. Geissler, P and Greene, S.W. (1982). Bryophyte Taxonomy: Methods, Practices and Floristic Exploration. J Cramer, Germany.
4. Hait, G., Bhattacharya, K. and Ghosh, A.K. (2011). Textbook of Botany. Volume 1. New Central Book Agency (P) Ltd., New Delhi.
5. Kumar, H.D. (1999). Introductory Phycology. Affiliated East-West Press Pvt. Ltd., New Delhi.
6. Lee, R.E. (2008). Phycology. Fourth Edition. Cambridge University Press.

7. Mitra, J.N., Mitra, D. and Chaudhuri, S.K. (2023). Studies in Botany. Volume I. 10<sup>th</sup> Revised Edition. Moulik Library, Kolkata.
8. Pandey, B.P. (2017). Botany for degree students. Biodiversity. S. Chand & Company Ltd., New Delhi.
9. Shaw, A.J. and Goffinet, B. (2000). Bryophyte Biology. Cambridge University Press.
10. Stevenson, R.J., Bothwell, M.L. and Lowe, R.L. (1996). Algal Ecology: Freshwater Benthic Ecosystems. Academic Press, Cambridge.
11. Van den Hoek, C., Mann, D.G. and Jahns, H.M. (1995). Algae. An Introduction to Phycology, Cambridge University Press.
12. Vanderpoorten, A. and Goffinet, B. (2009). Introduction to Bryophytes. Cambridge University Press.
13. Vashishta, P.C., Sinha, A.K., and Kumar, A. (2006). Botany for degree students. Pteridophyta (Vascular Cryptogams). S. Chand & Company Ltd., New Delhi.
14. Vashishta, B.R., Sinha, A.K., and Singh, V.P. (2010). Botany for degree students. Part-I Algae. S. Chand & Company Ltd., New Delhi
15. Vashishta, B.R., Sinha, A.K., and Kumar, A. (2010). Botany for degree students. Part-III Bryophyta. S. Chand & Company Ltd., New Delhi.

**BOT-150: PLANT DIVERSITY–II: GYMNOSPERMS, PALAEOBOTANY,  
ANGIOSPERM MORPHOLOGY AND ANATOMY**

**(Contact Hours: 75, Credits: 4)**

**Course Objectives (Cos):**

This paper provides an overview of the higher groups of plants, focusing on the interrelationships and evolutionary pathways that connect them. By studying this topic, students will develop a comprehensive understanding of how different plant groups are related to each other and how they have evolved over time. Through exploring the interconnections and evolutionary trajectories of higher plant groups, students will gain valuable insights into the diversity and complexity of the plant kingdom, enriching their knowledge of plant biology and evolution.

**Learning Outcomes (LOs):** Upon completion of the course, students will be able to:

1. Develop a critical understanding of the morphology, anatomy, and reproduction of Gymnosperms and Angiosperms.
2. Gain knowledge about the geological history of the Earth and the life forms that existed during prehistoric periods.
3. Comprehend the process of fossil formation and recognize different types of fossils.
4. Understand the fundamental concepts of plant morphogenesis and the development of organs.
5. Analyze the variations in morphology and internal structures among different parts of plants and across various plant groups, supporting the concept of evolution.
6. Demonstrate proficiency in utilizing experimental techniques and methods for the appropriate analysis of Gymnosperms.

7. Master the techniques for preparing double-stained specimens and studying anomalous growth in angiosperms.

### **Unit-I: Gymnosperms and Paleobotany**

1. Salient features and classification of gymnosperms by Coulter and Chamberlain (1910).
2. Phylogenetic relationship and affinities of gymnosperms.
3. Life cycle of *Cycas*, *Pinus*, and *Gnetum*.
4. Economic importance of gymnosperms.
5. Geological time scale; Fossil formation and plant fossil types.

### **Unit-II: Angiosperm Morphology**

1. Leaf morphology: Phyllotaxy and venation.
2. Types of stipules, bracts and inflorescence.
3. Floral morphology: Forms of calyx, corolla, and their aestivation.
4. Types of stamens and carpels.
5. Types of fruits, ovule forms, and placentation.
6. Types of seeds: albuminous and exalbuminous

### **Unit- III: Plant Anatomy**

1. Organization of apical meristem.
2. Types of stomata in angiosperms.
3. Components of xylem and phloem with their functions.
4. Concept of primary and secondary growth; Secondary growth in stem and root of dicots.
5. Anomalous secondary growth in *Bignonia* and *Dracaena*.
6. Root-stem transition.

### **Unit - IV: Practical**

1. Study of vegetative and reproductive structures of all prescribed gymnosperms by preparing temporary stained slides (dissection, sectioning, drawing, description, and identification up to genus).
2. Study of fossils through slides or specimens.
3. Sectioning and observation of placentation types, ovule structure, and anther through temporary preparations.
4. Study of permanent slide preparation by double staining techniques (Safranin and Haematoxylin or Safranin and fast green).
5. Anatomical studies of anomalous secondary structures of *Bignonia* and *Dracaena* by temporary double staining techniques (Safranin and Haematoxylin or Safranin and fast green).
6. Spotting: Includes those groups and sections not covered in the preparations.

### **Suggested Readings:**

1. Beck, B. (1988). Origin and Evolution of Gymnosperms. Columbia University Press.
2. Bhatnagar, A. K. and Moitra, A. (1996). Gymnosperms. New Age International (P) Ltd Publishers, New Delhi.
3. Bhattacharya, K., Hait, G. and Ghosh, A.K. (2015). A Textbook of Botany. Volume II. New Central Book Agency (P) Ltd., New Delhi.

4. Bhojwani, S.S. and Bhatnagar, S.P. (2000). The Embryology of Angiosperms. Vikas Publishing House.
5. Crang, R., Lyons-Sobaski, S., and Wise, R. (2018). Plant anatomy: A concept-based approach to the structure of seed plants. Springer.
6. Dickison, W.C. (2000). Integrative Plant Anatomy. Harcourt Academic Press, USA.
7. Evert, R.F. (2006). Esau's Plant Anatomy: Meristems, Cells, and Tissues of the Plant Body: Their Structure, Function, and Development. John Wiley and Sons, Inc.
8. Fahn, A. (1990). Plant Anatomy. Pergamon Press.
9. Mauseth, J.D. (1988). Plant Anatomy. The Benjamin/Cummings Publisher, USA.
10. Mishra, S. R. (2010). Textbook of Palaeobotany. Discovery Publishing House Pvt Ltd.
11. Mitra, J.N., Mitra, D. and Chaudhuri, S.K. (2023). Studies in Botany. Volume I. 10th Revised Edition. Moulik Library, Kolkata.
12. Pandey, B.P. (2017) A Textbook of Botany: Angiosperms. S. Chand & Company Pvt Ltd.

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### 3<sup>rd</sup> SEMESTER

**BOT-200**

**Economic Botany, Ethnobotany and  
Phytogeography**

**Total Credits: 4  
(Contact Hours:75)  
Total Marks:100**

#### **Course Objectives:**

This course is designed to acquaint students with certain plants which provide resources to mankind.

- The course will familiarise students with cultivation methods and processing of some economically important crops.
- It will also give an idea about various aspects of ethnobotany and phytogeography, with special emphasis to India.

#### **Learning Outcomes:**

On completion of the course, students are expected to:

- Have knowledge of various categories of economically important plants.
- Learn about cultivation and processing of rubber and tea.
- Identify teak and sal, with their distinguishing characters and method of cultivation.
- Understand the concept of ethnobotany and the relation between plants and indigenous communities, with emphasis on ethnobotany of North-Eastern India.
- Understand traditional knowledge and legal aspects of it.
- Understand the basic concepts of phytogeography and mechanism of plant distribution.

**(Theory)**

**Credits: 3  
(Contact Hours:45)**

#### **Unit 1.**

1. Vavilov's centers of origin of cultivated plants.
2. Study of economically important plants – cereals, pulses, oil yielding, spices, condiments, fibres, ornamentals and aromatic (with scientific names, families and parts used of at least three plants under each category).
3. Economic importance, cultivation and processing of tea and rubber.
4. Wood characteristics, cultivation and uses of timber-yielding plants (Teak and Sal); economic importance, cultivation and processing of aromatic (*Cymbopogon* spp) and medicinal plants (*Rauwolfia* spp).

#### **Unit 2.**

1. Ethnobotany and traditional knowledge; study of at least five ethnobotanical plants from each of the following categories: folk medicine, wild edibles used by the tribes of Northeast India.
2. Biopiracy and Intellectual Property Rights.

#### **Unit 3.**

1. Floristic regions of India.
2. Continuous and discontinuous plant distribution (definitions, types); theories of discontinuous plant distribution in India.
3. Plant endemism
4. Plant migration: definition and mechanism; barriers to plant migration.

**Unit 4.****(Practical)****Credit: 1  
(Contact Hours:30)**

1. Qualitative detection of starch, protein, fat and cellulose in plant materials by chemical tests.
2. Study of at least ten economically important plant parts and plant products prescribed in syllabus.
3. Submission of ten specimens each of economically and ethnobotanically important plants/plants produce.
4. Identifying characters and economic/ conservational importance of at least three endemic plant species of Meghalaya (based on field observation/ specimens/ illustrations)

**Suggested readings:**

1. Bhattacharya, K., Ghosh, A. and Hait, G. 2020. A Textbook of Botany: Vol IV. New Central Book Agency, Kolkata.
2. Hill, A.F. 2012. Economic Botany: A Textbook of Useful Plants and Plant Products. 2<sup>nd</sup> edition. Surjeet Publications.
3. Jain, S.K. 1981. Glimpses of Indian Ethnobotany. Oxford IBH, New Delhi.
4. Jain, S.K. 1987. A Manual of Ethnobotany. Scientific Publishers, Jodhpur.
5. Jain, S.K. and Mundgal, V. 1999. Handbook of Ethnobotany. Bishen Singh Mahendra Pal Singh, Dehradun.
6. Kochar, S.L. 2016. Economic Botany : A Comprehensive Study. 5<sup>th</sup> edition. Cambridge English.
7. Negi, S.S. 2004. Handbook of Forest Ecology and Biology. International book distributors, Dehradun.
8. Puri, G.S. 1990. Forest Ecology. Oxford IBH, New Delhi
9. Santra, S.C., Chatterjee, T.P. and Das, A.P. 2012. College Botany- Practical. Volume 2. New Central Book Agency.
10. Sen, S. 2016. Economic Botany. New Central Book Agency.
11. Singh, V., Pande, P.C. and Jain, D.K. 2018. Economic Botany. 3<sup>rd</sup> revised edition. Rastogi Publications, Meerut.

**Course Objectives:**

- This course is designed to acquaint students with the concept and principles of plant systematics, major systems of classification and the distinctive characteristic features of certain important monocot and dicot families.

**Learning Outcomes:**

On completion of the course, students are expected to:

- Acquire a concept on plant systematics, different taxa and understand their positions in taxonomic hierarchy and know the major systems of plant classification.
- Ability to classify and describe plants in scientific terms and identification of plants using taxonomic keys.
- Have the required knowledge on collection and preservation of plant specimens through herbarium technique.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

**Unit 1.**

1. Introduction to systematics – plant identification, classification and nomenclature.
2. Concept of taxa (family, genus, species); categories and taxonomic hierarchy.
3. Types of taxonomic keys: single access (dichotomous) and multi-access.

**Unit 2.**

1. Major systems of classification – artificial (Linnaeus), natural (Bentham and Hooker), phylogenetic (Hutchinson) and APG system.
2. I.C.N. – principles of botanical nomenclature, types and typification, rules and limitations of principles of priority. Nomenclature of cultivated plants.
3. Herbarium: methods of preparation of herbarium specimens (sheets, dried specimens, illustrations and bottled specimens); importance of herbarium, important herbaria of India.

**Unit 3.**

1. Distinguishing features and economic importance of the following dicotyledonous families: Ranunculaceae, Fabaceae, Asteraceae and Solanaceae.
2. Distinguishing features and economic importance of the following monocotyledonous families: Liliaceae, Orchidaceae and Poaceae.

**Unit 4.**

**(Practical)**

**Credit: 1  
(Contact Hours: 30)**

1. Taxonomic studies of plants belonging to both dicot and monocot families mentioned in the theory paper 201: flower dissection, drawing and description in technical terms and identification of the plant specimen up-to genus.
2. Techniques of preparation of herbarium sheets of flowering plants and submission of at-least 5 herbarium sheets of different taxa.
3. Preparation of taxonomic keys based on own observation of at least three species of the same genus.
4. One field study of relevance to the course content and submission of field report.

### **Suggested readings:**

1. Bendre, A.M. and Kumar, A. 2019. A Textbook of Practical Botany-2. Rastogi Publications, Shivaji Road, Meerut, India.
2. Bhattacharya, K., Ghosh, A. and Hait, G. 2013. A Textbook of Botany. Vol II. New Central Book Agency, Kolkata.
3. Datta S.C. 2018. Systematic Botany. New Age International Private Limited.
4. Gupta, R.K. 1989. Textbook of Systematic Botany. Atma Ram & Sons, Delhi.
5. Jain, S.K. and Rao, R.R. 2016. Handbook of Field and Herbarium Methods. Today and Tomorrow's Printers and Publishers, New Delhi.
6. Jeffrey, C. 1982. An Introduction of Plant Taxonomy. Cambridge University Press, Cambridge.
7. Mitra, D., Guha, J. and Chaudhury, S.K. 2018. Studies in Botany. Vol I. Moulik Library, Kolkata.
8. Naik, V.N. 2014. Taxonomy of Angiosperms. Tata McGraw-Hill.
9. Radford, A.E. 1986. Fundamentals of Plant Systematics. Harper & Row, New York.
10. Shankar, U. 2021. Enumeration of the Flora of Northeast India - Onelist of over 10,000 taxa of flowering plants. Arshuma Famous Books, Agra, India.
11. Singh, G. 2018. Plant Systematics: Theory & Practice. 3<sup>rd</sup> edition. Oxford & IBH Pvt Ltd., New Delhi.
12. Sinha, S.K. 2014. A Textbook of Plant Taxonomy. Anmol Publications Pvt. Ltd. Delhi.

## 4<sup>th</sup> SEMESTER

**BOT-250**

**Mycology and Plant Pathology**

**Total Credits: 4  
(Contact Hours:75)  
Total Marks:100**

### **Course Objectives:**

This course is designed to

- Familiarize the students with habitats, classification, structure, life cycle and evolutionary trends of Fungi and about the ecological significance of Fungi and Lichen.
- To acquaint with various plant diseases, causal organisms and their control.

### **Learning Outcomes:**

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

- Identify, collect and preserve different types of fungi and lichen.
- Develop a basic understanding about the structure and life cycle of fungi and lichens.
- Identify diseases in crop plants and measures for their prevention and control.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

### **Unit 1.**

1. General features of fungi, classification of fungi by Ainsworth (1973) and Hawksworth (1995).
2. Range of vegetative structure and reproduction in fungi.
3. Types of fungal spores and mode of their liberation.
4. Economic importance of fungi.

### **Unit 2.**

1. General characteristics of Mastigomycotina, Ascomycotina, Basidiomycotina and Deuteromycotina.
2. Life cycle of *Phytophthora*, *Rhizopus*, *Erysiphe*, *Agaricus*, *Fusarium*.
3. Lichens: general characteristics, growth forms and range of thallus organization; economic importance of lichens.

### **Unit 3.**

1. Terms and concepts, general symptoms and geographical distribution of diseases; diagnosis, prevention and control of plant diseases; plant quarantine measures.
2. Symptoms, diagnosis and disease cycles of:
  - a. Early blight of potato, White rust of crucifers and Black stem rust of wheat.
  - b. Citrus canker, Angular leaf spot disease of cotton.
  - c. Tobacco Mosaic disease, Vein clearing in Malvaceae.

### **Unit 4.**

**(Practical)**

**Credit: 1  
(Contact Hours: 30)**

1. Study of the vegetative and reproductive parts of the specimens prescribed in unit II with the help of temporary preparations and permanent slides: sectioning, drawing, description, identification and classification of the specimens.
2. Study of diseased specimens prescribed in unit III by temporary preparations and permanent slides.
3. Collection, identification and submission of at least 5 diseased plant specimens.

**Suggested readings:**

1. Agrios, G.N. 2005. Plant Pathology. 5<sup>th</sup> edition. Academic Press, U.K.
2. Alexopoulos, C.J., Mims, C.W., Blackwell, M. 1996. Introductory Mycology. John Wiley & Sons (Asia) Singapore. 4th edition.
3. Dube, H.C. 2022. An Introduction to Fungi. 4<sup>th</sup> revised edition. Scientific Publishers, India.
4. Mehrotra, R. S. 2011. Plant Pathology. Tata McGraw-Hill Publishing Company Limited, New Delhi.
5. Mehrotra, R. S. and Aggrawal, A. 2017. Plant Pathology. 3<sup>rd</sup> edition. Tata McGraw-Hill Publishing Company Limited, New Delhi.
6. Mishra, B. K. 2017. Mycology and Phytopathology. Kalynai Publishers, New Delhi.
7. Sethi, I.K. and Walia, S.K. 2011. Text book of Fungi and Their Allies. Macmillan Publishers India Ltd.
8. Sharma, P. D. 2017. Mycology and Phytopathology. Rastogi Publication, Meerut.
9. Sharma, P.D. 2016. Plant Pathology. 2<sup>nd</sup> edition. Rastogi Publication, Meerut, India.
10. Webster, J. and Weber, R. 2007. Introduction to Fungi. 3<sup>rd</sup> edition. Cambridge University Press, Cambridge.

**BOT-251**

**Microbiology**

**Total Credits: 4**  
**(Contact Hours:75)**  
**Total Marks:100**

**Course Objectives:**

- To provide the basic knowledge about the microbial world and various microbial techniques for microbial study.
- To gain understanding of bacteria and viruses, their morphology, classification, ultrastructure, reproduction and importance.
- To provide basic information of the different applications of microorganisms.

**Learning Outcomes:**

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

- Understand the concepts of basic microbiological techniques.
- Understand in detail, about structure, classification and importance of bacteria and viruses.
- Gain knowledge about application of microorganisms in different fields.

**(Theory)**

**Credits: 3**  
**(Contact Hours: 45)**

**Unit 1.**

1. Microscopy: principles and applications of bright field microscopy.
2. Ultra-structure of a bacterial cell; gram positive and gram-negative cell wall.
3. Basic concepts of Archaea, Mycoplasma and Cyanobacteria.
4. Bacterial reproduction (asexual and sexual methods).

**Unit 2.**

1. Discovery and classification of viruses (Baltimore system).
2. General structure and symmetry of virus; structure of T<sub>4</sub> and TMV.
3. Replication of virus (general account): lytic and lysogenic cycles.
4. Economic importance of viruses with brief reference to vaccine production.

**Unit 3.**

1. Microbial nutrition (nutritional requirements, nutritional types) and growth (growth characteristics, monoauxic growth- batch-culture).
2. Role of microorganisms in nitrogen fixation and decomposition of organic matter.
3. Basic concepts of food spoilage, food poisoning and food preservation.
4. Antibiotics: source, types and mode of action.

**Unit 4.**

**(Practical)**

**Credit: 1**  
**(Contact Hours: 30)**

1. Studies on microbiological techniques: sterilization (dry and moist heat), preparation of different types of culture media – plates (nutrient agar medium / potato dextrose agar) and their inoculation by soil inoculum.
2. Preparation of slant, stab and pouring of plate.
3. Calibration of microscope and measurement of microbial spores (fungal/bacterial).
4. Study of gram positive and gram negative bacteria (curd and leguminous root nodules) by Gram staining technique.
5. Demonstration of fungal or bacterial population density calculation (Yeast / spores) using haemocytometer.

**Suggested readings:**

1. Anathanarayan, R., Paniker, C.K. J. (Kanugo, R and Saxena, S. eds.). 2022. Text Book of Microbiology. Orient and Longman, New Delhi.
2. Dubey, R.C. and Maheshwari, D.K. 2013. Text book of Microbiology. 4<sup>th</sup> edition. S. Chand & Company Ltd., New Delhi.
3. Frazier, W.C., Wasthoff, D.C and Vanitha, N.M. 2017. Food Microbiology. Tata McGraw-Hill Publishing Company Ltd., New Delhi.
4. Gray N F. 2004. Biology of Wastewater Treatment. 2<sup>nd</sup> edition. Imperial College Press, London.
5. Patel, A.H. 2011. Industrial Microbiology. Laxmi Publications.
6. Pelczer, M. J. and Chan, E.C.S. and Krieg, NR. 2023. Elements of Microbiology. 5<sup>th</sup> edition. Affiliated East West Press Private Limited New Delhi.
7. Prescott, L.M., Harley, J.P. & Klein, D.A. 2008. Microbiology. Mac Graw Hill Higher Education.
8. Ramesh, Vijaya. 2019. Environmental Microbiology. MJP Publisher.
9. Sharma, P.D. 2020. Microbiology. 4<sup>th</sup> edition. Rastogi Publication, Meerut.
10. Singh, R.P. 2020. Microbiology. Kalyani Publishers.
11. Stainer, RY, Ingraham, JL, Wheelis, ML., and Painter, PR. 2000. General Microbiology. The Macmillan Press Ltd.
12. Subba Rao, N.S. 1999. Soil microorganisms and plant growth. 2<sup>nd</sup> edition. Science Publishers, U.S.

**BOT-252**

**Reproductive Biology of Angiosperms**

**Total Credits: 4  
(Contact Hours:75)  
Total Marks:100**

**Course Objectives:**

- To provide knowledge of the basic concepts in plant morphogenesis, embryology and organ development, in both monocot and dicot plants.

**Learning Outcomes:**

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

- Comprehend developmental processes in plants, including the processes of fertilization, embryogenesis and seed development.
- Understand the complete life cycle of an angiospermic plant.
- Appreciate the interactions between the developmental pathways resulting in the differentiation of plant body.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

**Unit 1.**

1. Anther: anther wall (structure and functions), microsporogenesis, callose deposition and its significance. Microgametogenesis; pollen wall, pollenkit.
2. Pollen morphology; palynology and its scope.
3. Ovule: general structure; special structures–endothelium, obturator, aril, caruncle and hypostase; female gametophyte: megasporogenesis (monosporic, bisporic and tetrasporic)
4. Megagametogenesis (details of polygonum type); organisation and ultrastructure of mature embryo sac.

**Unit 2.**

1. Fertilization: structure of stigma and style; path of pollen tube in pistil; double fertilisation.
2. Self incompatibility: basic concepts (interspecific, intraspecific, homomorphic, heteromorphic, GSI and SSI); physiological and biochemical basis of self incompatibility; methods to overcome self- incompatibility: mixed pollination, bud pollination, stub pollination, intraovarian and in vitro pollination, modification of stigma surface, parasexual hybridization.
3. Endosperm: types, development, structure and functions; endosperm haustoria.
4. Embryo: general pattern of development of dicot and monocot embryo; suspensor: structure and functions.

**Unit 3.**

1. Seed: structure and development, classification.
2. Polyembryony: introduction, classification, causes and applications.
3. Apomixis: categories, types, causes and practical importance.
4. Pollen allergy: diagnosis and management.

**Unit 4.****(Practical)****Credit: 1  
(Contact Hours: 30)**

1. Preparation of slides using acetolysis method and study of pollen morphology.
2. Studies on pollen germination in Brewbaker and Kwack's medium.
3. Ovule: types-anatropous, orthotropous, amphitropous/campylotropous, circinotropous, unitegmic, bitegmic; tenuinucellate and crassinucellate. (permanent slides/specimens/photographs).
4. Endosperm: dissections of developing seeds for endosperm with free-nuclear haustoria.
5. Embryogenesis: study of development of dicot embryo through permanent slides; dissection of developing seeds for embryos at various developmental stages.

**Suggested readings:**

1. Bhattacharya K, Majumdar M.R. and Bhattacharya, S. 2006. A textbook of Palynology. New Central Book Agency Pvt Ltd, Kolkata.
2. Bhojwani, S.S. and Bhatnagar, S.P. 2011. The Embryology of Angiosperms. Vikas Publishing House. Delhi. 5th edition.
3. Johri, B M. 2011. Embryology of Angiosperms. Springer Verlag, Berlin.
4. Maheshwari, P. 2020. An introduction to embryology of Angiosperms. Tata McGraw Hill, New Delhi.
5. Pandey, A. K. 2000. Introduction to Embryology of Angiosperms. CBS Publishers and Distributors, New Delhi.
6. Pulliah, I., Lakshminarayana, K. and Rao, H. 2019. Plant Reproduction. 2<sup>nd</sup> edition. Scientific Publishers, Jodhpur.
7. Raghavan, V. 1999. Development Biology of Flowering Plants. Springer, New Delhi.
8. Raghavan, V. 2000. Developmental Biology of Flowering Plants. Springer, Netherlands.
9. Shivanna, K.R. and Rangaswami, N.S. 1993. Pollen Biolog:, A Laboratory Manual. Narosa Publishing House, New Delhi.
10. Shivanna, K.R. 2003. Pollen Biology and Biotechnology. CRC press.

**Course Objectives:**

- Insights to biodiversity and global ecological crisis, sustainable development and pros and cons of human intervention.
- To appreciate and recognise the need to conserve biodiversity.
- Address environmental issues related to biodiversity.
- Importance of various conservation strategies, laws and regulatory authorities.
- Create social awareness in biodiversity conservation and sustainable utilisation of bioresources

**Learning Outcomes:**

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

- Understand biodiversity and it's value to mankind.
- Assess the value of biodiversity wealth of our state and nation.
- Analyze various threats to our biodiversity and able to suggest measures for conservation strategies.
- Contribute in creating social awareness on the need for sustainable utilization of biodiversity.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

**Unit 1.**

1. Concepts of biodiversity: genetic diversity, species diversity, ecosystem diversity.
2. Value of biodiversity- intrinsic, consumptive, productive use, social, ethical, aesthetic and option values. Utilitarian values of biodiversity- goods, services and information.
3. Biodiversity at global, national and local levels. India as a mega diversity nation.

**Unit 2.**

1. Hotspots of biodiversity, criteria for determining hot spots, biodiversity hot spots in India: Himalayas, Indo Burma, Sundaland and Western Ghats and Sri Lanka.
2. Threats to biodiversity; species extinction: extinction process, mass extinctions; endangered and endemic plant species of India. IUCN Red data book and red list.
3. Conservation of biodiversity- *in-situ* conservation: protected area network, biosphere reserves, national parks, sanctuaries, sacred groves. *Ex situ* conservation: gene banks, botanical gardens, bio-parks, seed bank, cryopreservation.

**Unit 3.**

1. Biodiversity policy and legislation: Indian biodiversity act 2002, Biodiversity rules 2006, Access and benefit sharing guidelines.
2. Conservation practices in India and world, organizations involved in resource conservation: IUCN, WWF, UNEP, UNESCO, Biodiversity International, IPGRI, FAO, BSI.

**Unit 4.****(Practical)****Credit: 1  
(Contact Hours: 30)**

1. Field Survey for studying plant species diversity (gymnosperm and angiosperm) in any locality.
2. To prepare an inventory of threatened plants of your campus and its vicinity.
3. One seminar presentation on topics relevant to unit 1, 2, 3.
4. A report based on a visit to National Park/ Wildlife Sanctuary/ Biodiversity Park or any other wildlife conservation site.

**Suggested readings:**

1. Fiedler P.L and Kareiva, P.M. 1997. Conservation Biology. Chapman and Hall International Thompson Publishing.USA.
2. Gabriel M. 2000. Biodiversity and Conservation. Oxford and IBH publishing company Pvt Ltd. New Delhi.
3. Krishnamoorthy, K.V. 2004. An Advanced Text Book on Biodiversity- Principles and Practice. Oxford and IBH publishing company Pvt. Ltd., New Delhi.
4. Krishnamurthy, K.V. 2003. Text book on Biodiversity. Science Publishers, New Hampshire.
5. Kumar, U. and Sharma, A.K. 2008. Plant Biotechnology and Biodiversity Conservation. Agrobios, India.
6. Leveque, C. and Mounolou, J. 2003. Biodiversity. New York: John Wiley.
7. Negi, S.S. 2002. Biodiversity and its Conservation in India. Indus Publishing Company.
8. Pal, D. K. 2019. Ecosystem Services and Tropical Soils of India. Springer.
9. Primack, R.B. 2014. Essentials of Conservation Biology. 6<sup>th</sup> edition. OUP, USA.
10. Shankar, U. 2021. Enumeration of the Flora of Northeast India - Onelist of over 10,000 taxa of flowering plants. Arshuma Famous Books, Agra, India.
11. Sharma P.D. 2003. Ecology and Environmental Sciences. Rastogi Publications, Meerut, India.
12. Swaminathan, M.N. & Jain, R.S. 1982. Biodiversity: Implications for Global Security. Macmillan.
13. Trivedi, P. C. 2007. Global Biodiversity Status and Conservation. Pointer publishers, Jaipur India.
14. Wilson E.D. 2001. Diversity of Life. Penguin Books Ltd.

## 5<sup>th</sup> SEMESTER

**BOT-300**

**Plant Physiology**

**Total Credits: 4  
(Contact Hours:75)  
Total Marks:100**

### **Course Objectives:**

- The course aims to give students a greater appreciation of the plant world we depend on and to stimulate student learning of basic concepts in plant and biological science.
- This course provides an introduction to basic principles of plant function, primarily covering physical processes in plants, metabolism, and introducing principles of growth and development.

### **Learning Outcomes:**

After completing this course, students should be able to:

- Correlate morphology, anatomy, cell structure and biochemistry with plant functioning.
- Describe how cell, tissue and whole-plant structures are related to their function.
- Explain the uptake and utilisation of nutrients in plants.
- Describe how plants synthesise and use energy.
- Understand how hormones control plant growth and development.
- Explain the fixation and metabolism of nitrogen in plants.
- Apply the knowledge of physiological aspects of flowering and seed dormancy in practical field.
- Apply knowledge of physiological processes in plants to new research on how plants function and are used by humans.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

### **Unit 1.**

1. Water relations in plants: concepts of diffusion, imbibition, osmosis (endosmosis, exosmosis and osmotic pressure), plasmolysis. Water potential and its components. Concepts of symplast, apoplast and transmembrane movement of water.
2. Transpiration and factors affecting transpiration, antitranspirants, mechanism of stomatal transpiration- starch-sugar hypothesis, proton transport theory.
3. Macro- and micronutrients, criteria for essentiality, Functions and deficiency symptoms of macro elements- N, P, K, Ca and Mg. Functions and deficiency symptoms of micronutrients-Zn, Mn, B and Cu. Hydroponics and its applications.
4. Mechanism of mineral salt absorption: passive absorption – diffusion, facilitated diffusion, ion exchange. Active absorption- types and mechanism: cytochrome pump theory, protein lecithin theory.

### **Unit 2.**

1. Photosynthesis: photosynthetic pigments, absorption spectrum and action spectrum, red drop and Emerson's effect, photosystems I and II, photosynthetic electron transport chain-cyclic and non-cyclic, photolysis of water. C<sub>3</sub>, C<sub>4</sub> and CAM pathway. Blackman's law of limiting factors.
2. Respiration: respiratory substrates and respiratory quotient. Mechanism of aerobic respiration – glycolysis, Krebs cycle and electron transport chain.
3. Photorespiration: mechanism and significance.
4. Mechanism of biological nitrogen fixation: requirements for nitrogen fixation, nitrogenase enzyme complex (components and function), pathway of nitrogen fixation in symbiotic and non-

symbiotic systems; ammonia assimilation- GDH and GS-GOGAT system.

### **Unit 3.**

1. Physiology of flowering: photoperiodism, concept of florigen, CO-FT model for long-distance transport of flowering stimulus, ABC model of flowering (in brief), vernalization.
2. Phytochrome: chemical nature and physiological role; cryptochrome.
3. Seed dormancy: causes and methods to overcome dormancy.
4. Physiological roles and commercial applications of auxins, gibberellins, cytokinins, abscisic acid, ethylene. Brief introduction to brassinosteroids, jasmonic acid, salicylic acid and strigolactones.

### **Unit 4.**

**(Practical)**

**Credit: 1  
(Contact Hours: 30)**

1. Determination of osmotic potential of plant cell sap by plasmolytic and gravimetric method.
2. Microscopic observation of different types of stomata in monocot and dicot plants.
3. Study of transpiration rate in dorsiventral leaves by Blackman's apparatus.
4. Separation of plant pigments by paper chromatography method.
5. Determination of effect of CO<sub>2</sub> concentration on photosynthesis by bubble count method.
6. Determination of RQ of germinating seeds using Ganong's respirometer.

### **Suggested readings:**

1. Bhatla, S.C. and Lal, M.A. 2018. Plant Physiology: Development and Metabolism. Springer Nature, Singapore Pvt. Ltd.
2. Devlin, R.M. 2017. Outline of Plant Physiology. Scientific International.
3. Ghosh, A., Hait, G. and Bhattacharya, K. 2015. A Textbook of Botany: Vol III. New Central Book Agency, Kolkata.
4. Jain V.K. 2017. Fundamentals of Plant Physiology. S Chand Publishers.
5. Jain, J. L., Jain, S. and Jain, N. 2020. Fundamentals Of Biochemistry. S. Chand & Co Ltd., India.
6. Mitra, D., Guha, J. and Chaudhury, S.K. 2000. Studies in Botany Vol II. Moulik Library, Kolkata.
7. Mukherjee, S. and Ghosh, A.K. 2009. Plant Physiology. 3<sup>rd</sup> edition. New Central Book Agency.
8. Nelson, D. L. and Cox, M. M. 2012. Lehninger Principles of Biochemistry. 6<sup>th</sup> edition. W.H. Freeman and Co. Publishers.
9. Pandey, S.N. and Sinha, B.K. 2001. Plant Physiology. 3<sup>rd</sup> edition. Vikas Publishing House Pvt. Ltd, New Delhi.
10. Salisbury, F.B and Ross, C.W. 2006. Plant Physiology. 3<sup>rd</sup> edition. CBS Publishers and Printers, New Delhi.
11. Taiz, L. and Zeiger, E. 2002. Plant Physiology. Sinauer Associates, USA.
12. Verma, S.K. 2013. Text book of Plant Physiology and Biochemistry. S. Chand & Company, New Delhi.

**Course Objectives:**

- To impart comprehensive knowledge on the fundamental concepts of Biochemistry.
- The course is aimed at achieving the main goal that students will be able to comprehend the scope and inter- relationships between the different topics to be transacted during theory classes. This will ensure that they will have a firm grasp of basic Biochemical Principles which will serve as a strong foundation for further learning in similar or related fields.

**Learning Outcomes:**

- The students will have gained comprehensive knowledge on basic molecular structure, properties and functions of nutrients, Bioenergetic considerations based upon the laws of Thermodynamics, Enzyme catalysis, basic mathematical concepts related to enzyme activity via Michaelis-Menten's Kinetics and its reciprocal form i.e., Lineweaver-Burke plots, Fundamentals of Chemiosmotic mechanism of ATP formation and secondary plant products.
- Students will have gained practical experience and developed foundational analytical skills by performing the varied collection of introductory level experiments designed to cover the breadth and depth of the Topics as prescribed in this paper.

**(Theory)****Credits: 3  
(Contact Hours: 45)****Unit 1.**

1. Chemical foundations of biochemistry: basic biochemical terms and their significance (molecular weight, equivalent weight, molarity, normality, pH, buffer solutions).
2. Structure, classification and function of carbohydrates, amino acids and lipids.
3. Levels of protein structure (primary, secondary, tertiary and quaternary).

**Unit 2.**

1. Laws of thermodynamics (-1, 0, 1, 2 & 3), biological energy transformation (Gibbs free energy, enthalpy and entropy, spontaneous and induced processes, reversible and irreversible processes).
2. Enzyme structure and function (three-dimensional structure, active site, allosteric site) and IUBMB nomenclature and classification, cofactors and co-enzymes (with special reference to vitamins) and their functions.
3. Theories of mode of enzyme action (lock and key, induced fit hypothesis), mechanism of catalysis (activation energy; general acid-base, nucleophilic-electrophilic catalysis).
4. Michaelis-Menten kinetics (mathematical derivation of Michaelis-Menten constant and equation) and Lineweaver Burke plots.

**Unit 3.**

1. Redox potential and electrochemical gradient.
2. Ultra-structure of mitochondria; ATP-synthase: ultra-structure and function of the various components.
3. Mitchells chemiosmotic hypothesis, oxidative phosphorylation and production of ATP in mitochondria.
4. Secondary plant products: properties and functions of phenolics, anthocyanins and terpenoids.

**Unit 4.****(Practical)****Credit: 1  
(Contact Hours: 30)**

1. Preparation of solutions (weight/volume, molar, normal).
2. Separation of amino acids, sugars and lipids by paper/thin layer chromatography.
3. Preparation of standard curve and estimation of unknown for:
  - a. Starch by I<sub>2</sub>-KI method.
  - b. Soluble proteins by Lowry's method.
  - c. Lipids by sodium dichromate method.
4. Study of acid phosphatase activity in plant material (effect of substrate concentration and temperature).

**Suggested readings:**

1. Atkins, Peter. 2010. The Laws of Thermodynamics-A Very Short Introduction. Oxford University Press.
2. Berg, J.M., Stryer, L., Tymoczko, J.L and Gatto, G.J. 2015. Biochemistry. 8<sup>th</sup> edition. W.H. Freeman & Co Ltd.
3. Berg, J.M., Tymoczko, J.L. and Stryer, L. 2011. Biochemistry. 5<sup>th</sup> edition. W.H. Freeman & Co.
4. Buchanan, B.B., Wilhelm, G. and Russel, J. 2003. Biochemistry and Molecular Biology of Plants. ASPB. US.
5. Jain, J. L., Jain, S. and Jain, N. 2020. Fundamentals Of Biochemistry. S. Chand & Co Ltd., India.
6. Mathews, C.K., Van Holde, K.E. & Ahern, K.G. 2000. Biochemistry. Macmillan Worth.
7. Monk, P. 2004. Physical Chemistry-Understanding our Chemical World. John Wiley & Sons Ltd, England.
8. Nelson, D.L. and Cox, M.M. 2017. Lehninger, Principles of Biochemistry. 7<sup>th</sup> edition. W.H. Freeman & Co.
9. Taiz, Lincoln and Zeiger, Eduardo. 2010. Plant Physiology. International edition. Sinauer Associates, USA.
10. Verma, S.K. 2013. Text book of Plant Physiology and Biochemistry. S. Chand& Company, New Delhi.
11. Voet, D.J., Voet, J.G. & Pratt, C.W. 2008. Principles of Biochemistry. John Wiley Inc.

**BOT-302**

**Plant Ecology  
(Major)**

**Total Credits: 4  
(Contact Hours:75)  
Total Marks:100**

**Course Objectives:**

- To introduce the students with the basic principles of ecology. The course also aims at making them understand complex community patterns and processes, and ecosystem functioning.

**Learning Outcomes:**

The course will familiarise the students

- With complex interrelationship between organisms and environment;
- Make them understand methods to studying vegetation, community patterns and processes and ecosystem functions.
- The knowledge is critical in evolving strategies for sustainable natural resource management and also for biodiversity conservation.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

**Unit 1.**

1. Ecological factors: climatic (light, temperature, precipitation and fire), edaphic (soil formation process, soil types, soil texture, soil profile and soil organic matter), physiographic (slope and aspect of mountain) and biotic factors (living organisms in an ecosystem). Concept of limiting factors, Liebig's law of minimum, Shelford's law of tolerance.
2. Ecological levels of organization: organism, population, community, ecosystem, landscape, biome and biosphere.
3. Ecological adaptations: morphological and anatomical adaptations of hydrophytes, xerophytes, epiphytes and halophytes.

**Unit 2.**

1. Population ecology: attributes of plant populations: density, mortality, natality, survivorship curves, age structure, territoriality and population growth.
2. Population interactions: mutualism, commensalism, proto-cooperation, ammensalism, parasitism, predation and competition.
3. Community ecology: qualitative and quantitative attributes of community; ecological niche, ecotone and edge effect; community dynamics: primary and secondary succession, stages of succession; hydrosere and xerosere.

**Unit 3.**

1. Structural attributes of ecosystem: abiotic components (inorganic elements, organic compounds and climatic regimes) and biotic components (producers, macroconsumers and microconsumers).
2. Functional attributes of ecosystem: flow of energy: energy flow models (box and pipe model and Y channel model), concepts of productivity, food chain and food web.
3. Biogeochemical cycles: hydrological cycle, gaseous cycle (carbon) and sedimentary cycle (phosphorus).

**Unit 4.****(Practical)****Credit: 1  
(Contact Hours: 30)**

1. Determination of pH of soil samples of various sites using pH meter.
2. Determination of soil organic matter content of different soil samples by Walkley and Black's rapid titration method.
3. Determination of requisite size and requisite number of quadrats for the study of a plant community.
4. Determination of frequency, density and abundance by quadrat method.
5. Study of morphological and anatomical features of xerophytes, hydrophytes and epiphytes.

**Suggested readings:**

1. Ambasht, R.S. and Ambasht, N.K. 2023. A Text Book of Plant Ecology. 16<sup>th</sup> edition. CBS Publishers and Distributors, New Delhi.
2. Begon, M. and Harper, J.L. 2000. Essentials of Ecology. Blackwell Publishing.
3. Begon, M. Townsend, C.R. and Harper, J.L. 2006. Ecology from Individuals to Ecosystem. 4<sup>th</sup> edition. Blackwell Publishers.
4. Dash, M.C. 2001. Fundamentals of Ecology. 2<sup>nd</sup> edition. McGraw hill Companies.
5. Hill, M.K. 2020. Understanding Environmental Pollution. 4<sup>th</sup> edition. Cambridge University Press, Cambridge.
6. Koromondy, E.J. 2017. Concepts of Ecology. 4<sup>th</sup> edition. Pearson Education.
7. Misra, K.C. 1988. Manual of Plant Ecology. 3<sup>rd</sup> edition. Oxford and IBH Publishing Co. New Delhi.
8. Mitra, D., Guha, J. and Chaudhury, S.K. 2000. Studies of Botany. Vol II. Moulik Library, Kolkata.
9. Mohapatra, A.C., Barik, S.K. and Rao, C.S. 2000. Man and Environment. Star Publ. House, Shillong.
10. Molles, M.C. 2015. Ecology – Concepts and Applications. 7<sup>th</sup> edition. McGraw Hill Education.
11. Odum, E.P. 2017. Fundamentals of Ecology. 5<sup>th</sup> edition. Cengage India Private Limited.
12. Sharma, P.D. 2013. Ecology and Environment. Rastogi Publishers.
13. Singh, J.S., Singh, S.P. and Gupta, S.R. 2014. Ecology, Environmental Science and Conservation. S. Chand publishing, Delhi.
14. Tiwari, S.C. 2005. Concepts of Modern Ecology. Bishen Singh Mahendra Pal Singh, Dehradun.
15. Weaver, J.E. and Clements, F.E. 1986. Plant Ecology. 2<sup>nd</sup> edition. Tata McGraw, New Delhi.

**BOT-302**

**Angiosperm Taxonomy, Ecology  
and  
Economic Botany (Minor)**

**Total Credits: 4  
(Contact Hours:75)  
Total Marks:100**

**Course Objectives:**

- This course is designed to familiarize students with the concept and principles of plant taxonomy and basic concepts of ecology; also, to acquaint students with certain plants which provide resources to mankind.

**Learning Outcomes:**

On completion of the course, students are expected to:

- Acquire a concept on plant systematics, different taxa and understand their positions in taxonomic hierarchy and know the major systems of plant classification.
- Ability to classify and describe plants in scientific terms and identification of plants using taxonomic keys.
- Have the required knowledge on collection and preservation of plant specimens through herbarium techniques.
- Understand and interpret the complex interrelationship between organisms and environment; and to understand vegetation, community patterns and processes and ecosystem functions.
- Know certain categories of economically important plants, their characteristics, cultivation and processing.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

**Unit 1.**

1. Artificial, natural and phylogenetic classification systems; outline of Bentham and Hooker's system of classification.
2. Plant nomenclature: ICN, principles of nomenclature; herbaria: collection, preparation and functions.
3. Distinguishing features and economic importance of Ranunculaceae, Fabaceae, Asteraceae, Poaceae and Orchidaceae.

**Unit 2.**

1. Basic concepts of ecology; ecological factors: climatic, edaphic, biotic and physiographic; ecological adaptations; positive and negative population interactions.
2. Ecological succession; ecosystem structure: biotic components.
3. Functional attributes of ecosystem: primary productivity; flow of energy, food chains and food webs, ecological pyramids.

**Unit 3.**

1. Economically important cereals, pulses, spices, condiments, fiber yielding plants (scientific names and families of at least three plants of each category and the parts used).
2. Vavilov's centers of origin of cultivated plants.
3. Cultivation and processing of tea and rubber; cultivation and processing of aromatic (*Citronella*) and medicinal plants (*Cinchona*); wood characteristics and uses of timber yielding plants (Teak, Sal).

**Unit 4.****(Practical)****Credit: 1  
(Contact Hours: 30)**

1. Taxonomic studies of angiosperm plants belonging to families mentioned in unit-1 of paper Bot-302 by flower dissection, drawing and description in technical language, and identification up to genera.
2. Qualitative detection of starch, protein, fat and cellulose in plant materials by chemical tests.
3. Study of economically important plants or plant products prescribed in Paper 302.
4. Techniques for preparation of herbarium sheets of flowering plants and submission of at least 5 herbarium sheets.

**Suggested readings:**

1. Ambasht, R.S. and Ambasht, N.K. 2011. A Text Book of Plant Ecology. 15<sup>th</sup> edition. CBS Publishers and Distributors, New Delhi.
2. Bhattacharya, K., Ghosh, A. and Hait, G. 2013. A Textbook of Botany: Vol II. New Central Book Agency, Kolkata.
3. Dash, M.C. 2001. Fundamentals of Ecology. 2<sup>nd</sup> edition. McGraw Hill Companies
4. Gupta, R.K. 2006. Textbook of Systematic Botany. 7<sup>th</sup> edition. CBS.
5. Hill, A.F. 2003. Economic Botany: A Textbook of Useful Plants and Plant Products. Textbook Publishers
6. Koromondy, E.J. 2017. Concepts of Ecology. 4<sup>th</sup> edition. Pearson Education.
7. Misra, K.C. 1988. Manual of Plant Ecology. 3<sup>rd</sup> edition. Oxford and IBH Publishing Co. New Delhi.
8. Mitra, D., Guha, J. and Chaudhury, S.K. 2000. Studies in Botany. Vol I. Moulik Library, Kolkatta.
9. Mitra, D., Guha, J. and Chaudhury, S.K. 2000. Studies of Botany, Vol II. Moulik Library, Kolkat
10. Naik, V.N. 2014. Taxonomy of Angiosperms. Tata McGraw-Hill.
11. Odum, E.P. 1971. Fundamentals of Ecology. 3<sup>rd</sup> edition. W.B. Saunders co., Philadelphia.
12. Pandey, B. P. 2009. Economic Botany. 5<sup>th</sup> edition. S Chand & Company.
13. Sen, S. 2016. Economic Botany. New Central Book Agency.
14. Sharma, P.D. 2013. Ecology and Environment. Rastogi Publishers.
15. Singh, G. 2018. Plant Systematics: Theory & Practice. 3<sup>rd</sup> Edition. Oxford & IBH Pvt Ltd., New Delhi.
16. Singh, V., Pande, P.C. and Jain, D.K. 2018. Economic Botany. 3<sup>rd</sup> revised edition. Rastogi Publications, Meerut.
17. Sinha, S.K. 2014. A Textbook of Plant Taxonomy. Anmol Publications Pvt. Ltd., Delhi.
18. Tiwari, S.C. 2005. Concepts of Modern Ecology. Bishen Singh Mahendra Pal Singh, Dehradun.

**Course Objectives:**

- To provide a learning opportunity at the field/experiment level.
- To provide opportunity to understand various researches going on Plant Sciences.
- To equip them with technical skills as future researchers.

**Learning Outcomes:**

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

- Experience working on different plants and microbes.
- Learn practical application of plants and microbes.
- Learn from the field and experiments the importance of plants and microbes.

Sl. No.	Evaluation of Interns	Marks Distribution	Credits
1.	Field Work/ Experiments (at least 72 hours)	50	2
2.	Internship Report	25	1
3.	Presentation and Viva	25	1
	<b>Total</b>	<b>100</b>	<b>4</b>

**Suggested readings on Internship:**

1. Aniket Singh. (2018). The complete book of internships in India: Intern abroad this summer. Notion Press, Incorporated.
2. Woodard, E. (2015). The ultimate guide to internships: 100 steps to get a great internship and thrive in it. Allworth Press.
3. McLachlan, J. E., & Hess, P. F. (2015). Get an internship and make the most of it: Practical information for high school and community college students. Rowman & Littlefield Publishers.
4. Green, M. E. (1997). Internship success: Real-world, step-by-step advice on getting the most out of internships. VGM Career Horizons.
5. Houry, R. J., & Selby, J. (2021). How to intern successfully: Insights and actions to optimize your experience. Waterside Productions.
6. Shindell, R. (2019). Total internship management supervisor's handbook: A manager's guide to delivering an amazing internship experience. Intern Bridge, Incorporated.
7. Labor, S. L. (2020). Student internship success workbook (Supervisor's guide): 20+ Lessons and activities for student intern career readiness. Independently published.

## 6<sup>th</sup> SEMESTER

**BOT-350**

**Genetics and Plant Breeding**

**Total Credits: 4**  
**(Contact Hours:75)**  
**Total Marks:100**

### **Course Objectives:**

- To develop understanding on mechanism of cell division and organisation of genetic material.
- To impart knowledge on genetic basis of inheritance.
- To develop an understanding of chromosomal abnormalities and sex chromosomes.
- To gain an awareness of plant breeding and crop improvement.

### **Learning Outcomes:**

After the completion of the course, the students will be able to understand:

- Cell cycle and its regulation in eukaryotes.
- Organisation and inheritance of hereditary material.
- Principles of Mendelian genetics, their deviations and the evolution and inheritance of sex chromosomes.
- Chromosomal aberrations and their genetic significance.
- Principles of crop breeding and crop improvement in self- and cross-pollinated plants.

**(Theory)**

**Credits: 3**  
**(Contact Hours: 45)**

### **Unit 1.**

1. Eukaryotic cell cycle - G1, S, G2 and M phase; mechanism of meiosis (stages, chromosome pairing, chiasma formation, recombination, synaptonemal complex). Cell cycle checkpoints, positive and negative regulation of cell cycle.
2. Eukaryotic chromosome: morphology and ultrastructure; Polytene and Lampbrush chromosomes; chromosomal theory of inheritance and sex-linked inheritance.
3. Extra-nuclear inheritance: inheritance of plastid genes in *Mirabilis jalapa* and cytoplasmic male sterility in plants.

### **Unit 2.**

1. Mendelian genetics - laws of inheritance; multiple alleles (ABO blood group and self incompatibility in plants); deviations from Mendelism: incomplete dominance and co-dominance, complementary gene interaction, supplementary gene interaction, epistasis (dominant and recessive) and duplicate genes; linkage and crossing over.
2. Mechanisms of sex determination: environmental, chromosomal and genetical.
3. Chromosomal aberrations in plants: structural (deletion, duplication, inversion and translocation) and numerical (aneuploidy and euploidy).

### **Unit 3.**

1. Principles of crop improvement: domestication, introduction, hybridisation and artificial selection; pure line selection and mass selection.
2. Hybrid varieties: methods of development, merits, demerits and achievements. Breeding in asexually propagated crops: clonal selection.
3. Heterosis and inbreeding depression. Gene mutation; mutation breeding and its application in crop improvement.

**Unit 4.****(Practical)****Credit: 1  
(Contact Hours: 30)**

1. Study and identification of mitotic stages in onion root tips.
2. Study and identification of meiotic stages in flower buds.
3. Study of monohybrid and dihybrid ratios and their modifications by using Chi square test of significance.
4. Numerical exercises on linkage and crossing over.
5. Emasculation, bagging, tagging and pollination techniques in self-pollinated and cross-pollinated plants.

**Suggested readings:**

1. Acquaah, G. 2020. Principles of Plant Genetics and Breeding. 3<sup>rd</sup> edition. Wiley-Blackwell.
2. Brown, T. 2012. Introduction to Genetics - A Molecular Approach. Taylor and Francis.
3. Gardner, E.J., Simmons, M.J. and Snustad, D.P. 2002. Principles of Genetics. 8<sup>th</sup> edition. John Wiley & Sons Inc.
4. Griffiths, Anthony J.F., Doebley, J. and Peichel, C. 2020. Introduction to Genetic Analysis. W.H. Freeman.
5. Gupta, P.K. 2014. Genetics. Rastogi Publications, Meerut.
6. Krebs, J.E., Goldstein, E.S. and Kilpatrick, S.T. 2018. Lewin's genes XII. Jones and Barlett.
7. Lodish, H., Berk, A., Matsudaira, P., Kaiser, C.A., Krieger, M., Scott, M.P., Zipursky, L. and Darnell, J. 2004. Molecular Cell Biology. W.H. Freeman.
8. Singh, B.D. 2022. Plant Breeding: Principles and Methods. 12<sup>th</sup> edition. MedTech Science Press.
9. Singh, B.D. 2022. Fundamental of Genetics. Medtech Science Press, New Delhi.
10. Snustad, D.P. and Simmons M.J. 2015. Principles of Genetics. John Wiley and Sons.
11. Strickberger, M.W. 2015. Genetics. Pearson Education India.
12. Verma, P.S. and Agarwal, V.K. 2016. Cell Biology, Genetics, Molecular Biology, Evolution and Ecology. S. Chand and Co., New Delhi.

**Course Objectives:**

- To develop an understanding of nucleic acids and their respective structural conformations.
- Students will be able to gain fundamental knowledge of gene concept and organisation of genes.
- Students will be equipped to understand the three fundamental aspects of molecular biology: Replication, Transcription and Translation; and the processes involved.

**Learning Outcomes:**

After the completion of the course, the students will be able to:

- Understand nucleic acid structure, organisation and replication.
- Understand gene structure and mechanisms of gene expression.
- Understand protein synthesis, protein modifications and trafficking.
- Practice hands-on skills in fundamental molecular biology techniques.

(Theory)

Credits: 3  
(Contact Hours: 45)

**Unit 1.**

1. DNA as the carrier of genetic information (Griffith's, McLeod and McCarty experiment).
2. Chemistry of nucleic acids - structure of purines and pyrimidines; properties of nitrogenous bases and nucleotides; structure and properties of DNA and its A, B and Z conformations.
3. Structure and properties of RNA - mRNA and t-RNA.
4. Chemistry of DNA synthesis (Kornberg's discovery); semi-conservative model of DNA replication, enzymes involved in DNA replication.

**Unit 2.**

1. Modern concept of gene - cistron, recon and muton.
2. General features of gene organisation in prokaryotes and eukaryotes; organisation of a typical eukaryotic gene - exons, introns, regulatory sequences, promoter, enhancer.
3. Mechanism of transcription in prokaryotes; gene regulation in prokaryotes - *lac* operon and *trp* operon in *E. coli*.
4. mRNA processing: mRNA splicing, group I and group II intron splicing, alternative splicing, 5'cap, 3'polyA tail.

**Unit 3.**

1. Ribosome structure and assembly; genetic code: ambiguity, degeneracy and universality of genetic code, wobble hypothesis.
2. Protein synthesis: charging of t-RNA, mechanisms of initiation, elongation and termination of polypeptides in prokaryotes.
3. Post-translational modification of proteins: acetylation; phosphorylation; ubiquitination; methylation; glycosylation.

**Unit 4.****(Practical)****Credit: 1  
(Contact Hours: 30)**

1. Isolation of DNA from common plants using CTAB method.
2. Agarose gel electrophoresis of DNA.
3. Quantification of nucleic acids and estimation of nucleic acid purity by UV-VIS spectrophotometry.
4. Estimation of soluble protein from plant tissues by Bradford's assay.

**Suggested readings:**

1. Brown, T. 2012. Introduction to Genetics - A Molecular Approach. Taylor and Francis.
2. Griffiths, Anthony J.F., Doebley, J. and Peichel, C. 2020. Introduction to Genetic Analysis. W.H. Freeman.
3. Klug, W.S., Cummings, M.R, Spencer, C.A., Palladino, M.A. and Killian, D.J. 2019. Concepts of Genetics. 12<sup>th</sup> edition. Pearson.
4. Krebs, J.E., Goldstein, E.S.and Kilpatrick, S.T. 2017. Lewin's Genes XII. 12<sup>th</sup> edition. Jones & Bartlett Learning.
5. Lodish, H., Berk, A., Matsudaira, P., Kaiser, C.A., Krieger, M., Scott, M.P., Zipursky, L. and Darnell, J. 2004. Molecular Cell Biology. W.H. Freeman.
6. Malacinski, G.M. 2015. Freifelder's Essentials of Molecular Biology. 4<sup>th</sup> edition. Jones & Bartlett Student edition, Viva Publisher.
7. Snustad, D.P. and Simmons, M.J. 2015. Principles of Genetics. John Wiley and Sons.

**Course Objectives:**

- Provide students with understanding of plant stress and its causes.
- Provide an understanding of plant response and acclimation to stresses.
- Students will also learn about the stress-sensing mechanisms in plants and their adaptations to stress.

**Learning Outcomes:**

After the completion of the course, the students will be able to:

- Understand plant responses to stress and the mechanisms involved.
- Learn stress sensing mechanisms and role of bio-molecules in plant stress responses.
- Understand the principles of crop improvement programmes for combating stress.
- Acquire basic experimental skills for study of plant stress biology.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

**Unit 1.**

1. Plant responses to stress: water, light, high temperature, chilling, heavy metal and salt; interaction between biotic and abiotic stress.
2. Mechanisms of stress resistance: draught, water, high temperature and chilling; role of membrane lipids in temperature stress tolerance, heat-shock proteins.

**Unit 2.**

1. Stress sensing mechanisms - calcium modulation, phospholipid signaling, productions and scavenging of reactive oxygen species (ROS).
2. Plant-pathogen interaction - genetics and zig-zag model; roles of pathogenesis-related (PR) proteins, hypersensitive response (HR); systemic acquired resistance (SAR): events associated with establishment of SAR, SAR activators, SAR genes.

**Unit 3.**

1. Hormone regulation of stress responses - roles of Abscisic acid, Salicylic acid and Jasmonic acid in plant stress responses; roles of enzymes SOD, CAT, APX and GPX in plant stress responses.
2. Basic principles of crop improvement programmes under stress.

**Unit 4.**

**(Practical)**

**Credit: 1  
(Contact Hours: 30)**

1. Comparative study of plants/seedlings subjected to different degrees of drought, light and heat stress by estimation of proline.
2. To study the effect of salt and heavy metal stress on seed germination and seedling growth of any two plants.
3. Estimation of superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD) activity in plant seedlings in the presence and absence of stress.

**Suggested readings:**

1. Buchanan, B.B., Gruissem, W. and Jones, R.L. (eds). 2000. Biochemistry & Molecular Biology of Plants. 2<sup>nd</sup> ed.. Wiley Blackwell, U.K.
2. Dwivedi, P. and Dwivedi, R.S. 2005. Physiology of abiotic stress in plants. Agrobios, India.
3. Hopkins, W.G. and Huner, A. 2008. Introduction to Plant Physiology. 4<sup>th</sup> edition. John Wiley and Sons, U.S.A.
4. Panda, S.K. 2002. Advances in Stress Physiology of Plants. Scientific Publishers, Jodhpur.
5. Taiz, L., Zeiger, E., Moller, I.M. and Murphy, A. 2018. Plant Physiology and Development. International 6<sup>th</sup> edition. Sinauer Oxford University Press.

**Course Objectives:**

- To understand the fundamental aspects of plant tissue culture.
- Students will be equipped to gain fundamental understanding of techniques applied in plants for the production of transgenics.
- To understand the role of biotechnology in production of GM crops.
- Gain an understanding of biosafety and bioethics in plant biotechnology.

**Learning Outcomes:**

After the completion of the course, the students will be able to:

- Gain fundamental understanding of plant tissue culture techniques and their applications in plant biotechnology.
- Understand the different techniques for production of GM crops.
- Gain an understanding of biosafety and bioethics.
- Practice hands-on skills in fundamental techniques of plant biotechnology.

**(Theory)**

**Credits: 3  
(Contact Hours: 45)**

**Unit 1.**

1. Totipotency, organogenesis and embryogenesis.
2. Tissue culture media: composition and types of media. Callus culture, single cell culture, suspension culture and their significance.
3. Organ culture: meristem, embryo and anther culture; production of haploid plants and their significance.
4. Somatic hybridization: protoplast isolation, fusion and culture, identification and selection of hybrid cells; somaclonal variation; somatic embryogenesis, artificial seeds and their cryopreservation.

**Unit 2.**

1. Concept of gene cloning: tools and techniques.
2. Cloning vectors - plasmids, viral vectors, cosmids and bacteriophage.
3. Analysis of transgenic plants for the presence, integration and expression of transgenes; gene silencing in transgenic plants.

**Unit 3.**

1. Achievements in plant biotechnology (production of GM crops, metabolites, medicines and edible vaccines).
2. Concerns about GM crops: environmental, biosafety and ethical issues.
3. Applications of plant biotechnology in phytoremediation, climate-resilient agriculture and bio-fuel production.

**Unit 4.**

**(Practical)**

**Credit: 1  
(Contact Hours: 30)**

1. Preparation of Murashige and Skoog medium for tissue culture.
2. Initiation of callus culture of carrot root tissue.
3. Initiation of anther culture for haploid production.
4. Isolation of protoplasts from leaves by enzymatic method.

**Suggested readings:**

1. Alberts, B., Heald, R., Johnson, A., Morgan, D., Raff, M., Roberts, K. and Walter, P. 2022. *Molecular Biology of The Cell*. 7<sup>th</sup> edition. W.W. Norton & Company.
2. Bhojwani, S.S. and Razdan, M.K. 2003. *Plant Tissue Culture: Theory and Practice*. Elsevier.
3. Brown, T.A. 2020. *Gene Cloning and DNA Analysis: An Introduction*. 8<sup>th</sup> edition. Wiley Blackwell.
4. Griffiths, A.J.F., Doebley, J., Peichel, C. and Wassarman, D.A. 2020. *Introduction to Genetic Analysis*. 12<sup>th</sup> edition. WH Freeman & Co.
5. Howe, C. 2015. *Gene Cloning and Manipulation*. Cambridge University Press.
6. Krebs, J.E., Goldstein, E.S. and Kilpatrick, S.T. 2017. *Lewin's Genes XII*. 12<sup>th</sup> edition. Jones & Bartlett Learning.
7. Malacinski, G.M. 2015. *Freifelder's Essentials of Molecular Biology*. 4<sup>th</sup> edition. Jones & Bartlett student edition, Viva Publisher.
8. Prasad, B.K. 2016. *Outline of Plant Biotechnology*. Kalyani Publishers.
9. Slater, A., Scott, N.W. and Fowler, M.R. 2008. *Plant biotechnology: the genetic manipulation of plants*. 2<sup>nd</sup> edition. Oxford.
10. Snustad, D.P. and Simmons, M.J. 2015. *Principles of Genetics*. 7<sup>th</sup> edition. Wiley.
11. Strickberger, M.W. 2015. *Genetics*. Pearson Education India.
12. Tamarin, R.H. 2017. *Principles of Genetics*. 7<sup>th</sup> edition. McGraw Hill.
13. Watson, J., Baker, T., Bell, S., Gann, A., Levine, M. and Losick, R. 2013. *Molecular Biology of the Gene*. 7<sup>th</sup> edition. Pearson.