



दिल्ली विश्वविद्यालय University of Delhi

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CNC-II/093/1/EC-1282/26/5(ii)

Dated: 25.05.2026

18/07

NOTIFICATION

Sub: Amendment to Ordinance V

(ECR 4-1-6/ dated 29.04.2026)

Following addition be made to Annexure-II-A to the Ordinance V (2-A) of the Ordinances of the University;

Add the following:

The syllabi of following Department under the Faculty of Inter-disciplinary and Applied Sciences based on Postgraduate Curriculum Framework 2024 are notified herewith for the information of all concerned:

DEPARTMENT	SYLLABI
Microbiology	(i) 2 Year M.Sc. Microbiology for Semester-III/IV- Appendix-87
Biochemistry	(i) 2 Year M.Sc. Bio-chemistry for Semester-III/IV- Appendix-88
Plant Molecular Biology	(i) 2 Year M.Sc. Plant Molecular Biology and Biotechnology for Semester-III/IV - Appendix-89

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REGISTRAR

UNIVERSITY OF DELHI
MASTER OF SCIENCE (MICROBIOLOGY)
based on
NEP-PGCF-2024
2nd Year MSc. Microbiology Syllabus

As approved in the meeting of 'Committee of Courses' held on 24th Feb 2025
& 12-02-2026, in the meeting of 'Faculty of Interdisciplinary and Applied
Sciences' held on 23-02-2026, and meeting of 'Standing Committee' held on
13-03-2026

PROGRAMME BROCHURE



I. About the Department

Historical Background of Department

The Department of Microbiology was established in 1984, initially functioning in the University's main campus at the Patel Chest Institute where classes for the M.Sc. Microbiology program were held. The M.Sc. program was initiated with the enrollment of five students each year. The current intake for this program is fifteen students each year.

The Department moved to the South Campus in 1986 and became affiliated with the Faculty of Interdisciplinary and Applied Sciences upon its establishment in 1988. The students who graduate from our Master's program take up positions in academia/industry or pursue higher studies. The Microbiology Department started the Ph.D. program as well in 1988. Since then, more than one hundred students have carried out their doctoral research work in the Department, and several of them now hold leadership positions in academia and industry.

Department Highlights

The Department is now well established, currently with seven faculty members. Extramural grants from DBT, DST, ICMR, CSIR, UGC, ICAR and DRDO, as well as intramural grants from the University of Delhi, have strengthened the Department's research. The Department has also been funded under the DST-FIST, UGC-SAP and DU-DST PURSE programs. Every faculty member has a well-equipped laboratory with the necessary instruments to carry out research. The departmental Central Instrumentation Facility houses several pieces of high-end equipment. More than six hundred research papers have been authored by faculty members of the Department in peer-reviewed journals of international repute. The achievements of the Department have been recognized in the form of several awards conferred on the Department's faculty and students.

About the Program

The M.Sc. Microbiology program offered by Delhi University is of two years' duration and is divided into four semesters. The various courses of the program are designed to include classroom teaching and lectures, laboratory work, project work, viva, seminars, and assignments.

Six categories of courses are being offered in this program: Department Specific Core (DSC) Courses, Department Specific Elective (DSE) Courses, Generic Elective (GE) courses (student may opt for any of the Generic Elective courses offered by any other Department of the Faculty of Interdisciplinary and Applied Sciences), Skill Based Courses (SBC), Research methods/ tools/ writing courses, and Dissertation/ Problem-based Research work. The Core Courses and Discipline Specific Elective Courses are four-credit courses. The Generic Electives are also four-credit courses. The student is required to accumulate twenty-two credits each semester: a total of eighty-eight credits over four semesters to fulfill the requirements for a Master of Science degree in Microbiology (two-year program), and forty-four credits over two semesters to fulfill the requirements for a Master of Science degree in Microbiology (one-year program) .

About Post-Graduate Attributes

The curriculum is designed to train the students in basic and advanced areas of Microbiology, keeping in mind the latest advances in the field. Particular emphasis is laid on the practical aspects of the field. Students are taught how to plan experiments, perform them carefully, analyze the data accurately, and present qualitative and quantitative results. To enable them to develop speaking and presentation skills they are encouraged to deliver seminars on a wide range of topics covering the different areas of Microbiology. This also leads them to read about different themes and enhances their assimilation abilities. A major component of their course in Structure 2 and Structure 3 is a research project they work on in their final year. The student is guided in choosing a research problem, executing experiments related to it, collecting data and analyzing it, and presenting the results in the form of an oral presentation as well as a thesis. The student presents their research orally at the end of the final semester of the program, coupled with a viva-voce exam. This not only equips the student for a career in research/industry, but also fosters self-confidence and self-reliance in the student as they learn to work and think independently. At the end of the program the student will be well-versed in essential microbiology as well as be familiar with the most recent advances in microbiology, and will have gained hands-on experience in microbiology, including fermentation technology and molecular biology techniques. The student will be able to design a short research problem, plan and execute experiments to investigate the problem, as well as analyze and present the results obtained both qualitatively and quantitatively. The student will be able to take up a suitable position in academia or industry, and be equipped to pursue a career in research if so desired.

Program Objectives (POs):

At the time of completion of the program the student will have developed extensive knowledge in various areas of Microbiology. Through the stimulus of scholarly progression and intellectual development the program aims to equip students with excellence in education and skills, thus enabling them to pursue a career of their choice. By cultivating talents and promoting all-round personality development through multi-dimensional education, a spirit of self-confidence and self-reliance will be infused in the student. The student will be instilled with values of professional ethics and be made ready to contribute to society as responsible individuals.

Program Specific Outcomes (PSOs):

At the end of the two-year program, the student will understand and be able to explain different branches of Microbiology such as Bacteriology and Virology. The student will be able to explain various applications of Microbiology such as Environmental Microbiology, Industrial Microbiology, Food Microbiology, and Microbial Pathogenicity. They will be able to design and execute experiments related to Basic Microbiology, Immunology, Molecular Biology, Recombinant DNA Technology, and Microbial Genetics, and will be able to execute a short research project incorporating techniques of Basic and Advanced Microbiology under supervision. The student will be equipped to take up a suitable position in academia or industry and pursue a career in research if desired.

About Program Structure

The M.Sc. Microbiology program is a two-year program divided into four semesters, or a one-year program divided into two semesters. A student has to accumulate twenty-two credits in each semester. Under the two-year M.Sc. program a student is required to complete eighty-eight credits for completion and award of M.Sc. degree, while under the one-year M.Sc. program a student is required to complete forty-four credits for completion and award of M.Sc. degree. The program structure is based on the Post Graduate Curricular Framework (PGCF) under New Education Policy (NEP)-2020.

Under PGCF, in the first year of the two-year program, the student is required to study mandatory Discipline Specific Core courses (three DSC in each semester) and a total of four / Discipline Specific Elective courses (two DSE in each Semester). In lieu of one DSE in each Semester, the student may choose to study a Generic Elective course offered by any other Department of FIAS. In addition, the student will also be required to study one mandatory Skill based course (SBC) in each semester of the first year.

In the second year of the two-year program, the student will have an option to choose any one of the three structures: Structure 1 (PG with only coursework), Structure 2 (PG with coursework and research), or Structure 3 (PG with coursework and more emphasis/weightage on research). The details regarding these structures have been summarized in tabular form.

Course Credit Scheme

Program Structure-1: (PG with only coursework)

Sem	Core courses		Elective courses		Skill Based courses		Res Method courses		Dissertation/ Project		Total Credits
	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	
I	3	12	2	8	1	2	-	-	-	-	22
II	3	12	2	8	1	2	-	-	-	-	22
III	2	8	3	12	1	2	-	-	-	-	22
IV	2	8	3	12	1	2	-	-	-	-	22
Total Credits	40		40		8		-		-		88

Program Structure-2: (PG with coursework and research)

Sem	Core courses		Elective courses		Skill based courses		Res Method courses		Project work		Total Credits
	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	
I	3	12	2	8	1	2	-	-	-	-	22
II	3	12	2	8	1	2	-	-	-	-	22
III	2	8	2	8	-	-	-	-	1	6	22
IV	2	8	2	8	-	-	-	-	1	6	22
Total Credits	40		32		4		-		12		88

Program Structure-3: (PG with coursework and more emphasis on research)

Sem	Core courses		Elective courses		Skill based courses		Res Method courses		Dissertation/ Project		Total Credits
	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	No. of Courses	Total Credit	
I	3	12	2	8	1	2	-	-	-	-	22
II	3	12	2	8	1	2	-	-	-	-	22
III	1	4	1	4	-	-	2	4	1	10	22
IV	-	-	1	4	-	-	1	2	1	16	22
Total Credits	28		24		4		6		26		88

SEMESTER-WISE PROGRAM STRUCTURE of M.Sc. MICROBIOLOGY COURSE (NEP-PGCF)**First year (common in Program Structure 1, 2 and 3)****Semester-1**

	Credits in each course			
	Theory	Practical	Tutorial	Credits
Discipline Specific Core (DSC) courses				
DSC-01: Bacteriology	3	1	0	4
DSC-02: Molecular Virology	3	1	0	4
DSC-03: Microbial Physiology and Metabolism	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-01: Immunology	3	1	0	4
DSE-02: Cell Biology	3	1	0	4
Generic Elective (GE) courses*				
GE-01: Essentials of Microbiology	3	0	1	4
Skill based course (SBC)/ workshop/ Specialized laboratory/ Hands-on Learning				
SBC-01: Basic Microbiological Techniques	0	2	0	2
Research Methods/ Tools/ Writing	-	-	-	-
Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research				
-	-	-	-	-
Total credits				22

* (a student can opt for either two DSE courses, or one DSE with one GE)

Semester-2

	Credits in each course			
Course	Theory	Practical	Tutorial	Credits
Discipline Specific Core (DSC) courses				
DSC-04: Environmental Microbiology	3	1	0	4
DSC-05: Industrial Microbiology	3	1	0	4
DSC-06: Microbial Pathogenicity	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-03: Molecular Biology	3	1	0	4
DSE-04: Plant Pathogen Interactions	3	1	0	4
Generic Elective (GE) courses*				
GE-02: Microbial Biotechnology	3	0	1	4
Skill based course (SBC)/ workshop/ Specialized laboratory/ Hands-on Learning				
SBC-02: Environmental, Industrial & Molecular Microbiology Techniques	0	2	0	2
Research Methods/ Tools/ Writing	-	-	-	-
Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research				
-	-	-	-	-
Total credits				22

* (a student can opt for either two DSE courses, or one DSE with one GE)

Second Year: Program Structure -1 (PG with only coursework)

Semester-3

	Credits in each course			
Course	Theory	Practical	Tutorial	Credits
Discipline Specific Core (DSC) courses				
DSC-07: Food Microbiology	3	1	0	4
DSC-08: Fundamentals of Mycology and Phycology	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-05: Microbial Genetics	3	1	0	4
DSE-10: Advances in Antimicrobial Resistance Management	3	0	1	4
DSE-11: Extremophile Microbiology	3	0	1	4
Generic Elective (GE) courses*				
GE-03: Emerging Trends in Microbial Biotechnology	3	0	1	4
Skill basedcourse (SBC)/ workshop/ Specialized laboratory/ Hands-on Learning				
SBC-03: Mycology & Biochemical Techniques	0	2	0	2
Research Methods/ Tools/ Writing	-	-	-	-
Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research				
-	-	-	-	-
Total credits				22

* (a student can opt for either three DSE courses, or two DSE with one GE)

Semester-4

Course	Theor y	Practical	Tutorial	Credits
Discipline Specific Core (DSC) courses				
DSC-09: Medical Microbiology	3	1	0	4
DSC-10: Biosafety, Biosecurity and Biosurveillance	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-09: Bacterial Biofilms and Chronic Infection	3	1	0	4
DSE-12: Microbial Ecology	3	0	1	4
DSE-13: Facets of Protozoan Biology	3	0	1	4
Generic Elective (GE) courses*				
GE-04: Downstream Processing of Microbial Products	3	0	1	4
Skill-based course (SBC) / workshop/ Specialized laboratory/ Hands-on Learning				
SBC-04: Antimicrobial & Microscopy Techniques	0	2	0	2
Research Methods/ Tools/ Writing	-	-	-	-
Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research				
-	-	-	-	-
Total credits				22

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* (a student can opt for either three DSE courses, or two DSE with one GE)

Second Year: Program Structure -2 (PG with Coursework and Research)**Semester-3**

	Credits in each course			
Course	Theory	Practical	Tutorial	Credits
Discipline Specific Core (DSC) courses				
DSC-07: Food Microbiology	3	1	0	4
DSC-08: Fundamentals of Mycology and Phycology	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-05: Microbial Genetics	3	1	0	4
DSE-06: Biochemical Methods [#]	3	1	0	4
DSE-10: Advances in Antimicrobial Resistance Management	3	0	1	4
DSE-11: Extremophile Microbiology	3	0	1	4
Generic Elective (GE) courses*				
GE-03: Emerging Trends in Microbial Biotechnology	3	0	1	4
Skill-based course (SBC)/ workshop/ Specialized laboratory/ Hands-on Learning				
-	-	-	-	-
Research Methods/ Tools/ Writing				
-	-	-	-	-
Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research				
RES-01: Project Work- I	-	6	-	6
Total credits				22

* (a student can opt for either two DSE courses, or one DSE and one GE) [#] Research Track Paper**Semester-4**

	Credits in each course			
Course	Theory	Practical	Tutorial	Credits
Discipline Specific Core (DSC) courses				
DSC-09: Medical Microbiology	3	1	0	4
DSC-10: Biosafety, Biosecurity and Biosurveillance	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-07: Enzymology and Biocatalysis	3	1	0	4
DSE-08: Introduction to Genomics [#]	3	1	0	4
DSE-12: Microbial Ecology	3	0	1	4
DSE-13: Facets of Protozoan Biology	3	0	1	4
Generic Elective (GE) courses*				
GE-04: Downstream Processing of Microbial Products	3	0	1	4
Skill-based course (SBC)/ workshop/ Specialized laboratory/ Hands-on Learning				
-	-	-	-	-

Research Methods/ Tools/ Writing				
-	-	-	-	-
Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research				
RES-02: Project Work- II	-	6	-	6
Total credits				22

* (a student can opt for either two DSE courses, or one DSE and one GE) # Research Track Paper

Second Year: Program Structure -3 (PG with Coursework and more emphasis on Research)

Semester-3

	Credits in each course			
Course	Theory	Practical	Tutorial	Credits
Discipline specific Core (DSC) courses				
DSC-11: Principles of Genetic engineering [#]	3	1	0	4
Discipline specific Elective (DSE) courses				
DSE-05: Microbial Genetics	3	1	0	4
DSE-06: Biochemical Methods [#]	3	1	0	4
DSE-10: Advances in Antimicrobial Resistance Management	3	0	1	4
DSE-11: Extremophile Microbiology	3	0	1	4
Generic Elective (GE) courses				
-	-	-	-	-
Skill-based course (SBC)/ workshop/ Specialized laboratory/ Hands-on Learning				
-	-	-	-	-
Research Methods/ Tools/ Writing				
RM-01: Advanced Research Methodology	2	0	0	2
RM-02: Tools for Research	2	0	0	2
Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research				
RES-03: Dissertation- I	-	10	-	10
Total credits				22

* (a student can opt for one DSC and one DSE courses, and 2 RM courses) # Research Track Paper

Semester-4

	Credits in each course			
Course	Theory	Practical	Tutorial	Credits
Discipline Specific Core (DSC) courses				
-	-	-	-	-
Discipline Specific Elective (DSE) courses				
DSE-07: Enzymology and Biocatalysis	3	1	0	4
DSE-08: Introduction to Genomics [#]	3	1	0	4
DSE-09: Bacterial Biofilms and Chronic Infection	3	1	0	4
DSE-12: Microbial Ecology	3	0	1	4
DSE-13: Facets Of Protozoan Biology	3	0	1	4
Generic Elective (GE) courses				
-	-	-	-	-

Skill-based course (SBC)/ workshop/ Specialized laboratory/ Hands-on Learning				
-	-	-	-	-
Research Methods/ Tools/ Writing				
RM-03: Techniques of Research Writing	2	0	0	2
Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research				
RES-04: Dissertation- II	-	16	-	16
Total credits				22

* (a student can opt for one DSE courses, and 1 RM courses) # Research Track Paper

Discipline Specific Core (DSC) courses

DSC-01: Bacteriology
DSC-02: Molecular Virology
DSC-03: Microbial Physiology and Metabolism
DSC-04: Environmental Microbiology
DSC-05: Industrial Microbiology
DSC-06: Microbial Pathogenicity
DSC-07: Food Microbiology
DSC-08: Fundamentals of Mycology and Phycology
DSC-09: Medical Microbiology
DSC-10: Biosafety, Biosecurity and Biosurveillance
DSC-11: Principles of Genetic Engineering #

Discipline Specific Elective (DSE) courses*

DSE-01: Immunology
DSE-02: Cell Biology
DSE-03: Molecular Biology
DSE-04: Plant Pathogen Interactions
DSE-05: Microbial Genetics
DSE-06: Biochemical Methods#
DSE-07: Enzymology and Biocatalysis
DSE-08: Introduction to Genomics#
DSE-09: Bacterial Biofilms and Chronic Infection
DSE-10: Advances in Antimicrobial Resistance Management
DSE-11: Extremophile Microbiology
DSE-12: Microbial Ecology
DSE-13: Facets of Protozoan Biology

Generic Elective (GE) courses*

GE-01: Essentials of Microbiology
GE-02: Microbial Biotechnology
GE-03: Emerging Trends in Microbial Biotechnology
GE-04: Downstream Processing of Microbial Products

Skill based course (SBC)/ workshop/ Specialized laboratory/ Hands-on Learning

SBC-01: Basic Microbiological Techniques
SBC-02: Environmental, Industrial & Molecular Microbiology Techniques
SBC-03: Mycology & Biochemical Techniques
SBC-04: Antimicrobial & Microscopy Techniques

Research Methods/ Tools/ Writing

RM-01: Advanced Research Methodology

RM-02: Tools for Research

RM-03: Techniques of Research Writing

Dissertation/ Academic Project/ Entrepreneurship/ Intensive problem-based research

RES-01: Project Work- I

RES-02: Project Work- II

RES-03: Dissertation- I

RES-04: Dissertation- II

DISCIPLINE SPECIFIC CORE COURSE : DSC-07 FOOD MICROBIOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-07: FOOD MICROBIOLOGY	4	3	0	1	B.Sc. in any branch of Life Sciences	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- This course aims to give students an overview of taxonomical classification, phenotypic characteristics, and biochemical identification of molds, yeasts, yeast-like fungi, and food-related bacteria.
- They will learn about strategies for producing both fermented and non-fermented dairy products.
- They will be introduced to methods for creating plant-based fermented products, fish and meat items.
- The student will be conversant with various malt beverages, wines, distilled spirits, and kinds of vinegar.
- They will learn how microbes contribute to food spoilage and preservation.
- They will be acquainted with various preservation techniques used in the food processing industry
- Students will develop an understanding of various foodborne illnesses.

Learning Outcomes:

The Learning Outcomes of this course are as follows:

- The student will be able to describe various starter cultures and fermented milk products while understanding the production and use of probiotics, prebiotics, and nutraceuticals.
- The student will learn about fermentation protocols for producing microbial biomass, including edible yeasts, mushrooms, and single-cell proteins.
- The student will comprehend the information regarding microbes that cause food intoxication and foodborne infections.
- The student will gain knowledge of various traditional food preservation techniques.

- The student will differentiate between several modern preservation techniques in the food processing industry.
- The student will acquire insight into conventional methods for food quality analysis.
- The student will grasp the microbial standards essential for food safety and quality assurance programs that enhance food safety.

SYLLABUS OF DSC-07:

UNIT- I (12 hours)

Microbiology of food products: Taxonomical classification of microbes associated with food products, their phenotypic and biochemical identification. Food-associated molds, yeasts, yeast-like fungi, and bacteria. Microbiome of food material, Microbial habitat of specific food materials, adaptations and changes in the microbiome of vegetables, fruits, milk, fermented and non-fermented milk products, fresh meats, poultry and non-dairy fermented foods.

Essential reading:

1. Food Microbiology by W.C. Frazier, D.C. Westhoff, K.N. Vanitha. 5th edition. McGraw Hill Education. 2013. (Chapter 1&2).
2. Modern Food Microbiology by J.M. Jay, M.J. Loessner, D.A. Golden. 7th edition. Springer. 2006. (Chapter 2&3).
3. Food Microbiology by M. R. Adams, M. O. Moss, P. McClure. 4th edition. Royal Society of Chemistry. 2015. (Chapter 2&3).

UNIT- II (8 hours)

Microbial spoilage of milk, vegetables, cereals and meat products: Study of microorganisms responsible for spoilage and microbial succession during spoilage, Brief insights into chemical and physical spoilage of foods. Spoilage of milk and milk products. Types and causes of spoilage of cereals and cereals products, Spoilage of vegetables and fruits. Spoilage of meat and meat products, spoilage of fish and other seafoods, spoilage of eggs and other poultry products

Essential reading:

1. Food Microbiology by W.C. Frazier, D.C. Westhoff, K.N. Vanitha. 5th edition. McGraw Hill Education. 2013. (Chapter 11, 13, 14, 15, 16, 24, 25 & 26).
2. Food Microbiology by M. R. Adams, M. O. Moss, P. McClure. 4th edition. Royal Society of Chemistry. 2015. (Chapter 5).

UNIT- III (17 hours)

Food preservation and Food-borne diseases: General principles of food preservation, various classical, physical, chemical, and biological methods of preservation. New developments in food preservation techniques. Analysis of practical implementation of such techniques. Blockchain technology (BCT) in food safety and quality control, IoE and AI in food processing industry; Food-borne bacterial, viral, and fungal infections. Study of infections due to food-borne parasites. In-depth study of various types and causes of food intoxication. Summary of prevention of microbial food infections. Identification and first aid for specific types of food infections.

Essential reading:

1. Food Microbiology by W.C. Frazier, D.C. Westhoff, K.N. Vanitha. 5th edition. McGraw Hill Education. 2013. (Chapter 5, 6, 7, 8, 9 & 10).

2. Food Microbiology by M. R. Adams, M. O. Moss, P. McClure. 4th edition. Royal Society of Chemistry. 2015. (Chapter 3, 4, 5 7&8).

UNIT- IV (8 hours)

Fermentation processes, Food beverages and enzymes: Concept of the human microbiome, probiotics and prebiotics. Insight into health benefits of fermented milk products. Understanding the benefits of traditional and non-traditional fermented foods. Production of fermented milk and milk products, plant-based products, fish products, meat products and nutraceuticals. Manufacture of starter cultures from lab to pilot scale. Batch submerged and solid-state fermentation of foods. Introduction to bioactive compounds and a brief study of such compounds from fermented foods including malt beverages, wines, distilled liquors and vinegar.

Essential reading:

1. Food Microbiology by W.C. Frazier, D.C. Westhoff , K.N. Vanitha. 5th edition. McGraw Hill Education. 2013. (Chapter 21, 22&23).
2. Food Microbiology by M. R. Adams, M. O. Moss, P. McClure. 4th edition. Royal Society of Chemistry. 2015. (Chapter 9).

Practical component (30h)

1. To study the microbial flora of a fruits, milk, milk products and vegetables.
2. Biochemical and molecular Characterization of the bacteria isolated from the kitchen food product.
3. Preparation of *Lactobacillus* inoculum,
4. Preparation of fermented Food Products
5. Testing of milk and water quality using different biochemical methods
6. Preparation of cheese, yogurt and dahi,
7. Pickling of vegetables using microorganisms
8. Production of wine from grape juice.

Essential reading:

1. Food Microbiology by M. R. Adams, M. O. Moss, P. McClure. 4th edition. Royal Society of Chemistry. 2015. (Chapter 10).
2. Practical Food Microbiology Diane Roberts, Melody Greenwood 3rd Edition Blackwell Publishing Ltd. 2003.

Suggested Readings:

3. Food Microbiology by W.C. Frazier, D.C. Westhoff , K.N. Vanitha. 5th edition. McGraw Hill Education. 2013.
4. Modern Food Microbiology by J.M. Jay, M.J. Loessner, D.A. Golden. 7th edition. Springer. 2006.
5. Fundamental Food Microbiology by B. Ray and A. Bhunia. 5th edition. CRC press. 2013.
6. Food Microbiology by M. R. Adams, M. O. Moss, P. McClure. 4th edition. Royal Society of Chemistry. 2015.
7. Food Microbiology: Fundamentals and Frontiers by M. P. Doyle, L. R. Beuchat. 3rd edition. ASM press. 2007.
8. Food Microbiology: An Introduction by T. Montville, K. Matthews, K. Kniel. 4th edition. ASM press. 2017.

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9. Practical Food Microbiology Diane Roberts, Melody Greenwood 3rd Edition Blackwell Publishing Ltd. 2003.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE : DSC-08 FUNDAMENTALS OF MYCOLOGY AND PHYCOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-08: FUNDAMENTALS OF MYCOLOGY AND PHYCOLOGY	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The major objective of this course is to introduce the students to the essentials of mycology and phycology.
- The students will be able to comprehend fungal and algal life cycles, physiology, and metabolism
- The course will familiarize the students with fungal cell division, genome organization and survival.

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Students will be able to describe the structural components of a fungal and algal cell in detail; and study the major fungal and algal groups.
- Students will be able to recall the features of fungal spore, spore dispersal and dormancy.
- Students will be able to define the role of fungus in the ecosystem and in-nutrient cycling.
- Students will be able to develop an industrial application of fungus. Understand the role of fungus in the biotechnology industry.
- Students will be able to apply algae for biotechnology.

SYLLABUS OF DSC-08

UNIT-I (14 hours)

Introduction to Mycology: History and scope of mycology. Characteristic features of Fungi. Overview of fungal diversity. Major fungal groups: Chytridiomycota, Zygomycota, Glomeromycota, Ascomycota, Basidiomycota. Life cycle of one representative genus of each major fungal groups. Structural and functional biology of fungi (hyphae, spores, fruiting bodies). Fungal cell structure: cell wall, membrane, and organelles. Reproduction (sexual and

asexual), and life cycles. Sporulation and spore dispersal, dormancy. Yeast as a model organism. Fungal genome organization and gene expression. Mating types and sexual compatibility. Horizontal gene transfer in fungi. Use of molecular tools for fungal identification (PCR, sequencing).

Essential reading:

1. The Fungi by Michael J. Carlile, Sarah C. Watkinson. 2nd edition. Elsevier. 2000. (Chapter 1, 2, 4)
2. Fungal Biology by Jim Deacon. 4th edition. Wiley. 2005. (Chapter 2, 3, 10,)
3. Fungi: Biology and application by Kevin Kavanagh. Wiley Blackwell. 2017. (Chapter 1)

UNIT-II (12 hours)

Fungal Ecology and Biotechnology: Role of fungi in ecosystems (decomposers, mutualists, pathogens). Symbiotic relationships (mycorrhizae, lichens). Fungal biogeography and their role in nutrient cycling. Environmental impact of fungi (bioremediation, soil health), Industrial applications: enzyme production, organic acids, antibiotics, and biopesticides. Fungi in food production: fermentation, edible mushrooms.

Essential reading:

1. The Fungi by Michael J. Carlile, Sarah C. Watkinson. 2nd edition. Elsevier. 2000. (Chapter 6, 7)
2. Fungal Biology by Jim Deacon. 4th edition. Wiley. 2005. (Chapter 11, 12, 13)
3. Fungi: Biology and application by Kevin Kavanagh. Wiley Blackwell. 2017. (Chapter 4, 5)

UNIT-III (10 hours)

Introduction to Phycology: General characteristics of algae. Classification of algae (Chlorophyta, Rhodophyta, Phaeophyta, Bacillariophyta, Cyanobacteria, Dinophyta, Charophyta, Chrysophyta). Life cycles of different algal groups. Algal cell structure and function. Photosynthesis in algae: Light absorption and pigment diversity.

Essential reading:

1. Algae: An introduction to phycology by C. van dan Hoek, David Mann, and H.M. Jahns. Cambridge University Press. 1996. (Chapter 1, 2)
2. Phycology by Robert Edward Lee. 5th edition. Cambridge University Press. 2018. (Chapter 1, 2)

UNIT-IV (9 hours)

Applied Phycology: Algae in biotechnology: Biofuels, biofertilizers, pharmaceuticals. Algal toxins and harmful algal blooms (HABs). Edible algae and nutraceutical applications. Algae in aquatic ecosystems (planktonic and benthic communities). Role of algae in global carbon cycling and climate change impact.

Essential reading:

1. Phycology by Robert Edward Lee. 5th edition. Cambridge University Press. 2018. (Chapter 23)

Practical component (30 hours)

1. Macroscopic identification of algae and fungi (immature and mature colony of fungi).
2. Microscopic characterization
3. Fungal and algal staining and permanent mount of fungi.
4. Identification of yeast by negative staining.
5. Molecular characterization of algae and Fungi by sequencing of ITS region.
6. Evaluating the susceptibility of the fungal isolate to a range of anti-fungal agents

7. Screening of soil for production of secondary metabolites

Essential/recommended readings

Theory:

1. The Fungi by Michael J. Carlile, Sarah C. Watkinson. 2nd edition. Elsevier. 2000.
2. Fungal Biology by Jim Deacon. 4th edition. Wiley. 2005.
3. Fungi: Biology and application by Kevin Kavanagh. Wiley Blackwell. 2017.
4. Algae: An introduction to phycology by C. van dan Hoek, David Mann, and H.M. Jahns. Cambridge University Press. 1996.
5. Phycology by Robert Edward Lee. 5th edition. Cambridge University Press. 2018.

Practicals:

1. Microbiology: A laboratory manual by Cappuccino and Welsh. 12th edition. Pearson Education. 2019.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE: DSC-09:
MEDICAL MICROBIOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-09: MEDICAL MICROBIOLOGY	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives:

The Learning Objectives of this course are as follows:

- To introduce the students to the clinical aspects of medical microbiology
- To expose students to the latest research-based advances in the management (diagnostics and treatment strategies) of infectious diseases.

Learning Outcomes:

The Learning Outcomes of this course are as follows:

- The student will be able to understand the different microbes associated with humans and their clinical significance.
- The student will be able to contrast the concepts of the pathology of important bacterial and viral diseases and gain knowledge on managing these diseases.
- The student will comprehend the fungi and parasites causing human diseases and will have the understanding of the management of fungal and parasitic infections.
- The student will gain in-depth knowledge on the principle of diagnosis of infectious diseases and understand the basics of developing diagnostic kits.
- The student will be able to recall the concepts of resistance acquisition in microbes against available therapeutics.
- The student will be able to appraise the new strategies against antibiotic-resistant pathogens and will be exposed to recent approaches.

SYLLABUS OF DSC-09

UNIT - I: (15 hours)

Metagenomics and Epidemiology of infectious diseases: Microbiota of skin, throat, gastrointestinal tract, urogenital tract. Significance of microbiome, symbiosis, dysbiosis, metagenomics in microbiome analysis. Impact of drugs on gut microbiota. Microbial communities coexisting with humans. Factors affecting the microbiota and impact on health. Classification and diversity of infectious agents, various factors affecting infections (epidemiological, social, economic and political conditions of countries). Important bacterial acute and chronic infections and their management: Mycobacteriosis and anaerobic

infections, Meningitis, upper and lower respiratory infections, colitis, urinary tract infections, diabetic foot ulcers, dental caries and ear infections. Viral pathogens and management: SARS Cov-2 and COVID-19, Polio, Herpes, Hepatitis, Rabies, Dengue, AIDS, Influenza (swine flu and bird flu), Ebola, Chikungunya, Japanese Encephalitis, Rotavirus, Zika virus.

Essential Reading:

1. Brock Biology of Microorganisms by Madigan, M.T. and Martinko, J.M. 15th edition. Prentice Hall International Inc., USA. 2017. (Chapter 24, 25, 29)
2. Prescott's Microbiology by Willey, J. M., Sandman, K. and Wood, D. 11th edition. McGraw Hill Higher Education, USA. 2019. (Chapter 30, 33)
3. Metagenomics: Perspectives, Methods and Applications. Edited by M. Nagarajan. 2nd edition. Academic Press. 2024. (Chapters 10, 11, 18, 21)

UNIT - II: (8 hours)

Mycosis and parasitology in Infectious diseases: Identify the etiology and management (diagnosis and treatment) of common mycosis infections such as Athlete's foot, candidiasis and aspergillosis. Basic understanding and management of parasitosis with special emphasis on parasites important to the Indian sub-continent (Malaria, Kala-azar, helminths).

Essential Reading:

1. Brock Biology of Microorganisms by Madigan, M.T. and Martinko, J.M. 15th edition. Prentice Hall International Inc., USA. 2017. (Chapter 33)
2. Prescott's Microbiology by Willey, J. M., Sandman, K. and Wood, D. 11th edition. McGraw Hill Higher Education, USA. 2019. (Chapter 23)
3. Textbook of Microbiology by Ananthanarayan, R. and Paniker. C.K.J. Universities Press, India. 2017. (Chapter 62, 63 and 64)

UNIT - III: (8 hours)

Principle of Diagnosis of Infectious Diseases: Manifestations of infections, Collection, transport and culturing of clinical specimens. Microbiological examinations (Direct examination techniques, culture-dependent and independent methods, serological diagnosis and biochemical assays). Principle and mechanism of different diagnostic tests: ELISA (rapid diagnostic kits) and agglutination-based tests (Widal test: qualitative & quantitative and VDRL test for Syphilis). Immunoassays, Molecular diagnostic approaches, microscopy in diagnostics of infectious diseases. Advanced techniques in diagnosing pathogens such as flow cytometer.

Essential Reading:

1. Brock Biology of Microorganisms by Madigan, M.T. and Martinko, J.M. 15th edition. Prentice Hall International Inc., USA. 2017. (Chapter 28)
2. Prescott's Microbiology by Willey, J. M., Sandman, K. and Wood, D. 11th edition. McGraw Hill Higher Education, USA. 2019. (Chapter 32)
3. Textbook of Microbiology by Ananthanarayan, R. and Paniker. C.K.J. Universities Press, India. 2017. (Chapter 67, 82)

UNIT - IV: (14 hours)

Antimicrobial resistance and emerging strategies against MDR pathogens: Concept of "One health". Social medicine. Recent concepts – multidrug efflux pumps, extended-spectrum β -lactamases (ESBL), X-MDR *M. tuberculosis*, methicillin-resistant *S. aureus* (MRSA), role of integrons. Recombinant vaccines, subunit vaccines, DNA vaccines, Vaccinia-BCG- and HIV vector-based vaccines. CRISPR-Cas9 Gene Editing as therapeutics, Gene silencing, nanoparticles, probiotic bacteria, antibacterial vaccines, phage therapy, phytochemicals and

combination therapies.

Essential Reading:

1. Prescott's Microbiology by Willey, J. M., Sandman, K. and Wood, D. 11th edition. McGraw Hill Higher Education, USA. 2019. (Chapter 31)
2. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases by John E. Bennett, Raphael Dolin and Martin J. Blaser. 8th Edition Saunders 2015. Chapter 17-34). (Chapter 18 and 19)

Practicals (30 hours):

1. Culture-based diagnosis of infectious agents.
2. Detection of antigen or antibody by sandwich ELISA.
3. Detecting Treponemes by VDRL assay.
4. Perform antibacterial sensitivity by Kirby-Bauer method.
5. Determination of minimum inhibitory concentration by broth dilution method as per CLSI.
6. Isolation and purification of phages from different sources against clinically relevant bacteria.
7. Assessment of anti-biofilm potential of purified phages.

Essential/Recommended Reading:

1. Textbook of Microbiology by Ananthanarayan, R. and Paniker. C.K.J. Universities Press, India. 2017.
2. Jawetz, Melnick and Adelberg's Medical Microbiology by Carroll, K.C., Morse, S.A., Mietzner, T.A. and Miller, S. 27th edition. McGraw Hill Education. 2016.
3. Brock Biology of Microorganisms by Madigan, M.T. and Martinko, J.M. 15th edition. Prentice Hall International Inc., USA. 2017.
4. Microbiology: An Introduction. By Tortora, G.J., Funke, B.R., Case, D., Weber, D. and Bair, W. 13th edition. Pearson Education, USA. 2019.
5. Prescott's Microbiology by Willey, J. M., Sandman, K. and Wood, D. 11th edition. McGraw Hill Higher Education, USA. 2019.
6. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases by John E. Bennett, Raphael Dolin and Martin J. Blaser. 8th Edition Saunders 2015.

Practicals:

1. Microbiology: A laboratory manual by Cappuccino and Welsh. 12th edition. Pearson Education. 2019.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE: DSC-10 BIO SAFETY, BIOSECURITY, & BIOSURVEILLANCE

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-10: BIO SAFETY, BIOSECURITY, & BIOSURVEILLANCE	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- Student will be introduced to concepts of biosafety and biosecurity in Microbiology labs, and biosurveillance
- Student will gain understanding of biosafety levels, biosafety programs, and biosurveillance strategies
- Students will learn about risk assessments in Biological Laboratories

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Student will be able to recall levels of biosafety laboratories and their facilities
- Student will be able to assess risks associated with a microbiological laboratory and identify practices required to mitigate those
- Student will be able to categorize laboratory biosafety levels with facilities and practices associated with them
- Student will be able to create a laboratory biosecurity program
- Student will be able to describe the proper use and handling of biosafety cabinets
- Student will be able to categorize animal laboratory biosafety levels with facilities and practices associated with them
- Student will be able to describe biosurveillance strategies

SYLLABUS OF DSC-10

UNIT – I (13 hours)

Introduction to Biosafety and Biosecurity, Biological Risk Assessment: Definitions, the occurrence of Laboratory-associated Infections, Evolution of Biosafety Guidelines, Risk criteria

for establishing ascending levels of containment, Record keeping and biosafety documentation, labeling biohazard material. The risk management process, Risk communication, Facilitating a culture of safety through Risk assessment, Safety equipment (Primary Barriers), Personal Protective Equipment, Facility Design and Construction (Secondary Barriers), Facility practices and procedures, Animal Facilities, Clinical Laboratories

Essential reading:

1. Biosafety in Microbiological and Biomedical Laboratories by US Department of Health and Human Services, NIH. , 6th Edition. June 2020. Section-I, II, and III, Appendix A (Part-2)
2. Laboratory Biosafety Manual by WHO. 4th Edition. 2020. Section-2

UNIT – II (8 hours)

Laboratory Biosafety Levels, and Biosafety cabinets: For Biosafety Level 1 to Biosafety Level 4 - Standard Microbiological Practices, Special Practices, Safety Equipment (Primary Barriers and Personal Protective Equipment, Laboratory Facilities (Secondary Barriers). Introduction to Biological Safety Cabinets, High-Efficiency Particulate Air (HEPA) Filters and the development of biological containment devices, Types of biosafety cabinets, their use, operation and handling of materials inside the Biosafety cabinets. Other Laboratory Hazards and Risk Assessment. Maintenance and decontamination of Biosafety cabinets.

Essential reading:

1. Biosafety in Microbiological and Biomedical Laboratories by US Department of Health and Human Services, NIH. , 6th Edition. June 2020. Section-IV, Appendix A (Part-3, 5, 7)

UNIT – III (8 hours)

Principles of Laboratory Biosecurity: Biosafety and laboratory biosecurity, Performing Risk Assessments in Biological Laboratories, Biohazard Risk Assessment- Pathogen, Procedures, and Personnel, Developing a laboratory biosecurity program, risk assessment and management process, elements of a laboratory biosecurity program, emergency and spill response, Administrative and work practices, personnel medical surveillance, disinfection and sterilization, shipping regulated biological materials

Essential reading:

1. Biosafety in Microbiological and Biomedical Laboratories by US Department of Health and Human Services, NIH. , 6th Edition. June 2020. Section-VI
2. Laboratory Biosafety Manual by WHO. 4th Edition. 2020. Section-8

UNIT – IV (16 hours)

Animal Biosafety, Biosurveillance Strategies: For Animal Biosafety Level 1 to Biosafety Level 4- Standard Microbiological Practices, Special Practices, Safety Equipment (Primary Barriers and Personal Protective Equipment, Animal Facilities (Secondary Barriers). Biosurveillance strategies, biothreat detection, waste-water surveillance, industrial waste safety, syndromic surveillance systems, alternative surveillance systems, laboratory surveillance, environmental surveillance, remote detection systems, limitations and challenges.

Essential reading:

1. Biosafety in Microbiological and Biomedical Laboratories by US Department of Health and Human Services, NIH. , 6th Edition. June 2020. Section-V

Practical component (30 hours)

1. Facilities and working in biosafety level 1 and 2 laboratories.
2. Use of laminar flow, biosafety precautions. Operation and handling of materials inside the Biosafety cabinets.
3. Case studies on laboratory-acquired infections.
4. Decontamination of equipment before and after use. Quality assessment of sterilization and decontamination procedure.
5. Fundamentals, importance, types of personal protective equipment, Waste management of the biorisk materials and biomedical waste management regulations.
6. Packaging, shipping and transportation of materials inside and outside the biosafety laboratory, Work Safety with Sharp Instruments

Recommended readings**Theory:**

1. Biological Safety: Principles and Practices by Dawn P. Wooley (Editor), Karen B. Byers (Editor). 5th Edition. ASM Press. 2017.

Practicals:

1. Laboratory Biosafety Manual by WHO. 4th Edition. 2020.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE : DSC-11
PRINCIPLES OF GENETIC ENGINEERING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-11: PRINCIPLES OF GENETIC ENGINEERING	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The objective of this course is to introduce the students to the essentials of recombinant DNA technology.
- The students will become familiar with the techniques currently used to manipulate/ analyze DNA, RNA and proteins.
- They will learn about the methods used to clone genes, and make and screen libraries.
- They will be educated about the various applications of PCR.
- They will be introduced to the methods currently used to carry out genome sequencing, as well as global analyses of transcription and protein expression.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Student will be able to discuss cloning vectors, and basic methods of DNA, RNA and protein analysis.
- Student will be able to describe the various applications of PCR, and know how to make and screen genomic and cDNA libraries.
- Student will be able to outline the methods by which DNA is sequenced and discuss how genomes of organisms are sequenced.
- Student will be able to apply the many uses of reporter genes, and methods to study the transcriptome.
- Student will be able to analyze protein-DNA and protein-protein interactions, protein engineering, and proteomic methods.

SYLLABUS OF DSC-11

UNIT – I (8 hours)

Basics of DNA analysis, cloning, and construction of DNA libraries: Nucleic acid analysis by electrophoresis methods: agarose gel electrophoresis, polyacrylamide gel electrophoresis

(native and Urea-PAGE), pulsed-field gel electrophoresis. Nucleic acid analysis by blotting techniques: Southern and Northern blotting, labelling probes. RFLP analysis and its application in disease diagnosis. DNA fingerprinting and its applications in forensics. Simple cloning and cloning using linkers and adaptors. Uses of different cloning into various kinds of vectors: plasmids, phage lambda and M13, phagemids, cosmids, BACs and YACs. Selection and screening of clones. Vectors used in the construction of cDNA versus genomic DNA libraries. Steps in the construction of cDNA versus genomic DNA libraries. Screening libraries by colony hybridization and colony PCR. Screening expression libraries. Enriching for clones in cDNA libraries by subtractive hybridization.

Essential reading:

1. Molecular Biology by D.P. Clarke, N. Pazdernik, M.R. McGehee. 3rd edition. Academic Cell. 2018. (Chapters 5, 7)

UNIT – II (10 hours)

Polymerase chain reaction, genome sequencing, and genome manipulations: Concept of PCR. Thermophilic polymerases. Primer design. Cloning PCR products. Inverse PCR. RAPD fingerprinting. Ligation Chain Reaction. Overlap PCR. Site-directed mutagenesis: Traditional versus PCR-based methods. Reverse-transcription PCR. 5' RACE and 3' RACE. Real-Time PCR. Use of SYBR green, Taqman and Scorpion probes. Multiplex PCR. Sanger's DNA sequencing: manual versus cycle sequencing. Concept of primer walking. Shotgun sequencing. Next-generation sequencing methods and their applications. Creating genomic knockouts and conditional knockouts. Genome editing using CRISPR-Cas technology. Animal cloning methods.

Essential reading:

1. Molecular Biology by D.P. Clarke, N. Pazdernik, M.R. McGehee. 3rd edition. Academic Cell. 2018. (Chapters 6, 8, 9, 20)

UNIT-III (15 hours)

Transcriptomics and analysis of protein-DNA and protein-protein interactions: Types and applications of reporter genes. Use of reporter genes in transcriptional analysis. DNA microarrays and their applications in genomics as well as transcriptomics. RNA-seq analysis. Analysis of protein-DNA interactions: Gel retardation assays, DNA footprinting by DNaseI and DMS, yeast one-hybrid assays, ChIPs and ChIP-seq. Analysis of protein-protein interactions: yeast two-hybrid and three hybrid assays, co-immunoprecipitations and pulldown assays, FRET and BiFC, phage display.

Essential reading:

1. Molecular Biology by D.P. Clarke, N. Pazdernik, M.R. McGehee. 3rd edition. Academic Cell. 2018. (Chapter 21)

UNIT – IV (12 hours)

Protein expression systems and proteomics: Protein analysis by electrophoresis methods: native and SDS-PAGE, 2D gel electrophoresis, DIGE. Protein analysis by blotting techniques: Western blotting and Southwestern blotting. Bacterial expression systems: *E.coli* systems driven by lac, T7 and Tet-regulatable promoters. Yeast expression systems: *S.cerevisiae* and *P.pastoris* systems. Baculovirus overexpression system. Mammalian cell overexpression systems. Proteome analysis by 2D gel electrophoresis coupled to mass spectrometric analysis. Principles of MALDI-TOF and LC-MS platforms. PMF versus MS/MS. Protein arrays and their

applications.

Essential reading:

1. Molecular Biology by D.P. Clarke, N. Pazdernik, M.R. McGehee. 3rd edition. Academic Cell. 2018. (Chapter 15)

Practical component: (30 hours)

1. Analysis of plasmid DNA: Isolation of plasmid by alkaline lysis method and analysis of the different forms of plasmid DNA by agarose gel electrophoresis. Determination of plasmid size by restriction digestion followed by agarose gel electrophoresis.
2. Insertional activation: Alpha complementation and its use in gene cloning- simple cloning experiment.
3. Analysis of gene expression by real time PCR. Comparative analysis of mRNA using SYBR green and $2^{-\Delta\Delta C_t}$ method.

Recommended readings:

Theory:

1. Gene Cloning and DNA Analysis: An Introduction by T.A. Brown. 8th edition. Wiley- Blackwell Publishers. 2020.
2. Molecular Biology of the Gene by J. Watson, T. Baker, S. Bell, A. Gann, M. Levine, R. Losick. 7th edition. Pearson. 2014.
3. Molecular Cloning: A laboratory manual by J. Sambrook, D. Russell. 4th edition. Cold Spring Harbor laboratory Press. 2012.

Practicals:

1. Molecular Cloning: A laboratory manual by J. Sambrook, D. Russell. 4th edition. Cold Spring Harbor laboratory Press. 2012

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE : DSE-05 MICROBIAL GENETICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-05: MICROBIAL GENETICS	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The major objective of this course is to introduce the students to the essentials of microbial genetics.
- The students will gain knowledge about the mechanisms of genetic transfer in bacteria.
- They will become familiar with phage genetics and gene regulation.
- They will be educated about the effects and uses of bacterial transposition.
- They will be introduced to the general mechanism of gene regulation in bacteria and the concept of negatively and positively regulated operons.

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Student will be able to discuss the importance of mutation analysis, analyze mutations by complementation and recombination tests, and design a strategy to create gene replacement in bacteria.
- Student will be able to outline how plasmid copy number is regulated, and construct a genetic map of the bacterial genome using a conjugation-based method.
- Student will be able to compare and contrast generalized versus specialized transduction, and construct genetic linkage maps using two-factor and three-factor crosses.
- Student will be able to describe the events in the lytic and lysogenic phases of the lambda phage life cycle and the regulatory factors and events involved.
- Student will be able to review inducible and repressible systems and describe the regulation of the lac, trp, gal, ara and tol operons.

SYLLABUS OF DSE-05

UNIT-I (5 hours)

Genetic analysis of bacteria: Mutations and mutagenesis. Inheritance in bacteria: Directed Change versus Random Mutation hypotheses. Types of mutations. Types of mutagens. Reversion versus suppression. Complementation Tests and their applications. Cloning genes

by complementation. Recombination Tests and their applications. Cloning genes by marker rescue. Making bacterial and yeast gene knockouts.

Essential reading:

1. Snyder and Champness Molecular Genetics of Bacteria by T. Henkin and J. Peters. 5th edition. ASM Press, USA. 2020. Chapter 3.

UNIT-II: (10 hours)

Phage genetics and host defenses against phage infection: Icosahedral and filamentous phage life cycles. Virulent versus temperate phages. T4 and T7 phage biology: gene regulation. Use of T4 phage genetics in deciphering the genetic code. Lambda phage biology: Organization of lambda phage genome. Lytic versus lysogeny in lambda phage. Regulation of gene expression in the lytic cycle. Regulation of gene expression in the lysogenic cycle. Role of *cII* and *cI* in the establishment and maintenance of lysogeny. Events leading to lambda lysogen induction. Lambda immunity region and immunity to superinfection. Role of *cI* and *Cro* in regulating the lytic/ lysogenic switch. Role of restriction-modification systems and CRISPR-Cas systems in host defense against phage.

Essential reading:

1. Snyder and Champness Molecular Genetics of Bacteria by T. Henkin and J. Peters. 5th edition. ASM Press, USA. 2020. Chapter 7.
2. Molecular Genetics of Bacteria by L. Snyder, J.E. Peters, T.M. Henkin, and W. Champness. 4th edition. ASM Press, USA. 2013. Chapter 7, 8.

UNIT- III (15 hours)

Mechanisms of genetic transfer in bacteria and bacterial transposition: Genetic transfer by conjugation: Plasmid compatibility and copy number control mechanisms. Fertility in bacteria. Self-transmissible versus mobilizable plasmids. Molecular mechanism of horizontal gene transfer by conjugation. Regulation of conjugation. Hfr strains and F' plasmids. Using interrupted mating to map bacterial genomes. Ti plasmid transfer system and its role in making plant transgenics. Genetic transfer by transformation: Natural competence. DNA uptake systems in Gram-negative and Gram-positive bacteria. Regulation of competence in *B.subtilis*. Genetic transfer by transduction: Generalized and specialized transduction. Co-transduction-based mapping. Bacterial transposition: Types of transposons. Mechanisms of transposition. Effects of bacterial transposition. Conjugative transposons. Transposon mutagenesis. Cloning out genes by transposon mutagenesis. Mu transposon: life cycle of Mu phage. Mud transposons and their use in cloning out genes. Yeast Ty-1 retroposon. Site-specific recombinases: lambda phage integrase system, P1 phage *loxP*-Cre system, *Salmonella* phase variation system.

Essential reading:

1. Snyder and Champness Molecular Genetics of Bacteria by T. Henkin and J. Peters. 5th edition. ASM Press, USA. 2020. Chapters 4, 5, 6, 8.

UNIT-IV (15 hours)

Gene regulation in bacteria: Negative and positive gene regulation. Repressors, activators and inducers. Attenuation. Gene regulation in the *lac*, *trp*, *gal*, *ara* and *tol* operons. Global

regulation: regulons and stimulons. Stress responses in bacteria: Iron regulation in *E. coli*. Regulation of virulence genes in bacteria: diphtheria.

Essential reading:

1. Molecular Genetics of Bacteria by L. Snyder and W. Champness. 3rd edition. ASM Press, USA. 2007. Chapter 12.

Practical component: (30 hours)

1. Analysis of genetic transfer by bacterial transformation: Preparation of competent cells and transformation of *E. coli* with plasmid DNA. Determination of transformation efficiency.
2. Analysis of genetic transfer by conjugation: Transfer of an antibiotic resistance marker from one bacterial strain to another by bacterial mating and selection of exconjugants.
3. Determination of phage titer in lysate: Bacterial infections with serial dilutions of phage lysate and determination of pfu/ml.

Recommended readings

Theory:

1. Microbial Genetics edited by M.K. Rai, S. Okon, B. Zimowska. CRC Press. 2024.
2. Genetics of Bacteria by Sheela Srivastava. Springer-Nature India. 2013.
3. Fundamental Bacterial Genetics by N. Trun, J. Trempy. 1st edition. Wiley-Blackwell Publishing. 2004.
4. Modern Microbial Genetics edited by U.N. Streips, R.E. Yasbin. 2nd edition. Wiley-Liss Publishers. 2002.
5. Microbial Genetics by S.R. Maloy, J.E. Cronan, Jr., D. Freifelder. 2nd edition. Jones and Bartlett Publishers. 1994.

Practicals:

1. Experiments in Bacterial Genetics: A laboratory Manual by A Cell Biology Manual. Edited by L. Bossi, A. Camilli, A. Grundling. Cold Spring Harbor Laboratory Press. 2024.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE: DSE-06 BIOCHEMICAL METHODS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-06: BIOCHEMICAL METHODS	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The objective of this course is to train students in basic principles and applications of essential laboratory equipment.
- To expose the students to various advanced laboratory techniques in the areas of biochemistry and molecular biology.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Students will be able to understand the basic principles of electrochemistry and buffer preparation.
- Students will be able to analyze the data from spectroscopy, instrumentation, and applications.
- Students will be able to design a multi-step purification protocol for a target protein through chromatography.
- Students will be able to understand the applications and instrumentation of various kinds of microscopy.
- Students will be able to explain and execute DNA and protein labelling experiments.

SYLLABUS OF DSE-06:

UNIT – I (13 hours)

Basic principles of electrochemistry: Electrolytes, Ionization of weak acids and bases. Measurement of the pH: the pH electrode, pH buffers, pH buffer capacity, selection of biochemical buffers, preparation of phosphate buffer, Ionization properties of amino acids: zwitterion ion, isoelectric point. **Principles and techniques of spectroscopy:** Principle of spectroscopy, Beer-Lambert's Law, concept of absorptions, transmission, scattering, phosphorescence, fluorescence, luminescence, diffraction spectra regions of electromagnetic spectrum. Principle, instrumentation and applications of UV - visible and IR spectroscopy. Hypo and Hyperchromicity, Fluorimetry: Flow cytometry.

Essential reading:

1. The Physical and Chemical Basis of Molecular Biology by Thomas E Creighton. Published by Helvetian

Press. 2010. (Chapter 1, 2, 3, 10).

2. Principles and Techniques of Biochemistry and Molecular Biology by Wilson, K. and Walker, J. 8th edition. Cambridge University Press, Cambridge. 2022 (Chapter 10 & 13).

UNIT – II (17 hours)

Separation Techniques -I: Chromatography: Basics principles and applications of various chromatography methods: Paper and thin layer chromatography, Column Chromatography: Gel-filtration, Ion-exchange, affinity, Reversed-phase, Hydrophobic interaction chromatography. High, Ultra and Fast Performance Liquid Chromatography (HPLC, UPLC, FPLC). Gas-Liquid Chromatography (GLC). **Separation Techniques -II: Centrifugation:** Basic principles of sedimentation, RCF/RPM, Sedimentation (s). Types of centrifuges: Bench-top centrifuge and High-Speed refrigerated centrifuge (Ultracentrifugation). Types of rotors: Preparative centrifugation, Differential centrifugation, Density-Gradient centrifugation. Analytical ultracentrifugation: molecular weight determination.

Essential reading:

1. The Physical and Chemical Basis of Molecular Biology by Thomas E Creighton. Published by Helvetian Press. 2010. (Chapter 16, 18 & 20).
2. Principles and Techniques of Biochemistry and Molecular Biology by Wilson, K. and Walker, J. 8th edition. Cambridge University Press, Cambridge. 2022 (Chapter 5 & 12).

UNIT- III (08 hours)

Microscopy: Basics of microscopy: image formation, magnification, resolution, Biological applications and instrumentation of various kinds of microscopy: Bright field, Phase-contrast, Fluorescence and Confocal Microscopy, Electron Microscope – Scanning and Transmission Electron Microscopy, Atomic Force Microscopy. Histopathology – definition, fixation, decalcification, tissue processing, cutting, staining, and analysis.

Essential reading:

1. The Physical and Chemical Basis of Molecular Biology by Thomas E Creighton. Published by Helvetian Press. 2010. (Chapter 8).
2. Principles and Techniques of Biochemistry and Molecular Biology by Wilson, K. and Walker, J. 8th edition. Cambridge University Press, Cambridge. 2022 (Chapter 11).

UNIT – IV (07 hours)

DNA and Protein labelling: DNA probes, Types of DNA probes and applications, Molecular beacons. Types of Probe Labelling (enzymatic/chemical). Protein Labelling Methods & Mechanisms: Chemical Labelling, Enzymatic Labelling, Genetic Labelling (Fusion Proteins), Isotopic Labelling. Optimization of Labelling Efficiency. Maintaining Protein Activity Post-Labelling.

Essential reading:

1. The Physical and Chemical Basis of Molecular Biology by Thomas E Creighton. Published by Helvetian Press. 2010. (Chapter 21).
2. Biophysical chemistry, Principles and Techniques by Upadhyay A, Upadhyay K and Nath N; Himalaya Publishing House, India. 2016. (Chapter 13).

Practical component (30 hours):

1. To draw the titration curve of the acid and base.
2. Preparation of different buffers (phosphate buffer) and pH calibration.
3. Instrumentation and analysis of data generated from the spectrophotometer. Estimation

of protein/DNA concentration using spectrophotometer.

4. Preparation and demonstration of column chromatography.
5. Preparation of density-gradient columns for centrifugation experiments.
6. Demonstration of high-speed refrigerated ultracentrifuge.
7. Analysis of GFP labeled protein using fluorescent microscopy for sub-cellular localization.
8. Visualization and analysis of bacteria/tissue samples under microscopy.

Essential/recommended readings

Theory:

1. Principles and Techniques of Biochemistry and Molecular Biology by Wilson, K. and Walker, J. 8th edition. Cambridge University Press, Cambridge. 2022
2. The Physical and Chemical Basis of Molecular Biology by Thomas E Creighton. Published by Helvetian Press. 2010.
3. Biophysical Chemistry by James, P. Allen. Wiley Blackwell, New Jersey. 2008.
4. Fundamentals of Light Microscopy and Electron Imaging by Murphy, D.B. and Davidson, M. W. Wiley-Blackwell, New Jersey. 2012.
5. Physical Biochemistry- Application to Biochemistry and Molecular Biology by Freifelder, D.M. W.H. Freeman, New York. 1983.
6. Analytical Biochemistry: 3rd edition. Holme DJ, Peck H. Prentice Hall.
7. Biophysical chemistry, Principles and Techniques by Upadhyay A, Upadhyay K and Nath N; Himalaya Publishing House, India. 2016.
8. Conjugation of enzymes to antibodies by Winston, S.E. Current Protocols in Molecular Biology. 2001.
9. Unraveling protein dynamics to understand the brain—the next molecular frontier by Brewer, Kyle D., Sophia M. Shi, and Tony Wyss-Coray. Molecular Neurodegeneration. 2022.

Practicals:

1. Molecular Cloning: A laboratory manual by Joseph Sambrook, David Russell, 4th edition. Cold Spring Harbor Laboratory Press. 2012.
2. Fundamentals of Light Microscopy and Electron Imaging by Murphy, D.B. and Davidson, M. W. Wiley-Blackwell, New Jersey. 2012.
3. Current Protocols in Molecular Biology by F. M. Ausubel, R. Brent, R.E. Kingston, D. D. Moore, J. A. Smith, K. Struhl (editors). John Wiley and Sons, USA. 2007.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE : DSE-07 ENZYMOLGY AND BIOCATALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-07: ENZYMOLGY AND BIOCATALYSIS	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The major objective of this course is to introduce students to the fundamentals of enzymology, including enzyme structure, kinetics, and mechanisms.
- The students will gain insights into advanced enzyme technology, including enzyme engineering and large-scale production.
- They will become familiar with industrial and medical applications of enzymes, emphasizing extremozymes and whole-cell biocatalysis.
- The students will gain knowledge of enzyme commercialization, entrepreneurial opportunities, and sustainability-focused enzyme applications.
- The students will develop hands-on expertise in enzyme purification, kinetics, immobilization, and biotechnological techniques.

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Students will be able to explain enzyme structure, catalytic mechanisms, and factors affecting enzyme activity.
- Students will be able to analyze enzyme kinetics and apply graphical methods to study enzyme activity.
- Students will be able to explore the properties and applications of extremozymes and whole-cell biocatalysts.
- Students will be able to demonstrate enzyme production methods, immobilization techniques, and their applications.
- Students will be able to examine enzyme engineering strategies and evaluate challenges in scaling enzyme production.
- Students will be able to gain entrepreneurial insights through case studies on enzyme-based startups and explore commercialization strategies.

SYLLABUS OF DSE-07:**UNIT – I (16 hours)**

Fundamentals of Enzymology and Enzyme Kinetics: Introduction to enzymology, historical background, and significance. Structure and classification of enzymes: holoenzyme, apoenzyme, cofactors, coenzyme, prosthetic groups, and metalloenzymes. Catalytic mechanisms: activation energy, transition state theory, and enzyme-substrate interaction models (lock-and-key and induced fit). Factors affecting enzyme activity: enzyme concentration, substrate concentration, temperature, pH, and inhibitors. Kinetics of enzyme activity. Significance of K_m , catalytic efficiency, turnover number. Michaelis-Menten equation, determination of K_m and V_{max} using Lineweaver-Burk and other plots. Inhibition and regulation: competitive, non-competitive, uncompetitive inhibition, and allosteric regulation.

Essential reading:

1. ENZYMES: A Practical Introduction to Structure, Mechanism, and Data Analysis by R.A. Copeland. 2nd edition. Wiley, USA. 2000. (Chapters 1 and 5)
2. Lehninger Principles of Biochemistry by D.L. Nelson & M.M. Cox. 6th edition. W.H. Freeman, USA. 2017. (Chapter 6)
3. Principles and Techniques of Biochemistry and Molecular Biology by K. Wilson and J. Walker. 7th edition. Cambridge University Press, UK. 2010. (Chapters 15)

UNIT – II (6 hours)

Study of Extremozymes – Exploring Unique Enzymatic Features: Extremozymes: unique properties, stability, and activity under extreme conditions (temperature, pH, and salinity). Adaptations of extremophiles: thermostable, halotolerant, and cold-active enzymes, along with their structural features. Applications of extremozymes: industrial uses in molecular biology, pharmaceutical synthesis, and green chemistry.

Essential reading:

1. Extremophiles: From Biology to Biotechnology (Editors: R. Durvasula & V. Subba Rao). CRC Press, USA. (Chapters 1, 7 and 11)

UNIT – III (15 hours)

Enzyme Engineering and Advances in Biocatalysis: Enzyme engineering techniques such as site-directed mutagenesis to enhance enzyme activity and stability. Methods to optimize enzyme-substrate interactions, improve catalytic efficiency, and increase stability under various conditions such as high temperature, extreme pH, and organic solvents. Designer enzymes: computational and rational design for tailored industrial and biomedical applications. Whole-cell biocatalysis concept, benefits, and applications in biotransformation and bioprocessing. Cell-free protein synthesis (CFPS), its advantages, challenges, and applications in protein production. Use of these biocatalysis strategies in pharmaceuticals, biofuels, and green chemistry.

Essential reading:

1. Lehninger Principles of Biochemistry by D.L. Nelson & M.M. Cox. 6th edition. W.H. Freeman, USA. 2017. (Chapter 6)
2. Cell-Free Protein Synthesis: Methods and Protocols edited by J. Swartz. Methods in Molecular Biology, Vol. 1118. Springer, USA. 2014. (Chapter 4 and 6)

UNIT – IV (8 hours)

Commercialization and Entrepreneurship in Enzyme Technology: Lab-to-market journey of enzyme technologies with case studies. Entrepreneurship in enzyme technology: intellectual

property, patents, and funding opportunities. Future directions: enzyme applications in the circular bioeconomy, green chemistry, and sustainability.

Essential Reading:

1. Biotechnology Entrepreneurship (Ed. Craig Shimasaki), Elsevier, 2014. (Chapters 14, 15)
2. The Business of Bioscience: What Goes into Making a Biotechnology Product by C.D. Shimasaki. 1st edition. Springer, USA. 2014. (Chapters 2, 6 and 13)

Practical Component (30 hours):

1. Determination of enzyme activity and specific activity of a purified enzyme sample.
2. Determination of kinetic parameters (K_m , V_{max} , and K_{cat}) using Michaelis-Menten and Lineweaver-Burk plots.
3. Study of pH optima, pH stability, temperature optima, and temperature stability of a given enzyme sample.
4. Calculation of inactivation constant (K_d) and $t_{1/2}$ for enzyme reaction.
5. Comparative analysis of extremozymes and mesophilic enzymes to understand adaptive mechanisms.

Suggested Readings:

Theory:

1. Molecular Cell Biology by H. Lodish et al. 9th edition. W.H. Freeman. 2021.
2. Essential Cell Biology by B. Alberts et al. 5th edition. W.W. Norton & Co. 2019.
3. Karp's Cell and Molecular Biology by G. Karp et al. 9th edition. Wiley. 2019.
4. The Cell: A Molecular Approach by G.M. Cooper. 8th edition. Sinauer Associates. 2018.
5. Principles of Enzymology by N.C. Price. 4th edition. Oxford University Press. 2013.
6. Biocatalysts and Enzyme Technology by K. Buchholz, V. Kasche, U.T. Bornscheuer. 2nd edition. Wiley-VCH, Weinheim, Germany. 2012.
7. Guide to Protein Purification edited by M. P. Deutscher. 2nd edition. Academic Press, USA, 2009.
8. Enzymes: Biochemistry, Biotechnology, Clinical Chemistry by Trevor Palmer. 2nd edition. Horwood Publishing House, England, 2007.
9. Biocatalysis – Fundamentals and Applications by A.S. Bommarius, B.R. Riebel. Wiley-VCH, Weinheim, Germany. 2004.
10. Enzymology Labfax by P.C. Engel. BIOS Scientific Publishers, Academic Press, USA. 1996.
11. Enzyme Inhibitors by U. Brodbeck. Verlag Chemie, Weinheim, Germany. 1980.
12. Biochemical Calculations by Irwin Segel. 2nd edition. John Wiley and Sons, USA. 1976.

Practical component:

1. A Cell Biology Manual by J. Francis, Kendall/Hunt Publishing. 2022.
2. Practical Laboratory Manual- Cell Biology by A. Gupta, B.K. Sati, Lambert Academic Publishing. 2019.
3. Essential Cell Biology Vol. 1 & 2 by J. Davey and M. Lord. Oxford University Press. 2003.
4. Enzyme Kinetics and Mechanism by P. F. Cook, W.W. Cleland. Garland Science Publishing, USA. 2007.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE : DSE-08 INTRODUCTION TO GENOMICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-08: INTRODUCTION TO GENOMICS	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The objective of this course is to introduce the students to the essential concepts and recent discoveries in genomics.
- The students will become familiar with the currently used techniques to sequence whole genomes.
- They will gain knowledge about the methods used to annotate genome sequences.
- They will be educated about the various applications of genomics in human health.
- They will be introduced to the applications of metagenomic analyses.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Student will be able to discuss how complex genomes are sequenced *de novo*.
- Student will be able to describe the various high-throughput methods used to sequence genomes.
- Student will be able to list the various databases used to store genomics data.
- Student will be able to relate the uses of genomics in the prediction of human diseases.
- Student will be able to compare the different methods of genome editing.

SYLLABUS OF DSE-08

UNIT – I (12 hours)

First generation and next generation genome sequencing methods: DNA sequencing by chain termination: Sanger's manual versus automated methods. Concept of primer walking and chromosome walking. Principles of shotgun genome sequencing. Whole genome versus hierarchical shotgun sequencing approach. The Human Genome Sequencing Project. Next generation sequencing platforms: pyrosequencing-based, reversible terminator-based, single-molecule real-time sequencing-based, ion torrent sequencing, nanopore sequencing. Preparation of libraries for NGS. Importance and applications of NGS.

Essential reading:

1. Molecular Biology by D.P. Clarke, N. Pazdernik, M.R. McGehee. 3rd edition. Academic Cell. 2018. (Chapters 8, 9)

UNIT-II (8 hours)

Genome sequence annotation: Databases, databanks, and genome browsers. Computer program overview for genomics: Genome Linux, NCBI blast tools. Annotation at the nucleotide level. Nucleic acid sequence databases. Annotation at the protein level. Protein sequence databases. Databases of genetic diseases. Databases of structures. AlphaFold: breakthrough in protein structure prediction. Databases of proteomics and metabolic pathways. The Kyoto Encyclopedia of Genes and Genomes (KEGG).

Essential reading:

1. Introduction to Genomics by Arthur Lesk. 4th edition. Oxford University Press. 2025. (Chapter 3)

UNIT –III (12 hours)

Genomics in human health and disease: Identification of human biomarkers using genomics. Genome-wide association studies (GWAS) and their application in human health and personalized medicine. Comprehensive whole-genome sequencing projects: 1000 Genomes Project (The International Genome Sample Resource), 10,000 Genomes Project (Genome India Project), 100,000 Genomes Project (Genomics England initiative). Neonatal genome sequencing: benefits and risks. Application of genomics in the understanding, detection and treatment of cancer. Genome editing using CRISPR-Cas.

Essential reading:

1. Introduction to Genomics by Arthur Lesk. 4th edition. Oxford University Press. 2025. (Chapters 1, 10)

UNIT-IV (13 hours)

Metagenomics and its applications: Investigating complex microbial communities: gut microbiome and its role in human health and disease. Soil and water microbiomes as a measure of pollutants and climate change. Role of soil microbiome in crop health, and development of biofertilizers. Identification of microbial enzymes and pathways useful in industrial processes in soil microbiota genomes.

Essential reading:

1. Metagenomics: Perspectives, Methods and Applications. Edited by M. Nagarajan. 2nd edition. Academic Press. 2024. (Chapters 10, 11, 18, 21)

Practical component (30 hours)

1. Use of genome browsers: Trawling genome sequence databases for information with respect to the organization of the genome, genes, proteins and metabolic pathways.
2. Protein structure prediction and modeling: Use of Phyre 2 and AlphaFold to model protein structure from amino acid sequence.

Recommended readings**Theory:**

1. Gene Cloning and DNA Analysis: An Introduction by T.A. Brown. 8th edition. Wiley-Blackwell Publishers. 2020.

Department of Microbiology, University of Delhi, M.Sc. Microbiology Syllabus (NEP-PGCF 2024)

2. Molecular Biology of the Gene by J. Watson, T. Baker, S. Bell, A. Gann, M. Levine, R. Losick. 7th edition. Pearson. 2014.
3. Introduction to Genomics by Arthur Lesk. 4th edition. Oxford University Press. 2025.

Tutorials:

1. Use of NCBI tools, use of Phyre 2 and AlphaFold: <https://www.ncbi.nlm.nih.gov.in>, <https://www.sbg.bio.ic.ac.uk/~phyre2/>, <https://alphafoldserver.com/welcome>

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE: DSE-09
BACTERIAL BIOFILMS AND CHRONIC INFECTIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE 09: BACTERIAL BIOFILMS AND CHRONIC INFECTIONS	4	3	0	1	B.Sc. in any branch of Life Science	NA

Learning Objectives:

- The objective of this course is to make the students understand the difference between biofilm and planktonic modes of life.
- The students will learn about the medical complications associated with biofilms.
- The course will enable students to understand the tools available to study biofilms.

Learning Outcomes:

Upon successful completion of the course:

- The student will be able to understand how biofilm bacteria are different from their planktonic counterparts.
- The student will be able to describe the characteristics of bacterial biofilms.
- The student will be able to study and critique the various biofilm-associated diseases impacting humans
- The student will be able to understand various *in vitro* and *in vivo* models to study biofilm which will help them design their research
- The student will be able to gather information on how chronic infections are diagnosed and what treatment options available.

SYLLABUS OF DSE-09

UNIT- I (12 hours)

Introduction to biofilms and chronic infections: Planktonic and biofilm-growing bacteria. Where do biofilms grow: environment, artificial materials, and live cells. Stages of biofilm formation and role of different biomolecules. Biofilm matrix polysaccharides and other components of biofilms. Key features of biofilms including quorum sensing. Chronic infections and host responses. Immune evasion responses. Treatment failures and persistence: role of persister cells. Biofilm in chronic infections: Introduction, Oral biofilms, Skin Microbiology, Commensal Biofilm- gut flora, Bacteria and Biofilms are ubiquitous, Cystic fibrosis, chronic wounds, Implants, Tissue filler, Otitis Media, Intravascular catheters.

Essential reading:

1. Bacterial Biofilms by Tony Romeo. Springer 2008 (Chapter 2, 3, 7, 8, 9, 12)

UNIT – II (13 hours)

***In vitro* and *ex vivo* models to study biofilms:** Characteristics, advantages and uses of different model systems. *In vitro* models (Open systems: micro-titer plate assays, biofilm ring test, Calgary biofilm device; closed systems: Kadouri system, flow cells, CDC bioreactor, drip flow reactor, micro-fermenters, modified Robbins Device, microfluidic biochips and continuous flow system. Microcosms: Zurich Oral biofilm model, Zurich burn biofilm model, Reconstitute human epithelia (RHE), microfluidic co-culture model); *Ex vivo* models: Root canal biofilms, cardiac valve *ex vivo* model, Candidiasis in vaginal mucosa.

Essential reading:

1. From *in vitro* to *in vivo* models of bacterial biofilm-related infections. Lebeaux D, Chauhan A, Rendueles O, Beloin C. *Pathogens*. May 13;2(2):288-356. (2013) doi: 10.3390/pathogens2020288.
2. Analytical Methodologies for Biofilm Research by Bhowmik, A., Malhotra, A., Jana, S., Chauhan, A. Nag, M., Lahiri, D. (eds). Springer Protocols Handbooks. Springer, New York, NY. (2021). https://doi.org/10.1007/978-1-0716-1378-8_1
3. Critical review on biofilm methods. Azeredo, J., Azevedo, N. F., Briandet, R., Cerca, N., Coenye, T., Costa, A. R., Sternberg, C. Critical Reviews in Microbiology, 43 (3), 313-351. (2017) <https://doi.org/10.1080/1040841X.2016.1208146>

UNIT-III (10 hours)

Animal models (*in vivo*) to study biofilms: Non-mammalian animal models: drosophila, Zebrafish, *C. elegans* as model systems; Mammalian models: a) tissue related models: burn wound infection biofilm model, native valve endocarditis infection model, b) urinary tract catheters, vascular catheter model, orthopedic implants, prosthetic joints and endotracheal tubes.

Essential reading:

1. Lebeaux D, Chauhan A, Rendueles O, Beloin C. (2013) From *in vitro* to *in vivo* models of bacterial biofilm-related infections. *Pathogens*. May 13;2(2):288-356. doi: 10.3390/pathogens2020288.
2. Analytical Methodologies for Biofilm Research by Bhowmik, A., Malhotra, A., Jana, S., Chauhan, A. (2021). Nag, M., Lahiri, D. (eds). Springer Protocols Handbooks. Springer, New York, NY. https://doi.org/10.1007/978-1-0716-1378-8_1

UNIT – IV (10 hours)

Diagnosis and treatment of chronic infections: Diagnosis of biofilm infections and challenges. Culture dependent, molecular methods (PCR etc.) and microscopy. Treatment of chronic infections. Pharmacokinetic of a drug in context with biofilm infections and comparison with planktonic bacteria. Minimum biofilm inhibitory concentration vs. minimum inhibitory concentration. Antimicrobial resistance/tolerance/persistence of biofilms. Role of persister cells in treatment options. Various innovative approaches from recent research.

Essential reading:

1. Lebeaux D, Chauhan A, Rendueles O, Beloin C. (2013) From *in vitro* to *in vivo* models of bacterial biofilm-related infections. *Pathogens*. May 13;2(2):288-356. doi: 10.3390/pathogens2020288.
2. Allison, K., Brynildsen, M. & Collins, J. (2011). Metabolite-enabled eradication of bacterial persisters by aminoglycosides. *Nature* **473**, 216–220. <https://doi.org/10.1038/nature10069>

3. Baquero, F., Levin, B.R. Proximate and ultimate causes of the bactericidal action of antibiotics. (2021) *Nat Rev Microbiol* **19**, 123–132. <https://doi.org/10.1038/s41579-020-00443-1>

Practical component (30 hours):

1. Growth of bacterial biofilms in a microfuge tube.
2. Growth of biofilms in a micro-titre plate.
3. Evaluation of different staining methods for biofilms.
4. Effect of media and substrate on biofilm growth.
5. Visualization of biofilm under microscope.
6. Comparing antibacterial and antibiofilm activity of different compounds: MIC vs. MBIC.

Essential/recommended readings

1. Oral Biofilms in Health and Disease by Hyun Koo, Nicholas Jakubovics, Bastiaan P. Kron. Springer. 2025.
2. Biofilm Matrix by Courtney Reichhardt. Springer 2024
3. Antibiofilm Strategies by Katharina Richter and Kasper Norskov Kragh. Springer 2022.
4. Control of Biofilm Infections by Single Manipulation. By Naomi Balaban. Springer. 2008
5. Bacterial Biofilms by Tony Romeo. Springer 2008.
6. Allison, K., Brynildsen, M. & Collins, J. (2011). Metabolite-enabled eradication of bacterial persisters by aminoglycosides. *Nature* **473**, 216–220. <https://doi.org/10.1038/nature10069>
7. Baquero, F., Levin, B.R. Proximate and ultimate causes of the bactericidal action of antibiotics. (2021) *Nat Rev Microbiol* **19**, 123–132. <https://doi.org/10.1038/s41579-020-00443-1>
8. Lebeaux D, Chauhan A, Rendueles O, Beloin C. (2013) From *in vitro* to *in vivo* models of bacterial biofilm-related infections. *Pathogens*. May 13;2(2):288-356. doi: 10.3390/pathogens2020288.
9. Analytical Methodologies for Biofilm Research by Bhowmik, A., Malhotra, A., Jana, S., Chauhan, A. (2021). Nag, M., Lahiri, D. (eds). Springer Protocols Handbooks. Springer, New York, NY. https://doi.org/10.1007/978-1-0716-1378-8_1

Practical:

1. O'Toole GA. Microtiter dish biofilm formation assay. *J Vis Exp*. 2011 Jan 30;(47):2437. doi: 10.3791/2437. PMID: 21307833; PMCID: PMC3182663.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time

DISCIPLINE SPECIFIC ELECTIVE COURSE: DSE-10 ADVANCES IN ANTIMICROBIAL RESISTANCE MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-10: Advances in Antimicrobial Resistance Management	4	3	0	1	Class B.Sc. pass with Biology/ Biotechnology/ Biochemistry	NA

Course Objectives

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

- Perform and interpret standardized laboratory techniques for antimicrobial susceptibility testing (AST), including MIC determination (Broth Microdilution) and phenotypic detection of key resistance determinants (e.g., ESBL, inducible resistance) using CLSI/EUCAST guidelines.
- Design and execute basic molecular biology protocols (DNA extraction, PCR) to detect and confirm the presence of specific antimicrobial resistance genes (ARGs) in clinical or environmental isolates.
- Analyze and interpret complex microbiological data sets, including MIC distributions, anti-biograms, and epidemiological data, using appropriate statistical and data visualization tools.
- Appraise and critique primary scientific literature concerning antimicrobial development and resistance mechanisms, identifying key hypotheses, methodological limitations, and future research directions.
- Demonstrate professional responsibility and ethical awareness regarding the appropriate use of antimicrobials and the handling of clinical and research data in the context of AMR.

Course Learning Outcomes:

Upon successful completion of the course:

- The student will be able to understand the global challenge of Antimicrobial Resistance (AMR) from molecular, clinical, and public health perspectives.
- The student will be able to analyze the mechanisms of action for major classes of antibiotics and the corresponding resistance mechanisms.
- The student will be able to evaluate current strategies and novel approaches for discovering and developing new antimicrobial agents.
- The student will be able to execute essential laboratory techniques for antimicrobial susceptibility testing, resistance mechanism identification, and antimicrobial screening.

SYLLABUS OF DSE-10

Unit 1 (12 hours)

The Biology of Antimicrobial Agents: History and Classification of antibiotics: Brief history of antibiotics (e.g., Penicillin, Streptomycin). Classification based on chemical structure, mechanism of action, and spectrum of activity. Mechanisms of Action: Detailed examination of how key classes of antibiotics kill or inhibit bacteria: Cell Wall Synthesis Inhibitors: beta-Lactams (Penicillins, Cephalosporins, Carbapenems, Monobactams), Glycopeptides (Vancomycin). Protein Synthesis Inhibitors: Aminoglycosides, Macrolides, Tetracyclines, Lincosamides. Nucleic Acid Synthesis Inhibitors: Fluoroquinolones, Rifamycins. Metabolic Pathway Inhibitors: Sulfonamides, Trimethoprim.

Essential Reading:

1. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases by John E. Bennett, Raphael Dolin and Martin J. Blaser. 8th Edition Saunders 2015. (Chapter 17-34)

Unit 2 (12 hours)

Mechanisms and Spread of Antimicrobial Resistance: Molecular Mechanisms of Resistance: Enzymatic Degradation/Inactivation: beta-Lactamases (ESBLs, KPCs), Aminoglycoside-modifying enzymes. Target Modification: Altered PBP (MRSA), Ribosomal modifications (Macrolide resistance), D-Ala-D-Lac substitution (Vancomycin resistance). Efflux Pumps: Structure and function of major efflux systems (e.g., RND family) and their role in multi-drug resistance (MDR). Reduced Permeability: Role of outer membrane porins (e.g., *Pseudomonas aeruginosa*). Genetic Basis of Resistance: Role of Plasmids and Transposons in horizontal gene transfer (Conjugation, Transformation, and Transduction). The concept of the Resistome. Clinical and Epidemiological Issues: Emergence of "Superbugs" (e.g., MRSA, VRE, CRE, MDR-TB).

Essential Reading:

1. Molecular mechanisms of antibiotic resistance by Blair, J., Webber, M., Baylay, A. *et al. Nat Rev Microbiol* **13**, 42–51 (2015)
2. Extending the Potency and Lifespan of Antibiotics: Inhibitors of Gram-Negative Bacterial Efflux Pumps. Jumde, R. P., da Costa, R. M. A., Ropponen, H.-K., & Piddock, L. J. V. *ACS Infectious Diseases*, **10**(5), 1438–1454. (2024)
3. Mechanisms of antimicrobial resistance in biofilms by Liu, H.Y., Prentice, E.L. & Webber, M.A. *npj Antimicrob Resist* **2**, 27 (2024)
4. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases by John E. Bennett, Raphael Dolin and Martin J. Blaser. 8th Edition Saunders 2015. (Chapter 18 and 19)

Unit 3 (11 hours)

Antimicrobial Discovery, Development, and Innovation Management: Traditional Discovery Strategies: The "Golden Age" Legacy: The Waksman platform and systematic screening of Soil Actinomycetes. Bioprospecting: Exploration of extreme environments (marine, endophytic, and deep-sea microbes) for novel chemical scaffolds. Chemical Libraries: Principles of combinatorial chemistry and the synthesis of "diversity-oriented" libraries. Case Study: The discovery of Teixobactin as a paradigm shift in natural product screening. Modern Drug Design & Screening Technologies: Target-Based vs. Phenotypic Screening: * Target-based: Using genomics to identify "essential" bacterial proteins (e.g., FtsZ, LpxC). Phenotypic: Whole-cell screening and the advantage of capturing "prodrugs" and permeability. High-Throughput Screening (HTS): Automation, assay miniaturization (384/1536-well plates), and fluorescence-based readouts. Non-Traditional & Adjunct Therapies: Antibiotic Adjuvants: Reversing resistance through synergy (e.g., beta-lactamase inhibitors like Avibactam; Efflux Pump

Inhibitors). Biological Alternatives: Phage Therapy: Biology of lytic phages, "Phage cocktails," and regulatory hurdles. Antimicrobial Peptides (AMPs): Structure-activity relationships and membrane-targeting mechanisms. Anti-virulence Strategies: Targeting Quorum Sensing (QS) and toxin production to reduce pathogenicity without killing the microbe. Vaccines and Immunotherapies against resistant pathogens.

Essential Reading:

1. Bacteriophage therapy for multidrug-resistant infections: current technologies and therapeutic approaches. Kim, M. K., Suh, G. A., & D'Hérelle, G. *Journal of Clinical Investigation*, 135(2), e187996. 2025.
2. ARG Context Profiler: extracting and scoring the genomic contexts of antibiotic resistance genes using assembly graphs. Moumi, N. A., Ahmed, S., Brown, C., Pruden, A., & Zhang, L. *Frontiers in Cellular and Infection Microbiology*, 15, 1582613. 2025

Unit 4(10 hours)

Management of AMR: Global Health, Policy, and Diagnostics: Public Health, Policy, and "One Health" The One Health Triad: The interconnectedness of human medicine, veterinary usage (growth promoters), and environmental reservoirs (water/soil). Global Surveillance: Role of the WHO GLASS (Global Antimicrobial Resistance and Use Surveillance System). Antimicrobial Stewardship (AMS): Core elements of hospital-based AMS programs; "Right drug, right dose, right time." National Action Plans: Analyzing government policies for reducing antibiotic consumption. Advanced Diagnostics & Stewardship: Phenotypic Standards: Mastery of CLSI/EUCAST guidelines for Disk Diffusion and Broth Microdilution (MIC/MBC). Rapid Molecular Diagnostics: * Nucleic Acid Amplification: PCR, LAMP, and Multiplex assays for rapid "Gene-to-Result" (e.g., GeneXpert for MDR-TB). Whole Genome Sequencing (WGS): Real-time outbreak tracing and "In silico" resistome profiling. Point-of-Care (POC) & Biosensors: Development of rapid, bedside tests to differentiate viral vs. bacterial infections (e.g., Procalcitonin, CRP, or microfluidic chips). The Economics and Regulatory Landscape: The "Market Failure" of Antibiotics: Why the R&D pipeline is dry; the low Return on Investment (ROI) compared to chronic disease drugs. Incentivizing Innovation: * Push Mechanisms: Grants, tax credits, and public-private partnerships (e.g., CARB-X). Pull Mechanisms: Market Entry Rewards (MER) and the "Subscription Model" (The Netflix Model for antibiotics). Regulatory Pathways: FDA/EMA expedited approvals (LPAD pathway) for drugs targeting unmet medical needs.

Essential Reading:

- Jawetz, Melnick, & Adelberg's Medical Microbiology by Stefan Riedel, Jeffery A. Hobden, Steve Miller, Stephen A. Morse, Timothy A. Mietzner, Barbara Detrick, Thomas G. Mitchell, Judy A. Sakanari, Peter Hotez, Rojelio Mejia. 28th Edition. A & L Lange Series. McGraw Hill 2019 (Chapter 47)
- *Antibiotic Use and Stewardship in the United States, 2024 Update: Progress and Opportunities*. Centers for Disease Control and Prevention. CDC 2024
- Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases by John E. Bennett, Raphael Dolin and Martin J. Blaser. 8th Edition Saunders 2015. (Chapter 51)

Practical Component (30 hours)

1. Antimicrobial Susceptibility Testing (AST): Perform Disk Diffusion (Kirby-Bauer) assay and interpret results using CLSI standards. Determine the Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) via Broth Microdilution.
2. Identification of Resistance Phenotypes: Screen for beta-Lactamase activity (e.g., using nitrocefin). Perform the Combined Disk Test for Extended-Spectrum beta-Lactamase (ESBL) detection.
3. Basic Antimicrobial Screening: Primary screening of an unknown compound/natural product extract against a panel of test organisms using the Agar Well Diffusion method.
4. Molecular Detection of Resistance Genes: Genomic DNA extraction from a resistant organism. Perform Polymerase Chain Reaction (PCR) to detect a common resistance gene (e.g., a *bla* gene, *mecA*, or *vanA*).
5. Data Analysis and Reporting: Interpretation of MIC/MBC data and comparison with clinical breakpoints. Statistical analysis of screening data.

Essential/Recommended readings

These provide the foundational knowledge necessary for the entire course.

1. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases by John E. Bennett, Raphael Dolin and Martin J. Blaser. 8th Edition Saunders 2015.
2. Medical Microbiology by Patrick R. Murray, Ken S. Rosenthal, and Michael A. Pfaller. 2nd Edition Elsevier 2025
3. Goodman & Gilman's: The Pharmacological Basis of Therapeutics by Laurence L. Brunton, Björn C. Knollmann. 14th Edition. McGraw Hill. 2022.
4. Jawetz, Melnick, & Adelberg's Medical Microbiology by Stefan Riedel, Jeffery A. Hobden, Steve Miller, Stephen A. Morse, Timothy A. Mietzner, Barbara Detrick, Thomas G. Mitchell, Judy A. Sakanari, Peter Hotez, Rojelio Mejia. 28th Edition. A & L Lange Series. McGraw Hill 2019
5. Extending the Potency and Lifespan of Antibiotics: Inhibitors of Gram-Negative Bacterial Efflux Pumps. Jumde, R. P., da Costa, R. M. A., Ropponen, H.-K., & Piddock, L. J. V. ACS Infectious Diseases, 10(5), 1438–1454. 2024
6. Mechanisms of antimicrobial resistance in biofilms by Liu, H.Y., Prentice, E.L. & Webber, M.A. npj Antimicrob Resist 2, 27 (2024)
7. ARG Context Profiler: extracting and scoring the genomic contexts of antibiotic resistance genes using assembly graphs. Moumi, N. A., Ahmed, S., Brown, C., Pruden, A., & Zhang, L. Frontiers in Cellular and Infection Microbiology, 15, 1582613. 2025
8. Bacteriophage therapy for multidrug-resistant infections: current technologies and therapeutic approaches. Kim, M. K., Suh, G. A., & D'Hérelle, G. Journal of Clinical Investigation, 135(2), e187996. 2025
9. Rapid Diagnostic Tests and Antimicrobial Stewardship Programs for the Management of Bloodstream Infection: What Is Their Relative Contribution to Improving Clinical Outcomes? A Systematic Review and Network Meta-analysis. Peri, A. M., Chatfield, M. D., et al. Clinical Infectious Diseases, 79(2), 502–515. 2024
10. Antibiotic Use and Stewardship in the United States, 2024 Update: Progress and Opportunities. Centers for Disease Control and Prevention. CDC 2024

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11. Molecular mechanisms of antibiotic resistance by Blair, J., Webber, M., Baylay, A. et al. *Nat Rev Microbiol* **13**, 42–51 (2015)

Practical:

1. Microbiology: A laboratory manual by JG Cappucino, C.T. Welsh. 11th edition. Pearson. 2017.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE: DSE-11
EXTREMOPHILE MICROBIOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-11: Extremophile Microbiology	4	3	1	0	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The primary objective of this course is to introduce students to microorganisms that thrive in extreme environments and to highlight the ecological significance of extreme ecosystems.
- The students will learn about the diversity, physiology, and molecular adaptations of extremophiles, including thermophiles, psychrophiles, halophiles, acidophiles, alkaliphiles, barophiles, and polyextremophiles.
- They will become familiar with methods used for bioprospecting extreme habitats, including culture-dependent and culture-independent approaches, metagenomics, and meta-omics tools.
- The students will explore the mechanisms of microbial stress response and biofilm formation under extreme physicochemical conditions.
- They will understand the potential of extremophiles and extreme-environment microbes in blue biotechnology, bioremediation, biodegradation, and resource discovery.
- The students will gain exposure to modern tools such as environmental DNA (eDNA), AI-based protein structure prediction, and planetary simulation studies relevant to extremophile research.

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Students will be able to describe major extreme habitats and explain the diversity and ecological roles of microorganisms living under extreme conditions.
- Students will be able to explain the molecular and physiological strategies that enable microbial survival under stress conditions such as high temperature, high salinity, extreme pH, pressure, radiation, and desiccation.
- Students will be able to evaluate bioprospecting strategies and interpret metagenomic and meta-omic data relevant to the discovery of novel biomolecules from extreme environments.
- Students will be able to examine microbial stress-response pathways and analyze biofilm

behavior in extreme and engineered environments.

- Students will be able to assess the potential of extremophiles in blue biotechnology, biodegradation, and bioremediation of pollutants under high-stress environmental conditions.
- Students will be able to integrate modern approaches, including eDNA monitoring, synthetic biology, and astrobiology frameworks, to understand and apply concepts in extreme-environment microbiology.

SYLLABUS OF DSE-11

UNIT-I (14 hours)

Extreme Ecosystems and Polyextreme Microorganisms: Major extreme habitats: deep sea, hydrothermal vents, Polar Regions, hypersaline lakes, deserts, acidic and alkaline environments. Diversity, occurrence, and ecological significance of thermophiles, psychrophiles, halophiles, acidophiles, alkaliphiles, barophiles, xerophiles, and polyextremophiles. Core physiological and molecular adaptations to temperature, salinity, pH, pressure, radiation, and nutrient limitation. Microbial dark matter and uncultured lineages in extreme ecosystems; importance of single-cell approaches. Astrobiology relevance of extremophiles: survival under vacuum, radiation, desiccation and extreme temperatures; use as models for life on Mars and icy moons; planetary-protection and life-detection missions. Modern exploration and sampling approaches: remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), deep-sea modules, and polar ice-coring systems. Impact of climate change on expansion and transformation of extreme habitats (warming oceans, salinization, desertification) and microbial responses.

Essential readings:

1. Extremophiles: From Biology to Biotechnology, edited by Ravi Durvasula & D.V. Subba Rao. CRC Press, 2018. (Chapters 1, 7, 8, 9, 11, 16).
2. **Extreme Environments: Unique Ecosystems – Amazing Microbes**, edited by Anita Pandey & Avinash Sharma. CRC Press, USA. 2021. (Chapters 1 and 11)
3. Astrobiology: Understanding Life in the Universe by Charles S. Cockell. 1st edition. John Wiley & Sons, Ltd., UK. 2015. (Chapter 1).

UNIT-II (15 hours)

Bioprospecting of Extreme Environments and Metagenomic Exploration: Principles of bioprospecting extreme habitats: sampling design, handling, and contamination control. Culture-dependent isolation strategies tailored to extreme conditions. Culture-independent exploration: amplicon and shotgun metagenomics; MAG recovery; functional annotation for stress-related traits. Genome-based bioprospecting: identification of genes for stability, tolerance, biosynthesis of unique metabolites, osmolytes, pigments, biosurfactants, and other novel biomolecules. Field-to-application pipeline: transition from environmental sample to candidate biomolecule of industrial or ecological relevance. Introduction to genome-resolved meta-omics (metaproteomics, metabolomics) for functional discovery in extreme microbiomes. Ethical, legal and biodiversity regulations governing extreme-environment bioprospecting (Nagoya Protocol).

Essential readings:

1. Extremophiles: From Biology to Biotechnology, edited by Ravi V. Durvasula and D. V. Subba Rao. CRC Press (Taylor & Francis), USA. 2018. (Chapters 2 and 3).
2. Bioprospecting of Novel Extremozymes From Prokaryotes – The Advent of Culture-Independent Methods by Sysoev M., Grötzinger S.W., Renn D., Eppinger J., Rueping M., and Karan R. *Frontiers in Microbiology*. 2021. Volume 12, Article 630013.
3. Understanding Bioinformatics by Marketa Zvelebil and Jeremy O. Baum. 2nd edition. Garland Science / Taylor & Francis, UK. 2020. (Chapters 10 and 12).

UNIT-III (8 hours)

Stress Adaptation Mechanisms and Biofilms in Extreme Settings: Cellular stress responses to heat, cold, osmotic, oxidative, pressure and solvent stress; stress regulons and protective systems. Biofilms in extreme conditions: EPS composition, structural adaptations, survival advantages, and strategies for controlling biofilms in engineered extreme systems. Microbial communities in high-stress industrial analogues: desalination plants, oilfield brines, hypersaline reactors, and high-pressure systems. Overview of cryo-electron microscopy (cryo-EM) and AI-driven protein structure prediction (AlphaFold/RosettaFold) for understanding stability determinants of extremophile proteins. Basics of synthetic biology approaches for engineering stress-resilient or chimeric extremophilic microorganisms.

Essential readings:

1. Extremophiles: From Biology to Biotechnology, edited by Ravi V. Durvasula and D. V. Subba Rao. CRC Press (Taylor & Francis), USA. 2018. Chapters 7 and 9.
2. Extremophiles: Sustainable Resources and Biotechnological Implications, **edited by Om V. Singh**. Elsevier, Netherlands. 2025. Chapter 1.
3. Protein intrinsic disorder and adaptation to extreme environments: Resilience of chaos by Vladimir N. Uversky. Journal of Molecular Biology. 2025. 14;169547.

UNIT-IV (8 hours)

Blue Biotechnology and Extreme Environment Bioremediation: Marine extremophiles and their ecological roles in deep-sea, coral reef, hydrothermal, and hypersaline marine systems. Resource potential of marine microbial communities: cold-active catalysts, osmoadapted metabolites, exopolymers, pigments, and biosurfactants. Biodegradation potential under extreme conditions: hydrocarbons, dyes, plastics, and heavy metals in hypersaline, high-temperature, and high-pressure environments. Extremophile-based bioremediation strategies: hypersaline effluents, geothermal sites, oilfield brines, and deep-sea contamination. Emerging tools: environmental DNA (eDNA) and meta-omics approaches for monitoring, profiling, and assessing extreme ecosystems.

Essential readings:

1. Marine Biotechnology: Applications in Food, Drugs and Energy edited by Se-Kwon Kim. CRC Press (Taylor & Francis), USA. 2012. (Chapters 1 and 2).
2. Extremophiles: From Biology to Biotechnology, edited by Ravi V. Durvasula and D. V. Subba Rao. CRC Press (Taylor & Francis), USA. 2018. (Chapters 2, 6, 9 and 15).
3. Extremophiles: Sustainable Resources and Biotechnological Implications, **edited by Om V. Singh**. Elsevier, Netherlands. 2025. (Chapter 5-11).

Tutorial Component (15 hours)

The tutorial will include:

1. Group discussions: Case studies and recent research articles on extremophiles, extreme ecosystems, astrobiology relevance, and microbial survival strategies under extreme physicochemical conditions.
2. Tasks based on bioprospecting workflows, metagenomic datasets, extreme-environment sampling strategies, and analysis of stress-adaptation mechanisms.
3. Flip classroom training and assessment: Presentation preparation, Q & A covering the theory taught in the main lectures.

Essential / Recommended Readings

1. Extremophiles as Astrobiological Models edited by Seckbach, J., Oren, A. and Stan-Lotter, H. Scrivener Publishing / Wiley. 2013.
2. Marine Microbiology: Ecology & Applications by Munn, C.B., Priest, F.G., Roberts, M., Seymour, J., Warwick-Dugdale, J. and Zettler, E. CRC Press (Routledge). 3rd Edition. 2023.

3. Marine Microbiome and Microbial Bioprospecting edited by Radhakrishnan, M.G. Elsevier. 2022.
4. Thermophilic Microbes in Environmental and Industrial Biotechnology edited by Satyanarayana, T., Littlechild, J. and Kawarabayasi, Y. Springer, Cham. 2nd Edition. 2019.
5. Extremophiles: From Biology to Biotechnology edited by Ravi V. Durvasula, D. V. Subba Rao. CRC Press (Taylor & Francis). 2018.
6. Microbial Biodegradation: From Omics to Function edited by Jerzy Dlugonski. Caister Academic Press. 2016.
7. Modern Tools and Techniques to Understand Microbes edited by Varma, A. and Sharma, A.K. Springer Nature, Singapore. 2017.
8. Life at Extremes: Environments, Organisms and Strategies for Survival edited by Bell, E. CABI Publishing, UK. 2012.
9. Deep-Sea Microbiology: Prokaryotes and Eukaryotes edited by Nagano, Y., Danovaro, R. and Gobet, A. Elsevier. 2021.
10. Bioprospecting for Sustainable Development edited by Singh, J., Sharma, D., Kumar, G. and Sharma, N.R. Springer. 2019.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE: DSE-12
MICROBIAL ECOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-12: MICROBIAL ECOLOGY	4	3	1	0	B.Sc. in any branch of Life Science	NA

Learning Objectives:

- The objective of this course is to understand the basic concepts of microbial ecology and their role in the environment.
- It would also help to understand the interaction between microbes and other organism.
- It would also help the students understand the role of microbes in biogeochemical cycles and mineralization

Learning Outcomes:

Upon successful completion of the course:

- The student will be able to understand the fundamental of microbial ecology
- The student will be able to gather information about interaction of microbes with other microbes and higher organisms as well.
- The student will be able to comprehend the role of microbes in biogeochemical cycles.
- The student will be able to understand the process of Biomineralization and the process of microbial weathering.

SYLLABUS OF DSE-12

UNIT – I (10 hours)

Introduction to microbial ecology: General ecological concepts: biotic and abiotic components, ecosystem, population, community, habitat and niche. Microbial environment: Surfaces, Biofilms and Biomats. Terrestrial Environment: Components, Mineral fraction, Organic matter, microorganism, Composition of soil microbial communities, Litho echosphere- role in ecology. Aquatic Environment: Freshwater ecosystem, Marine ecosystem, lakes, rivers, Key features of aquatic environments, phototrophs and oxygen relationships, The deep sea, Hydrothermal vents.

Essential readings:

1. Microbial Ecology by Larry L. Barton and , Diana E. Northup. A JOHN WILEY & SONS, INC., PUBLICATION, 2011 (Chapter 4)
2. Brock Biology of Microorganisms by M. Madigan, K. Bender, D. Buckley, W. Sattley, D. Stahl. 15th Edition. Pearson Education. 2018 (Chapter 20)
3. Microbial Ecology: Fundamentals and Applications by R.M. Atlas, R. Bartha. 4th edition. Pearson Education, 1998. (Chapter 9)

UNIT-II (15 hours)

Population Interactions: Microbe-Microbe interactions (Neutralism, commensalism, Competition, Parasitism, Predation, Antagonism, Syntrophism) , Interaction between microbes and Plants (Interaction in the Rhizosphere, Mycorrhizae, Nitrogen fixing bacteria and higher plants, Bacteria supporting plant growth, Interaction with aerial plant structure, Microbial disease of plants) Microbes in sustainable agriculture (Biofertilizers, microbial inoculants, PGPR) , Interaction between microbes and animals (Primary and Secondary Symbionts, Microbe–Animal Interactions: Parasitism, Microbe–Animal Interactions: Mutualism, Microbial–Vertebrate Interactions, Grazing and Predation by Animals, Human microbiome), Insects and other invertebrates as microbial habitat.

Essential readings:

1. Microbial Ecology : Fundamentals and Applications by R.M. Atlas, R. Bartha. 4th edition. Pearson Education. 1998. (Chapter 3, 4 and 5)
2. Microbial Ecology by Larry L. Barton and , Diana E. Northup. A JOHN WILEY & SONS, INC., PUBLICATION, 2011 (Chapter 6, 7, 8)
3. Brock Biology of Microorganisms by M. Madigan, K. Bender, D. Buckley, W. Sattley, D. Stahl. 15th Edition. Pearson Education. 2018 (Chapter 23)
4. Microbial Inoculants in Sustainable Agricultural Productivity by D.P. Singh, H. B. Singh and R. Prabha, Springer 2016. (Chapter 2, 3, 9 12, 15)

UNIT-III (10 hours)

Microbial Roles in Biogeochemical Cycle: Oxygen and Carbon cycling: key process in oxygen and carbon cycle. Nitrogen cycling: key steps in nitrogen cycle- nitrogen fixation, nitrification, assimilation, ammonification. Sulfur cycling: Sulfur uptake by plants and microbes. Phosphorus cycling, iron cycling, cycling of manganese and selenium, Mercury transformation.

Essential readings:

1. Microbial Ecology: Fundamentals and Applications by R.M. Atlas, R. Bartha. 4th edition. Pearson Education. 1998. (Chapter 10 and 11)
2. Microbial Ecology by Larry L. Barton and , Diana E. Northup. A JOHN WILEY & SONS, INC., PUBLICATION, 2011 (Chapter 10)
3. Brock Biology of Microorganisms by M. Madigan, K. Bender, D. Buckley, W. Sattley, D. Stahl. 15th Edition. Pearson Education. 2018 (Chapter 21)

UNIT-IV (10 hours)

Biomining and Microbial weathering: Passive versus Active Biomining, Cell Characteristics and Metal Binding, Dissolution Versus Precipitation, Formation of Ores and Minerals, Microbial Participation in Silicification, Biomining of Ferromanganese Deposits, Microbial Carbonate Microbialites, Stromatolites

Essential readings:

1. Microbial Ecology by Larry L. Barton and , Diana E. Northup. A JOHN WILEY & SONS, INC., PUBLICATION, 2011 (Chapter 11)
2. Process in Microbial Ecology by David L. Kirchman. 2nd Edition, Oxford University Press, 2018 (Chapter 13)

Tutorial Components (15 hours)

1. Identification of unknown microorganisms from different environments by 16S rRNA sequencing and bioinformatics studies.
2. Enrichment culture techniques
3. Microbial interaction studies

Suggested Readings:

Theory:

1. Microbial Ecology: Fundamentals and Applications by R.M. Atlas, R. Bartha. 4th edition. Pearson Education, 1998.
2. Microbial Ecology by Larry L. Barton and, Diana E. Northup. A JOHN WILEY & SONS, INC., PUBLICATION, 2011
3. Brock Biology of Microorganisms by M. Madigan, K. Bender, D. Buckley, W. Sattley, D. Stahl. 15th Edition. Pearson Education. 2018.
4. Process in Microbial Ecology by David L. Kirchman. 2nd Edition, Oxford University Press 2018
5. Environmental Microbiology by Ian L. Pepper, Charles P. Gerba, Terry J. Gentry. 3rd Edition. Academic Press.2015

Tutorials:

1. Laboratory Exercises in Microbiology by Nathan Rigel and Javier Izquierdo. 12th edition. Mc Graw Hill Education. 2022.
2. Environmental Microbiology: A Laboratory Manual by C.J. Hurst. 2nd edition. American Society for Microbiology, 2016.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE : DSE-13 FACETS OF PROTOZOAN BIOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-13: FACETS OF PROTOZOAN BIOLOGY	4	3	1	0	BSc in any branch of Life Sciences	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The objective of this course is to introduce the students to general and specific aspects of protozoan micro-organisms.
- The students will gain knowledge and understanding about protozoan diseases in humans.
- The students will become familiar with the remarkable tactics used by *Trypanosoma* species to evade the host defense system
- They will gain knowledge about the unique modes of transcription and gene regulation in *Leishmania* species.
- They will be educated about the unusual method *Plasmodium* species employ to evade the host immune system.
- The students will become acquainted with *Tetrahymena thermophila* as a model organism which has been used to study various molecular phenomena.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Student will become familiar with diseases caused by protozoan micro-organisms.
- Student will be able to describe the switching of VSG gene expression in *Trypanosoma brucei* as a mechanism to evade the host defense systems.
- Student will become familiar with state-of-the-art methods used to analyze the 3D organization of genomes in the nucleus of an organism.
- Student will be able to outline the mode of transcription in *Leishmania* species.
- Student will be able to describe the use of *var* genes by *Plasmodium* species to evade the host immune system
- Student will be able to discuss important findings from studies with *Tetrahymena thermophila*.

SYLLABUS OF DSE-13

UNIT – I (9 hours)

Protozoans and human disease: Etiology, epidemiology, diagnosis, clinical manifestations and therapeutic interventions of the following protozoan diseases: giardiasis, amoebiasis, different forms of leishmaniasis, African trypanosomiasis, American trypanosomiasis, trichomoniasis, malaria, toxoplasmosis, cryptosporidiosis.

Life cycles of the parasites causing these diseases.

Essential reading:

1. Parasitic Diseases by D. Despommier, D. Griffin, R. Gwadz, P.J. Hotez, C.A. Knirsch. 7th edition. Springer-Verlag, USA. 2019. Chapters 1, 2,3,4

UNIT – II (13 hours)

Strategies used by *Trypanosoma brucei* and *Plasmodium falciparum* to evade the host defence system: Organization of the *T. brucei* genome. Role of variable surface glycoproteins (VSGs) in the host-parasite relationship. Organization of variable surface glycoprotein (VSG) genes in the *T. brucei* genome. Antigenic variation by VSG switching. Mechanisms of VSG switching: transcriptional silencing mechanism and recombination-based switching mechanism. Analysis of the 3D organization of the chromosomes of the *T. brucei* genome in the nucleus: use of chromosome conformation capture (3C) and its high-throughput version (Hi-C). Use of Assay for Transposase-Accessible Chromatin with high-throughput sequencing (ATAC-seq) to determine the 3D organization of transcriptionally active versus silent regions of the *T. brucei* genome. Role of the 3D organization of the *T. brucei* genome/ chromosomes in the nuclear space in VSG switching. Role of *Plasmodium falciparum* erythrocyte membrane protein 1 (EMP1) in virulence. Organization of *var* genes (encoding EMP1) in the genome. Structure of *var* genes and three major *var* groups. Switches in *var* gene expression: transcriptional and epigenetic mechanisms of *var* gene switch, role of long ncRNAs in regulating *var* activation, role of 3D organization of *var* genes in nuclear space.

Essential reading:

1. Trypanosomes and Trypanosomiasis edited by S. Magez and M. Radwanska. Springer. 2014. Chapter 1
2. Malaria. Biology in the Era of Eradication edited by D.F. Wirth and P.L. Alonso. Cold Spring Harbor Perspectives in Medicine. 2017. Chapter 16.

UNIT – III (13 hours)

Gene regulation, genome plasticity and RNA editing in kinetoplastids: Organization of the *Leishmania* genome. Unique polycistronic mode of transcription coupled to post-transcriptional processes including trans-splicing. Regulation of gene expression using histone variants and base J. Epigenetics mechanisms modulating transcription: roles of specific histone acetylation and methylation marks. Alternate mode of transcription from internal promoters. Plasticity of *Leishmania* genome and its implications in emerging drug resistance. Structure of the kinetoplast cell. Organization of kinetoplast DNA: maxi and mini circles. Replication of kinetoplast DNA. Role of maxi and mini circles. RNA editing as a mode for producing mitochondrial proteins. Mechanisms of RNA editing: guide RNAs, editosomes.

Essential reading:

1. Molecular Biology of Kinetoplastid Parasites edited by H.K. Majumder. 1st edition. Caister Academic Press. 2018. Chapter 1
2. *Leishmania*: after the genome edited by P.J. Myler and N. Fassel. 1st edition. Caister Academic Press. 2008. Chapter 2

UNIT – IV (10 hours)

***Tetrahymena thermophila* as a model organism:** A model organism for studying the existence of two genetic systems in the same cell. Nuclear dimorphism: somatic and germline nuclei, roles of the two nuclei in the development cycle. Discovery of dynein, role of dynein as a molecular motor. Discovery of ribozymes. Discovery of telomerase, role of telomerase in chromosome end-replication and in ageing. Discovery of histone modifying enzymes. Study of secretory granule biogenesis. Unusual genetic code. Reversible gene amplification.

Essential reading:

1. Methods in Cell Biology: *Tetrahymena thermophila* edited by Kathleen Collins. Vol. 109. Academic Press. 2012. Chapters 2, 3, 4, 5, 6.

Tutorial Component (15 hours)

The tutorial will include: Discussion about Nobel Prize-winning work carried out in protozoan organisms. Challenges faced in developing vaccines against diseases like malaria and leishmaniasis. Mechanisms some of these parasites have developed to combat drug treatments. Challenges faced in trying to eradicate these diseases. Protozoan diseases in animals and their implication in human health. Tutorial for the use of genome sequence databases of *Plasmodium* and *Trypanosoma brucei* in the context of studying virulence and pathogenesis.

Recommended readings:

1. Advances in Parasitology. Book series. Vols. 119, 121, 128, 129, 130. 1st edition. Elsevier Press. 2025.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

**GENERIC ELECTIVE COURSE: GE-03
EMERGING TRENDS IN MICROBIAL BIOTECHNOLOGY**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
GE-03: EMERGING TRENDS IN MICROBIAL BIOTECHNOLOGY	4	3	1	0	-	NA

Learning Objectives

- The objective of this course is to introduce students to the current research and developments in microbiology.
- The students will learn about novel microbial technologies in health care, industrial, and environmental applications.
- They will become familiar with the uses of microbes in biotechnology, diagnostics, and bioenergy.
- They will explore the interaction among microbes in agriculture, industry, and biopharmaceuticals.
- The students will learn to scrutinize microbial innovations and their role in addressing global challenges.
- They will be introduced to cutting-edge research in extremophiles, bioinformatics, and synthetic biology.

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Students will be able to summarize recent progress in microbial applications in various sectors.
- Students will be able to analyze the role of microbes in biofuels, pharmaceuticals, and environmental sustainability.
- Students will be able to evaluate the significance of microbes in sustainable agriculture and integrated pest management.
- Students will be able to assess the impact of artificial intelligence and big data in microbiological research.
- Students will be able to explore extremophiles, microbial biosensors and diagnostics in healthcare and environmental monitoring.

SYLLABUS OF GE-03**UNIT-I (08 hours)**

Emerging Microbial Strategies for Environmental and Climate Resilience: Microbes in sustainable ecology, bioremediation, and carbon sequestration. Microbial processes for greenhouse gas mitigation. The use of composts and microbial systems in waste management and ecosystem recovery. Case studies of microbes in environmental restoration and climate adaptation.

Essential reading:

1. Environmental Microbiology by E.L. Madsen. 2nd edition. Wiley, USA. 2016. (Chapters 1, 3, 8)
2. Brock Biology of Microorganisms by Madigan et al. 16th edition. Pearson, USA. 2021. (Chapters 19, 20, 21, 22)

UNIT-II (16 hours)

Emerging Technologies in Unlocking Microbial Dark Matter: Advances in high-throughput culturing techniques for novel microbes, overcoming traditional cultivation limitations through metagenomic and metatranscriptomic approaches. Applications of metagenomics, proteomics, metabolomics, and single-cell techniques in understanding microbial communities and discovering novel microbial lineages. Emerging Innovations in Extremophiles: Adaptations and Industrial Applications: Exploring the latest discoveries in extremophiles - thermophiles, psychrophiles, halophiles, acidophiles, and alkaliphiles. Advances in understanding their unique metabolic and enzymatic adaptations. Exploration of extremophiles in space research and astrobiology. Emerging applications of extremozymes in next-generation biotechnology, pharmaceuticals, and industrial processes. Optozymes: light-activated enzymes for controlled catalysis, biosensors, and synthetic biology.

Essential Reading:

1. Brock Biology of Microorganisms by Madigan et al. 16th edition. Pearson, USA. 2021. (Chapters 10, 13, 14, 17)
2. Prescott's Microbiology by Willey, Sherwood & Woolverton. 11th edition. McGraw-Hill, USA. 2020. (Chapters 16, 17, 18)
3. Environmental Microbiology by E.L. Madsen. 2nd edition. Wiley, USA. 2016. (Chapters 4,7)
4. Extremophiles: From Biology to Biotechnology, edited by Ravi Durvasula & D.V. Subba Rao. CRC Press, 2018. (Chapters 1, 7, 8, 9, 11, 16)

UNIT-III (16 hours)

Microbial Bio Energy and Sustainable Energy Technologies: Production of microbial biofuels – bioethanol, biodiesel, biohydrogen, and biogas. Microbial fuel cells (MFCs) for bioelectrochemical energy. Electrochemically aided microbial processes for biohydrogen production and valorization of black liquors. Microbial process in circular economy and waste to energy conversion. Case studies of microbial bioenergy applications. Innovations in Microbial Technology in Sustainable Agriculture: Biofertilizers, microbial pesticides, biocontrol agents. Innovations in plant-microbe interactions that enhance crop productivity and resilience to climate change. Integrated pest management (IPM) strategies using microbial consortia for effective pest control. Microbial inoculants to promote soil health and nutrient cycling.

Essential Reading:

1. Microbial Biotechnology for Bioenergy, Elsevier, 2024. (Chapters 2, 7)
2. Environmental Microbiology by E.L. Madsen. 2nd edition. Wiley, USA. 2016. (Chapter 8)

UNIT-IV (05 hours)

AI-Driven Microbial Technologies, Commercialization, and Entrepreneurship: AI-driven microbial genome analysis, predictive modeling of microbial ecosystems, and machine learning applications in drug discovery and diagnostics. Automation in synthetic biology and personalized medicine. Microbial biotechnology in industry, entrepreneurship, and commercialization. High-value microbial products, patenting, intellectual property rights (IPR), and ethical considerations. Industrial applications, and startup opportunities in microbial innovation.

Essential Reading:

1. Biotechnology Entrepreneurship (Ed. Craig Shimasaki), Elsevier, 2014. (Chapters 14, 15)
2. Mondal, R.S., Akter, L., Bhuiyan, M.N.A. (2025). *Integrating AI and ML Techniques in Modern Microbiology*. Applied IT & Engineering Review, 3(1), 1–10.

Tutorials (15 hours)

1. Tutorial sessions will include interactive discussions, case studies, and group activities.
2. The course will explore case studies of how microbes are used in the real world today in agriculture, bioenergy, and medicine.
3. Group discussions and student presentations focusing on new trends and developments in microbiology will be held.
4. In Problem-solving sessions, students will use what they learn to devise strategies to tackle global challenges — such as climate change, antibiotic resistance and sustainable resource management.

Essential/Recommended Readings**Theory:**

1. Brock Biology of Microorganisms by M.T. Madigan, K.S. Bender, D.H. Buckley, and W.M. Sattley. 16th edition. Pearson, USA. 2021.
2. Prescott's Microbiology by J. Willey, L. Sherwood, and C. Woolverton. 11th edition. McGraw Hill, USA. 2020.
3. Microbial Biotechnology: Fundamentals of Applied Microbiology by A. Timmis. 2nd edition. Wiley-Blackwell, USA. 2019.
4. Industrial Microbiology by L.E. Casida. 2nd edition. Wiley, USA. 2018.
5. Environmental Microbiology by R. Mitchell, J.D. Gu. 3rd edition. Wiley-Blackwell, USA. 2016.
6. Advances in Microbial Biotechnology by R.K. Singh, S.K. Mandal, and D. Singh. 1st edition. Springer, USA. 2015.

Tutorials/Presentations & Assignments:

1. Microbiology: A Laboratory Manual by J.G. Cappuccino, N. Sherman. 11th edition. Pearson, USA. 2021.
2. Practical Handbook of Microbiology by E. Goldman, L.H. Green. 4th edition. CRC Press, USA. 2020.

Department of Microbiology, University of Delhi, M.Sc. Microbiology Syllabus (NEP-PGCF 2024)

3. Laboratory Manual in Microbiology by P. Gunasekaran. New Age International Publishers, India. 2019.
4. Manual of Environmental Microbiology by C.J. Hurst, R.L. Crawford, J.L. Garland, D.A. Lipson. 4th edition. ASM Press, USA. 2016.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE: GE-04
DOWNSTREAM PROCESSING OF MICROBIAL PRODUCTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
GE-04: DOWNSTREAM PROCESSING OF MICROBIAL PRODUCTS	4	3	1	0	-	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The objective of this course is to give students an overview of different strategies used in microbial product recovery.
- The students will become familiar with different cell lysis methods and their applications in extracting intracellular and extracellular products.
- They will learn about batch filtration techniques and continuous centrifugation used at an industrial scale.
- They will develop hands-on expertise in enzyme immobilization and nanocatalyst techniques.
- They will be educated about different analytical methods used during product recovery and testing for the finished products
- They will be introduced to quality control requirements for finished products.
- The students will gain an understanding of reducing the recovery cost.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Student will be able to discuss important concepts of downstream processing and their industrial application.
- Student will be able to describe the designing of different recovery processes for industrial and commodity products
- Student will be able to list different methods used in enzyme immobilization and nano biocatalysis
- Student will be familiar with various chromatography techniques used in product recovery
- Student will be able to compare various cell lysis methods

SYLLABUS OF GE-04

UNIT-I (13 hours)

Concepts of downstream processing and production of Enzymes and Biopharmaceuticals:

Introduction to the recovery operations of microbial products, Downstream Processing Equipment, challenges in bioseparation processes, Clean room classification, sterility, maintenance, decontamination, and sanitization, Differences between manufacturing processes for Enzymes and Biopharmaceuticals. Separation of cells from culture broth, clarification strategies of fermentation broth, Fermentation media conditioning, Applications of coagulation and flocculation in industries

Essential Reading:

1. Downstream Industrial Biotechnology: Recovery and Purification by Michael C. Flickinger. J. Wiley. 2013. (Chapter 1,2, 3, 4, 5, 19 & 20)
2. Principles of Fermentation Technology by P.F. Stanbury, A.Whitaker and S.J. Hall. 3rd Edition. Elsevier Science Ltd, Netherlands. 2016. (Chapter 10)
3. Modern Industrial Microbiology and Biotechnology by N. Okafor and B.C. Okeke. 2nd Edition. CRC Press, UK. 2018. (Chapter 12)

UNIT-II (16 hours)

Recovery methods for fermentation products, Enzyme immobilization and Nanobiocatalysts: Physiochemical and biological methods for cell disruption, batch filtration, ultrafiltration, membrane fouling in ultrafiltration, centrifugation, precipitation, spray drying, lyophilization, Crystallization, Concepts and operational principles of different chromatographic techniques (ion exchange, gel permeation, affinity and reverse phase chromatography), Design of chromatographic separations for industrial products, Methods of enzyme immobilization, Advantages and disadvantages of immobilization techniques. Large-scale applications of immobilized enzymes: glucose isomerase and penicillin acylase, Nanobiocatalysts and their reusability

Essential Reading:

1. Downstream Industrial Biotechnology: Recovery and Purification by Michael C. Flickinger. J. Wiley. 2013. (Chapter 6, 8, 12,34)
2. Principles of Fermentation Technology by P.F. Stanbury, A.Whitaker and S.J. Hall. 3rd Edition. Elsevier Science Ltd, Netherlands. 2016. (Chapter 10)
3. Modern Industrial Microbiology and Biotechnology by N. Okafor and B.C. Okeke. 2nd Edition. CRC Press, UK. 2018. (Chapter 10)

UNIT-III (6 hours)

Development of biomanufacturing processes: Differences between *E. coli*, yeast and mammalian cultures as expression hosts, Manufacturing Facilities, and cGMP biomanufacturing, Advantages and disadvantages of inclusion body processing, Recovery of Industrial and Commodity Products

Essential Reading:

1. Downstream Industrial Biotechnology: Recovery and Purification by Michael C. Flickinger. J. Wiley. 2013. (Chapter 42, 47 &48)
2. Principles of Fermentation Technology by P.F. Stanbury, A.Whitaker and S.J. Hall. 3rd Edition. Elsevier Science Ltd, Netherlands. 2016.
3. Methods in Enzymology "Refolding Solubilized Inclusion Body Proteins" by Richard R. Burgess Volume 463, 2009, Pages 259-282 (Chapter 17)

UNIT-IV (10 hours)

Quality control and Process economics: Analytical support of downstream Processing: High-performance liquid chromatography, gas chromatography, Gas chromatography-mass

spectrometry (GC-MS), Liquid chromatography-mass spectrometry (LC-MS), Quality assurance and control; Capital cost for downstream equipment, Process economics of production and recovery process. Effluent treatment and environment management

Essential Reading:

1. Advanced technologies in biopharmaceutical processing by Roshni L. Dutton and Jenö M. Scharer. Blackwell Publishers. 2007. (Chapter 4&5)
2. Principles of Fermentation Technology by P.F. Stanbury, A. Whitaker and S.J. Hall. 3rd Edition. Elsevier Science Ltd, Netherlands. 2016. (Chapter 11&12)
3. Modern Industrial Microbiology and Biotechnology by N. Okafor and B.C. Okeke. 2nd Edition. CRC Press, UK. 2018. (Chapter 30)

Tutorial Component (15 hours)

1. Discussion about development of industrial scale downstream processing equipment and operational challenges.
2. How to address the challenges of membrane fouling.
3. Learning of different quality control differences between industrial enzyme production and therapeutic drugs.
4. Demonstration of how combinatorial biomass processing approaches result in cost effective product recovery.
5. Assembling of lab Scale fermenters.
6. Live demonstration of HPLC and FPLC operations

Essential reading

1. Principles of Fermentation Technology by P.F. Stanbury, A. Whitaker and S.J. Hall. 3rd Edition. Elsevier Science Ltd, Netherlands. 2016. (Chapter 7, 8 & 10)
2. Modern Industrial Microbiology and Biotechnology by N. Okafor and B.C. Okeke. 2nd Edition. CRC Press, UK. 2018. (Chapter 30)
3. <https://www.jove.com/v/10156/operation-of-high-performance-liquid-chromatography-hplc>
4. <https://www.jove.com/v/10187/gas-chromatography-gc-with-flame-ionization-detection>
5. <https://pmc.ncbi.nlm.nih.gov/articles/PMC12094072/>

Suggested Reading:

1. Downstream Industrial Biotechnology: Recovery and Purification by Michael C. Flickinger. J. Wiley. 2013.
2. Pharmaceutical Biotechnology: Concepts and Applications by Gary Walsh. J. Wiley. 2007.
3. Advanced technologies in biopharmaceutical processing by Roshni L. Dutton and Jenö M. Scharer. Blackwell Publishers. 2007.
4. Industrial Microbiology by L.E. Casida. 2nd Edition. New Age International publisher. 2019.
5. Modern Industrial Microbiology and Biotechnology by N. Okafor and B.C. Okeke. 2nd Edition. CRC Press, UK. 2018.
6. Crueger's Biotechnology: A Textbook of Industrial Microbiology by W. Crueger and K.R. Aneja. 3rd Edition. Medtech Publisher, India. 2017.
7. Biotechnology Industrial Microbiology. A textbook by W. Clarke. CBS Publishers, India. 2016.
8. Industrial Microbiology by K.L. Benson. CBS Publishers & Distributors. 2016.
9. Principles of Fermentation Technology by P.F. Stanbury, A. Whitaker and S.J. Hall. 3rd Edition. Elsevier Science Ltd, Netherlands. 2016.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

SKILL BASED COURSE: SBC-03 MYCOLOGY & BIOCHEMICAL TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
SBC-03: MYCOLOGY & BIOCHEMICAL TECHNIQUES	2	0	0	2	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The main objective of this course is to introduce the students to various techniques used in microbiological research.
- The course will equip the student with the skills necessary for performing several experiments involved in microbiology.

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Students will be able to prepare buffers and adjust the pH of a solution.
- Students will be able to analyze various data generated by spectrophotometer
- Students will be able to determine the molecular weight of proteins.
- Students will be able to pack and perform the affinity column chromatography.
- Students will be able to distinguish between budding and fission yeast
- Students will be able to perform the transformation of yeast cells

SYLLABUS OF SBC- 03

UNIT – I (30 hours)

Biochemical methods: Preparation of Tris buffer (pH 6.8 and 8.8). Preparation of 0.5 M, 100ml EDTA solution. Preparation of different Molar of HEPES/phosphate buffer solution. Instrumentation and analysis of generated data from the spectrophotometer for protein/DNA analysis. Analysis of fluorescence emission of a sample using GFP-tagged protein. To separate the components based on their densities using a density-gradient medium (e.g. sucrose). Demonstration of the ultracentrifuge for high-speed separation using bacterial cell (membrane/cytosolic fraction). **Chromatographic techniques:** Separation of the components of a mixture using paper or TLC. Analysis of data for molecular weight determination by using

gel filtration chromatography. Column packing and recombinant protein purification by using column chromatography. Analysis of different fractions of column chromatography purified protein by using SDS-PAGE.

UNIT – II (30 hours)

Identification of yeasts: Microscopic examination of budding and fission yeast. Identification and differentiation of *Candida* species by Chromogenic Agar. **Genetic transfer into yeast:** Preparation of media for yeast auxotroph strain. Generation of yeast-competent cells by Lithium acetate method. Transformation of yeast cells.

Essential reading:

1. Yeast Genetics: Methods and protocols by Jeffrey S. Smith and Daniel J. Burke. Springer, 2014. (Chapter 1)

Essential/recommended readings

1. Yeast Genetics: Methods and protocols by Jeffrey S. Smith and Daniel J. Burke. Springer, 2014.
2. Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology by Andreas Hofmann and Samuel Clokie. 8th Edition. Cambridge University press. 2018.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

SKILL BASED COURSE: SBC-04 ANTIMICROBIALS AND MICROSCOPY TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
SBC-04: ANTIMICROBIALS & MICROSCOPY TECHNIQUES	2	0	0	2	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The students will learn about the physical and chemical agents that control microbial growth.
- They will become familiar with advanced antimicrobial agents.
- They will be educated about advanced microscopy in microbiology research.
- They will be introduced to the cutting-edge science of stem cell technology, and its production and various applications.

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Student will be able to describe the different techniques to control microbial growth.
- Student will be able to recall techniques used to detect the presence of endotoxin and microbes in sterile formulations.
- Student will be able to evaluate the advanced antimicrobial techniques.
- Student will be able to analyze and describe the importance of advanced microscopy in microbiology research.
- Student will be able to analyze and compile the differences between the two modes of bacterial lifestyles

SYLLABUS OF SBC-04

UNIT – I (30 hours)

Physical and chemical agents for controlling microbial growth and detection techniques:

Temperature, osmotic pressure and radiation as physical agents; 3% Hydrogen peroxide, 70% isopropyl alcohol and 5% chlorine bleach as chemical agents. Microbial Limit test, and endotoxin analysis. **Advanced Antimicrobial Agents:** Synthesis of nanoparticles by chemical and biological methods. Basic characterization of nanoparticles. Antibacterial of nanoparticles.

Phytochemical extraction from different plants in different solvents and assessing their antibacterial and anti-viral efficacies. Assessment of combination therapies (Determination of synergy or antagonism by checkerboard assay).

Essential reading:

1. Microbiology: A laboratory manual by JG Cappucino, CT Welsh. 11th Edition. Pearson. 2017. (Chapter 41 - 46)

UNIT – II (30 hours)

Advanced Microscopy: Inverted fluorescence microscopy, confocal microscopy and SEM analysis of microbial samples. **Differentiating planktonic and sessile mode of lifestyle:** Growing biofilms of Gram-positive and Gram-negative bacteria on different substrates and in presence of different media. Assessing different antimicrobial agents against biofilms.

Essential reading:

1. Microbiology: A laboratory manual by JG Cappucino, CT Welsh. 11th Edition. Pearson. 2017. (Chapter 5-7)
2. O'Toole GA. Microtiter dish biofilm formation assay. J Vis Exp. 2011 Jan 30;(47):2437. doi: 10.3791/2437. PMID: 21307833; PMCID: PMC3182663.

Essential/recommended readings

1. Microbiology: A laboratory manual by JG Cappucino, CT Welsh. 11th Edition. Pearson. 2017.
2. Molecular Microbiology: Diagnostic Principles and Practice by Persing DH, Tenover FC, Hayden R, Leven M, Miller MB, Nolte FS, Tang YW, Belkum AAV. 3rd edition. Washington, American Society for Microbiology Press, 2016
3. Infectious Disease Epidemiology: Theory and Practice by Nelson KE, Williams CM. 4th Edition. Jones and Bartlett, 2019.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

**RESEARCH METHODOLOGY COURSE: RM-01
ADVANCED RESEARCH METHODOLOGY**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
RM-01: ADVANCED RESEARCH METHODOLOGY	2	2	0	0	B.Sc. in any branch of Life Science	None

Learning Objectives

The Learning Objectives of this course are as follows:

- Student will be introduced to concepts of philosophy of research
- Student will gain an understanding of the research methods and tools
- Students will learn about using logical reasoning principles to describe science

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Student will be able to recall different research approaches
- Student will be able to recall different types of research methods
- Student will be able to describe experimental designs and data analysis approaches
- Student will be able to describe principles of logical reasoning in science, and ethical principles

SYLLABUS OF RM-01

UNIT- I (14 hours)

Research & Philosophy of Research: Acquiring knowledge, what is research, qualities of a researcher, history of research, induction and deduction in research, hypothesis, theory, law, facts, the scientific methods, the research process, academic research. Philosophy of research, empiricism, rationalism, skepticism, falsifiability, pseudoscience, reductionism

Research methods: Intuition, serendipity, unexpected results, ideas from other disciplines, variables in research, formal approaches to research. Major research methods, natural observation, historical research, ethnographic research, cross-sectional study, longitudinal study, cohort study, case study, correlational research, model building, action research

Essential reading:

1. Research Methodology & Scientific Writing. 2nd edition by C George Thomas (2021). Springer Publication (Chapter 1, 2, 3, 4).

UNIT- II (16 hours)

Experimental research, Collection & analysis of Data: Cause-and-effect relationships, hypothesis testing in experiments, validity of experiments, principles of experimentation, controls in experiments, experimental design, field experiments, randomized controlled trials,

paired design, requirements of a good experiment. Sampling, collection of data, observation, surveys, possible errors in research, analysis of data, descriptive statistics, inferential statistics, common statistical tests

Reasoning and Ethics in research: Arguments and premises, assumptions, statements, facts and opinions, validity and soundness of arguments, Evidences, inductive and deductive reasoning, fallacious reasoning, common fallacies. Ethical issues in research, the Nuremberg Code, concepts in ethics, fraud and misconduct in science, unscientific practices in science, and scientific values.

Essential reading:

1. Research Methodology & Scientific Writing. 2nd edition by C George Thomas (2021). Springer Publication (Chapter 5, 6, 14, 23).

Recommended readings

1. Research Methodology: The Aims, Practices & Ethics of Science. 1st edition by Peter Pruzen (2016). Springer Publication
2. Research Methodology: Methods and Techniques. 2nd edition by C. R. Kothari (2004). New Age International Publishers, India
3. Testing treatments: Better research for better healthcare. 2nd edition by Evans, I., Thornton, H., & Chalmers I (2011). London: Pinter & Martin.
4. Research Methodology A Step-by-Step Guide for Beginners. 5th edition by Ranjit Kumar (2019). SAGE Publication.
5. Research Methodology: The Aims, Practices & Ethics of Science. 1st edition by Peter Pruzen (2016). Springer Publication.
6. The Craft of Research. 4th edition by Wayne C Booth, Gregory G. Colomb, Joseph M. Williams, Joseph Bizup, William T. Fitzgerald (2016). The University of Chicago Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

RESEARCH METHODOLOGY COURSE: RM-02
TOOLS FOR RESEARCH

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
RM-02: TOOLS FOR RESEARCH	2	2	0	0	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- The objective of this course is to introduce the students to the need for research, scientific data extraction, scientific writing, reference management tools, and the use of statistics in biology for data interpretation.
- The students will learn to extract research data from the available resources.
- They will become familiar with research writing tools.
- They will be educated about the use of modern reference organizer tools.
- They will develop a proper understanding of data collection and interpretation of data by using statistical methods.

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Students will be able to discuss the content of research proposals, PhD thesis/dissertation.
- Students will be able to collect/extract research content from databases.
- Students will be able to understand the importance of Scopus, PubMed, and ORCID, and analyze different research writing tools.
- Students will be able to compile the references for the different text file/data.
- Students will be able to predict the significance of the biological phenomenon on the basis of available data sets by using statistical methods.

SYLLABUS OF RM- 02

UNIT – I (14 hours)

Foundation of Research: Introduction, review of literature/background of the study, aims/objective, Problem Identification and formulation, /concept of theory, significance of the study, , Research design, materials and methods, result and discussion, graphical and tabular presentation, summary, Scope of future work. **Research data sources, extraction and writing**

tools: Artificial intelligence (AI) tools as a search engine for academic research. Abstract and citation database: Scopus, Web of Science. Health science database: PubMed. Free academic search engine: Google Scholar, Open Researcher and Contributor ID (ORCID). **Research writing tools:** Open educational resources. Artificial intelligence (AI) tools. Research integrity and plagiarism, the workings of plagiarism software (Turnitin).

Essential reading:

1. Research Methodology: Methods and Techniques by C. R. Kothari, New Age International Publishers, India. 2004. (Chapter 1, 2, 4, 6).
2. Using artificial intelligence in academic writing and research: An essential productivity tool by Mohamed Khalifa & Mona Albadawy, Computer Methods & Programs in Biomedicine Update 5(2024) 100145. (Review).
3. Using AI in Academic Writing and Research: A Complete Guide to Effective and Ethical Academic AI by Eldar Haber, Palgrave Macmillan Cham, Springer Nature Switzerland AG. 2025 (Chapter 3).
4. How to conduct a basic search? - Scopus tutorials (<https://service.elsevier.com>); <https://scholar.google.com>; <https://info.orcid.org/video-tutorials/>.
5. Scopus database: a review by F Burnham., University of South Alabama Biomedical Library, 316 BLB, Mobile, AL 36688, USA. 2006.
6. Research integrity in the era of artificial intelligence Challenges and responses by Xuhong Chen, Medicine 2024;103:27(e38811).

UNIT – II (16 hours)

Reference tool organizer: Why is there a need for reference organizers? Mendeley, EndNote, Zotero, etc. Image processing tools: High resolution, Image processing software (ImageJ, Adobe Photoshop etc.), Image representation. **Biostatistics:** Introduction to biostatistics, Frequency distribution, Variable and attribute. Measurement of Central Tendency: Mean, Median and Mode, Analysis of Variance, Standard deviation, Standard error of the mean, Chi-square test, Student's t-test, Fisher's t-test. Non parametric statistical test (WSR-Test, Mann-Whitney Test). Binomial Distribution. Testing of goodness: Null hypothesis, Alternative Hypothesis. Learning of biostatistics online tools/software for data analysis in life sciences (GraphPad).

Essential reading:

1. What Makes A Good Reference Manager? A quantitative Analysis of Bibliography Management Applications by Cai. T., Chen, C., Huang, T. and Ritter, F.E. College of Information Sciences and Technology, Pennsylvania State University, USA. 2021.
2. Reference Management by Martin Fenner, Kaja Scheliga and Sönke Bartling. Public Library of Science, San Francisco, CA, USA. S. Bartling and S. Friesike (eds.), Opening Science. 2014.
3. A Text book of Biostatistics by A.K.Sharma. 1st Edition. Discovery Publishing Pvt.Ltd. 2008. (Chapter 5,6,7,15). Introduction to Biostatistics by Pranab Kumar Banerjee. S. Chand Publishers. 2007. (Chapter 2 to 12).
4. Statistics for the Life Sciences by Myra L. Samuels, Jeffrey A. Witmer & Andrew Schaffner. 5th Edition. Pearson. 2021. (Chapter 2, 3, 4, 5).
5. Publication Ethics in the Era of Artificial Intelligence by Zafer Kocak, Journal of Korean Medical Sciences. 2024 Aug 26;39(33):e249.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

RESEARCH METHODOLOGY COURSE: RM-03
TECHNIQUES OF RESEARCH WRITING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
RM-03: TECHNIQUES OF RESEARCH WRITING	2	2	0	0	B.Sc. in any branch of Life Science	None

Learning Objectives

The Learning Objectives of this course are as follows:

- Student will be introduced to scientific writing
- Student will gain understanding of scientific presentations
- Students will learn about writing research articles and thesis

Learning Outcomes

The Learning Outcomes of this course are as follows:

- Student will be able to describe the process of research writing
- Student will be able to outline the steps in research paper writing
- Student will be able to discuss the steps in preparing and presenting research talk and posters
- Student will be able to describe the thesis writing process

SYLLABUS OF RM-03

UNIT – I (16 hours)

Research projects, Academic databases: Research projects, finding a research problem, analysis of research ideas, planning a proposal, proposal outline, presentation and evaluation of proposal. Bibliographic databases, General search engines, metasearch engines, academic search engines, citation indexes, citation analysis, online searching methods.

Writing research paper and thesis: Research papers, selecting a Journal, structure of research paper, review and peer review, copyediting and proofreading. Thesis and dissertation, parts of thesis, the abstract, thesis editing, tables, illustrations, bar diagrams, pie-charts, line graph, line drawings, photograph.

Essential reading:

1. Research Methodology & Scientific Writing. 2nd Edition by C George Thomas (2021). Springer Publication (Chapter 7, 9, 11, 12, 13).

UNIT – II (14 hours)

Writing skills and presentation skills: Using paragraphs, titles, verbs, active or passive voice, use of articles, prepositions, relative pronouns, transitional words and phrases, economy in words, singular and plural words, commonly confused words, unnecessary phrases, avoiding clichés, punctuation marks and abbreviations, units and numbers. Conference presentation and posters, scientific meetings, planning and delivering a presentation, preparing presentation slides, poster presentation, group and panel discussion.

Plagiarism: What is plagiarism, acknowledging sources, paraphrasing, direct and indirect quotations, summarizing, plagiarism checking.

Essential reading:

1. Research Methodology & Scientific Writing. 2nd Edition by C George Thomas (2021). Springer Publication (Chapter 16, 17, 18, 19, 20, 24).

Recommended readings

1. A Student Guide to Writing Research Reports, Papers, Theses and Dissertations- by Cathal O Siochru (2023). Taylor & Francis
2. Science Research Writing: For Non-native Speakers of English by Hilary Glasman-deal. 2nd edition (2021). World Scientific Publishing Europe Ltd.
3. Write It Up: Practical Strategies for Writing and Publishing Journal Articles by Paul J. Silvia. 1st Edition (2015). APA Life tools.
4. Writing Science: how to write papers that get cited and proposals that get funded- by Joshua Schimel (2012) Oxford University Press.
5. Writing Science Right: Strategies for Teaching Scientific and Technical Writing. By Sue Neuen and Elizabeth Tebeaux (2018). Taylor and Francis

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

RESEARCH WORK: RES-01
PROJECT WORK-I

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
RES 01: PROJECT WORK-I	6	0	0	6	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- Student will be introduced to laboratory research in Microbiology
- Student will gain an understanding of the functioning of a research lab
- Student will understand the process of conceptualizing a hypothesis, designing and performing research experiments to test that hypothesis in a Microbiology lab
- Student will understand how to analyze the data and design the next set of experiments
- Student will understand how to troubleshoot common experimental problems in a Microbiology lab

Learning Outcomes

The following four outcomes must be achieved by the end of the third Semester:

- 1) Research Problem identification
- 2) Review of literature
- 3) Research design formulation
- 4) Commencement of experimentation, fieldwork, or similar tasks

RESEARCH WORK: RES-02 PROJECT WORK-II

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
RES-2: DISSERTATION-II	6	0	0	6	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- Student will be introduced to laboratory research in the field of Microbiology
- Student will gain an understanding of the functioning of a research lab
- Student will understand the process of conceptualizing a hypothesis, designing and performing research experiments to test that hypothesis in a Microbiology lab
- Student will understand how to analyze the data and design the next set of experiments
- Student will understand how to troubleshoot common experimental problems in a Microbiology lab
- Student will learn how to write a dissertation/ thesis summarizing the work
- Student will learn how to present and explain the work

Learning Outcomes

The following three outcomes must be achieved by the end of fourth Semester:

- 1) Completion of experimentation/ fieldwork
- 2) Submission of dissertation
- 3) Research output in the form of any one of the following –
 - i. Prototype or product development/ patent
 - ii. Any other scholastic work as recommended by the BRS and approved by the Research Council (*thesis submission followed by presentation and defense of same*)
 - iii. Publication in a reputed Journals such as Scopus-indexed journals or other similar-quality journals
 - iv. Book or Book Chapter in a publication by a reputed publisher

RESEARCH WORK: RES-03
DISSERTATION - I

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
RES-03: DISSERTATION-I	10	0	0	10	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- Student will be introduced to laboratory research in the field of Microbiology
- Student will gain an understanding of the functioning of a research lab
- Student will understand the process of conceptualizing a hypothesis, designing and performing research experiments to test that hypothesis in a Microbiology lab
- Student will understand how to analyze the data and design the next set of experiments
- Student will understand how to troubleshoot common experimental problems in a Microbiology lab

Learning Outcomes

The following four outcomes must be achieved by the end of third Semester

- 1) Research Problem identification
- 2) Review of literature
- 3) Research design formulation
- 4) Phase I of research (for e.g. Initial phase of research experimentation, completion of pilot project etc.)

RESEARCH WORK: RES-04 DISSERTATION - II

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
RES-04: DISSERTATION-II	16	0	0	16	B.Sc. in any branch of Life Science	NA

Learning Objectives

The Learning Objectives of this course are as follows:

- Student will be introduced to laboratory research in the field of Microbiology
- Student will gain an understanding of the functioning of a research lab
- Student will understand the process of conceptualizing a hypothesis, designing and performing research experiments to test that hypothesis in a Microbiology lab
- Student will understand how to analyze the data and design the next set of experiments
- Student will understand how to troubleshoot common experimental problems in a Microbiology lab
- Student will learn how to write a dissertation/ thesis summarizing the work
- Student will learn how to present and explain the work

Learning Outcomes

The following **three** outcomes must be achieved by the end of fourth Semester

- 1) **Phase II** of research - Final phase of experimentation/ fieldwork
- 2) Dissertation/ project report submission
- 3) Attain **at least one** of the following outcomes:
 - i. Developed a prototype or product which meets the **Technology Readiness Level 3/4** (TRL-3 or TRL-4) as defined by CSIR
 - ii. Publication in Scopus indexed journals #
 - iii. Patent
 - iv. Any other scholastic work as recommended by the BRS and approved by the Research Council (*thesis submission followed by presentation and defense of same*)
 - v. Publication of a book by a reputed publisher (National/International) as recommended by the BRS and approved by the Research Council.

Publication must be in Scopus-indexed journals and the authors have to be the student concerned and his/her supervisor(s). Addition of any author [other than the student and supervisor(s)] in the publication has to be with the permission of the Chairperson, Research Council. This permission must be mandatorily taken prior to commencement of Phase-II of the research.

UNIVERSITY OF DELHI

MASTER OF SCIENCE (BIOCHEMISTRY) (PGCF NEP-2020)



**Syllabus approved by Committee of Courses on
18th February 2026 and FIAS on 23 February 2026**

SEMESTER-WISE PROGRAM STRUCTURE OF M.Sc. BIOCHEMISTRY COURSE**(PGCF NEP-2020)****PG Curricular structure with only course work – 1st year / 2nd year****Semester-3**

	Credits in each course			
	Theory	Tutorial	Practical	Credits
Discipline Specific Core (DSC) courses				
DSC-07: Experimental Methods in Biochemistry	3	0	1	4
DSC-08: Gene Expression and Gene Regulation	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-05: Advanced Immunology	3	1	0	4
DSE-06: Biosafety, Bioethics and Biosecurity	3	1	0	4
DSE-07: Principles in Genetics	3	0	1	4
Skill enhancement course (SEC)/ workshop/ Specialized laboratory/ Hands-on Learning				
SBC-03: Tools for Biostatistics and Data Visualization	0	0	2	2
Total credits				22
Generic Elective (GE) courses*				
GE-3: Biochemistry of Human Diseases	3	1	0	4

Semester-4

	Credits in each course			
	Theory	Tutorial	Practical	Credits
Discipline Specific Core (DSC) courses				
DSC-09: Recombinant DNA Technology and Functional Genomics	3	1	0	4
DSC-10: Biotechnology for Human Health	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-08: Advanced Proteomics and Metabolomics	3	0	1	4
DSE-09: Disease Models and Clinical Research	3	1	0	4
DSE-10: AI and its applications in Biomedicine and Biotechnology	3	0	1	4
Skill enhancement course (SEC)/ workshop/ Specialized laboratory/ Hands-on Learning				
SBC-04: Scientific Research writing	0	0	2	2
Total credits				22
Generic Elective (GE) courses*				
GE-4: Biochemical Techniques and Applications	3	1	0	4

SEMESTER-WISE PROGRAM STRUCTURE OF M.Sc. BIOCHEMISTRY COURSE
(PGCF NEP-2020)

PG Curricular structure with course work + Research – 1st year / 2nd year

Semester-3

	Credits in each course			
	Theory	Tutorial	Practical	Credits
Discipline Specific Core (DSC) courses				
DSC-07: Experimental Methods in Biochemistry	3	0	1	4
DSC-08: Gene Expression and Gene Regulation	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-05: Advanced Immunology	3	1	0	4
DSE-06: Biosafety, Bioethics and Biosecurity	3	1	0	4
Dissertation/ Academic Project/ Entrepreneurship	0	0	6	6
Total credits				22
Generic Elective (GE) courses*				
GE-3: Biochemistry of Human Diseases	3	1	0	4

Semester-4

	Credits in each course			
	Theory	Tutorial	Practical	Credits
Discipline Specific Core (DSC) courses				
DSC-09: Recombinant DNA Technology and Functional Genomics	3	1	0	4
DSC-10: Biotechnology for Human Health	3	1	0	4
Discipline Specific Elective (DSE) courses*				
DSE-08: Advanced Proteomics and Metabolomics	3	0	1	4
DSE-09: Disease Models and Clinical Research	3	1	0	4
Dissertation/ Academic Project/ Entrepreneurship	0	0	6	6
Total credits				22
Generic Elective (GE) courses*				
GE-4: Biochemical Techniques and Applications	3	1	0	4

SEMESTER-WISE PROGRAM STRUCTURE OF M.Sc. BIOCHEMISTRY COURSE

(PGCF NEP-2020)

PG Curricular structure with Research only – 1st year / 2nd year (Only for B.Sc. (H) Biochemistry)

Semester-3

	Credits in each course			
	Theory	Tutorial	Practical	Credits
Discipline Specific Core (DSC) courses				
DSC-11: Advanced Techniques in Biochemistry	3	0	1	4
Discipline Specific Elective (DSE) courses*				
DSE-05: Advanced Immunology	3	1	0	4
Skill enhancement course (SEC)/ workshop/ Specialized laboratory/ Hands-on Learning				
SEC-RM: Advanced Research Methodology	1	0	1	2
SBC-03: Tools for Biostatistics and Data Visualization	1	0	1	2
Dissertation/ Academic Project/ Entrepreneurship	0	0	10	10
Total credits				22

Semester-4

	Credits in each course			
	Theory	Tutorial	Practical	Credits
Discipline Specific Elective (DSE) courses*				
DSE-08: Advanced Proteomics and Metabolomics	3	0	1	4
Skill enhancement course (SEC)/ workshop/ Specialized laboratory/ Hands-on Learning				
SBC-04: Scientific Research writing	0	0	2	2
Dissertation/ Academic Project/ Entrepreneurship	0	0	16	16
Total credits				22

**DISCIPLINE SPECIFIC CORE COURSE – DSC-07:
EXPERIMENTAL METHODS IN BIOCHEMISTRY**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre- requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-07: Experimental Methods in Biochemistry	04	03	0	01	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 45 (T) + 30 (P)

Course Objectives:

This course is intended to provide a comprehensive understanding of modern laboratory methods widely used in biochemical and molecular research. It covers experimental approaches for cell-based studies, nucleic acid and protein analysis, regulation of gene expression, amplification and sequencing methods, and their use in research and biotechnology. The paper also familiarizes students with experimental design, data interpretation, and laboratory safety associated with contemporary biological techniques.

Learning Outcomes

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

1. Carry out and interpret cell-based experimental approaches used for studying growth, survival, proliferation, and gene manipulation;
2. Apply laboratory methods for isolation, detection, and analysis of DNA, RNA, and proteins;
3. Examine gene regulation and nucleic acid–protein interactions using molecular assays;
4. Perform and interpret amplification-based and sequencing-based approaches for analysis of genes and transcripts;
5. Analyze experimental results and relate suitable techniques to specific biological questions in research and biotechnology.

Course Contents

Unit I Cell Culture methods

11 Hours

Introduction to mammalian cell culture and its role in biomedical research. Basic principles of maintaining and handling cultured cells. Overview of gene manipulation in cells and generation of lines. Basic concepts of the cell cycle and methods used to study cell cycle progression, various cell-based assays to evaluate cell viability, cytotoxicity, proliferation, and apoptosis.

Essential Readings:

1. Sambrook, J. & Russell, D. W. *Molecular Cloning: A Laboratory Manual*, Vol. I, 4th Edition, Cold Spring Harbor Laboratory Press. Chapters 16, 17, 18.
2. Wilson, K. and Walker, J. (2010). *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition, Cambridge University Press. Chapters 2, 6, 7.
3. Alberts, B. et al. (2022). *Molecular Biology of the Cell*, 7th Edition, W. W. Norton & Company. Chapters 6, 7, 8, 9, 12, 17.
4. Ramkumar, K. M., Senthilkumar, R., & Hoque, Md Enamul (Eds.). (2023). *Advanced Mammalian Cell Culture Techniques: Principles and Practices*. CRC Press. Chapters 7, 13, 14, 15, 21, 23, 25.

Unit II: Techniques for Studying Gene Expression and Regulation**12 Hours**

Introduction to the basic concepts of nucleic acid isolation, and quality assessment of plasmid DNA, genomic DNA, and RNA, and their importance in biological research. Principles of gel electrophoresis for the separation and analysis of nucleic acids. Overview of classical blotting techniques including Southern, Northern, and Western blotting and their applications in detecting DNA, RNA, and proteins. Basic concepts of *in vitro* transcription and translation systems used to examine gene expression and protein synthesis. Overview of RNase protection assay for analyzing transcript expression. Principles of chromatin immunoprecipitation (ChIP) and reporter gene assays for investigating transcriptional regulation.

Essential Readings:

1. Wilson, K. and Walker, J. (2010). *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition, Cambridge University Press. Chapters 5, 6, 9.
2. Alberts, B. et al. (2022). *Molecular Biology of the Cell*, 7th Edition, W. W. Norton & Company. Chapters 6, 7, 9.
3. Ramkumar, K. M., Senthilkumar, R., & Hoque, Md Enamul (Eds.). (2023). *Advanced Mammalian Cell Culture Techniques: Principles and Practices*. CRC Press. Relevant chapters.
4. Sambrook, J. & Russell, D. W. *Molecular Cloning: A Laboratory Manual*, Vol. I, 4th Edition, Cold Spring Harbor Laboratory Press. Chapters 6-9, 11, 12, 15.

Unit III: Techniques for Studying Proteins and their Interactions**11 Hours**

Experimental approaches to study proteins- Mass Spectrometry, CD and NMR. Techniques for protein-protein and DNA-protein interaction studies, including Immunoaffinity methods, Electrophoretic Mobility Shift Assay (EMSA), DNA footprinting, Two-hybrid System,

Essential Readings:

1. Wilson, K. and Walker, J. (2010). *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition, Cambridge University Press. Chapters 7, 9 and 11.
2. Srivastava, S. (2023) From Proteins to Proteomics. Basic concepts, techniques and Applications. Sanjeeva Srivastava, 2023, CRC Press, Taylor & Francis Ltd. Chapter 1, 2.
3. Gross, Juergen H; Roepstorff, Peter (2011, 2nd edition). *Mass Spectrometry: A Textbook*, Springer. Chapter 4, 5.

Unit IV: Amplification, gene modification, and sequencing methods**11 Hours**

Principles of nucleic acid amplification and parameters influencing reaction performance. Primer planning, reaction assembly, and optimization steps. Different PCR formats, including conventional PCR, nested PCR, multiplex PCR, reverse transcription PCR, and quantitative real-time PCR. Introduction to site-directed mutagenesis and its use in sequence alteration studies. Fundamentals of DNA and RNA sequencing, including Sanger chain-termination sequencing, chromatogram reading, and interpretation. Overview of next-generation sequencing workflow and its applications in biological research.

Essential Readings:

1. Sambrook, J. & Russell, D. W. *Molecular Cloning: A Laboratory Manual*, 4th Edition, Cold Spring Harbor Laboratory Press. Chapters 7–10.
2. Krebs, Jocelyn E., Goldstein, Stephen B., & Kilpatrick, Elliott W. *Lewin's GENES XII*, 12th Edition, Jones & Bartlett Learning. Chapter 3.

Practical**30 Hours**

1. Maintenance and subculturing of mammalian cells; cell counting, viability testing.
2. Isolation of plasmid DNA and RNA; agarose gel analysis; restriction digestion; preparation and analysis of amplification reactions including PCR and RT-PCR/qRT-PCR data interpretation.
3. Demonstration-based exposure to immunoprecipitation and mass spectrometry.
4. Analysis of sequencing chromatograms, primer design exercises, amplification planning, and guided interpretation of representative datasets related to gene expression and sequencing-based experiments.

Essential Readings:

1. Sambrook, J. & Russell, D. W. *Molecular Cloning: A Laboratory Manual Vol I* (4th Edition, Cold Spring Harbor Laboratory Press). Chapters- 16, 18, 17
2. K. Wilson and J. Walker. (2010) *Principles and Techniques of Biochemistry and Molecular Biology* (7th Edition), Cambridge University Press: Chapters: 2, 7 and 6
3. Alberts, B., Heald, R., Johnson, A., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2022). *Molecular Biology of the Cell* (7th ed.). W. W. Norton & Company. Chapters 6,7,8, 9,12 and 17.
4. Ramkumar, K. M., Senthilkumar, R., & Hoque, Md Enamul (Eds.). (2023). *Advanced Mammalian Cell Culture Techniques: Principles and Practices*. CRC Press. Chapters 7,13, 14,15,21,23 and 25.

Suggested Readings:

1. G.M. Cooper. 2000. *The Cell: Molecular Approach*, ASM Press, Washington, D.C. USA.
2. J.R. Harris, J. M. Graham, D. Rickwood. (2006) *Cell Biology Protocols*. J Wiley and Sons Inc.
3. D. Sheehan. 2009. *Physical Biochemistry: Principles and Applications* (2nd Ed.), John Wiley and Sons Ltd, Chichester, England. ISBN: 978-0-470-85603-1.

4. J. Cavanagh, W.J. Fairbrother, A.G. Palmer III, M. Rance, N. J. Skelton. 2007. Protein NMR Spectroscopy: Principles and Practice, Academic Press, San Diego, USA. ISBN: 978-0-12-164491-8.
5. Advanced Biophysical Techniques in Biosciences. Editors: Nirmal Mazumder, Rajib Biswas, Guan-Yu Zhuo. Springer
6. Biophysical Techniques in Biochemistry and Molecular Biology – Van Holde & Johnson, Prentice Hall
7. Molecular Biophysics – Michel Daune, Oxford Univ. Press

**DISCIPLINE SPECIFIC CORE COURSE – DSC-08:
GENE EXPRESSION AND GENE REGULATION**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-08: Gene Expression and Gene Regulation	04	03	01	0	-	-

Number of hours: 45 (T) + 15 (T)

Learning Objectives:

The objective is to offer detailed knowledge about the concept of genome, mechanisms of DNA replication, gene expression and translation in prokaryotes and eukaryotes so that students can apply this knowledge in enhancing their analytical and research problem solving skills.

Learning Outcomes:

- Students will acquire basic concepts of genome, its organization and maintenance in various life forms.
- Students will learn how DNA is replicated and repaired and hence the consequences of improper processes.
- Students will gain knowledge about the mechanisms of transcription, post-transcriptional processes and regulatory mechanisms governing over-expression and under-expression of genes. The knowledge gained will be utilized to design experiments.
- Students will understand the concept of Open Reading Frame and will be able to apply it in design of primers for gene amplification and cloning for heterologous expression.

Course Contents

Unit I: The structure of DNA and RNA; Organization of Microbial Genomes, Biosynthesis of RNA (Transcription) in prokaryotes: General features of transcription, Discovery of RNA polymerase, Bacterial RNA polymerase, Identification and characterization of promoters, consensus sequences, up and down mutations in promoters. Conserved regions of sigma factors and their role in DNA binding. Elongation, Termination, intrinsic and rho dependent termination, mechanism of action of rho. Anti-termination and gene regulation, Inhibitors of transcription and applications as anti-microbial drugs.

11 hours

Essential Readings:

1. B. Lewin, J. Krebs, S.T. Kilpatrick, E.S. Goldstein (2018). Genes XII, Jones and Bartlett Publishers, Sudbury, Massachusetts, USA. Chapters: 1, 4, 7, 8, 17, 19.
2. J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick. (2013). Molecular Biology of the Gene (7th ed). Benjamin Cummings, San Francisco, USA. Chapters: 4,5, 6, 8, 13, 14, 18, 19,20

Unit II: Organization of Eukaryotic Genomes. DNA Replication: isolation and mapping of replication origins. Discovery and properties of DNA polymerases. Mode of action of inhibitors and their therapeutic applications. Regulation of replication initiation, role of replication enzymes and modes of replication. Discovery and mechanism of action of Reverse transcriptase and Telomerase and their significance. DNA Repair: Types of DNA damages, DNA repair systems including photoreactivation, excision repair, base flipping, mismatch repair, recombination repair, transcription coupled repair and SOS repair. Diseases associated with DNA replication and repair problems.

11 hours**Essential Readings:**

1. B. Lewin, J. Krebs, S.T. Kilpatrick, E.S. Goldstein (2018). Genes XII, Jones and Bartlett Publishers, Sudbury, Massachusetts, USA. Chapters: 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 11
2. J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick. (2013). Molecular Biology of the Gene (7th ed). Benjamin Cummings, San Francisco, USA. Chapters: 8, 9, 10, 11, 12

Unit III: Eukaryotic Transcription: Characteristics of promoter and enhancer elements. Activators and repressors of transcription, different DNA binding domains. Discovery, properties and functions of three eukaryotic RNA polymerases, their mode of action and specific inhibitors. Composition and function of basal transcription apparatus, including general transcription factors involved in initiation, elongation, and termination. as well as maturation pathways for rRNA and tRNA. Introduction to ribozymes and catalytic RNA mechanisms, and RNA editing. Regulation of gene expression at the chromatin level, with emphasis on chromatin remodeling complexes, histone modifications, and epigenetic gene silencing pathways such as DNA methylation and RNA interference.

12 hours**Essential Readings:**

1. B. Lewin, J. Krebs, S.T. Kilpatrick, E.S. Goldstein (2018). Genes XII, Jones and Bartlett Publishers, Sudbury, Massachusetts, USA. Chapters: Chapter – 17, 18, 19, 20, 21, 26, 27, 28, 30
2. J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick. (2013). Molecular Biology of the Gene (7th ed). Benjamin Cummings, San Francisco, USA. Chapters: 13, 14, 16, 15, 18, 19,20

Unit IV: Protein synthesis in prokaryotes and eukaryotes: Concept of Genetic code Relationship between genes and proteins, concept of tRNA, triplet nature of genetic code, concept of mRNA, elucidation of genetic code, universality of genetic code, Wobble hypothesis and exceptions, degeneracy of genetic code, general features translation, activation of amino acids. Initiation: initiator tRNAs, RBS, initiation complex, initiation factors.

Elongation: Elongation factors, peptide bond formation, translocation. Termination: release factors, ribosome release factors, polycistronic/ monocistronic synthesis, differences between prokaryotes and eukaryotes, coupling of transcription and translation. Role of antibiotics in understanding protein synthesis, Mode of action of various antibiotics in the inhibition of protein synthesis. Principles of gene regulation, negative and positive regulation, concept of operons, regulatory proteins.

12 hours

Essential Readings:

1. B. Lewin, J. Krebs, S.T. Kilpatrick, E.S. Goldstein (2018). Genes XII, Jones and Bartlett Publishers, Sudbury, Massachusetts, USA. Chapters: 22,23,24, 25, 26
2. J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick. (2013). Molecular Biology of the Gene (7th ed). Benjamin Cummings, San Francisco, USA. Chapters: 14, 15, 16, 22

Tutorial

15 Hours

1. Critical analysis of landmark discoveries in DNA replication, transcription, and translation, emphasizing the experimental techniques employed and the significance of their findings.
2. Discussion on the experimental workflow for elucidation of the Genetic Code.
3. Discussion on variations in pathogenic bacteria in Gene expression and its relevance in pathogenesis.
4. Case studies on diseases linked to defects in DNA replication, repair, and transcription, followed by critical discussions on underlying molecular mechanisms and therapeutic implications.

Essential Readings:

1. B. Lewin, J. Krebs, S.T. Kilpatrick, E.S. Goldstein (2018). Genes XII, Jones and Bartlett Publishers, Sudbury, Massachusetts, USA.
2. J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick. (2013). Molecular Biology of the Gene (7th ed). Benjamin Cummings, San Francisco, USA.

Suggested Readings:

1. D.L. Nelson, M.M. Cox. (2021). Lehninger Principles of Biochemistry (8th Edition), W.H. Freeman and Company, New York, USA.
2. J.M. Berg, J.L. Tymoczko, L. Stryer. (2012) Biochemistry (7th Edition), W.H. Freeman and Company; New York, USA.
3. B. Lewin, J. Krebs, S.T. Kilpatrick, E.S. Goldstein (2018). Genes XII, Jones and Bartlett Publishers, Sudbury, Massachusetts, USA.
4. J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick. (2013). Molecular Biology of the Gene (7th edition). Benjamin Cummings, San Francisco, USA.
5. R.F. Weaver (2007). Molecular Biology. (4th edition). McGraw Hill. New York. USA.
6. B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P. Walter (2015). Molecular Biology of the Cell (6th Edition), Garland Science, New York, USA.

7. H. Lodish, B. Harvey, Arnold, S. Zipursky, S. Lawrence, P. Matsudaira, D. Baltimore, J. Darnell, E. James. (2008). Molecular Cell Biology. (6th Edition) W.H. Freeman and Company, New York, USA.
8. G. M. Cooper and R.E. Hausman. (2013). The Cell: A Molecular Approach (6th Edition), Sinauer Associates, Inc. Massachusetts, USA.
9. R.H. Garrett, C.M. Grisham. 2010. Biochemistry, Saunders College Publishers, Texas, USA

**DISCIPLINE SPECIFIC CORE COURSE – DSC-09:
RECOMBINANT DNA TECHNOLOGY AND FUNCTIONAL GENOMICS**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre- requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-09: Recombinant DNA Technology and Functional Genomics	04	03	01	0	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 45 (T) + 15 (T)

Learning Objectives:

The course aims to provide an in-depth understanding of the molecular principles and experimental strategies underlying recombinant DNA technology and modern genomics. It introduces students to restriction–modification systems, plasmid and phage vector biology, and the design of cloning strategies for gene manipulation. The course further familiarizes students with next-generation sequencing technologies, transcriptomic approaches, and advanced genome-editing tools such as CRISPR–Cas systems. Emphasis is placed on developing conceptual and practical competence in genetic engineering, data interpretation, and the applications of these technologies in biotechnology and biomedical research.

Learning Outcomes

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

1. Explain the mechanisms and applications of restriction–modification systems and perform basic molecular techniques such as restriction digestion and electrophoresis.
2. Describe the biology of plasmids and bacteriophages and analyze their use in the design of cloning and expression vectors for gene manipulation.
3. Discuss the principles and workflows of next-generation sequencing (NGS), transcriptomics, and comparative genomics for genome-wide analysis.
4. Apply advanced genetic engineering tools including CRISPR–Cas systems and RNA interference for targeted genome modification and functional studies.
5. Evaluate modern applications of recombinant DNA and genome-editing technologies in biotechnology, functional genomics, and disease research.

Course Contents

Unit I: Restriction and modification systems and their significance in recombinant DNA technology; types and mechanisms of restriction endonucleases and modification enzymes; recognition sequences and cleavage patterns; applications of restriction enzymes in cloning and molecular diagnostics. Basic techniques in RDT: agarose gel electrophoresis for DNA separation and visualization, polyacrylamide gel electrophoresis (PAGE) for nucleic acids and proteins, and pulse-field gel electrophoresis for large DNA fragments.

12 Hours

Essential Readings:

1. Sambrook, J. & Russell, D.W. *Molecular Cloning: A Laboratory Manual* (4th Edition, Cold Spring Harbor Laboratory Press). Chapters: 5, 6, 8, 9.
2. Brown, T. A. *Gene Cloning and DNA Analysis: An Introduction* (7th Edition, Wiley-Blackwell). Chapters: 2, 3, 5, 6.
3. Wilson, K. & Walker, J. *Principles and Techniques of Biochemistry and Molecular Biology* (7th Edition, Cambridge University Press). Chapters: 2, 5, 7.

Unit II: Basic biology of plasmids: replication mechanisms, copy number control, and incompatibility groups. Design and development of plasmid vectors with selectable markers and reporter genes; screening and selection strategies in cloning. Biology of filamentous phages (M13) and development of phage and phagemid vectors for DNA sequencing, mutagenesis, and phage display. Biology of bacteriophage lambda (λ): promoters and control circuits, packaging mechanisms, and use in vector construction. Vectors for cloning large fragments of DNA-cosmids, BACs (bacterial artificial chromosomes), and YACs (yeast artificial chromosomes).

12 Hours

Essential Readings:

1. Brown, T. A. *Gene Cloning and DNA Analysis: An Introduction* (7th Edition, Wiley-Blackwell). Chapters: 4, 7, 8, 9.
2. Sambrook, J. & Russell, D.W. *Molecular Cloning: A Laboratory Manual* (4th Edition, Cold Spring Harbor Laboratory Press). Chapters: 1, 3, 7, 17.
3. Primrose, S. B. & Twyman, R. M. *Principles of Gene Manipulation and Genomics* (7th Edition, Wiley-Blackwell). Chapters: 4, 5, 6, 8.

Unit III: Principles and applications of next-generation sequencing (NGS) technologies: whole-genome sequencing, exome sequencing, RNA sequencing (RNA-seq), and ATAC-seq for chromatin accessibility profiling. Single-cell genomics and spatial transcriptomics for cell-type-specific gene expression profiling. Comparative genomics and evolutionary insights from genome-wide analyses.

11 Hours

Essential Readings:

1. Brown, T. A. *Genomes* (4th Edition, Garland Science). Chapters: 16, 17, 18, 19.
2. Gibson, G. *A Primer of Genome Science* (3rd Edition, Sinauer/Oxford). Chapters: 6, 7, 8.
3. Lesk, A. M. *Introduction to Genomics* (3rd Edition, Oxford University Press). Chapters: 9, 10, 11.

Unit IV: Genome editing tools: CRISPR–Cas systems, base editing, and prime editing technologies; comparison with ZFNs and TALENs. RNA interference (RNAi): mechanism, design of siRNA and shRNA, and applications in gene silencing. Gene knock-out and knock-in models using homologous recombination and CRISPR technologies in various organisms.

10 Hours

Essential Readings:

1. Doudna, J. A. & Sternberg, S. H. *A Crack in Creation: Gene Editing and the Unthinkable Power to Control Evolution* (Houghton Mifflin Harcourt). (For concept + ethics overview; instructor-guided.)
2. Glick, B. R., Pasternak, J. J., & Patten, C. L. *Molecular Biotechnology* (4th Edition, ASM Press). Chapters: (Genome editing, RNAi, gene silencing—relevant sections).
3. Watson, J. D. et al. *Recombinant DNA: Genes and Genomes—A Short Course* (3rd Edition, W.H. Freeman). Chapters: (Gene targeting, transgenics, genome manipulation— relevant sections).

Tutorial

15 Hours

1. Demonstration of restriction digestion and agarose gel electrophoresis for visualizing DNA fragments.
2. Interactive exploration of plasmid and phage vector maps using tools like SnapGene or Benchling.
3. Virtual simulation of CRISPR–Cas genome editing and RNA-seq data analysis using web-based platforms.
4. Case study–based discussion on experimental design in recombinant DNA technology, including selection of appropriate vectors (plasmid, phage, BAC/YAC), cloning strategies for large DNA fragments, and interpretation of NGS-based genome editing outcomes.

Essential and Suggested Reading

1. Krebs, Jocelyn E., Goldstein, Stephen B., & Kilpatrick, Elliott W. *Lewin's GENES XII* (12th Edition), Jones & Bartlett Learning.
2. Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine, M., & Losick, R. *Molecular Biology of the Gene* (7th Edition), Benjamin Cummings.
3. Alberts, B. et al. *Molecular Biology of the Cell* (7th Edition), W.W. Norton & Company.
4. Nelson, D. L. & Cox, M. M. *Lehninger Principles of Biochemistry* (8th Edition), W.H. Freeman.
5. Berg, J. M., Tymoczko, J. L., Gatto, G. J., & Stryer, L. *Biochemistry* (9th Edition), W.H. Freeman.
6. Strachan, T. & Read, A. P. *Human Molecular Genetics* (5th Edition), Garland Science.
7. Pevsner, J. *Bioinformatics and Functional Genomics* (4th Edition), Wiley-Blackwell.
8. Lesk, A. M. *Introduction to Genomics* (3rd Edition), Oxford University Press.
9. Gibson, G. *A Primer of Genome Science* (3rd Edition), Sinauer Associates / Oxford University Press.
10. Lodish, H. et al. *Molecular Cell Biology* (8th Edition), W.H. Freeman.

**DISCIPLINE SPECIFIC CORE COURSE – DSC-10:
BIOTECHNOLOGY FOR HUMAN HEALTH**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-10: Biotechnology for Human Health	04	03	01	0	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 45 (T) + 15 (T)

Learning Objectives:

The course aims to provide fundamental insights to biological processes for the manufacturing of products that have industrial significance. It blends the principles from diverse science and engineering disciplines. The major focus of this course is on the industrial applications for students to gain practical knowledge with emphasis on major bottlenecks for the operation of biotechnology industries.

Learning Outcomes:

1. Students will be able to understand the fundamental principles of industrial biotechnology.
2. Students will be able to understand the importance of microbial, plant, and animal systems for the biotechnologically relevant products.
3. Students will be able to understand the drug discovery platforms and vaccine development technology and have an overview of the production side of these technologies beyond the discovery stages.
4. Students will be able to critically analyze any bioprocess from a market point of view.
5. Students will be able to apply this knowledge to examine the importance of microbial/enzymatic industrial processes in the food and fuel industry

Course Contents

Unit I: Introduction to Basics of Industrial Biotechnology, Microbes, Plant and Animal Based Biological Processes relevant to Industrial Biotechnology, Fundamental concepts of Biomanufacturing, Production of safe and effective biopharmaceuticals, Expression systems to produce biotherapeutics, Microbial growth, Microbial growth kinetics, High Density Microbial and eukaryotic fermentation for biomanufacturing, Role of Biochemistry in Ayurveda medicine

11 hours

Essential Reading-

Microbial Biotechnology: Technological Challenges and Developmental Trends. (2017). United States: Apple Academic Press. (Chapter- 17 & 18)
 Microbial Biotechnology: Basic Research and Applications. (2020). Germany: Springer Nature Singapore. (Chapter 1 & 10)

Unit II: Concepts and research pipeline of drug discovery, various approaches such as high throughput virtual screening, structure-based drug design, rational drug design, repurposing of drugs, preclinical models, concepts of pharmacokinetics, trials, drug manufacturing, formulations and quality testing.

11 hours**Essential Reading-**

1. Textbook of Drug Design and Discovery (5th Edition) — Edited by Kristian Strømgaard, Povl Krogsgaard-Larsen & Ulf Madsen, CRC Press (chapter 1, 4, 5)
2. Drug Design and Discovery: Methods and Protocols — Edited by Seetharama D. Satyanarayanajois. (chapter 1,2)
3. Fundamentals of Antimicrobial Pharmacokinetics and Pharmacodynamics. Edited by Alexander A. Vinks, Hartmut Derendorf, Johan W. Mouton (2014, 1st edition) (chapter 2,4)

Unit III : Vaccine Technology, vaccine production in laboratory and industry, vaccine pre-clinical models and its trials, Cytokine and hormone-based therapeutics, adjuvants, mechanism of action, types of adjuvants

12 hours**Essential Reading-**

1. Novel Technologies for Vaccine Development. (2014). Austria: Springer Vienna. (Chapter-2 & 6)
2. Barrett, A. D., Stanberry, L. R. (2009). Vaccines for Biodefense and Emerging and Neglected Diseases. Netherlands: Elsevier Science. (Chapter- 4, 6 & 8)

Unit IV: Fundamental concepts of Antibody Engineering, Biosimilars, antibody conjugates for diagnostics and therapeutics, Recombinant antibody production and characterization for clinical use.

11 hours**Essential Reading-**

1. Antibody Engineering: Methods and Protocols, Third Edition (2018) MIMB, volume 1827: Springer International Publishing. (Chapter- 1, 4, 6)
2. Introduction to Antibody Engineering. (2021) Springer International Publishing. (Chapter- 2, 5-10)

Tutorial**15 Hours**

1. Case study discussion on the manufacturing of one protein
2. Case study discussion on the manufacturing of one vaccine
3. Case study discussion on the manufacturing of one drug molecule/ hormone
4. Case study discussion on the manufacturing of one recombinant antibody

Recommended Readings:

1. Samuel Cate Prescott and Cecil Gordon Dunn. Industrial Microbiology: ISBN-10: 0333336305, Publisher: Palgrave Macmillan; 4th edition (1 May 1982)
2. Wulf Crueger and Anneliese Cruege, A textbook of Industrial Microbiology: ISBN-10: 9385998633, Publisher: Medtech (1 January 2017); scientific international
3. Bailey and Ollis, Biochemical Engineering Fundamentals: ISBN-10: 9780070701236, Publisher: McGraw Hill Education; 2nd edition (1 July 2017)
4. Blanch and Clark, Biochemical Engineering: ISBN-13: 979-0824700996, Publisher: T&F India (1 January 2007)
5. Antibody Engineering: Methods and Protocols, Third Edition (2018) MIMB, volume 1827: Springer International Publishing.
6. Introduction to Antibody Engineering. (2021) Springer International Publishing.

Suggested Reading-

1. Chen, G.Q. (2012). New challenges and opportunities for industrial biotechnology. *Microbial cell factories*, 11(1), 111.
2. Yu, L.P., Wu, F.Q. & Chen, G.Q. (2019). Next-generation industrial biotechnology-transforming the current industrial biotechnology into competitive processes. *Biotechnology Journal*, 14(9), 1800437.
3. Mesbah, N.M. (2022). Industrial biotechnology based on enzymes from extreme environments. *Frontiers in Bioengineering and Biotechnology*, 10, 870083.
4. Textbook of Drug Design and Discovery (5th Edition) — Edited by Kristian Strømgaard, Povl Krosgaard-Larsen & Ulf Madsen, CRC Press
5. Drug Design and Discovery: Methods and Protocols — Edited by Seetharama D. Satyanarayanajois.
6. Fundamentals of Antimicrobial Pharmacokinetics and Pharmacodynamics. Edited by Alexander A. Vinks, Hartmut Derendorf, Johan W. Mouton (2014, 1st edition)

**DISCIPLINE SPECIFIC CORE COURSE – DSC-11:
ADVANCED TECHNIQUES IN BIOCHEMISTRY**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre- requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-11: Advanced Techniques in Biochemistry	04	03	0	01	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 45 (T) + 30 (P)

Course Objectives:

This course aims to provide students with in depth understanding of advanced experimental methodologies in cell biology, molecular biology, biophysical techniques, recombinant DNA technology, and genetic engineering. The course also trains students to effectively apply cloning, sequencing, and expression technologies in research and biotechnology on biosafety and regulatory compliance.

Learning Outcomes

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

1. Demonstrate proficiency in advanced cell culture techniques, protein interaction, gene expression, silencing and post-translational modification assays.
2. Understand key molecular biology techniques including nucleic acid isolation, blotting, hybridization, and reporter assays.
3. Understand principles and applications of advanced biophysical techniques used in biological research.
4. Apply advanced molecular tools such as PCR, qPCR, mutagenesis, and sequencing for gene manipulation and expression studies, while adhering to biosafety regulations.
5. Critically analyze experimental data and integrate multidisciplinary approaches to address research questions in modern biotechnology.

Course Contents

Unit I: Cell biology: Introduction to mammalian cell culture techniques, including 2D and 3D culture systems. Principles and applications of cell immortalization, along with strategies for gene overexpression and gene silencing. Generation and characterization of transient and stable cell lines. Cell synchronization methods and cell cycle analysis using flow cytometry (FACS). Assessment of cell viability, cytotoxicity, apoptosis, proliferation, and assays for cell migration and invasion. Subcellular fractionation techniques and identification of cellular

compartments. Cell staining methods and immunofluorescence for visualization of cellular structures. Analysis of protein–protein interactions using pull-down and immunoprecipitation assays.

12 hours

Essential Readings:

1. Sambrook, J. & Russell, D. W. *Molecular Cloning: A Laboratory Manual Vol I* (4th Edition, Cold Spring Harbor Laboratory Press). Chapters- 16, 18, 17
2. K. Wilson and J. Walker. (2010) *Principles and Techniques of Biochemistry and Molecular Biology* (7th Edition), Cambridge University Press: Chapters: 2, 7 and 6
3. Alberts, B., Heald, R., Johnson, A., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2022). *Molecular Biology of the Cell* (7th ed.). W. W. Norton & Company. Chapters 6,7,8, 9,12 and 17.
4. Ramkumar, K. M., Senthilkumar, R., & Hoque, Md Enamul (Eds.). (2023). *Advanced Mammalian Cell Culture Techniques: Principles and Practices*. CRC Press. Chapters 7,13, 14,15,21,23 and 25.

Unit II: Molecular biology: Isolation and analysis of plasmid DNA, genomic DNA, and RNA; gel electrophoresis for nucleic acid assessment. Principles and methodologies of Northern, Southern, and Western blotting for detecting nucleic acids and proteins. In situ hybridization for spatial gene expression analysis. In vitro transcription and translation assays for studying gene expression and protein synthesis. Electrophoretic Mobility Shift Assay (EMSA) and DNA footprinting for examining DNA-protein interactions, along with RNase protection assays for transcript mapping. Chromatin immunoprecipitation (ChIP) and reporter assays for analyzing transcriptional regulation. Introduction to radioisotopes in biological research and essential laboratory safety practices for their proper handling.

12 hours

Essential Readings:

1. Sambrook, J. & Russell, D.W. *Molecular Cloning: A Laboratory Manual Vol I* (4th Edition, Cold Spring Harbor Laboratory Press). Chapters- Chapter 17, 5, 6, 7,8, 9, 18.
2. K. Wilson and J. Walker. (2010) *Principles and Techniques of Biochemistry and Molecular Biology* (7th Edition), Cambridge University Press: Chapters: 5,7,10 and 14

Unit III: Biophysical Techniques: CD spectroscopy, NMR spectroscopy, X-ray crystallography, Fluorescence and confocal microscopy, Cryo-electron microscopy, Isothermal Titration Calorimetry (ITC), Differential Scanning Calorimetry (DSC), Surface Plasmon Resonance (SPR), Bio-Layer Interferometry (BLI), Mass Spectrometry (MS), Analytical Ultracentrifugation (AUC), Dynamic Light Scattering (DLS), Small-Angle X-ray Scattering (SAXS), Förster Resonance Energy Transfer (FRET)

10 hours

Essential Readings:

1. K. Wilson and J. Walker. (2010) *Principles and Techniques of Biochemistry and Molecular Biology* (7th Edition), Cambridge University Press: Chapters: 3, 4, 8, 9, 12, 13.
2. Sheehan, D. (2009) *Physical Biochemistry: Principles and Applications* (2nd Edition), John Wiley & Sons: Chapters: 3, 4, 7, 8.

Unit IV: PCR and Sequencing Technologies: Principle, components, and optimization parameters; primer design and reaction setup; types of PCR — standard PCR, nested PCR, multiplex PCR, reverse transcription PCR (RT-PCR), and quantitative real-time PCR (qRT-PCR). Introduction to DNA and RNA sequencing; Sanger sequencing — principle, chain-termination method, chromatogram interpretation, and applications. Introduction to next-generation sequencing (NGS) — basic workflow and applications.

Essential Readings:

1. Sambrook, J. & Russell, D. W. — *Molecular Cloning: A Laboratory Manual* (4th Edition, Cold Spring Harbor Laboratory Press). Chapter 7-10.
2. Krebs, Jocelyn E., Goldstein, Stephen B., & Kilpatrick, Elliott W. — *Lewin's GENES XII*
3. (12th Edition, Jones & Bartlett Learning). Chapter 3

11 hours

Practicals

30 Hours

1. Maintenance and subculturing of mammalian cells; cell counting and viability assays; apoptosis and proliferation assays; preparation of samples for flow cytometry and interpretation of FACS data.
2. Isolation of plasmid DNA and RNA; agarose gel electrophoresis; restriction digestion; PCR primer design, reaction setup, amplification and analysis; demonstration of RT-PCR/qRT-PCR data interpretation.
3. Immunoprecipitation and ELISA workflow demonstrations; exposure to DNA–protein interaction methods such as EMSA and ChIP (demonstration-based); interpretation of sequencing chromatograms.
4. Guided analysis of representative datasets from CD spectroscopy, DLS, ITC, SPR, and structural biology platforms to understand biomolecular interactions and structural properties.

Essential Readings:

1. Sambrook, J. & Russell, D.W. *Molecular Cloning: A Laboratory Manual Vol I* (4th Edition, Cold Spring Harbor Laboratory Press). Chapters- 16, 18, 17
2. K. Wilson and J. Walker. (2010) *Principles and Techniques of Biochemistry and Molecular Biology* (7th Edition), Cambridge University Press: Chapters: 2, 7 and 6
3. Alberts, B., Heald, R., Johnson, A., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2022). *Molecular Biology of the Cell* (7th ed.). W.W. Norton & Company. Chapters 6,7,8, 9,12 and 17.
4. Ramkumar, K.M., Senthilkumar, R., & Hoque, Md Enamul (Eds.). (2023). *Advanced Mammalian Cell Culture Techniques: Principles and Practices*. CRC Press. Chapters 7,13, 14,15,21,23 and 25.
5. Krebs, Jocelyn E., Goldstein, Stephen B., & Kilpatrick, Elliott W. — *Lewin's GENES XII* (12th Edition, Jones & Bartlett Learning).
6. Sheehan, D. (2009) *Physical Biochemistry: Principles and Applications* (2nd Edition), John Wiley & Sons: Chapters: 3, 4, 7, 8.

Suggested Readings:

1. G.M. Cooper. 2000. The Cell: Molecular Approach, ASM Press, Washington, D.C. USA.
2. J.R. Harris, J. M. Graham, D. Rickwood. (2006) Cell Biology Protocols. J Wiley and Sons Inc.
3. D. Sheehan. 2009. Physical Biochemistry: Principles and Applications (2nd Ed.), John Wiley and Sons Ltd, Chichester, England. ISBN: 978-0-470-85603-1.
4. J. Cavanagh, W.J. Fairbrother, A.G. Palmer III, M. Rance, N. J. Skelton. 2007. Protein NMR Spectroscopy: Principles and Practice, Academic Press, San Diego, USA. ISBN: 978-0-12-164491-8.
5. Advanced Biophysical Techniques in Biosciences. Editors: Nirmal Mazumder, Rajib Biswas, Guan-Yu Zhuo. Springer
6. Biophysical Techniques in Biochemistry and Molecular Biology – Van Holde & Johnson, Prentice Hall
7. Molecular Biophysics – Michel Daune, Oxford Univ. Press

**DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE-05:
ADVANCED IMMUNOLOGY**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-05: Advanced Immunology	04	03	01	0	-	-

Number of hours: 45 (H) + 15 (T)

Learning Objectives:

The objective of the course is to provide an insight into the components of the immune system, their development, their functions and their mechanisms of action as well as the diseases associated with defects or malfunctioning of the immune system. Further, applied aspects including vaccine development, antibody therapeutics and immunotherapy will be discussed.

Learning Outcomes:

1. Students will be able to describe the mechanisms used by the human body to fight foreign agents and disease-causing pathogens.
2. Students will be able to devise strategies to combat infection or diseases produced by altered self.
3. Students will develop ability to use this knowledge in the processes of immunization, antibody engineering, vaccine development, transplantation and cancer therapy.
4. Students will develop skill to use various techniques of immunology in research work.

Course Contents

Unit I: Introduction: Historical development of the branch “Immunology”, Overview of the immune system, Molecules, cells and organs involved in immunity. Haematopoiesis, Innate immunity, adaptive immunity, Antigens, Immunogens, Haptens, Epitopes. Antigen-Antibody interactions, Discovery of immunoglobulins.

10 hours

Essential Readings:

1. J. Owen, J. Punt, S. Stranford, (2012) Kuby Immunology (8th Edition), WH Freeman and Company, USA Chapter – 1, 2, 3, 4
2. K. Murphy (2011) Janeway’s Immunobiology (8th Edition), Garland Science, USA Chapters: 1, 2, 3, 4, 5, 6

Unit II: Adaptive Immune response: Humoral Immunity, Structure and function of various classes of immunoglobulins, Immunogenetics, Generation of antibody diversity, class switching among constant-region genes, B-cell activation and differentiation, B-cell receptor and the immunoglobulin superfamily, Generation of B cells, Responses, Immunological memory, Cell mediated immunity, MHC restriction and mechanism of antigen presentation, T- cell receptors, maturation, activation and differentiation, Generation of different types of T cells, Responses, Immunological memory.

15 hours

Essential Readings:

1. J. Owen, J. Punt, S. Stranford, (2012) Kuby Immunology (8th Edition), WH Freeman and Company, USA Chapter – 6, 7, 8, 9, 10, 11, 12, 13, 14
2. K. Murphy (2011) Janeway's Immunobiology (8th Edition), Garland Science, USA Chapters: 7, 8, 9, 10, 11.

Unit III: Immune effector mechanisms: Properties of cytokines, receptors, the complement systems, mechanism of complement activation, pathology related to complement proteins Allergy, Cell biology of hypersensitivity reactions, Tolerance, Mechanisms of induction of autoimmunity, treatment of autoimmune diseases.

10 hours

Essential Readings:

1. J. Owen, J. Punt, S. Stranford, (2012) Kuby Immunology (8th Edition), WH Freeman and Company, USA Chapter – 5, 15, 16
2. K. Murphy (2011) Janeway's Immunobiology (8th Edition), Garland Science, USA Chapters: 12, 13, 16.

Unit IV: Immune system in health and disease: Immunodeficiencies, AIDS, Transplantation immunology, Tumour antigens and cancer immunotherapy, Infections, Concepts of vaccines, whole-organism vaccines, recombinant vaccines, DNA vaccine, synthetic peptide and multivalent sub unit vaccines.

10 hours

Essential Readings:

1. J. Owen, J. Punt, S. Stranford, (2012) Kuby Immunology (8th Edition), WH Freeman and Company, USA Chapter – 16, 17, 18, 19, 20
2. K. Murphy (2011) Janeway's Immunobiology (8th Edition), Garland Science, USA Chapters: 13, 14, 15, 16.

Tutorial

15 Hours

1. Applications of antibodies in diagnostics and routine laboratory assay systems.
2. Principles of Agglutination, western blot, radioimmunoassay, ELISA, immunohistochemistry.
3. Flow cytometry for immunocytes identification and purification, visit to facility for demonstration of instrument and analysis of FACS data.
4. Development of monoclonal antibodies and their applications

Suggested Readings:

1. J. Owen, J. Punt, S. Stranford, (2012) Kuby Immunology (8th Edition), WH Freeman and Company, USA.
2. J.M. Berg, J.L. Tymoczko, L. Stryer. (2012) Biochemistry (7th Edition), WH Freeman and Company, USA.
3. D. Male, J. Brostoff, D. Roth, I. Roitt, (2012) Immunology (8th Edition), Saunders, Elsevier, USA.
4. K. Murphy (2011) Janeway's Immunobiology (8th Edition), Garland Science, USA.
5. A. Abbas, A. Lichtman, S. Pillai, (2014) Cellular and Molecular Immunology (8th Edition), Saunders, Elsevier, USA.

**DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE-06:
BIOSAFETY, BIOETHICS AND BIOSECURITY**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-06: Biosafety, Bioethics and Biosecurity	04	03	01	0	-	-

Number of hours: 45 (H) + 15 (T)

Learning Objectives:

This course aims to introduce the concepts of biosafety and biosecurity to the students. The course will delve into bringing the students out of the theoretical concepts and enable them to design a research lab, draft SOPs, perform risk assessment, be prepared for emergencies. Students will be taught the importance of sensitive agents, information and assets along with implementation of measures to mitigate biological untoward incidents.

Learning Outcomes

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

1. Understand the principles and practices of biosafety and biosecurity in biomedical research.
2. Understand the considerations and how to perform risk assessment while designing a new research lab or facility
3. Evaluate ethical considerations in conducting research involving hazardous organisms or having dual-use implications
4. Understand biorisk management system and its components.
5. Foster research responsibly, ethically, and help build an innovation culture towards it.

Course Contents

Unit I: Introduction to Biosafety, Biosecurity and Bioethics, historical perspectives, global and national scenarios and landscapes, Biological risk groups and biosafety levels, video demonstrations and video tour of various biosafety level labs, safe handling practices and procedures for pathogens, GMOs, toxins etc. Rules for the manufacture, use, import, export & storage of hazardous microorganisms, GE organisms or cells, 1989.

11 Hours

Essential Reading

1. Biosafety in Microbiological and Biomedical Laboratories 6th Edition. Centers for Disease Control and Prevention, National Institutes of Health (section I, III)
2. Laboratory Biorisk Management: Biosafety & Biosecurity (edited by Salerno & Gaudioso) – chapter 1

Unit II: Preparation of SOPs and layout for fictitious BSL3/BSL4 labs, role of protective barriers (PPE, biosafety cabinets), waste management, decontamination and disposal guidelines, safety measures and emergency protocols, Biosafety mock drills and their importance, gain-of-function research, risk assessment, biosafety incidents, its mitigation and emergency measures. Case studies to discuss disease outbreaks with respect to biosafety aspects. ABSL3 biosafety practices, IAEC and CCSEA guidelines for animal handling. ICMR guidelines for working with human samples.

12 Hours**Essential Reading**

1. Biosafety in Microbiological and Biomedical Laboratories 6th Edition. Centers for Disease Control and Prevention, National Institutes of Health (section II)
2. Laboratory Biorisk Management: Biosafety & Biosecurity (edited by Salerno & Gaudioso) – chapter 1, 11

Unit III: Importance of Biosecurity awareness, assets, threats, risk, eight pillar of biosecurity, biorisk management system and its elements, risk assessment framework, Dual-use research of concern (DURC), likelihood, consequences

10 Hours**Essential Reading**

1. Biosafety in Microbiological and Biomedical Laboratories 6th Edition. Centers for Disease Control and Prevention, National Institutes of Health (section VI)
2. WHO Laboratory biosecurity guidance 2024. (chapter 4,5,6)

Unit IV: Preparation of biosecurity SOPs for fictitious labs/situations, concepts of risk tolerance, mitigation measures, emergency preparedness, innovation in reporting and research culture, biosecurity mock drills, Principles of bioethics, ethics of genetic engineering and stem cell research, policy frameworks (WHO, CDC, NIH, RCGM, IBSC).

12 Hours**Essential Reading:**

1. Handbook for Institutional Biosafety Committees (IBSCs) by Department of Biotechnology Ministry of Science & Technology, Government of India (Third Revised Edition September, 2020) – chapter 1,2,3
2. Biosafety in Microbiological and Biomedical Laboratories 6th Edition. Centers for Disease Control and Prevention, National Institutes of Health (section II)

Tutorial**15 Hours**

1. Case studies - disease outbreaks and importance of biosafety
2. Discussion of various biosafety SOPs (BMBL, NIH etc.)
3. Group discussion – how to enhance biosafety/biosecurity awareness and measures
4. Performing a mock risk assessment study

Suggested Readings

1. Biosafety in Microbiological and Biomedical Laboratories 6th Edition, Centers for Disease Control and Prevention National Institutes of Health
2. Handbook for Institutional Biosafety Committees (IBSCs) by Department of Biotechnology Ministry of Science & Technology, Government of India
3. Laboratory biosecurity guidance, WHO (June 2024)
<https://www.who.int/publications/i/item/9789240095113#:~:text=Overview,responsibility%20of%20institutional%20biosafety%20committees>
4. A guide for the practical implementation of the WHO LABORATORY BIOSAFETY MANUAL FOURTH EDITION, WHO (February 2024).
<https://www.who.int/publications/i/item/9789290211051>

**DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE-07:
PRINCIPLES IN GENETICS**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre- requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-07: Principles in Genetics	04	03	0	01	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 45 (T) + 30 (P)

Learning Objectives:

This course aims to introduce students to the fundamental and advanced concepts of genetics, emphasizing both classical and molecular perspectives. It will provide a strong foundation in Mendelian and non-Mendelian inheritance, gene mapping techniques, microbial and human genetics, and the molecular mechanisms underlying mutation and recombination. The course will also integrate quantitative genetics and explore the genetic basis of complex traits and diseases, enabling students to understand how genetic variation contributes to phenotypic diversity and inheritance patterns.

Learning Outcomes

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

- Explain classical and non-Mendelian inheritance patterns and analyze genetic crosses.
- Apply gene mapping techniques to study linkage, recombination, and chromosomal abnormalities.
- Understand microbial genetic mechanisms and their applications in gene transfer and analysis.
- Interpret human pedigrees, karyotypes, and identify major genetic disorders.
- Describe the molecular basis and consequences of mutations, recombination, and quantitative trait inheritance.

Course Contents

Unit I: Mendelian principles—dominance, segregation, independent assortment. Concept of gene: allele, multiple alleles, pseudoallele, complementation tests. Extensions of Mendelian principles: codominance, incomplete dominance, gene interactions, pleiotropy, genomic imprinting, penetrance and expressivity.

12 Hours

Essential Readings:

Griffiths et al., *Introduction to Genetic Analysis*, 11th Edition (W.H. Freeman), Chapter 2, 3, 6

Klug, Cummings, Spencer, & Palladino – *Concepts of Genetics*, 12th Edition (Pearson), Chapter 3,4

Unit II: Structural and numerical alterations of chromosomes: deletion, duplication, inversion, translocation, ploidy and their genetic implications. Recombination: homologous and non-homologous recombination.

12 Hours

Essential Readings:

Klug, Cummings, Spencer, & Palladino – *Concepts of Genetics*, 12th Edition (Pearson) Chapter 6

Griffiths et al., *Introduction to Genetic Analysis*, 11th Edition (W.H. Freeman) Chapter 15,16

Unit III: Linkage and crossing over. Gene mapping methods: linkage maps, tetrad analysis, mapping with molecular markers. Human genetics: pedigree analysis, LOD score for linkage testing, karyotyping, genetic disorders, GWAS studies

11 Hours

Essential Readings:

Hartl & Ruvolo – *Genetics: Analysis of Genes and Genomes*, 8th Edition Chapter 4, 6, 7

Klug, Cummings, Spencer, & Palladino – *Concepts of Genetics*, 12th Edition (Pearson) Chapter 7, 8, 15, 26

Unit IV: Quantitative genetics: polygenic inheritance, heritability and its measurements, QTL mapping. Mutation: types, causes and detection, mutant types—lethal, conditional, biochemical, loss of function, gain of function, germinal versus somatic mutants, insertional mutagenesis.

10 Hours

Essential Readings:

Klug, Cummings, Spencer, & Palladino – *Concepts of Genetics*, 12th Edition (Pearson) Chapter 23, 25

Hartl & Ruvolo – *Genetics: Analysis of Genes and Genomes*, 8th Edition, Chapter 12, 13, 16

Practical

30 Hours

- 1 Study and analysis of Mendelian and non-Mendelian inheritance patterns through monohybrid and dihybrid crosses, test cross analysis, and problem-based determination of genotypic and phenotypic ratios.
- 2 Demonstration and identification of chromosomal abnormalities using karyotypes/idiograms; study of structural and numerical chromosomal alterations such as deletion, duplication, inversion, translocation, aneuploidy, and polyploidy through case-based analysis.
- 3 Construction and analysis of pedigree charts and linkage maps, including identification of modes

of inheritance, estimation of recombination frequency, and basic LOD score calculation for linkage analysis.

4. Calculation and interpretation of quantitative genetic parameters, including problems on polygenic inheritance, estimation of heritability, basic QTL mapping exercises, and classification/analysis of different types of mutations.

Suggested Readings:

1. Griffiths et al. – Introduction to Genetic Analysis, 11th Edition (W.H. Freeman)
2. Klug, Cummings, Spencer & Palladino – Concepts of Genetics, 12th Edition (Pearson)
3. Hartl & Ruvolo – Genetics: Analysis of Genes and Genomes, 8th Edition (Jones & Bartlett Learning)
4. Snustad & Simmons – Principles of Genetics, 7th Edition (Wiley)
5. Pierce, Benjamin A. – Genetics: A Conceptual Approach, 7th Edition (Macmillan)
6. Russell, P. – iGenetics: A Molecular Approach, 3rd Edition (Pearson)
7. Brooker, R. J. – Genetics: Analysis and Principles, 6th Edition (McGraw-Hill)
8. Milner et al. – Essential Genetics and Genomics, 7th Edition (Oxford University Press)

**DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE-08:
ADVANCED PROTEOMICS AND METABOLOMICS**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-08: Advanced Proteomics and Metabolomics	04	03	0	01	-	-

Number of hours: 45 (H) + 30 (P)

Learning Objectives:

The course aims to provide detailed knowledge about the concepts and applications of proteomics and metabolomics and about mass spectrometry. This course emphasizes on the advancement from protein chemistry to the field of proteomics. The methodology and the instrumentation involved in conducting experiments to proteomics and metabolomics are discussed in the course.

Learning Outcomes

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

1. Explain the principles and methodologies of proteomics, and metabolomics. Importantly, they will be able to learn the benefits of using proteomics and metabolomics tools over other approaches.
2. Demonstrate understanding of multi-omics data generation, analysis workflows, and data integration strategies.
3. Interpret biological significance through pathway and network analysis using real datasets.
4. Critically analyze published proteomics and metabolomics studies and identify their relevance in disease biology and biotechnology.
5. Gain a detailed knowledge of mass spectrometry along with its various components and its applicability in proteomics and metabolomics.

Course Contents

Unit I: Introduction to proteome, proteomics technology, types and kinds of proteomics investigation, overview of systems biology, evolution from protein chemistry to proteomics, importance of proteomics. Quantitation proteomics, Interaction Proteomics, Structural and functional proteomics. Protein Extraction and Sample Preparation- sample collection and lysis methods, solubilization, digestion and reduction/alkylation of proteins, quantification, cleanup

and desalting for MS analysis. Two-dimensional gel electrophoresis (2-DE), 2D-DIGE, Merits and demerits of gel-based proteomics. Chromatographic methods, MudPIT.

10 Hours

Essential Reading:

1. Srivastava, S. (2023) From Proteins to Proteomics. Basic concepts, techniques and Applications. Sanjeeva Srivastava, 2023, CRC Press, Taylor & Francis Ltd. (Chapter 1,2)

Unit II: Mass spectrometry (Ionizers, analyzers and detectors) technology, Principles of ionization and mass detection. Ionization methods: ESI, MALDI. Mass analyzers: Quadrupole, Ion-traps, TOF, Q-TOF, Orbitrap. Tandem MS (MS/MS) and fragmentation methods. ICAT, SILAC, iTRAQ, data-dependent and data-independent acquisition, SWATH, targeted proteomics, nanopore-based proteomics. Understanding proteomics for PTM analysis. Proteomics for protein-protein interactions: from conventional Y2H to proteomic scale Y2H, protein microarrays and interactomics, Tandem affinity purification.

12 Hours

Essential Reading:

1. Srivastava, S. (2023) From Proteins to Proteomics. Basic concepts, techniques and Applications. Sanjeeva Srivastava, 2023, CRC Press, Taylor & Francis Ltd. (Chapter 3)
2. Gross, Juergen H; Roepstorff, Peter (2011, 2nd edition). Mass Spectrometry: A Textbook, Springer (chapter 4,5)

Unit III: Data analysis – database searching: MASCOT, MxQuant, SEQUEST, Protein databases: UniProt, PDB, PRIDE, PeptideAtlas. Data normalization, FDR, and statistical validation. Functional annotation tools: DAVID, STRING, Cytoscape. Application of proteomics for drug discovery, Biomarker discovery, drug targets identification, Validation of drug targets, toxicological assessment and personalized medicine. Emerging Technologies and Trends –Single cell proteomics, top-down proteomics, Immunopeptidomics, AI in proteomics.

12 Hours

Essential Reading:

1. Statistical Analysis of Proteomics, Metabolomics, and Lipidomics Data Using Mass Spectrometry by Bart J. A. Mertens, Susmita Datta (2016) (chapter 6,7)
2. Immunoproteomics: Methods and Protocols by Kelly M. Fulton, Susan M. Twine. Springer protocols (Third edition, 2026) chapter 2

Unit IV: Introduction to metabolomics world. Historical perspectives. Targeted vs untargeted metabolomics; metabolite extraction strategies, Metabolite profiling, metabolic fingerprinting and biomarker discovery, Introduction to systems biology: data processing, statistical methods (PCA, clustering), metabolite identification databases: METLIN, HMDB, network analysis, metabolic modeling, and pathway integration, Applications in disease biology, nutrition, and personalized medicine.

11 Hours

Essential Reading:

1. Alessandra Sussulini (2017). Metabolomics: From Fundamentals to Clinical Applications Springer (chapter 1,4)
2. Raúl González-Domínguez (2023) Mass Spectrometry for Metabolomics. Humana Press (chapter 6,7,2021)

Tutorial**15 Hours**

1. Case study discussions on sample preparation and experimental design on published multi-omics datasets spanning proteomics, and metabolomics.
2. Retrieving datasets from published repositories such as GEO, PRIDE, and the Metabolomics Workbench
3. Visit to Mass-spectrometry facility, equipment demonstration and Hands-on data analysis using various proteomics tools
4. Group discussion and analysis of metabolomics data

Suggested Readings

1. Srivastava, S. (2023) From Proteins to Proteomics. Basic concepts, techniques and Applications. Sanjeeva Srivastava, 2023, CRC Press, Taylor & Francis Ltd.
2. Gross, Juergen H; Roepstorff, Peter (2011, 2nd edition). Mass Spectrometry: A Textbook, Springer
3. Immunoproteomics: Methods and Protocols by Kelly M. Fulton, Susan M. Twine. Springer protocols (Third edition, 2026)
4. Alessandra Sussulini (2017). Metabolomics: From Fundamentals to Clinical Applications Springer
5. Raúl González-Domínguez (2023) Mass Spectrometry for Metabolomics. Humana Press

**DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE-09:
DISEASE MODELS AND CLINICAL RESEARCH**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-09: Disease Models and Clinical Research	04	03	01	0	-	-

Number of hours: 45 (H) + 15 (T)

Learning Objectives:

This course aims to introduce students to the use of model organisms in biomedical research and the foundational principles of clinical research. It focuses on how disease models are established, validated, and translated into clinical applications. Students will explore ethical and regulatory frameworks, understand the design of clinical trials, and gain insights into biomarker discovery and personalized medicine through real-world case studies and data-driven analysis.

Learning Outcomes

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

1. Explain the rationale for using specific model organisms in studying human diseases.
2. Analyze the design, phases, and regulatory aspects of clinical trials.
3. Evaluate ethical considerations in animal and human studies, including CPCSEA and ICMR guidelines.
4. Interpret clinical trial data and assess the translational relevance of disease models.
5. Identify potential diagnostic and prognostic biomarkers from experimental and clinical datasets.

Course Contents

Unit I: Introduction to Disease Models. Definition and importance of model organisms in biomedical research; Criteria for model selection; Overview of in vitro, ex vivo, and in vivo models; Transgenic and knockout animal models; Ethical considerations in animal research (CPCSEA guidelines); Alternatives to animal models.

12 Hours

Essential Reading:

1. Animal Models in Research- Principles and Practice. Editors- Harikrishnan Vijayakumar Sreelatha, Satish Patel, Perumal Nagarajan (2024), Springer (chapter 1, 2, 5)

2. Animal Models for the Study of Human Disease, P. Michael Conn. Academic Press (2nd edition) (chapter 1)

Unit II: Experimental Disease Models and Applications. Models of infectious diseases; Cancer models; Metabolic disorders; neurodegenerative disease models; Inflammatory and autoimmune disease models; Toxicological models for drug safety evaluation. In vitro and in vivo models for pharmacokinetics of drug candidates.

12 Hours

Essential Reading:

1. Rodent Models of Neurodegenerative Disease, Edited by Pegah Javadpour, Sahar Askari, Rasoul Ghasemi, (1st edition, 2026) CRC Press (chapter 1,3)
2. Handbook of Animal Models and its Uses in Cancer Research, edited by Surajit Pathak, Antara Banerjee, Atil Bisgin (1st edition), Springer (chapter 2,8)

Unit III: Basics of Clinical Research and Study Design. Importance of clinical research, phases of clinical trials (I–IV); Types of study designs—observational, interventional, randomized controlled trials, cohort and case-control studies; Blinding and randomization; Informed consent and ethical clearance; Data collection, monitoring, and adverse event reporting; Good Clinical Practices (GCP); Role of Institutional Ethics Committees and regulatory authorities (ICMR, CDSCO, WHO, DCGI, FDA, EU).

11 Hours

Essential Reading:

1. Fundamentals of Clinical Trials. Editors - Lawrence M. Friedman, Curt D. Furberg, David L. DeMets, David M. Reboussin, Christopher B. Granger. (2015) Springer (chapter 1, 2, 5, 6)

Unit IV: Translational Research. Translational pipeline from bench to bedside; Concepts of drug discovery, vaccine design, and biomarker discovery. Concepts of personalized and precision medicine; Preclinical to clinical transition—challenges and strategies; Role of biomarkers in diagnosis, prognosis, and therapy response; Companion diagnostics; Case studies on translational success stories in oncology, infectious diseases, and metabolic syndromes.

10 Hours

Essential Reading:

1. Translational Medicine. The future of therapy. Editors -James Mittra, Christopher-Paul Milne (2013) CRC Press (chapter 1, 3, 6,7)

Tutorial

15 hours

1. Case-based discussions on model organisms in studying cancer and metabolic diseases.
2. Case-based discussions on model organisms in studying infectious diseases.
3. Clinical trial protocol evaluations, review ethical documentation including CPCSEA formats, and explore the principles of the 3Rs.
4. Group discussions analyzing translational success stories and challenges in clinical research.

Suggested Readings

1. Animal Models for the Study of Human Disease, P. Michael Conn. Academic Press (2nd edition)
2. Animal Models in Research- Principles and Practice. Editors- Harikrishnan Vijayakumar Sreelatha, Satish Patel, Perumal Nagarajan (2024), Springer
3. Fundamentals of Clinical Trials. Editors - Lawrence M. Friedman, Curt D. Furberg, David L. DeMets, David M. Reboussin, Christopher B. Granger. (2015) Springer
4. Translational Medicine. The future of therapy. Editors -James Mittra, Christopher-Paul Milne (2013) CRC Press
5. Rodent Models of Neurodegenerative Disease, Edited by Pegah Javadpour, Sahar Askari, Rasoul Ghasemi, (1st edition, 2026) CRC Press
6. Handbook of Animal Models and its Uses in Cancer Research, edited by Surajit Pathak, Antara Banerjee, Atil Bisgin (1st edition), Springer

**DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE-10:
AI AND ITS APPLICATIONS IN BIOMEDICINE AND BIOTECHNOLOGY**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre- requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE-10: AI and its applications in Biomedicine and Biotechnology	04	03	0	01	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 45 (T) + 30 (P)

Learning Objectives:

The primary objective of this course is to introduce postgraduate students to the fundamental concepts of artificial intelligence and machine learning. This course will help them understand how AI-based solutions are strengthening human healthcare, biomedical research, and their potential to change clinical decisions. The integration of machine learning- based artificial intelligence in healthcare is transforming the way medical professionals diagnose, treat, and manage patients. This course will cover topics such as the basics of artificial intelligence and its integration with human health, machine learning algorithms, medical imaging, personalized medicine, and ethical regulations. Students will be encouraged for group case studies, hands-on experience, and guest lecturers to explore the opportunities and challenges to apply their knowledge to transform human health with minimal risk.

Learning Outcomes:

1. Students will be able to get hands-on experience with AI tools and platforms through practical exercises and projects.
2. Students will be able to experience the fundamentals of artificial intelligence and machine learning and their applications in medicine.
3. Students will be able to hands on experience of AI in medical imaging, diagnostics, disease prediction, treatment planning and transforming them to make digital health.
4. Students will be able to apply analytical knowledge to examine the ethical, legal, and social implications of AI in medicine, including issues of bias, privacy, and equity.

Course Contents

Unit I: Basic concepts of Artificial Intelligence, machine learning and deep learning, generative AI, Definition and scope of AI in healthcare, Historical perspective and milestones in AI research, Applications of AI in clinical practice, biomedical research and agriculture.

11 hours

Essential Reading-

Future of AI in Biomedicine and Biotechnology. (2024). United States: IGI Global. (Chapter- 1 & 2)

Artificial Intelligence-Based System Models in Healthcare. (2024). United Kingdom: Wiley. (Chapter- 2 & 6)

Unit II: Supervised, semi-, and unsupervised learning, Big data, Neural networks (ANN, CNN and RNN), feature selection and dimensionality reduction (PCA, t-SNE), digital health, model building, and evaluation of clinical datasets and data handling.

11 hours

Essential Reading-

Future of AI in Biomedicine and Biotechnology. (2024). United States: IGI Global. (Chapter- 2 & 4)

Artificial Intelligence-Based System Models in Healthcare. (2024). United Kingdom: Wiley. (Chapter- 2, 4 & 6)

Unit III: AI in Medical Imaging, Radiology, histopathology and quantitative imaging biomarkers, AI for data analytics and data mining, AI for omics data analysis, AI in Diagnostics and Disease Prediction, Diagnostic decision support systems, predictive models – protein structure prediction, protein-protein interactions

11 hours

Essential Reading-

Future of AI in Biomedicine and Biotechnology. (2024). United States: IGI Global. (Chapter- 2 & 4)

Artificial Intelligence-Based System Models in Healthcare. (2024). United Kingdom: Wiley. (Chapter- 2, 4 & 6)

Unit IV: AI in Personalized Medicine and Treatment Planning, Drug discovery, virtual screening, QSAR, prediction of drug-target interactions, and repurposing using AI approaches, Ethical, Legal, and Social Implications of AI in Medicine, Bias and fairness in AI algorithms, Privacy and security of healthcare data, Regulation and policy considerations for AI in healthcare. Opportunities and challenges in using AI.

12 hours

Essential Reading-

Future of AI in Biomedicine and Biotechnology. (2024). United States: IGI Global. (Chapter- 2 & 4)

Artificial Intelligence-Based System Models in Healthcare. (2024). United Kingdom: Wiley. (Chapter- 2, 6 & 8)

Practical**30 Hours**

1. Data analysis and group activity for diagnostic prediction of human diseases
2. AI based small group projects to identify inhibitors against specific disease
3. Group activity of ML modeling and data analysis on biological datasets
4. Group activity on AI based clinical algorithm for ethical regulations

Recommended Readings:

1. Stuart Russell and Peter Norvig. (2009). Artificial Intelligence: A Modern Approach (3rd ed.). Prentice Hall Press, Upper Saddle River, NJ, USA.
2. Tony J. Cleophas and Aeilko H. Zwinderman. (2015). Machine Learning in Medicine - a Complete Overview. Springer.
3. V.K. Prajapati. (2024), Volume 139: Translational Bioinformatics, Advances in Protein Chemistry and Structural Biology. ISBN: 978-0-443-19348-4, Academic Press Inc
4. Peter Harrington. (2012). Machine Learning in Action. Manning Publications Co., Greenwich, CT, USA.

Suggested Reading-

Altara, R., Basson, C.J., Biondi-Zoccai, G., & Booz, G.W. (2024). Exploring the promise and challenges of artificial intelligence in biomedical research and clinical practice. *Journal of cardiovascular pharmacology*, 83(5), 403-409.

Blasimme, A., & Vayena, E. (2019). The ethics of AI in biomedical research, patient care and public health. *Patient Care and Public Health (April 9, 2019). Oxford Handbook of Ethics of Artificial Intelligence, Forthcoming.*

Bali, J., Garg, R., & Bali, R.T. (2019). Artificial intelligence (AI) in healthcare and biomedical research: Why a strong computational/AI bioethics framework is required? *Indian journal of ophthalmology*, 67(1), 3-6.

SKILL BASED COURSE (SEC-RM) ADVANCED RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
SEC-RM: Advanced Research Methodology	02	01	0	01	B.Sc. Biochemistry and Allied Subjects	-

No. of hours: 15 (T) + 30 (P)

Learning Objectives:

The course aims to build foundational knowledge of research principles, biosafety, and ethics while training students to identify research problems, design experiments, and analyze data. It will help the students develop skills in scientific writing, referencing, plagiarism avoidance, and effective oral and poster presentation.

Learning Outcomes:

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

- Understand fundamental research principles, biosafety guidelines, and ethical standards governing scientific investigations.
- Identify and define a research problem through effective literature review and source evaluation.
- Design and execute experiments using appropriate methodologies, tools, and data validation techniques.
- Analyze, interpret, and document scientific data with accuracy and clarity.
- Communicate research effectively through professional writing, referencing, and oral/poster presentations.

Unit 1: Research Foundations, Ethics, and Biosafety

Comprehensive introduction to the principles underlying responsible and safe scientific research. Biosafety and bioethics guidelines, laboratory safety practices, radioactive and fire safety, biowaste management, and the handling of genetically modified organisms. Institutional biosafety and animal ethics compliance. Introduction to significance of research, identification of research problems, experimental design and execution, method selection, data validation, and scientific communication, referencing, and presentations. Research publication ethics.

7 hours

Essential Readings:

1. Thomas, C. G. (2021). Research Methodology and Scientific Writing. Germany: ANE Books Pvt. Limited. (Chapters: 1, 7, 8, 9, 10, 23)
2. Scientific Methods Used in Research and Writing. (2020). United Kingdom: CRC Press. (Chapters: 1 and 4)
3. Research paper: Steneck, N. H. (2006). Fostering integrity in research: Definitions, current knowledge, and future directions. Science and Engineering Ethics, 12(1), 53–74.
4. Kothari, C. R.; Garg, G. Research Methodology: Methods and Techniques (New Age International, 2019). Chapters: 1, 2 and 3

Unit 2: Intellectual Property Rights& Entrepreneurship

Introduction to entrepreneurship and intellectual property: Definition, concepts, Innovation, invention and creativity, Patents, copyright and trademarks, patentable and non-patentable, Patent Databases, Searching a patent, Types of patent applications, Incubators, research parks, Various Government policies, Technology Transfer

8 hours**Essential Readings:**

1. Narayanan, V. K., Managing technology and innovation for competitive advantage, first edition, Pearson education, New Delhi, (2006)
2. Idris, K. (2003), Intellectual property: a power tool for economic growth, second edition, WIPO publication no. 888, Switzerland.
3. <http://www.wipo.int/patents/en/>

8 hours**Practicals:****30 Hours**

1. Oral presentation
2. Poster presentation
3. Patent Search using online databases
4. Visit to Industry/ incubator set-up

Essential Readings:

1. Thomas, C.G. (2021). Research Methodology and Scientific Writing. Germany: ANE Books Pvt. Limited.
2. Scientific Methods Used in Research and Writing. (2020). United Kingdom: CRC Press.
3. Research paper: Steneck, N.H. (2006). Fostering integrity in research: Definitions, current knowledge, and future directions. Science and Engineering Ethics, 12(1), 53–74.
4. Kothari, C.R.; Garg, G. Research Methodology: Methods and Techniques (New Age International, 2019).
5. Narayanan, V. K., Managing technology and innovation for competitive advantage, first edition, Pearson education, New Delhi, (2006)
6. Idris, K. (2003), Intellectual property: a power tool for economic growth, second edition, WIPO publication no. 888, Switzerland.
7. <http://www.wipo.int/patents/en/>

Suggested Readings:

1. Cresswell, J. (2009). Research Design: Qualitative and quantitative Approaches Thousand Oaks CA, (3rd ed.), Sage Publications
2. Kothari, C.R. (2004). Research Methodology: Methods and Techniques (2nd ed.), New Age International Publishers.
3. Kumar, R. (2011). Research Methodology: A Step-by-Step Guide for Beginners (5th ed.), SAGE publisher
4. Walliman, N. (2017). Research Methods: The Basics, (2nd ed.), London; New York: Routledge
5. WHO. (2001). Health Research Methodology – A Guide for Training in Research Methods.

SKILL BASED COURSE – SBC-3 : TOOLS FOR BIOSTATISTICS AND DATA VISUALIZATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
SBC-3: Tools for Biostatistics and Data Visualization	02	0	0	02	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 60 (P)

Learning Objectives:

To provide students with a conceptual and practical understanding of biostatistical methods and graphical data representation used in biological research, enabling accurate analysis, interpretation, and presentation of experimental data.

Unit I

Hands-on training in basic biostatistics, including types of data and variables, measures of central tendency and dispersion, probability and normal distribution, and graphical representation of data using histograms, bar diagrams, and frequency polygons. Practical exercises will include experimental design, sampling, hypothesis testing, and application of parametric and non-parametric tests including t-test, ANOVA, and Chi-square test, along with correlation and regression analysis using biological datasets.

35 Hours

Essential Readings:

- Glantz, S.A. (2012). *Primer of Biostatistics*, 7th Edition, McGraw-Hill — Chapter 2: How to Summarize Data.
- Glantz, S.A. (2012). *Primer of Biostatistics*, 7th Edition, McGraw-Hill — Chapter 4: The Special Case of Two Groups: The t Test.
- Motulsky, H. (2018). *Intuitive Biostatistics: A Nonmathematical Guide to Statistical Thinking*, 4th Edition, Oxford University Press — Chapters 15–21: P Values and Statistical Significance, Chapter 32: Correlation, Chapter 33: Simple Linear Regression.

Unit II:

Hands-on training in scientific visualization and presentation of biological data using GraphPad Prism, Microsoft Excel, and R (ggplot2), including bar plots, box plots, scatter plots, violin plots, pie charts, heatmaps, volcano plots, and Venn diagrams. Practical exercises will also include interpretation and reporting of statistical results, presentation of data in figures and tables, reproducibility, ethical data handling, and case studies from published biological research.

25 Hours

Essential Readings:

- Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*, 2nd Edition, Springer — Chapter 1: Preface, Chapter 3: Mastering the grammar, Chapter 4: Build a plot layer by layer, Chapter 8: Polishing your plots for publication.
- Manisha, N., 2020. *Advanced Analytics with Excel 2019*. BPB Publications. Chapter 4: Data Visualization with New Chart types.
- Glantz, S.A. (2012). *Primer of Biostatistics*, 7th Edition, McGraw-Hill — Chapter 12: What Do the Data Really Show?
- Motulsky, H. (2018). *Intuitive Biostatistics*, 4th Edition, Oxford University Press — Chapter 44 – 48: Putting It All Together.

Suggested Readings

1. Glantz, S.A. (2012). *Primer of Biostatistics*, 7th Edition, McGraw-Hill Education, New York.
2. Motulsky, H. (2018). *Intuitive Biostatistics: A Nonmathematical Guide to Statistical Thinking*, 4th Edition, Oxford University Press, New York.
3. Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*, 2nd Edition, Springer-Verlag, New York.
4. Manisha, N. (2020). *Advanced Analytics with Excel 2019*, BPB Publications, New Delhi.
5. Khan, I.A. & Khanum, A. (2018). *Fundamentals of Biostatistics*, 4th Edition, Ukaaz Publications, Hyderabad.
6. Rosner, B. (2016). *Fundamentals of Biostatistics*, 8th Edition, Cengage Learning, Boston.
7. Sokal, R.R. & Rohlf, F.J. (2012). *Biometry: The Principles and Practice of Statistics in Biological Research*, 4th Edition, W.H. Freeman, New York.
8. Zar, J.H. (2010). *Biostatistical Analysis*, 5th Edition, Pearson Education, New Delhi.

SKILL BASED COURSE – SBC-4 : SCIENTIFIC RESEARCH WRITING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
SBC-4: Scientific Research Writing	02	0	0	02	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 60 (P)

Learning Objectives:

This course is designed to introduce students to basic scientific writing skills. Participants will review the general principles of clear, persuasive writing, and will apply these principles to writing for a scientific audience. Particular emphasis will be placed on conveying the significance of your research, outlining the aims, and discussing the results for scientific papers and grant proposals. The course will also provide an overview of the structure and style of research grant proposals and scientific manuscripts

Learning Outcomes

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

1. Understand the process of scientific writing
2. Explain the importance and application of current trends for manuscript and research grants
3. Understand the nature of figures, tables, and graphs and their use for scientific writing

Course Contents

Unit I: Introduction-Overview of science writing, discussion on how is scientific writing different from general writing, knowing your audience and readership. Writing exercises for general public, science reporting, Science news, explanatory writing, lengthy magazine article, popular articles and popular lectures. Collation of reading material: Popular science magazine articles. Discussion on ethics in writing, plagiarism, with exercises using, plagiarism checker online.

15 Hours

Essential Reading-

Thomas, C. G. (2021). Research Methodology and Scientific Writing. Germany: ANE Books Pvt. Limited. (chapter-5, 7 & 11)

Scientific Methods Used in Research and Writing. (2020). United Kingdom: CRC Press. (chapter- 1 & 4)

Unit II: Discussion on different formats for writing for scientific community, types of paper (short communication, original research article, review), various components (title, author affiliation, abstract, key words, introduction, material and methods, results and discussion, conclusion and bibliography). Writing and citation exercises for research grant, reports, Book review, write up mini profiles of prominent scientists, letters to the editor, opinion writing, interview with a scientist, career in scientific writing.

30 Hours

Essential Reading-

Thomas, C. G. (2021). Research Methodology and Scientific Writing. Germany: ANE Books Pvt. Limited. (chapter-5, 7 & 11)

Scientific Methods Used in Research and Writing. (2020). United Kingdom: CRC Press. (chapter- 1 & 4)

Recommended Reading-

Thomas, C. G. (2021). Research Methodology and Scientific Writing. Germany: ANE Books Pvt. Limited.

Scientific Methods Used in Research and Writing. (2020). United Kingdom: CRC Press.

Yadav, S.S., Gupta, S., Choudhary, A. K. (2025). Scientific Research Methodology: Principles, Tools, and Techniques. (n.p.): CRC Press.

Suggested Reading-

Dehesh, P. (2025). Scientific writing in a systematic review and Meta-Analyses. *Systematic Review and Meta-Analysis*, 195-208.

Zhang, Q., Ding, K., Lv, T., Wang, X., Yin, Q., Zhang, Y., ... & Chen, H. (2025). Scientific large language models: A survey on biological & chemical domains. *ACM Computing Surveys*, 57(6), 1-38.

Amobonye, A., Lalung, J., Mheta, G., & Pillai, S. (2024). Writing a scientific review article: comprehensive insights for beginners. *The Scientific World Journal*, 2024(1), 7822269.

**GENERIC ELECTIVE COURSE – GE-3:
BIOCHEMISTRY OF HUMAN DISEASES**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre- requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
GE-3: Biochemistry of Human Diseases	04	03	01	0	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 45 (T) + 15 (T)

Learning Objectives:

This course aims to introduce students to the biochemical nature of various human diseases including genetic, metabolic, infectious diseases along with diseases due to protein folding. Students will learn to explore biochemical principles for understanding disease diagnosis, disease symptoms, progression and treatment. Clinical case studies will also be discussed to make students understand the role of biochemical processes in various diseases.

Learning Outcomes

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

1. Understand the biochemical basis of various human diseases
2. Explain the molecular mechanisms that lead to various diseases
3. Understand the biochemical mechanisms of diseases such as cancer, obesity, diabetes, neurodegenerative disorders and genetic disorders
4. Evaluate diagnostic and therapeutic measures for various biochemical and metabolic diseases

Course Contents

Unit I: Introduction of macromolecules (proteins, lipids, carbohydrates and nucleic acids) in human health and diseases, integrative metabolism and systems biology, Cellular energy and bioenergetics – ATP, redox functions, mitochondrial function in health and disease, nutrient sensing and energy balance, amino acid and nitrogen metabolism in context to monogenic disorders - inborn errors of metabolism; nucleotide metabolism- G6PD deficiency, Integration of metabolism and diseases; carbohydrate metabolism and diabetes; lipid metabolism and obesity; lipoproteins, their transport and cardiovascular disease

11 Hours

Essential Reading:

1. Molecular Biochemistry of Human Diseases By George Feuer, F. A. de la Iglesia (2021) CRC Press (volume I). (chapter 3-5).

Unit II: Case studies and key examples to learn how defects in key cellular functions and processes lead to diseases. cell cycle, signaling pathway defects and genetic basis of cancer, Protein misfolding diseases – Parkinson's, Alzheimer's and Huntington's disease, biochemical changes due to infection (by virus, bacteria and parasites).

13 Hours

Essential Reading:

1. Molecular Mechanisms of Neurodegenerative Diseases by Marie-Françoise Chesselet (2001) Springer. (chapter 4,5,6)
2. Protein Misfolding Diseases: Current and Emerging Principles and Therapies. Editor(s): Marina Ramirez-Alvarado, Jeffery W. Kelly, Christopher M. Dobson (2010), John Wiley & Sons, Inc. (chapter 12,13)

Unit III: genetic diseases – microdeletion/duplication syndromes, imprinting diseases, structural arrangements; cytogenetic disorders (aneuploidy); inherited metabolic disorders - lysosomal storage diseases, Neimann-Pick disease, Gaucher's disease, glycogen storage diseases; structural defects - Duchenne muscular dystrophy; cystic fibrosis and transport defects; sickle cell anemia, thalassemia; mitochondrial diseases

13 Hours

Essential Reading:

1. Human Genetic Diseases edited by Dijana Plaseska-Karanfilska (2011) IntechOpen. Chapter 1,6,8

Unit IV: Treatment and management of metabolic disorders, gene therapy, enzyme replacement therapy, hormone therapy, gene editing, bone marrow transplantation, stem cell- based therapies

8 Hours

Essential Reading:

1. Human Molecular Genetics, 4th Edition by Tom Strachan and Andrew Red (2011) by Garland Science, Taylor & Francis Group, LLC. Chapter 21

Tutorial:

15 Hours

1. Clinical case studies taking examples of alterations in biochemical parameters for various diseases
2. Discussion on the role of identifying biochemical markers for diseases
3. Group discussions on novel innovations in treating genetic disorders (gene therapy/CRISPR)
4. Group discussions on discussing experimental approaches to study protein misfolding for neurodegenerative disorders

Suggested Reading:

Biochemistry by Jeremy M. Berg, John L. Tymoczko, Gregory J. Gatto, Lubert Stryer · 2015. Macmillan Learning

Molecular Biochemistry of Human Diseases by George Feuer, F. A. de la Iglesia (2021) CRC Press (volume I).

Protein Misfolding Diseases: Current and Emerging Principles and Therapies Editor(s): Marina Ramirez-Alvarado, Jeffery W. Kelly, Christopher M. Dobson (2010), John Wiley & Sons, Inc.

Human Molecular Genetics, 4th Edition by Tom Strachan and Andrew Read (2011) by Garland Science, Taylor & Francis Group, LLC. Chapter 21

Human Genetic Diseases edited by Dijana Plaseska-Karanfilska (2011) IntechOpen.

**GENERIC ELECTIVE COURSE – GE-4:
BIOCHEMICAL TECHNIQUES AND APPLICATIONS**

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

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre- requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
GE-4: Biochemical Techniques and Applications	04	03	01	0	B.Sc. Biochemistry and Allied Subjects	-

Number of hours: 45 (T) + 15 (T)

Learning Objectives:

This course introduces students to basic biochemical techniques commonly used in teaching and research laboratories. It aims to provide hands-on knowledge of how biological molecules like proteins and DNA are studied, and how these techniques are applied in health, food, and environmental fields.

Learning Outcomes

By the end of the course, students will be able to:

1. Understand and prepare biological buffers and use simple lab instruments like pH meter and spectrophotometer.
2. Perform basic protein and DNA isolation and analysis using gel electrophoresis.
3. Explain the working of advanced tools like chromatography and enzyme assays.
4. Understand how biochemical techniques are used in disease testing, food safety, and forensic analysis.
5. Follow biosafety and ethical practices in laboratory work.

Course Contents

Unit I: Introduction to Biochemical Tools. Concepts of pH and buffers and their importance in biological systems; principles and applications of colorimetry and spectrophotometry; introduction to fluorescence spectroscopy; fundamentals of centrifugation – analytical and preparative types, including ultracentrifugation and density gradient methods; overview of chromatographic techniques – paper, column, and thin-layer chromatography (TLC).

12 Hours

Unit II: Protein and Nucleic Acid Analysis. Principles of electrophoresis and its applications in biomolecule separation – SDS-PAGE, native PAGE, agarose gel, and capillary electrophoresis; protein quantification methods (Bradford, Lowry); isolation and purification

of DNA and RNA; introduction to the polymerase chain reaction (PCR) and its applications; advanced chromatographic methods – gel filtration, ion-exchange, affinity chromatography

11 Hours

Unit III: Advanced Analytical Instruments. Principles and applications of high- performance liquid chromatography (HPLC) and affinity chromatography; overview of mass spectrometry and its role in biomolecule identification; use of light-based analytical techniques such as UV–visible, fluorescence, and atomic absorption spectroscopy; principles and applications of radioisotopic and stable isotope tracing in biological research with emphasis on quantification, detection, and radiation safety

11 Hours

Unit IV: Applications in Daily Life. Application of biochemical techniques in disease diagnostics (ELISA, glucose estimation), food quality testing, environmental monitoring, and forensic analysis; introduction to bioethics, data integrity, and laboratory safety in biochemical research.

11 Hours

Tutorials

15 Hours

1. Discussion on experimental design in biochemistry and selection of appropriate analytical methods for different biological questions.
2. Interpretation of pH, buffer capacity, spectrophotometric data, electrophoretic profiles, and enzyme assay results.
3. Case-based discussion on chromatographic outputs and troubleshooting experimental challenges.
4. Applications of biochemical tools in research and diagnostics, including clinical testing, food safety, environmental monitoring, and ethical and safety considerations.

Suggested Readings

1. R.H. Garrett and C.M. Grisham (2017). Biochemistry, 6th Edition. Cengage Learning.
2. Keith Wilson and John Walker (2018). Principles and Techniques of Biochemistry and Molecular Biology, 8th Edition. Cambridge University Press.
3. J. Jayaraman (2011). Laboratory Manual in Biochemistry. New Age International Publishers.
4. David L. Nelson and Michael M. Cox (2023). Lehninger Principles of Biochemistry, 9th Edition. W.H. Freeman and Company.
5. R. Scopes (2013). Protein Purification: Principles and Practice, 3rd Edition. Springer-Verlag.

UNIVERSITY OF DELHI

MASTER OF SCIENCE
(TWO-YEAR PROGRAMME)

IN

PLANT MOLECULAR BIOLOGY AND BIOTECHNOLOGY
(Effective from the Academic Year 2025-2026)

BROCHURE



Department of Plant Molecular Biology
Faculty of Interdisciplinary and Applied Sciences
University of Delhi, South Campus
New Delhi – 110 021, India

NEP 2020 based syllabus as approved in the meeting of 'Committee of Courses' held on 04.12.2025, in the meeting of 'Faculty of Interdisciplinary and Applied Sciences' held on 23.02.2026, and meeting of 'Standing Committee' held on _____

*Revised Syllabus as approved by Academic Council on _____, 2026
and
Executive Council on _____, 2026*

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I. About the Department

The **Department of Plant Molecular Biology**, established in 1988 under the Faculty of Interdisciplinary and Applied Sciences (FIAS), advances research and education in frontier areas of plant molecular biology and biotechnology. It was enriched by the merger of the **Unit for Plant Cell and Molecular Biology** in 1988 (originally established by the DST) and the award of ‘Committee on Strengthening of Infrastructure for Science and Technology (COSIST)’ grant by the UGC (1990–1995). The Department was recognized under UGC’s Special Assistance Programme (DRS Phase I-III, 2002-2018) to strengthen research and teaching in Functional Genomics. Since its inception, the Department has been led by eminent scientists, including Prof. S.C. Maheshwari (1988–1992), Prof. Akhilesh K. Tyagi (1988, 1992–95, 1998–2001), Prof. Jitendra P. Khurana (1995–1998, 2001–2004, 2014–2016), Prof. Paramjit Khurana (2004–2007, 2016–19), Prof. Anil Grover (2007–2010, 2019–2022), Prof. Indranil Dasgupta (2010–2013), Prof. Madan Mohan (2013–2014), Prof. Sanjay Kapoor (2022–2025), and Prof. Girdhar K. Pandey (2025–present).

We are one of the India’s top-ranking institutions for Plant Science Education and Research, nestled within the secure and picturesque South Campus of the University of Delhi. With Delhi University’s rich legacy of academic and research excellence, the Department of Plant Molecular Biology is committed to upholding and advancing this tradition through its innovative teaching and cutting-edge research programmes. Since its establishment, DPMB has been at the forefront of numerous multinational research initiatives, fostering a dynamic, globally connected research community, notably through the Rockefeller Rice Biotechnology Program (1990-2000), which bolstered expertise in transgenics and gene analysis. With the turn of the millennium, the Department played a pivotal role in large-scale genome sequencing, contributing to the complete sequencing of the rice genome (2005), tomato genome (2012), and wheat genome (2019) as part of several international consortia. Our faculty maintains strong collaborations with leading international researchers through bilateral research programmes, providing young scientists with unparalleled opportunities to engage in world-class research and turn their aspirations into reality.

Faculty members have undertaken several research initiatives supported by major grants from DBT, DST, UGC, CSIR, DAE-BRNS, the European Commission, and the Rockefeller Foundation (in the area of the Centre for Plant Molecular Biology, Genome Sequencing Initiatives, and Functional Genomics). Faculty members actively participate in multi-institutional and international collaborations, producing 900+ publications in high-impact journals such as *Nature*, *Genome Research*, *Nucleic Acids Research*, *Trends in Biotechnology*, *Trends in Plant Science*, *Plant Journal*, *Plant Physiology*, *Plant Biotechnology Journal*, *New Phytologist*, *Journal of Experimental Botany*, *Plant Cell & Environment*, and *Bioessays*, and others, along with several patents. Their contributions have been recognized through national and international fellowships and awards.

While emphasizing fundamental research and training, the Department is committed to translational applications for human welfare. Its alumni hold key positions in academia and research institutions in the country and worldwide, including Washington State University;

University of Nebraska, Lincoln; Texas Tech University Health Sciences Centre Rothamsted Research Station), Guru Jambheshwar University (Hisar), Bioseed Research (Hyderabad), ICAR-IARI, ICGEB, BRIC-NIPGR, JNU, IIT Delhi, BRIC-NII, Indraprastha University, IISER (Bhopal), TERI University, CIMAP (Lucknow), Birsa Agricultural University (Ranchi), Assam Agricultural University (Jorhat), BITS (Hyderabad), NABI (Mohali), University of Hyderabad, among others. Many lead research groups in both academia and industry, making significant contributions to the advancement of plant molecular biology.

II. Introduction to NEP Programme

a. Scope

The National Education Policy (NEP) 2020 aims to transform post-graduate education by introducing flexibility, interdisciplinary, and skill-oriented learning. The program is structured to equip students with advanced knowledge and specialized skills, preparing them for research and innovation. The key features of this program include a flexible program structure, interdisciplinary learning, multiple entry and exit points, credit mobility, a focus on emerging fields, skill-based learning, continuous assessment, and an emphasis on research and skill development. NEP2020 modernizes post-graduate education by making it flexible, industry-aligned, and student-centric, empowering learners to shape their academic journey in line with their interests and career aspirations.

b. Definition of Keywords

- i. **“Discipline Specific Core (DSC)”** means a course that a student admitted to a particular programme must successfully complete to receive the degree, and which cannot be substituted by any other course. DSCs shall be the core credit courses of that particular discipline, appropriately graded and arranged across the semesters of study undertaken by the student, with multiple exit options as per NEP 2020.
- ii. **“Discipline Specific Elective (DSE)”** shall be a pool of credit courses of that particular discipline (single discipline programme of study) or those disciplines (multidisciplinary programme of study), as the case may be, which a student chooses to study from his/her particular discipline(s). This course is to be selected by a student out of such courses offered in the same or any other Department/Centre of FIAS.
- iii. **“Generic Electives (GEs)”** are a pool of courses designed to provide students with multidisciplinary or interdisciplinary education. Various disciplines of study (excluding the GEs offered by the parent discipline), in groups of odd and even semesters, from which a student can choose. The concerned Department would identify the GEs specified in the framework as GEs to be taught in a Programme.
- iv. **“Skill Enhancement Courses (SEC)”** are skill-based courses across all disciplines aimed at providing students with hands-on training, competencies, and proficiency. SEC courses may be chosen from a pool of courses designed to provide skill-based instruction.

- v. **“Dissertation”** means a research project completed and written as part of a postgraduate degree.
- vi. **“Credit”** is a unit by which the coursework is measured. It determines the number of hours of instruction required per week. One credit is equivalent to one hour of teaching (lecture or tutorial) or two hours of practical work/field work per week.
- vii. **“SGPA”** is the Semester Grade Point Average calculated for individual semesters.
- viii. **“CGPA”** is the Cumulative Grade Point Average calculated for all courses completed by the students at any time. The CGPA is calculated each year for both semesters combined.
- ix. **“Grand CGPA”** is calculated in the last year of the course by clubbing together the CGPAs of the two years, i.e., four semesters. Grand CGPA is given in the transcript form. To benefit the student, a formula for converting the Grand CGPA into percentage marks is provided in the transcript.

III. M.Sc. PMBB Programme Details

The **M.Sc. Programme in Plant Molecular Biology and Biotechnology (PMBB)** at the Department of Plant Molecular Biology (PMB), University of Delhi South Campus (UDSC), offers an enriching and dynamic learning experience at the forefront of modern plant sciences. Designed to keep pace with cutting-edge advancements, this program equips students with the expertise necessary for a potential career in Crop Biotechnology and allied fields. With a meticulously structured curriculum, the PMBB program nurtures future-ready researchers and skilled professionals, bridging the gap between academia and industry. Graduates of this program are well-positioned to contribute to leading research institutions and drive innovation in the rapidly growing Plant Biotechnology sector, both in India and abroad.

Our comprehensive curriculum encompasses Classroom Teaching, Laboratory Practical sessions, Tutorials in the form of Seminars, and an invigorating Dissertation component. Throughout this PG programme, students will explore courses in Discipline Specific Core, Discipline Specific Elective, Generic Elective, Advanced Research Methodology/Tools for Research, Techniques of Research Writing, and Skill-based papers, which are intelligently distributed across four Semesters. These courses will be taught within the PMB Department, while the students will have the opportunity to choose from a diverse array of topics offered by sister Departments within the Faculty of Interdisciplinary and Applied Sciences (FIAS) at UDSC for the remaining paper(s).

The journey begins in the **first semester** with three core Papers from the PMB Department, delving into the Basics of Genetics and Molecular Biology, Molecular Cell Biology, and Recombinant DNA technology. Additionally, the course also offers three elective courses focusing on advanced subjects: ‘Model Organisms in Molecular Biology Research’, ‘Plants in Human Health and Nutrition’, and ‘Laboratory Instrumentation & Safety’. Students can choose any two of the three DSE papers offered, or select one DSE offered by PMB and

one Generic Elective (GE) paper offered by other departments of FIAS. The DSEs and SEC papers provide an opportunity to delve deeper into specialized areas and expand the knowledge base. Notably, the paper on ‘Model Organisms in Molecular Biology Research’ is also open to students from other FIAS departments, as generic elective adding to the interdisciplinary learning experience.

In the **second semester**, students will dive into three captivating DSC papers viz. ‘Molecular Basis of Plant Development’, ‘Plant Biochemistry and Metabolism’, ‘Eukaryotic Gene expression and Regulation’ and any of the two DSE papers (‘Proteomics, Metabolomics, Cell Signaling’, ‘Plant-Environment Interaction’) or one DSE offered by PMB, and one GE offered by other departments of FIAS. Notably, the paper on ‘Proteomics, Metabolomics and Elementomics’ is also open as generic elective to students from other FIAS Departments.

In **third and fourth semester**, students may choose one of the three course structures offered: Structure 1 (PG with Course only), Structure 2 (PG with Course & Research), and Structure 3 (PG with Research only). In Structure 1, two core papers, four DSEs (of which one DSE is generic elective) along with one 2-credit course are offered in both semester 3 and 4. In Structure 2, two core, three DSEs (of which one DSE is generic elective) are offered along with dissertation work in semester 3 and two core, three DSEs (one DSE as generic elective) are offered along with dissertation work in semester 4. Structure 3 is research-intensive and offers one core, two DSEs and two 2-credit courses in semester 3 and two DSEs, one 2-credit course and dissertation work in semester 4. The details of papers are presented in the table below.

PMBB Programme Details

a. Programme Objectives:

The M.Sc. course in Plant Molecular Biology and Biotechnology at the Department of Plant Molecular Biology (PMB), UDSC, has been designed to provide students with comprehensive exposure to the latest advancements in the exciting and burgeoning areas of modern plant sciences. This program equips students with the necessary theoretical knowledge and practical skills to pursue cutting-edge research in plant molecular biology and related disciplines. Additionally, it aims to develop a skilled workforce capable of contributing to the rapidly growing Plant Biotechnology industry, opening avenues for careers in academia and industry.

b. Programme Specific Outcomes:

After successfully completing the program, students will have developed a comprehensive and in-depth understanding of plant systems at the molecular level. They will gain a clear and precise grasp of how plants respond at the molecular level to various environmental and developmental cues. In addition to building a strong theoretical foundation, students will acquire essential practical skills, encompassing both wet-lab techniques and computational analyses. This well-rounded training will equip them with the expertise necessary to undertake challenging research projects in their future careers. Furthermore, they will gain insights into the complexities of molecular engineering and its applications

in developing improved crop varieties. The program is designed to equip students with the knowledge and skills required to meet the criteria for conducting research in line with the BioE3 (Biotechnology for Economy, Environment, and Employment) Policy of the Government of India. By integrating advanced biotechnological approaches with principles of environmental sustainability, students will be prepared to contribute to innovative solutions that address the growing global demand for food and agricultural resilience.

c. Programme Structure:

The M.Sc. in Plant Molecular Biology and Biotechnology (PMBB) is a two-year programme offering a comprehensive, structured curriculum that provides both fundamental knowledge and advanced expertise in the field. The program includes:

- **Discipline Specific Core (DSC): DSCs (4 credits each)** provide a strong foundation, ensuring students gain up-to-date concepts in plant molecular biology and biotechnology.
- **Discipline Specific Elective (DSE): DSEs discipline or internal elective papers (4 credits each)** offer an advanced and in-depth exploration of specific topics that build upon concepts introduced in the core papers. These electives also incorporate substantial hands-on training to enhance practical understanding and research skills.
- **Generic Elective (GE): Select DSEs are offered as Generic Electives (4 credits)** to provide specialized knowledge and practical insights in an emerging area of biological sciences, accessible to a broader cohort of life sciences students.
- **SECs (2 credits each)** are designed to provide practical, industry-relevant, and research-driven skills that prepare students for both academic and industry settings.
- **Three papers, each of 2 credits**, focus on advanced research methods in the core discipline, basic and advanced research tools, and research writing techniques.
- **A dissertation (12/26 credits)** is structured to engage students in independent research, develop problem-solving skills, and contribute to scientific advancements in the field.

The well-balanced curriculum ensures that graduates acquire both theoretical expertise and practical proficiency, equipping them for careers in academic research, biotechnology industries, and related scientific fields.

d. Course Credit Scheme:

The **M.Sc. program in Plant Molecular Biology and Biotechnology** is a two-year course divided into four semesters. A student is required to complete 88 credits to complete the course and be awarded a degree. A student has to accumulate 22 credits in each of the four semesters. The program structure is based on the Post Graduate Curricular Framework (PGCF) under NEP-2020.

Two-Year PG Course Credit Scheme

Structure-1 (Level 6.5): (PG with only coursework)

Semester	Core Courses		Elective courses		Skill-based course/ Hands on Learning		Research Methods/ Tools/ Writing		Dissertation/ Project		Total Credits
	No. of cours es	Total credits	No. of course s	Total credi ts	No. of courses	Total credits	No. of course s	Total credits	No. of course s	Total credits	
I	3	12	2	8	1	2	-	-	-	-	22
II	3	12	2	8	1	2	-	-	-	-	22
III	2	8	3	12	1	2	-	-	-	-	22
IV	2	8	3	12	1	2	-	-	-	-	22
Total Credits	40		40		8		-		-		88

Structure-2 (Level 6.5): (PG with coursework and research)

Semester	Core Courses		Elective courses		Skill-based course/ Hands on Learning		Research Methods/ Tools/ Writing		Dissertation/ Project		Total Credits
	No. of cours es	Total credits	No. of cours es	Total credi ts	No. of courses	Total credit s	No. of cours es	Total credit s	No. of cours es	Total credits	
I	3	12	2	8	1	2	-	-	-	-	22
II	3	12	2	8	1	2	-	-	-	-	22
III	2	8	2	8	-	-	-	-	1	6	22
IV	2	8	2	8	-	-	-	-	1	6	22
Total Credits	40		32		4		-		12		88

Structure-3 (Level 6.5): (PG with research)

Semester	Core Courses		Elective courses		Skill-based course/ Hands on Learning		Research Methods/ Tools/ Writing		Dissertation/ Project		Total Credits
	No. of cours es	Total credits	No. of cours es	Total credits	No. of courses	Total credits	No. of cours es	Total credits	No. of cours es	To tal cr edi ts	
I	3	12	2	8	1	2	-	-	-	-	22
II	3	12	2	8	1	2	-	-	-	-	22
III	1	4	1	4	-	-	2	4	1	10	22
IV	-	-	1	4	-	-	1	2	1	16	22
Total Credits	28		24		4		6		26		88

e. Semester-wise Programme Structure:

PMBB P.G. PROGRAMME STRUCTURE**First-Year Course Details (Common in Structures 1, 2, and 3)**

PART- I		Semester 1		
Name of the Course	Credit Distribution of the Course			
	Theory/ Lecture	Tutorial	Practical	Total Credits
DISCIPLINE SPECIFIC CORE COURSES (DSC)				
PBSC101: Basic Molecular Biology and Genetics	3	0	1	4
PBSC102: Molecular Cell Biology	3	0	1	4
PBSC103: Recombinant DNA Technology- Concepts, Techniques, and Applications	3	0	1	4
DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)				
*PBSE104: Plants in Human Health and Nutrition	3	0	1	4
*PBSE105: Laboratory Instrumentation and Safety	3	0	1	4
\$PBSE106: Model Organisms in Molecular Biology Research	3	1	0	4
SKILL ENHANCEMENT COURSE				
PBSEC107: Biological Data Analysis and Interpretation	1	0	1	2
TOTAL CREDITS IN SEMESTER 1				22

\$PBSE106 is open to students from other departments as a generic elective.

Two DSEs OR one DSE* and one generic elective\$ (courses offered by any FIAS departments, including DPMB) can be selected.*

PART-I		Semester 2		
Name of the Course	Credit Distribution of the Course			
	Theory/ Lecture	Tutorial	Practical	Total Credits
DISCIPLINE SPECIFIC CORE COURSES (DSC)				
PBSC201: Molecular Basis of Plant Development	3	0	1	4
PBSC202: Plant Biochemistry and Metabolism	3	0	1	4
PBSC203: Eukaryotic Gene expression and Regulation	3	0	1	4
DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)				
*PBSE204: Cell Signaling and Communication	3	0	1	4
*PBSE205: Plant-Environment Interaction	3	0	1	4
\$PBSE206: Proteomics, Metabolomics, and Elementomics	3	1	0	4
SKILL ENHANCEMENT COURSE				
PBSEC207: Plant Tissue Culture and Transformation Methodologies	0	0	2	2
TOTAL CREDITS IN SEMESTER 2				22

\$PBSE206 is open to students from other departments as a generic elective.

Two DSEs OR one DSE* and one generic elective\$ (courses offered by any FIAS departments, including DPMB) can be selected.*

Second-Year Course Details (Structure 1 - PG with Coursework)

PART- II		Semester 3		
Name of the Course		Credit Distribution of the Course		
	Theory/ Lecture	Tutorial	Practical	Total Credits
DISCIPLINE SPECIFIC CORE COURSES (DSC)				
PBSC311: Plant Biotechnology	3	0	1	4
PBSC312: Molecular Plant Breeding	3	0	1	4
DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)				
*PBSE313: Metagenomics of Plant-associated Microbes	3	1	0	4
*PBSE314: Frontiers in Plant Molecular Biology	3	0	1	4
\$PBSE315: Introduction to Bioinformatics	3	1	0	4
*PBSE316: Molecular Plant Evolution and Biodiversity	3	1	0	4
SKILL ENHANCEMENT COURSE				
PBSEC317: Emerging Techniques in Plant Biology	1	0	1	2
TOTAL CREDITS IN SEMESTER 3				22

\$PBSE315 is open to students from other departments as a generic elective.

Three DSEs OR two DSEs* and one generic elective\$ (courses offered by any FIAS departments, including DPMB) can be selected.*

PART- II		Semester 4		
Name of the Course		Credit Distribution of the Course		
	Theory/ Lecture	Tutorial	Practical	Total Credits
DISCIPLINE SPECIFIC CORE COURSES (DSC)				
PBSC411: Advances in Crop Biotechnology	3	0	1	4
PBSC412: Plant Secondary Metabolism and Applications	3	0	1	4
DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)				
*PBSE413: Epigenetics and Small RNA Biology	3	0	1	4
\$PBSE414: Data Analytics and Biocuration	3	1	0	4
*PBSE415: Plant Phenomics	3	1	0	4
*PBSE416: Synthetic Biology	3	1	0	4
SKILL ENHANCEMENT COURSE				
PBSEC417: Advanced Research Methodology	1	0	1	2
TOTAL CREDITS IN SEMESTER 4				22

\$PBSE414 is open to students from other departments as a generic elective.

Three DSEs OR two DSEs* and one generic elective\$ (courses offered by any FIAS departments, including DPMB) can be selected.*

Second-Year Course Details (Structure 2 - PG with Coursework and Research)

PART- II		Semester 3		
Name of the Course		Credit Distribution of the Course		
	Theory/ Lecture	Tutorial	Practical	Total Credits
DISCIPLINE SPECIFIC CORE COURSES (DSC)				
PBSC321: Plant Biotechnology	3	0	1	4
PBSC322: Molecular Plant Breeding	3	0	1	4
DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)				
*PBSE323: Metagenomics of Plant-associated Microbes	3	1	0	4
*PBSE324: Frontiers in Plant Molecular Biology	3	0	1	4
\$PBSE325: Introduction to Bioinformatics	3	1	0	4
DISSERTATION				
PBRE326: Dissertation-I	0	0	6	6
TOTAL CREDITS IN SEMESTER 3				22

\$PBSE325 is open to students from other departments as a generic elective.

Two DSEs OR one DSEs* and one generic elective\$ (courses offered by any FIAS departments, including DPMB) can be selected.*

PART- II		Semester 4		
Name of the Course		Credit Distribution of the Course		
	Theory/ Lecture	Tutorial	Practical	Total Credits
DISCIPLINE SPECIFIC CORE COURSES (DSC)				
PBSC421: Advances in Crop Biotechnology	3	0	1	4
PBSC422: Plant Secondary Metabolism and Applications	3	0	1	4
DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)				
*PBSE423: Epigenetics and Small RNA Biology	3	0	1	4
\$PBSE424: Data Analytics and Biocuration	3	1	0	4
*PBSE425: Plant Phenomics	3	1	0	4
DISSERTATION				
PBRE426: Dissertation-II	0	0	6	6
TOTAL CREDITS IN SEMESTER 4				22

*\$PBSE424 is open to students from other departments as a generic elective.
Two DSEs* OR one DSE* and one generic elective\$ (courses offered by any FIAS departments, including DPMB) can be selected.*

Second-Year Course Details (Structure 3 - PG with Research)

PART- II		Semester 3		
Name of the Course		Credit Distribution of the Course		
	Theory/ Lecture	Tutorial	Practical	Total Credits
DISCIPLINE SPECIFIC CORE COURSES (DSC)				
PBSC331: Plant Biotechnology	3	0	1	4
DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)*				
PBSE334: Frontiers in Plant Molecular Biology	3	0	1	4
PBSE335: Introduction to Bioinformatics	3	1	0	4
RESEARCH METHODS/TOOLS/WRITING COURSES				
PBRM332: Advanced Research Methodology	1	0	1	2
PBRM333: Emerging Techniques in Plant Biology	1	0	1	2
DISSERTATION				
PBRE336: Dissertation-I	0	0	10	10
TOTAL CREDITS IN SEMESTER 3				22

*At least one elective course to be selected.

PART- II		Semester 4		
Name of the Course		Credit Distribution of the Course		
	Theory/ Lecture	Tutorial	Practical	Total Credits
DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)*				
PBSE433: Epigenetics and Small RNA Biology	3	0	1	4
PBSE434: Data Analytics and Biocuration	3	1	0	4
RESEARCH METHODS/TOOLS/WRITING COURSES				
PBRM431: Research Presentation and Communication	1	0	1	2
DISSERTATION				
PBRE432: Dissertation-II	0	0	16	16
TOTAL CREDITS IN SEMESTER 4				22

*At least one elective course to be selected.

Selection of Elective Courses

In each semester, students should opt for a specified number of Discipline Specific Elective (DSE) papers offered by the PMB department or open DSE/ generic elective (GE) papers offered by the sister departments of FIAS, UDSC. A minimum of **SIX** students must opt for the DSE/GE paper to be offered during the semester.

f. Eligibility for Admissions:

- A 3-year/6-semester bachelor's degree with a minimum of 120 credits for a 2-year/4-semester PG programme at level 6.5 on the National Higher Education Qualifications Framework (NHEQF).
- A student is eligible for admission in PMBB PG programs if the student qualifies the required papers of the Common University Entrance Test [CUET-(PG)] examination or the Graduate Aptitude Test-Biotechnology (GAT-B) examination (for DBT-supported postgraduate seats).
- All admissions are made in the order of merit in each category, which is based on the marks secured in the CUET(PG) or GAT-B examinations.
- An appropriate number of seats is reserved for the candidates belonging to reserved categories, and relaxation is applicable as per the university norms.

g. Assessment of Students' Performance:

The assessment of students in each semester under PGCF 2025 will be as per the University Notification No. Exam. VIII/Conduct/Misc./2025/12/19(i), dated: September 01, 2025 (Attached as Annexure- I) or any subsequent notifications. English shall be the medium of instruction and examination. The theory examination and internal assessment shall be a cumulative assessment of the teaching and learning in theory and tutorial classes. The end-term written examination for each course/paper shall be conducted at the end of the semester, as per the academic calendar notified by the University of Delhi. The distribution of marks for various courses is:

Total Credits	Lectures	Tutorials	Practical	End Term Theory Exam Marks	Duration of Theory Exam	Internal Assessment (IA) Marks	Tutorial CA	Practical Marks				Grand Total Marks
								CA	End Term Practical	Viva - voce	Total	
4	3	1	0	90	3 hrs	30	40	0	0	0	0	160
4	3	0	1	90	3 hrs	30	0	10	20	10	40	160
4	0	0	4	0	NA	0	0	40	80	40	160	160
4	1	0	3	30	1 hr	10	0	30	60	30	120	160
4	2	0	2	60	2 hrs	20	0	20	40	20	80	160
2	1	0	1	30	1 hr	10	0	10	20**	10	40	80
2	0	0	2	0	NA	0	0	20	40**	20	80	80

(IA= Internal Assessment; CA= Continuous Assessment; NA= Not Applicable)

**In the case of two credit courses (Skill-Based Courses), which have practical components, there may be either an end-term practical examination or an end-term written examination, as per the nature of the course.

In any course where 1 credit is attributed to 'Tutorial', an objective assessment process must be developed to adequately assess and record the credit earned by a student in each course. Further, out of forty marks allocated for the Continuous Assessment of 01 credit tutorial, five marks shall be for attendance, which shall be distributed as follows:

- 67% attendance or more but less than 70% attendance – 1 mark
- 70% attendance or more but less than 75% attendance – 2 marks
- 75% attendance or more but less than 80% attendance – 3 marks
- 80% attendance or more but less than 85% attendance – 4 marks
- 85% attendance or more – 5 marks

h. Guidelines for the Award of Internal Assessment Marks:

The Internal Assessment (Assignments/Presentations and class tests) will be conducted in a continuous mode throughout the semester. Internal Assessment (IA) marks shall be 25% of the total marks of theory. For instance, if a course is of 4 credits having Lecture-Tutorial-Practical credits (3-1-0), the total marks of the course shall be 160 marks (4 credits x 40 marks), the total theory component shall be of 120 marks (3 credits x 40 marks), out of which 90 marks shall be for the end-term written exam and the IA

component shall be of 30 marks (25% of 120 marks). Out of the 30 marks, 12 marks for class test and 12 marks for Assignments/Presentations, and 6 marks shall be for attendance. These six marks for attendance shall be distributed as follows:

- 67% attendance or more but less than 70% attendance – 1.2 marks
- 70% attendance or more but less than 75% attendance – 2.4 marks
- 75% attendance or more but less than 80% attendance – 3.6 marks
- 80% attendance or more but less than 85% attendance – 4.8 marks
- 85% attendance or more – 6.0 marks

i. Pass Percentage & Promotion Criteria:

- As per the UGC/University Examination Rules.

j. Conversion of Marks into Grades:

- As per the UGC/University Examination Rules.

k. Grade Points:

- As per the UGC/University Examination Rules.

l. CGPA Calculation:

- As per the UGC/University Examination Rules.

m. SGPA calculation:

- As per the UGC/University Examination Rules.

n. Grand SGPA calculation:

- As per the UGC/University Examination Rules.

o. Conversion of Grand CGPA into marks:

- As per the UGC/University Examination Rules.

p. Division of Degree into Classes:

- As per the UGC/University Examination Rules.

q. Attendance Requirement:

- As per the UGC/University Examination Rules.

r. Exit Point:

- Students who join a two-year postgraduate programme shall have only one exit point.

s. Span Period:

- As per the UGC/University Examination Rules.

IV. Course-wise Content Details for the PMBB Programme

SEMESTER 1

PBSC101: Basic Molecular Biology and Genetics

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC101: Basic Molecular Biology and Genetics	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The course aims to deliver in-depth knowledge of molecular biology with emphasis on genomic stability, DNA replication, transcription, translation, and gene regulation to the students using prokaryotic model systems. This course will also provide a deep understanding of genetic principles, from Mendelian inheritance to modern molecular genetics. Students will explore gene interactions, linkage, mapping techniques, and quantitative genetics. Through theoretical knowledge and analytical techniques, students will develop experimental and analytical skills in genetics and molecular biology.

Learning Outcomes

Upon completion, students will understand the processes of DNA replication, transcription, and translation, as well as the models of gene regulation. Students will have a strong foundation in classical and molecular genetics, enabling them to analyze genetic inheritance, gene mapping, and genome stability mechanisms. Students will develop skills in applying genetic analysis tools and interpreting experimental data. Students will learn methods to estimate point mutation, homologous recombination, and transposition. Further, students will acquire skills in cytogenetic techniques for chromosome analysis.

Course Content (45 hours)

Unit 1: Mechanism of Replication in Prokaryotes -- DNA polymerases and accessory proteins; Proteins at the origin of replication and replication fork; Concept of replicon; Fidelity of replication; Control of replication of chromosomes and extrachromosomal elements. **6 hours**

Essential Readings: Weaver, R.F. (2012) Molecular Biology. McGraw Hill, UK, ISBN:9780073525327, Chapter 20 (DNA Replication); Griffiths, A., et al. (2020) Introduction to Genetic Analysis. 12th edition, W.H. Freeman, USA, ISBN:9781319114787, Chapter 7 (DNA: Structure and Replication); Krebs, J.E., et al. (2018) Lewin's Genes XII. Jones and Bartlett Publishers Inc., USA, ISBN:9781284104493, Chapter 1 (DNA Replication).

Unit 2: Prokaryotic Transcription, Translation, and its Regulation -- Discovery of RNA; Initiation of transcription: Promoters and other control elements; RNA polymerases and accessory factors; Sigma factors and their interactions with promoters; Transcriptional controls; Concept of operons; Transcription termination; Rho factor and polar mutations; Gene regulation in Bacteriophages: lysogenic and lytic cycles, regulation of gene expression; Initiation, elongation, and termination of translation and the accessory proteins; Structural and

functional studies on ribosomes: ribosomal RNAs and proteins; Mapping the decoding and peptidyl transferase sites of ribosome; Transfer RNAs and genetic code; Translational fidelity.

16 hours

Essential Readings: Weaver, R.F. (2012) Molecular Biology. McGraw Hill, UK, ISBN:9780073525327, Chapter 6 (The mechanism of transcription in bacteria), Chapter 7 (Operons: fine control of bacterial transcription), Chapter 8 (Major shifts in bacterial transcription), Chapter 17 (The mechanism of translation I: Initiation), Chapter 18 (The mechanism of translation II: Elongation and termination).

Unit 3: Mendelian Principles, Gene Mapping, and Quantitative Genetics – Introduction to Mendelian Genetics; codominance, incomplete dominance, gene interactions (epistasis), pleiotropy, penetrance and expressivity, linkage and crossing over, sex linkage, genome imprinting; Genetic and physical maps; Molecular markers: RFLP, RAPD, AFLP, SSR, SNP; Mapping genes by interrupted mating, polygenic inheritance, QTL (Quantitative Trait Locus) mapping, LOD (Logarithm of Odds) score for linkage testing, pedigree analysis, karyotypes, tetrad analysis, Chi-square test in linkage analysis.

15 hours

Essential Readings: Griffiths, A., et al. (2020) Introduction to Genetic Analysis. 12th edition, W.H. Freeman, USA, ISBN:9781319114787, Chapter 2 (Single-gene inheritance), Chapter 3 (Independent assortment of genes), Chapter 4 (Mapping eukaryote chromosomes by recombination), Chapter 5 (Gene interaction), Chapter 18 (Population genetics), Chapter 19 (The inheritance of complex traits).

Unit 4: Maintenance of Genomic Flexibility and Integrity -- Spontaneous and induced mutations; Mutagens; Mechanisms of homologous and site-specific recombination (NHEJ, HR, MMEJ); Mechanism of meiotic crossing-over; DNA repair and retrieval systems; Transposons and retro-transposons.

8 hours

Essential Readings: Clarke, D. and Pazdernik, N. (2013) Molecular Biology. Academic Cell, USA, ISBN: 9780123785947, Chapter 13–15 (Mutations, recombination, and repair); Weaver, R.F. (2012) Molecular Biology. McGraw Hill, UK, ISBN:9780073525327, Chapter 20 (DNA replication, damage, and repair), Chapter 22 (Homologous recombination), Chapter 23 (Transposition).

Practicals (30 hours)

1. Extraction and analysis of genomic DNA from bacteria.
2. To perform bacteriophage plaque assay.
3. Study of frameshift mutation and homologous recombination by histochemical assays.
4. Visualization of chromatin structure using DAPI staining.
5. Analysis of cell ploidy by chromosomal counting at metaphase/flow cytometry.

Suggested Readings:

1. Clarke, D. and Pazdernik, N. (2013) Molecular Biology. Academic Cell, USA, ISBN:9780123785947.
2. Griffiths, A., et al. (2020) Introduction to Genetic Analysis. 12th edition, W.H. Freeman, USA, ISBN:9781319114787.
3. Tropp, B.E. (2014) Principles of Molecular Biology, Jones and Bartlett, USA, ISBN:9781449689179.
4. Weaver, R.F. (2012) Molecular Biology. McGraw Hill, UK, ISBN:9780073525327.
5. Krebs, J.E., et al. (2018) Lewin's genes XII. Jones & Bartlett Learning, ISBN:9781284104493.

PBSC102: Molecular Cell Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSC102: Molecular Cell Biology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This paper is designed to provide an in-depth understanding of cell biology, focusing on the molecular and biochemical processes that regulate cellular functions. A key emphasis is placed on the molecular organization of biological macromolecules and their role in forming distinct subcellular structures, enabling the precise coordination of essential cellular processes.

Learning Outcomes

Students would learn about the structure-function relationship of cellular organelles from a molecular perspective, focusing on macromolecules at both cellular and subcellular levels. Students will explore key molecular, biochemical, and imaging techniques employed for studying cells and cellular processes. By integrating mechanistic insights, this course will equip students with the knowledge to design strategies for manipulating cellular processes to address challenges in managing nutrition and food security.

Course Content (45 hours)

Unit 1: Investigating the Cell and Cell wall -- Fundamentals of microscopy and imaging, techniques for analyzing the cell and its organelles; Cell wall composition and architecture, biogenesis and assembly, dynamic aspects of the cell wall during growth and differentiation.

9 hours

Essential Readings: Alberts, B., et al. (2022) Molecular Biology of the Cell. W.W. Norton & Company, ISBN: 9780393884821, Chapter 9 (Visualizing cells and their molecules); Buchanan, B.B, et al. (2015) Biochemistry and Molecular Biology of the Plants, American Society of Plant Physiologists, USA, ISBN:9780470714225, Chapter 2 (The Cell Wall).

Unit 2: Membrane and Endomembrane Systems -- Structural models, composition and dynamics; Transport of ions and macromolecules: transporters and channels; Sensory physiology; Endo- and exo-cytosis; Membrane proteins and carbohydrates and their significance in cellular processes; Structure and function of Golgi apparatus, lysosomes and endoplasmic reticulum and microbodies; Intracellular membrane trafficking and vesicular transport; Membrane maturation and specialization, extracellular vesicles, multivesicular bodies, Kajal bodies, dicing bodies, and cytoplasmic bodies.

20 hours

Essential Readings: Buchanan, B.B, et al. (2015) Biochemistry and Molecular Biology of the Plants. American Society of Plant Physiologists, USA, ISBN:9780470714225, Chapter 3 (Membrane transport); Alberts, B., et al. (2022) Molecular Biology of the Cell. W.W. Norton & Company, ISBN:9780393884821, Chapter 10 (Membrane structures), Chapter 11 (Small-molecule transport and electrical properties of membranes), Chapter 12 (Intracellular organizations and protein sorting), Chapter 13 (Intracellular membrane traffic).

Unit 3: Mitochondria, Chloroplast, and Nucleus – Structure; Organization; Structure-function relationship; Import and export of molecules; Biogenesis, origin and evolution;

Structure and function (architecture); Chromatin organization and packaging: heterochromatin, euchromatin, nucleosomes; Nuclear envelope and nuclear pore complex, Import and export of molecules. 12 hours

Essential Readings: Alberts, B., et al. (2022) Molecular Biology of the Cell. W.W. Norton & Company, ISBN: 9780393884821, Chapter 14 (Energy conversion and metabolic compartmentation: Mitochondria and Chloroplasts); Kleinsmith, L.J. and Kish, V.M. (1996) Principles of Cell & Molecular Biology, Harper Collins College Publishers, USA, ISBN:9780065004045, Chapter 10 (The nucleus and transcription of genetic information).

Unit 4: Cytoskeleton and Cellular Motility -- Organization and role of microtubules and microfilaments; Actin-binding proteins and their significance; Molecular motors; Intermediate filaments. 4 hours

Essential Readings: Alberts, B., et al. (2022) Molecular Biology of the Cell. W.W. Norton & Company, ISBN:9780393884821, Chapter 16 (The cytoskeleton); Buchanan, B.B, et al. (2015) Biochemistry and Molecular Biology of the Plants. American Society of Plant Physiologists, USA, ISBN:9780470714225, Chapter 5 (The cytoskeleton).

Practicals (30 hours)

1. High-resolution imaging of epidermal peel cells of *Arabidopsis thaliana*/ *Nicotiana benthamiana* under confocal microscope.
2. Transient expression of fluorescent-tagged protein via *Agrobacterium*-based infiltration of leaf epidermal cells.
3. Monitor the localization of fluorescent-tagged protein at the subcellular level under a confocal microscope.
4. Preparation and visualization of leaf protoplasts of *Arabidopsis thaliana*/*Nicotiana benthamiana*.
5. To study the pollen viability and the effect of calcium on pollen germination.

Suggested Readings:

1. Alberts, B., et al. (2022) Molecular biology of the cell. W.W. Norton & Company, ISBN:9780393884821.
2. Buchanan, B.B, et al. (2015) Biochemistry and molecular biology of the plants. American Society of Plant Physiologists, USA, ISBN:9780470714218.
3. Karp, J.G. (2019) Cell and Molecular Biology. John Wiley & Sons, USA, ISBN:9781119598169.
4. Kleinsmith, L.J. and Kish, V.M. (1996) Principles of cell & molecular biology. HarperCollins College Publishers, USA, ISBN:978-0065004045.
5. Lodish, H., et al. (2016) Molecular cell biology. Freeman & Co., USA, ISBN:9781464183393.
6. Ruzin, S.E. (1999) Plant microtechniques and microscopy. Oxford University Press, USA, ISBN:9780195089561.

PBSC103: Recombinant DNA Technology - Concepts, Techniques, and Applications

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSC103: Recombinant DNA Technology - Concepts, Techniques, and Applications	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The course is designed to provide a comprehensive understanding of the principles, methodologies, and tools in recombinant DNA technology. This will familiarize students with advanced techniques in molecular biology and equip them with hands-on knowledge about genetic engineering tools. Furthermore, they will learn about the applications of recombinant DNA technology in agriculture, medicine, and industry, while addressing ethical, social and regulatory concerns. The course will prepare students for research and innovation in emerging fields such as synthetic biology, metabolic engineering, and genome editing. It will also provide a foundation for students to develop advanced knowledge for succeeding semesters.

Learning Outcomes

The candidate will develop an in-depth knowledge of the principles and applications of instrumentation, as well as basic and cutting-edge tools and techniques in recombinant DNA technology. Students will get acquainted with designing/conducting, and analyzing experiments and experimental data, respectively. The integration of theory and problem-solving exercises will motivate students to develop a keen research interest and enhance their understanding of the topics they are taught. They will be able to evaluate the impact of recombinant DNA technology in agriculture, healthcare, and industry. The course will enable students to develop innovative solutions in genetic engineering, synthetic biology, and protein engineering for real-world challenges.

Course Content (45 hours)

Unit 1: Introduction to Recombinant DNA Technology -- Historical perspectives and milestones; Basic principles and concepts; Methods of nucleic acids and protein analysis: Isolation and purification, electrophoresis techniques; Overview of genetic engineering tools.

6 hours

Essential Readings: Berg, P., et al. (2010) Personal reflections on the origins and emergence of recombinant DNA technology. *Genetics*, 184(1):9–17. DOI:10.1534/genetics; Primrose, S.B. and Twyman, R.M. (2006) *Principles of Genetic Manipulation and Genomics*. 7th edition. Blackwell Publishing, UK, ISBN:9781405135443, Chapter 1 (Gene manipulation: an all-embracing technique), Chapter 2 (Basic techniques), Chapter 3 (Cutting and joining DNA molecules).

Unit 2: DNA Cloning Methodologies and PCR -- Key enzymes: restriction endonucleases, nucleic acid modifying enzymes; Advanced cloning methods: TA cloning, topoisomerase-

based cloning, ligation-independent cloning, Gateway technology, Gibson cloning; Vectors for gene cloning: plasmids, phages, phagemids, cosmids, and other advanced vectors for cloning large DNA fragments; Methods for selection and screening of recombinant clones; Host systems: bacteria, yeast, and plant cells; Isolation of gene of interest: Direct selection, construction and screening of genomic and cDNA libraries, labelling and detection of nucleic acids, enriching clones by subtractive cloning and differential screening, differential display; Polymerase Chain Reaction (PCR): concept and enzymes employed, optimization of PCR, types of PCR (touch-up, touch-down, hot-start, inverse, nested, gradient, Rapid Amplification of cDNA Ends (RACE), semi-quantitative and quantitative, Gene Splicing by Overlap Extension (gene SoEing), and applications of PCR; DNA sequencing methods. **15 hours**

Essential Readings: Primrose, S.B. and Twyman, R.M. (2006) Principles of Genetic Manipulation and Genomics. 7th edition. Blackwell Publishing, UK, ISBN:9781405135443, Chapter 4 (Basic biology of plasmid and phage vectors), Chapter 5–9, 12 (Basic biology of plasmid and phage vectors, Cosmids, phasmids and other advanced vectors, Cloning strategies, Sequencing and mutagenesis, Cloning in bacteria other than *E. coli*, Cloning in *Saccharomyces cerevisiae* and other fungi, Gene transfer to plants); Brown, T.A. (2020) Gene Cloning and DNA Analysis: An Introduction. 8th edition. Wiley-Blackwell Publishing, UK, ISBN:9781119640783, Chapter 1–13 (Why Gene Cloning and DNA Analysis are important, Vectors for Gene Cloning: Plasmids and Bacteriophages, Purification of DNA from Living Cells, Manipulation of Purified DNA, Introduction of DNA into Living Cells, Cloning Vectors for *E. coli*, Cloning Vectors for Eukaryotes, How to Obtain a Clone of a Specific Gene, The Polymerase Chain Reaction, Sequencing Genes and Genomes, Studying Gene Expression and Function, Studying Genomes, Studying Transcriptomes and Proteomes, Production of Protein from Cloned Genes).

Unit 3: Methods to Study Gene Expression, Biomolecular Interactions and Protein Expression Systems -- Gene expression analyses at the transcriptional level (Northern blotting and its variants, real-time PCR, S1 nuclease mapping, *in situ* hybridization, RNase protection, nuclear run-on assays), translational level: Western blotting, Enzyme-Linked ImmunoSorbent Assay (ELISA) and immunofluorescence assays; DNA-protein: Electrophoretic Mobility Shift Assay (EMSA), DNase I footprinting, Chromatin ImmunoPrecipitation (ChIP), Yeast one-hybrid (Y1-H), RNA-protein: Y3-H, northwestern, RNA ImmunoPrecipitation (RIP); protein-protein interaction: Y2-H, pull down, Co-ImmunoPrecipitation (Co-IP), Fluorescence Resonance Energy Transfer (FRET), Bimolecular Fluorescence Complementation (BiFC); Protein Expression and Engineering: Tagging and overexpression of proteins in heterologous systems (*E. coli*, yeast, baculovirus, and mammals); Methods for mutagenesis of genes for obtaining altered proteins. **15 hours**

Essential Readings: Primrose, S.B. and Twyman, R.M. (2006) Principles of Genetic Manipulation and Genomics. 7th edition. Blackwell Publishing, UK, ISBN:9781405135443, Chapter 11 (Studying Gene Expression and Function); Segundo-Val, A.S., et al. (2016) Introduction to gene expression analysis. Methods in Molecular Biology, 1434:29-43. DOI:10.1007/978-1-4939-3652-6_3; Ferraz, R.A.C., et al. (2021) DNA-protein interaction studies: a historical and comparative analysis. Plant Methods, 17:82, DOI:10.1186/s13007-021-00780-z; Ramanathan, M., et al. (2019) Methods to study RNA-protein interactions. Nature Methods, 16:225–234. DOI:10.1038/s41592-019-0330-1; Rao, V.S., et al. (2014) Protein-protein interaction detection: methods and analysis. International Journal of Proteomics, 2014:147648, DOI:10.1155/2014/147648; Baranowski, C., et al. (2025) Can protein expression be ‘solved’? Trends in Biotechnology, 43(11):2724–2742. DOI:10.1016/j.tibtech.2025.04.021; Xia, Y., et al. (2015) New insights into the QuikChange™ process guide the use of Phusion DNA polymerase for site-directed mutagenesis. Nucleic Acids Research, 43(2):e12, DOI:10.1093/nar/gku1189.

Unit 4: Applications and Ethics of Recombinant DNA Technology -- Production of recombinant molecules for improving agronomic traits, diagnostic and therapeutic applications in human diseases; Impact and biosafety, moral, social, regulatory and ethical concerns; Future

perspectives and emerging trends (introduction to gene editing, synthetic biology, and genome engineering, the role of artificial intelligence or AI, etc.) 9 hours

Essential Readings: Begna, T. and Okonkwo, J.C. (2020) Role of Recombinant DNA Technology in Agriculture. International Journal of Agriculture and Biosciences, 9(5):254–259; www.ijagbio.com; Khan, S., et al. (2016) Role of recombinant DNA technology to improve life. International Journal of Genomics, 2016:2405954. DOI:10.1155/2016/2405954; Bharathi, J.K., et al. (2024) Exploring recent progress of molecular farming for therapeutic and recombinant molecules in plant systems. Heliyon, 10(18):e37634. DOI:10.1016/j.heliyon.2024.e37634; Sharma, R., et al. (2022) Chapter on ‘Ethical and Safety Concerns of Recombinant DNA Technology. In: A Complete Guide to Gene Cloning: From Basic to Advanced. Springer, ISBN:978-3-030-96850-2; Gholap, A.D., et al. (2025) Advances in artificial intelligence-envisioned technologies for protein and nucleic acid research. Drug Discovery Today, 30(5):10436, DOI:10.1016/j.drudis.2025.104362; Sun, S. (2025) Advancing Genetic Engineering through AI: Sequencing and Editing Innovations. Theoretical and Natural Science, 90(1):48–53, DOI:10.54254/2753-8818/2025.GU20450.

Practicals (30 hours)

1. Transformation of bacterial competent cells followed by blue-white screening for identification of recombinant plasmid.
2. Colony PCR for screening of recombinant plasmids.
3. Isolation of plasmid DNA from *E. coli* culture and quantitation of DNA.
4. Restriction digestion of plasmid DNA and resolution of the digested DNA by agarose gel electrophoresis.
5. Induction of protein expression in a heterologous bacterial system and analysis of the expressed protein using SDS-PAGE.

Suggested Readings:

1. Brown, T.A. (2020) Gene Cloning and DNA Analysis: An Introduction. 8th edition. Wiley-Blackwell Publishing, UK, ISBN:9781119640783.
2. Brown, T.A. (2024) Genomes 5. 5th edition. CRC Press, India, ISBN:9780367674076.
3. Dale J.W., et al. (2011) From Genes to Genomes: Concepts and Applications of DNA Technology. 3rd edition. John Wiley & Sons, UK, ISBN:9780470683859.
4. Glick B.R. and Patten C.L. (2022) Molecular Biotechnology: Principles and Applications of Recombinant DNA. 6th edition. ASM Press, USA, ISBN:9781683673668.
5. Watson, J.D, et al. (2006) Recombinant DNA: Genes and Genomes. 3rd edition. W.H. Freeman & Co, India, ISBN:9780716728665.
6. Green M.R. and Sambrook J. (2012) Molecular Cloning: A Laboratory Manual. 4th edition. CSHL Press, USA, ISBN:9781936113422.
7. Primrose, S.B. and Twyman, R.M. (2006) Principles of Genetic Manipulation and Genomics. 7th edition. Blackwell Publishing, UK, ISBN:9781405135443.

PBSE104: Plants in Human Health and Nutrition

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE104: Plants in Human Health and Nutrition	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

Plants play a crucial role in human health and nutrition by providing essential nutrients, bioactive compounds, and medicinal properties that support our well-being. The course aims to highlight the role of plants in human health and nutrition, and to explore the molecular basis of bioactive compounds found in plants. The students will gain knowledge of plant-derived pharmaceuticals, nutraceuticals, and functional food. Furthermore, strategies for improving plant nutrition and ethical issues will be taught.

Learning Outcomes

The students will be able to understand the role of plants in human life, analyse functional foods and nutraceuticals. They will be able to comprehend the molecular basis of phytochemical synthesis and explore the plants as pharmaceuticals. Utilizing this knowledge, the students will be able to design innovative and novel strategies for plant biofortification and metabolic engineering to develop novel plant-based foods and sustainable nutritional and drug resources.

Course Content (45 hours)

Unit 1: Role of Plants in Human Health and Nutrition -- Plants in human health from a biochemical perspective; History of plant-based nutrition and medicinal plants; Role of secondary metabolites in human health; Molecular basis of bioactive compounds and biosynthetic pathways. 10 hours

Essential Readings: Raskin, I., et al. (2002) Plants and human health in the twenty-first century. Trends in Biotechnology, 20(12):522–31, DOI:10.1016/s0167-7799(02)02080-2; El-Ramady, H., et al. (2022) Plant nutrition for human health: A pictorial review on plant bioactive compounds for sustainable agriculture. Sustainability, 14:8329, DOI:10.3390/su14148329; Xue, J., Yin, Y. (2024) Plant-based food: From nutritional value to health benefits. Foods, 13:3595, DOI:10.3390/foods13223595; Shahnawaz, M. and Sharma, P. (2026) Secondary metabolites for improvement of human health. Edited by: Srivastava A., and Mishra, A.K. In: Developments in applied microbiology and biotechnology, Secondary metabolites in stress and disease management, Academic Press, ISBN:9780443339592; Guo, M., et al. (2023) Strategies on biosynthesis and production of bioactive compounds in medicinal plants. Chinese Herbal Medicines, 16(1):13–26, DOI: 10.1016/j.chmed.2023.01.007.

Unit 2: Plant-based Nutraceuticals and Medicine Systems -- Phytochemicals, Traditional and non-traditional nutraceuticals; Plant-derived probiotics and prebiotics; Biotechnological approaches for biofortification for enhanced nutrition; Plant-based Medicine Systems: Traditional knowledge and ethnobotany; Ayurvedic, Yoga, Unani, Siddha, and Homeopathic (AYUSH), other traditional systems; Modern systems of plant-based medicine and their importance in human health. 15 hours

Essential Readings: Herbal Nutraceuticals: Products and Processes. (2024) Edited by: Upadhyay, S.K. and Singh, S.P., John Wiley & Sons Ltd., ISBN:9781394241545, Chapter 1 (Plants Based Nutraceuticals: An Overview), Chapter 2 (Herbal Nutraceutical as Alternative Medicine), Chapter 10 (The flavorful world: Exploring the applications of spices in nutraceuticals)]; Manisha, M., et al. (2025) Medicinal plants and traditional uses and modern applications. *Journal of Neonatal Surgery*, 14(3):162–175, DOI:10.52783/jns.v14.2210; https://ayushedu.bisag-n.gov.in/AYUSH_EDU/ayushknowledge.

Unit 3: Plants as Source of Pharmaceuticals -- Medicinal plants; Traditional plant-based formulations; Plant-derived molecules in drug development; Therapeutic use of poisonous plants; Pharmacogenomics; Ayurgenomics; Metabolic engineering for enhanced bioactive production; Good manufacturing practices (GMPs). 10 hours

Essential Readings: Wang, X., et al. (2025) Plant-based traditional remedies and their role in public health: ethnomedicinal perspectives for a growing population. *Journal of Health Population and Nutrition*, 44(1):300, DOI:10.1186/s41043-025-01036-5; Nasim, N., et al. (2022) Plant-derived natural products for drug discovery: current approaches and prospects. *Nucleus (Calcutta)*, 65(3):399–411, DOI:10.1007/s13237-022-00405-3; Rajbongshi, B.L. and Mukherjee, A.K. (2025) Drugs from poisonous plants: Ethnopharmacological relevance to modern perspectives. *Toxicon X*, 25:100215, DOI:10.1016/j.toxcx.2025.100215; Aneesh, T.P., et al. (2009) Pharmacogenomics: the right drug to the right person. *Journal of Clinical Medicine Research*, 1(4):191–194, DOI: 10.4021/jocmr2009.08.1255; Wallace, R.K. (2020) Ayurgenomics and Modern Medicine. *Medicina (Kaunas)*. 6(12):661, DOI:10.3390/medicina56120661; Martínez-Chávez, L.A. et al. (2024) Cutting-edge strategies to enhance bioactive compound production in plants: Potential value of integration of elicitation, metabolic engineering, and green nanotechnology. *Agronomy*, 14:2822, DOI:10.3390/agronomy14122822; <https://www.csir.res.in/en/csir-success-stories/ayurgenomics-bringing-age-old-wisdom-healthcare-future>; <https://www.who.int/teams/health-product-policy-and-standards/standards-and-specifications/norms-and-standards/gmp>; <https://www.genome.gov/about-genomics/educational-resources/fact-sheets/pharmacogenomics>.

Unit 4: Recent Advancements in Plant Science and Health – Plant vaccines; plant-focused biomanufacturing; DNA fingerprinting and barcoding of medicinal plants; Synthetic biology for producing plant-derived therapeutic agents; Plant-based meat alternatives and sustainable food sources; the role of microgreens and lower plants in nutrition; Climate change and its impact on beneficial plant compounds; Future perspectives and challenges; Ethical and regulatory guidelines. 10 hours

Essential Readings: Vo, D.K. and Trinh, K.T.L. (2025) Molecular farming for immunization: current advances and future prospects in plant-produced vaccines. *Vaccines*, 13:191, DOI:10.3390/vaccines13020191; Fujiyama, K., (2024) Recent advances in plant-based bioproduction. *Journal of Bioscience and Bioengineering*, 138(1):1–12, DOI:10.1016/j.jbiosc.2024.01.007; Chen, S., et al. (2023) DNA barcoding in herbal medicine: Retrospective and prospective. *Journal of Pharmaceutical Analysis*, 13(5):431–441, DOI:10.1016/j.jpha.2023.03.008; Selvakumari, E., et al. (2017) Application of DNA fingerprinting for plant identification. *Journal of Academia and Industrial Research*, 5(10):149–151, ISSN:2278-5213; Li, C.-Q., et al. (2021) Recent advances in the synthetic biology of natural drugs. *Frontiers in Bioengineering and Biotechnology*, 9:691152, DOI:10.3389/fbioe.2021.691152; Andreani, G., et al. (2023) Plant-based meat alternatives: Technological, nutritional, environmental, market, and social challenges and opportunities. *Nutrients*, 15(2):452. DOI:10.3390/nu15020452; Rawat, D., et al. (2025) Microgreens: cultivation, nutrition, journey to space and market trends. *International Journal of Plant & Soil Science*, 37(10):22–32, DOI:10.9734/ijpss/2025/v37i105758; Alum, E.U. (2024) Climate change and its impact on the bioactive compound profile of medicinal plants: implications for global health. *Plant Signalling and Behaviour*, 19(1):2419683, DOI:10.1080/15592324.2024.2419683; Subramaniam, A. (2014) Present scenario, challenges and future perspectives in plant-based medicine development. *Annals of Phytomedicine* 3(1):31–36; Henkhaus, N., et al. (2020) Plant science decadal vision 2020–2030: Reimagining the potential of plants for a healthy and sustainable future. *Plant Direct*, 4(8):e00252, DOI:10.1002/pld3.252.

Practicals (30 hours)

1. Pharmacognostic evaluation (macroscopic and microscopic) of medicinal plants.
2. Qualitative analysis of secondary metabolites: Alkaloids, Flavonoids, Tannins, Glycosides, etc.

3. Quantitative analysis of secondary metabolites: Alkaloids, Flavonoids.
4. Perform chromatographic analysis of plant extracts.
5. Survey of medicinally important plants.

Suggested Readings:

1. Kumar, S., et al. (2022) Biofortification of staple crops. Springer Nature Singapore Pte Ltd., ISBN:9789811632792.
2. Crozier, A., et al. (2006) Plant secondary metabolites: occurrence, structure and role in the human diet. Blackwell Publishing Ltd., ISBN:9781405125093.
3. Simopoulos, A.P. and Gopalan, C. (2003) Plants in Human Health and Nutrition Policy, Volume 91, S. Karger AG, ISBN:9783805575546, DOI:10.1159/isbn.978-3-318-00954-5.
4. The Ayurvedic Pharmacopoeia of India, Part I, Part II, Vol I- Vol III. Council for Research in Ayurvedic Sciences (CCRAS).
5. Database on Medicinal Plants used in Ayurveda and Siddha, Vol I- Vol VIII, Central Council for Research in Ayurvedic Sciences (CCRAS).
6. Chowdhury, S.R. (2023) Textbook of food science and nutrition. Aarahan Publishers, ISBN:9789387270084.
7. Mudambi, R.S. and Rajagopal, M.V (1983) Foods and Nutrition. Wiley Eastern Ltd. 2nd edition, New Delhi, ISBN:9780852265833.
8. Keservani, R.K. (2024) Plant metabolites and vegetables as nutraceuticals. Academic Press, ISBN:9781774915448.
9. Usman, S. and Budhrani N. (2020) Textbook of medicinal plant biotechnology. S Vikas and Company.
10. Bharti, P.K. (2018) Nutraceuticals and pharmaceutical from medicinal plants, Discovery Publishing House Pvt. Ltd., ISBN:9789386841551.

PBSE105: Laboratory Instrumentation and Safety

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE105: Laboratory Instrumentation and Safety	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The course aims to equip students with a comprehensive understanding of the essential laboratory instruments used in molecular biology, biotechnology, and related fields. It is designed to expose them to best practices and regulatory compliance necessary for maintaining a safe and efficient research environment.

Learning Outcomes

Students will understand the principles, operation, and applications of various laboratory instruments. They will develop proficiency in instrument calibration, maintenance, and troubleshooting to ensure accurate and reliable experimental outcomes. Students will gain hands-on experience with state-of-the-art laboratory equipment, preparing them for advanced research and industrial settings. They will also develop a strong understanding of laboratory best practices, including biosafety measures, waste disposal, and emergency response protocols.

Course Content (45 hours)

Unit 1: Introduction to Laboratory Safety and Waste Management -- Laboratory safety guidelines: safety rules, biosafety levels (BSL1–BSL4), handling biological specimens; Chemical, biological, and radiation safety: chemical and biological material labelling and inventory management; Chemical/non-chemical storage guidelines, transportation and usage precautions, chemical hazard and safety datasheets, safe handling of carcinogens, mutagens, and toxic chemicals, compressed gas cylinders and liquid cryogen containers; Biosafety cabinets and laminar airflow systems; Emergency preparedness and waste management: fire hazards, first-aid procedures for chemical spillage and exposure; Hazardous waste minimization and accumulation rules; Disposal of infectious or biological waste, including GMOs (modified microbes, transgenic plants). **15 hours**

Essential Readings: Mourya, D.T., et al. (2014) Establishment of Biosafety Level-3 (BSL-3) laboratory: important criteria to consider while designing, constructing, commissioning & operating the facility in Indian setting. Indian Journal of Medical Research, 140(2):171–183, PMID: PMC4216491; Regulations & Guidelines for Recombinant DNA Research and Biocontainment (2017), published by DBT, India. (https://dbtindia.gov.in/sites/default/files/uploadfiles/Regulations_%26_Guidelines_for_Reocminant_DNA_Research_and_Biocontainment%2C2017.pdf); Laboratory biosafety manual, 3rd edition, WHO (<https://www.who.int/publications/i/item/9241546506>); Meehan, P.J. and Potts, J. (2020) Biosafety in microbiological and biomedical laboratories, 6th edition, U.S. Department of Health and Human Services, CS308133-A.

Unit 2: Radiological Laboratories and Radiation Safety -- Nature of Radioactivity, biological effects of ionising radiation, operational radiation exposure limits, radiation hazard evaluation and control, planning of radioisotope laboratories, regulatory aspects of radioisotope laboratories, disposal of radioactive waste. **8 hours**

Essential Readings: Wilson, K., et al. (Eds.). (2018). Wilson and Walker's principles and techniques of biochemistry and molecular biology. Cambridge University Press, ISBN:9781316677056, DOI: 10.1017/9781316677056, Chapter 9 (Radioisotope Techniques); The Atomic Energy (Safe disposal of radioactive wastes) Rules, 1987- for the safe disposal of radioactive wastes.

Unit 3: Essential Laboratory Instrumentation -- Operation, principles, calibrations, maintenance, and applications of general instruments: weighing balances, pH meter, autoclave, centrifuges, electrophoresis, spectrophotometers (UV-Vis and nanodrop), fluorometers, thermal cyclers (PCR, digital droplet PCR, and real-time PCR machines), incubators/shakers, chromatography, gel documentation system, phosphor imaging systems, Sanger sequencing instrumentation and techniques. **10 hours**

Essential Readings: Tiwari, R., et al. (2025) An electronic analytical balance: a key instrument in the laboratory. Journal of Pharmaceutical and Biopharmaceutical Research, 7(1):25–534, DOI:10.25082/JPBR.2025.01.002; Ramstorp, M. (2003) Contamination control in practice: filtration and sterilisation. Wiley-VCH, ISBN:9783527612604, DOI:10.1002/9783527612604, Chapter 4 (Autoclaves and processes for the pharmaceutical industry); Beard, A., et al. (2023) Ullmann's encyclopedia of industrial chemistry, Wiley-VCH Verlag, Chapter (pH measurement and control, DOI:10.1002/14356007.e19_e01.pub2), Chapter (Centrifuges, Sedimenting, DOI: 10.1002/14356007.c05_c02.pub2); Green, M.R. and Sambrook, J. (2019) Analysis of DNA by agarose gel electrophoresis. Cold Spring Harbor Protocols, DOI:10.1101/pdb.top100388; Hou, Y., et al. (2023). Droplet-based digital PCR (ddPCR) and its applications. Trends in Analytical Chemistry, 158:116897, DOI:10.1016/j.trac.2022.116897; Bilkova, Z., et al. (2025) Fundamentals of protein affinity chromatography: How to prepare and properly use an affinity matrix. Journal of chromatography, 1756:466061. DOI:10.1016/j.chroma.2025.466061; Asad, N., et al. (2023) Sustainable and cost-effective gel documentation. Methods and Protocols, 6(2):21, DOI:10.3390/mps6020021; Upham, L.V. and Englert, D. (2003) Handbook of radioactivity analysis, 2nd edition, Chapter 13 (Radionuclide imaging), DOI:10.1016/B978-012436603-9/50018-1.

Unit 4: Advanced Instrumentation in Plant Molecular Biology Research -- Electroporators, Surface Plasmon Resonance (SPR) Systems, Isothermal Titration Calorimeter (ITC), BioLayer Interferometry (BLI), *in vivo* imaging system, phytotrons and greenhouses, photosynthesis measurement systems, Flow cytometry: fluidic system, optical system, signal detection and processing system, Fluorescent-Activated Cell Sorting (FACS); High-throughput plant phenomics systems, smart remote agriculture monitoring systems (Internet of Things or IoT-based monitoring, AI-based precision monitoring, data loggers). **12 hours**

Essential Readings: Li, F., et al. (2025) Current advances and future prospects of bulk and microfluidic-enabled electroporation systems. Biotechnology and Bioengineering, 122(6):1347–1365, DOI:10.1002/bit.28965; Butt, M.A. (2025) Surface Plasmon Resonance-based biodetection systems: Principles, progress and applications- a comprehensive review. Biosensors, 15(1):35, DOI:10.3390/bios15010035; Bastos, M., et al. (2023) Isothermal titration calorimetry, Nature Reviews Methods Primers, 3:17, DOI:10.1038/s43586-023-00199-x; Jug, A. et al. (2024) Biolayer interferometry and its applications in drug discovery and development. Trends in Analytical Chemistry, 176:117741, DOI:10.1016/j.trac.2024.117741.

Practicals (30 hours)

1. Precision measurement and liquid handling using micropipettes.
2. Preparation of molecular biology reagents and buffers.
3. Colorimetric analysis of different biomolecules using spectrophotometer.
4. Differential centrifugation for separation of cell organelles.
5. Demonstration of Sanger sequencing technology and flow cytometry instrument.

Suggested Readings:

1. Brown, T.A. (2023) Essential Molecular Biology: A Practical Approach, ISBN:9781383049282.
2. Robens, E., et al. (2014) Balances- instruments, manufacturers, history, Springer Berlin, Heidelberg, DOI:10.1007/978-3-642-36447-1.
3. Webster, J.G. and Eren, H. (2014). Measurement, Instrumentation, and Sensors Handbook, 2nd edition, CRC Press, ISBN:9781315217444, DOI:10.1201/b15664.
4. Westermeier, R. (2013) Chapter: Gel Electrophoresis *in book* Encyclopedia of life sciences, John Wiley & Sons, ISBN:9780470015902, DOI:10.1002/9780470015902.a0005335.pub2.
5. UV/Vis Spectrophotometry- Fundamentals and Applications (2025). Publisher: Mettler-Toledo Publication No. ME-30256131E.
6. The basics of UV-Vis spectrophotometry- a primer (2025), Agilent technologies. 5980-1397EN.
7. Instrumentation for Fluorescence Spectroscopy. In: Lakowicz, J.R. (eds) Principles of fluorescence spectroscopy (2006) Springer, Boston, MA, DOI:10.1007/978-0-387-46312-4_2.
8. Trouchet, A., et al. (2025) Digital PCR: from early developments to its future application in clinics. Lab on a chip, 25(16):3921–3961, DOI:10.1039/d5lc00055f.
9. Artika, I.M., et al. (2022). Real-time polymerase chain reaction: Current techniques, applications, and role in COVID-19 diagnosis. Genes, 13(12):2387, DOI:10.3390/genes13122387.
10. MicroPulser electroporator- Instruction manual and applications guide, 10000148532 Ver A (4006174) BIO-RAD.
11. Capelli, D. et al. (2023) Surface plasmon resonance technology: Recent advances, applications and experimental cases. TrAC Trends in Analytical Chemistry, 163:117079, DOI:10.1016/j.trac.2023.117079.
12. Wilson, K., et al. (2018) Wilson and Walker's principles and techniques of biochemistry and molecular biology. Cambridge University Press, ISBN:9781316677056, DOI:10.1017/9781316677056.
13. Green M.R. and Sambrook J. (2012) Molecular Cloning: A Laboratory Manual. 4th edition. CSHL Press, USA, ISBN:9781936113422.
14. McKinnon, K.M. (2018) Flow cytometry: an overview. Current Protocols in Immunology, 120(1):5–1, DOI:10.1002/cpim.40.
15. Doležel, J., et al. (2007) Estimation of nuclear DNA content in plants using flow cytometry. Nature Protocols, 2(9):2233–2244, DOI:10.1038/nprot.2007.310.

PBSE106: Model Organisms in Molecular Biology Research

This course is open to students of other departments as a GE course.

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE106: Model Organisms in Molecular Biology Research	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

Model organisms have a pivotal role in advancing our understanding of fundamental biological processes. The course aims to provide an in-depth understanding of the significance of model organisms in molecular biology research. It will familiarize students with the criteria for selecting model organisms and the diversity of models used across different biological kingdoms. It will provide an opportunity to examine the unique features, advantages, and limitations of various model systems. Information will be imparted on emerging model organisms and non-model organisms with unique features and cutting-edge advancements, such as artificial cell models. Ethical considerations will be discussed to ensure responsible research practices.

Learning Outcomes

Students will understand the importance of model organisms and their contributions to molecular biology research across different fields. They will be able to evaluate and select appropriate model systems for specific research objectives and explore the utility of emerging model systems and novel technologies in advancing molecular biology research. Students will be aware of ethical issues and guidelines for humane and sustainable research involving model organisms.

Course Content (45 hours)

Unit 1: Introduction to Model Organisms -- Fundamental concepts and importance of model organisms in molecular biology research, criteria for selecting model organisms, types of model organisms across different phyla, historical milestones, comparative overview between prokaryotic and eukaryotic model systems; Nobel prize-winning discoveries utilizing model organisms. 7 hours

Essential Readings: Müller, B. and Grossniklaus, U. (2010) Model organisms-a historical perspective. *Journal of Proteomics*, 73(11):2054–2063, DOI:10.1016/j.jprot.2010.08.002; Hedges, S.B. (2002) The origin and evolution of model organisms. *Nature Reviews Genetics*, 3(11):838–849, DOI:10.1038/nrg929; Davis R.H. (2004) The age of model organisms. *Nature Reviews Genetics*, 5(1):69–76, DOI:10.1038/nrg1250; Ambros, V. R., et al. (2025) From nematode to Nobel: How community-shared resources fueled the rise of *Caenorhabditis elegans* as a research organism. *PNAS*, 122(48):e2522808122, DOI:10.1073/pnas.2522808122.

Unit 2: Prokaryotic and Lower Eukaryotes Models -- Importance and utility of prokaryotic models and their genetic manipulation (e.g. *Escherichia coli*, *Bacillus subtilis*, etc.); Bacteriophages; Lower eukaryotes: Importance and utility of unicellular eukaryotes and their

genetic manipulation; Yeast (*Saccharomyces cerevisiae*, *Schizosaccharomyces pombe*); *Neurospora crassa*; *Dictyostelium discoideum*. 15 hours

Essential Readings: Davis, R.H. (2003) The microbial models of molecular biology: From genes to genome. Oxford Press, ISBN:9780195154368; Stülke, J., et al. (2023) *Bacillus subtilis*, a swiss army knife in science and biotechnology. Journal of Bacteriology, 205(5):e00102–23, DOI:10.1128/jb.00102-23; Akinsemolu, A.A., et al. (2024) Exploring *Bacillus subtilis*: Ecology, biotechnological applications and future prospects. Journal of Basic Microbiology, 64(6):2300614, DOI:10.1002/jobm.202300614; Nurse, P., et al. (1976) Genetic control of the cell division cycle in the fission yeast *Schizosaccharomyces pombe*. Molecular and General Genetics, 146(2):167–178, DOI:10.1007/BF00268085; Li, S.I. and Purugganan, M.D. (2011) The cooperative amoeba: *Dictyostelium* as a model for social evolution. Trends in Genetics, 27(2):48–54, DOI:10.1016/j.tig.2010.11.003.

Unit 3: Animal and Plant Models -- Importance and utility of animal models and their genetic manipulation, Invertebrates (*Drosophila melanogaster* and *Caenorhabditis elegans*), Vertebrates (*Mus musculus*, *Rattus norvegicus*, *Danio rerio*, *Xenopus laevis*, *Macaca* spp. and other primates); Cell lines as *in vitro* models; Human disease models; Plant models: Importance, utility and their genetic manipulation, single-celled green algae (*Chlamydomonas reinhardtii*, for biofuels-*Botryococcus braunii* and *Chlorella vulgaris*), lower plants (*Marchantia polymorpha* and *Physcomitrium patens*); Monocots (*Oryza sativa*, *Brachypodium distachyon*, *Panicum* spp., other models); Dicots (*Arabidopsis thaliana*, *Medicago truncatula*, *Jatropha curcas*, and other models). 15 hours

Essential Readings: Irion, U. and Nüsslein-Volhard, C. (2022) Developmental genetics with model organisms. PNAS, 119(30):e2122148119, DOI:10.1073/pnas.2122148119; Kimble, J. and Nüsslein-Volhard, C. (2022) The great small organisms of developmental genetics: *Caenorhabditis elegans* and *Drosophila melanogaster*. Developmental Biology, 485:93–122, DOI:10.1016/j.ydbio.2022.02.013; Standley, A., et al. (2024) Working with miraculous mice: *Mus musculus* as a model organism. Current Protocols, 4(10):e70021, DOI:10.1002/cpz1.70021; Giansanti, M.G., et al. (2025) *Drosophila melanogaster*: How and why it became a model organism. International Journal of Molecular Sciences, 26(15):7485, DOI:10.3390/ijms26157485; Chang, C., et al. (2016) Field guide to plant model systems. Cell, 167(2):325–339, DOI:10.1016/j.cell.2016.08.031; Goodenough, U. (2023) The *Chlamydomonas* sourcebook Volume 1: Introduction to *Chlamydomonas* and its laboratory use. Academic Press, ISBN:9780128224571, DOI:10.1016/C2019-0-02739-2; Al-Hammadi, M., and Güngörmüşler, M. (2024) New insights into *Chlorella vulgaris* applications. Biotechnology and Bioengineering, 121(5):1486–1502, DOI:10.1002/bit.28666; Bowman, J.L., et al. (2022) The renaissance and enlightenment of *Marchantia* as a model system. The Plant Cell, 34(10):3512–3542, DOI:10.1093/plcell/koac219; Rensing, S.A., et al. (2020) The moss *Physcomitrium (Physcomitrella) patens*: A model organism for non-seed plants. The Plant Cell, 32(5):1361–1376, DOI:10.1105/tpc.19.00828; Scholthof, K.B.G., et al. (2018) *Brachypodium*: A monocot grass model genus for plant biology. The Plant Cell, 30(8):1673–1694, DOI:10.1105/tpc.18.00083; Goff, S.A. (1999) Rice as a model for cereal genomics. Current Opinion in Plant Biology, 2(2):86–89, DOI:10.1016/S1369-5266(99)80018-1; Woodward, A.W. and Bartel, B. (2018) Biology in bloom: a primer on the *Arabidopsis thaliana* model system. Genetics, 208(4):1337–1349, DOI:10.1534/genetics.118.300755; Nandety, R.S., et al. (2022) *Medicago truncatula* resources to study legume biology and symbiotic nitrogen fixation. Fundamental Research, 3(2):219–224, DOI:10.1016/j.fmre.2022.06.018.

Unit 4: Emerging Model Organisms and Ethics -- Non-model species with unique features, such as Tardigrades, Axolotls, *Octopus bimaculoides*; Advances in model research: development of artificial cell models, other pioneering studies for insights into untapped species and their potential applications; Ethical considerations: animal welfare, regulatory guidelines, ethical issues, alternatives to animal models (such as organoids, *in silico* simulations, and integration of AI and computational models). 8 hours

Essential Readings: Weronika, E. and Łukasz, K. (2017) Tardigrades in Space Research - Past and Future. Origins of Life and Evolution of Biospheres, 47(4):545–553, DOI:10.1007/s11084-016-9522-1; Møbjerg, N., et al. (2011) Survival in extreme environments-on the current knowledge of adaptations in tardigrades. Acta Physiol (Oxf). 202(3):409–420, DOI:10.1111/j.1748-1716.2011.02252.x; Hashimoto, T., et al. (2016) Extremotolerant tardigrade genome and improved radiotolerance of human cultured cells by tardigrade-unique protein. Nature Communications, 7:12808, DOI:10.1038/ncomms12808; Arce, H., et al. (2025) Modeling proximalisation in axolotl limb regeneration. Sci Rep., 15(1):1–17, DOI:10.1038/s41598-025-10527-8; Adamson, C.J. et al. (2022)

The amazing and anomalous axolotls as scientific models. *Developmental Dynamics*, 251(6):922–933, DOI:10.1002/dvdy.470; Nowoshilow, S., et al. (2018) The axolotl genome and the evolution of key tissue formation regulators. *Nature*, 554:50–55, DOI:10.1038/nature25458; Albertin, C.B., et al. (2015) The octopus genome and the evolution of cephalopod neural and morphological novelties. *Nature*, 524(7564):220–224, DOI:10.1038/nature14668; Kim, J. et al. (2020) Human organoids: model systems for human biology and medicine. *Nature Reviews Molecular Cell Biology*, 21(10):571–584, DOI:10.1038/s41580-020-0259-3; Lukyanenko, R., et al. (2022) Conceptual modelling for life sciences based on systemist foundations. *BMC Bioinformatics*, 23(11):1–28, DOI:10.1186/s12859-023-05287-z; Harline, K., et al. (2021) A life cycle for modeling biology at different scales. *Frontiers in Plant Science*, 12:710590, DOI:10.3389/fpls.2021.710590.

Tutorials (15 hours)

1. Exploration of online data resources and data analysis tools on model organisms:
 - a. EcoCyc: Encyclopedia of *E. coli* genes and metabolism, and *Saccharomyces* Genome Database (SGD).
 - b. WormBase (*Caenorhabditis elegans*), FlyBase (*Drosophila*), and Rat Genome Database (RGD).
 - c. The *Arabidopsis* Information Resource (TAIR), Gramene and Rice Annotation Project Database (RAP-DB), Solanaceae Genomics Network (SGN), and LIS-Legume Information System.
2. Through role-play exercises, students will explore ethical considerations on the use of model organisms in research by debating from the perspective of a scientist, ethicist, and animal rights advocate.
3. Discussion on prospects of *in silico* simulation and computational models.

Suggested Readings:

1. Ankey, R.A. and Leonelli S. (2021) Model organisms. Cambridge University Press, ISBN: 9781108742320.
2. Grossman A.R. (2000) *Chlamydomonas reinhardtii* and photosynthesis: genetics to genomics. *Current Opinion in Plant Biology*, 3(2):132–137, DOI:10.1016/s1369-5266(99)00053-9.
3. Modlinska, K., and Pisula, W. (2020) The Norway rat, from an obnoxious pest to a laboratory pet. *eLife*, 9:e50651, DOI:10.7554/eLife.50651.
4. Boland, D.J., et al. (2024) Reclassification of *Botryococcus braunii* chemical races into separate species based on a comparative genomics analysis. *PloS One*, 19(7):e0304144, DOI: 10.1371/journal.pone.0304144.
5. Ishizaki, K., et al. (2016) Molecular genetic tools and techniques for *Marchantia polymorpha* research. *Plant & Cell Physiology*, 57(2):262–270, DOI:10.1093/pcp/pcv097.
6. Kohchi, T., et al. (2021) Development and Molecular Genetics of *Marchantia polymorpha*. *Annual Review of Plant Biology*, 72:677–702, DOI:10.1146/annurev-arplant-082520-094256.
7. Naramoto, S., et al. (2022) The bryophytes *Physcomitrium patens* and *Marchantia polymorpha* as model systems for studying evolutionary cell and developmental biology in plants. *The Plant Cell*, 34(1):228–246, DOI:10.1093/plcell/koab218.
8. Draper, J., et al. (2001) *Brachypodium distachyon*. A new model system for functional genomics in grasses. *Plant Physiology*, 127(4):1539–1555, DOI:10.1104/pp.010196.
9. Hasterok, R., et al. (2022) *Brachypodium*: 20 years as a grass biology model system; the way forward? *Trends in Plant Science*, 27(10):1002–1016, DOI:10.1016/j.tplants.2022.04.008.
10. McLaughlin, S.B. and Kszos, L.A. (2005) Development of switchgrass (*Panicum virgatum*) as a bioenergy feedstock in the United States. *Biomass and Bioenergy*, 28(6):515–535, DOI: 10.1016/j.biombioe.2004.05.006.
11. Izawa, T. and Shimamoto, K. (1996) Becoming a model plant: The importance of rice to plant science. *Trends in Plant Science*, 1(3):95–99, DOI:10.1016/S1360-1385(96)80041-0.
12. Strader, L.C. et al. (2025). Core biological principles and tools stemming from basic *Arabidopsis* research. *The Plant Cell*, 37(7):koaf141, DOI:10.1093/plcell/koaf141.

13. Barker, D.G., et al. (1990) *Medicago truncatula*, a model plant for studying the molecular genetics of the Rhizobium-legume symbiosis. *Plant Molecular Biology Reporter*, 8:40–49, DOI:10.1007/BF02668879.
14. de Bruijn, F. (2020) The model legume *Medicago truncatula*. John Wiley & Sons, ISBN:9781119409144, DOI:10.1002/9781119409144.
15. Riayatsyah, T.M.I., et al. (2022) Current Progress of *Jatropha Curcas* commoditisation as biodiesel feedstock: A comprehensive review. *Frontiers in Energy Research*, 9:815416, DOI:10.3389/fenrg.2021.815416.
16. Emerging model organisms: A Laboratory Manual Vol 1 (2009) Cold Spring Harbor Laboratory Press, ISBN:9780879698720.
17. Jarret, R.L and McCluskey, K. (2020) Biological resources of model organisms. 1st edition, CRC Press, ISBN:9781138294615.
18. Davis, R H. (2003) The Microbial Models of Molecular Biology: From Genes to Genome. OUP Oxford Press, ISBN:9780195154368.
19. Tang B, Wang Y, Zhu J, Zhao W. (2015) Web resources for model organism studies. *Genomics Proteomics Bioinformatics*, 13(1):64–68, DOI:10.1016/j.gpb.2015.01.003.
20. Latest research and review articles from Scientific journals and book chapters.

PBSEC107: Biological Data Analysis and Interpretation

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSEC107: Biological Data Analysis and Interpretation	2	1	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course provides an in-depth understanding of the fundamental and advanced research methodologies employed in plant molecular biology and biotechnology. It focuses on experimental design, data analysis, and scientific communication while integrating guest lectures of specialists (if required). Special emphasis will be given to high-throughput sequencing, genome editing, plant transformation techniques, and bioinformatics approaches relevant to molecular plant sciences.

Learning Outcomes

Upon completion of this course, students will be adept at designing robust biological experiments, performing comprehensive statistical analyses, and interpreting various data types with scientific rigor. They will gain proficiency in hypothesis testing, regression models, and survival analysis, while also understanding the ethical concerns in biostatistics. Learners will acquire knowledge to analyze transcriptomic data using tools like DESeq2 and DAVID. Additionally, they will develop the ability to create effective, publication-quality visualizations of complex biological datasets.

Course Content

(Lectures combined with problem-solving practical sessions; 15+30 = 45 hours)

Unit 1: Experimental Design and Biostatistics -- Principles of experimental design; Control groups, replication, and randomization; Types of biological data and measurement scales; descriptive statistics (mean, median, variance, standard deviation); Probability distributions (normal, binomial, Poisson); Hypothesis testing (t-tests, chi-square, ANOVA, non-parametric tests); Power analysis and sample size determination; Ethical considerations in biostatistics.

6 hours

Essential Readings: Triola, M., et al. (2018) Biostatistics for the Biological and Health Sciences, 3rd edition, Pearson, ISBN:9780137864102, Chapter 1 (Introduction to Statistics), Chapter 2 (Exploring Data with Tables and Graphs), Chapter 3 (Describing, Exploring, and Comparing Data), Chapter 4 (Probability), Chapter 5 (Discrete Probability Distributions), Chapter 6 (Normal Probability Distributions), Chapter 7 (Estimating Parameters and Determining Sample Sizes), Chapter 8 (Hypothesis Testing), Chapter 9 (Inferences from Two Samples), Chapter 10 (Correlation and Regression), Chapter 12 (Analysis of Variance); Maxwell, S.E., et al. (2008) Sample size planning for statistical power and accuracy in parameter estimation. Annual Review of Psychology, 59:537–563, DOI:10.1146/annurev.psych.59.103006.093735; Jackson, M. and Cox, D.R. (2013) The Principles of Experimental Design and Their Application in Sociology. Annual Review of Sociology, 39:27–49, DOI:10.1146/annurev-soc-071811-145443.

Unit 2: Gene Expression Analysis and Data Visualization -- Overview of transcriptomics; RNA sequencing (RNA-Seq), microarrays; Data preprocessing (quality control, normalization, transformation); Differential gene expression analysis; Functional enrichment, pathway analysis; Visualization techniques (heatmaps, volcano plots, expression profiles); Case studies; Hands-on analysis using tools like DESeq2, edgeR, STRING, DAVID; Principles of effective data visualization; Types of visualizations (bar plots, scatter plots, box plots, heatmaps); Visualization of complex biological data (networks, phylogenetic trees, multidimensional plots); Best practices for scientific presentations and publications. **9 hours**

Essential Readings: Pevsner, J. (2015) *Bioinformatics and Functional Genomics*, 3rd edition, Wiley-Blackwell, ISBN:9781118581780, Chapter 9 (Analysis of Next-Generation Sequence Data), Chapter 10 (Bioinformatic Approaches to Ribonucleic Acid (RNA)), Chapter 11 (Gene Expression: Microarray and RNA-seq Data Analysis); Van den Berge, K., et al. (2019) *RNA Sequencing Data: A Hitchhiker's Guide to Expression Analysis*. Annual Review of Biomedical Data Science, 2:139–173. DOI: 10.1146/annurev-biodatasci-072018-021255; O'Donoghue, S.I. et al. (2018) *Visualization of Biomedical Data*. Annual Review of Biomedical Data Science, 1:275–304, DOI:10.1146/annurev-biodatasci-080917-013424.

Practicals (30 hours)

1. Design an experiment (e.g., drug effect on bacteria) and identify variables, control groups, and the method of randomization.
2. Analyze sample datasets (e.g., plant development-based measurements during stress responses); Classify data and discuss implications for statistical tests.
3. Run t-tests, chi-square tests, and ANOVA on the provided datasets.
4. Identify genes differentially expressed across conditions (using microarray or NGS datasets) and interpret results (using log₂ fold changes, p-values, adjusted p-values).

Suggested Readings:

1. Quinn, G.P. and Keough, M.J. (2002) *Experimental design and data analysis for biologists*. Cambridge University Press, ISBN:9780521009768.
2. Heath, D. (1995) *An introduction to experimental design and statistics for biology*. UCL Press, ISBN:9781857281323, DOI:10.1201/b12546.
3. Welham, S.J., et al. (2015) *Statistical methods in biology: Design and analysis of experiments and regression*. CRC Press, ISBN:9781032918327.
4. Daniel, W.W. and Cross, C.L. (2018) *Biostatistics: A foundation for analysis in the health sciences*. 11th edition, Wiley, ISBN:9781118302798.
5. Barah, P., et al. (2021) *Gene expression data analysis: A statistical and machine learning perspective*. CRC Press, ISBN:9780367338893, DOI:10.1201/9780429322655.
6. Parmigiani, G., et al. (2003) *The analysis of gene expression data: Methods and software*. Springer New York, ISBN:9780387955773, DOI:10.1007/b97411.
7. Rangayyan, R.M. (2004) *Biomedical image analysis*. CRC Press, ISBN:9780849396953.
8. Hartvigsen, G. (2021) *A primer in biological data analysis and visualization using R*. 2nd edition, Columbia University Press, ISBN:9780231202138.

SEMESTER 2

PBSC201: Molecular Basis of Plant Development

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC201: Molecular Basis of Plant Development	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The objective of this course is to provide an in-depth understanding of plant differentiation, development, and the regulatory mechanisms that govern these processes. Students will explore key concepts, including totipotency, organogenesis, and tissue differentiation, as well as light perception, plant growth, leaf and root development, floral induction, and reproductive processes. The course also covers the hormonal and molecular control of plant development, including seed development, dormancy, germination, senescence, and programmed cell death.

Learning Outcomes

Upon completion, students will have a comprehensive understanding of plant growth and developmental processes, from cellular differentiation to reproductive mechanisms. They will be able to analyze the molecular and genetic regulation of plant responses to environmental signals, particularly light. Students will gain expertise in the light- and hormonal-control of plant development. Students will develop the skills to analyze the developmental stages of microspores and embryos. The course will enhance their ability to conduct research in plant biology and to apply their knowledge to crop improvement.

Course Content (45 hours)

Unit 1: Plant Differentiation and Photomorphogenesis -- Totipotency, meristems, organogenesis, adventive somatic embryogenesis, apomixis, trichome and stomata; Phloem and xylem differentiation; Gametogenesis and embryogenesis; Skotomorphogenesis and photomorphogenesis; Molecular mechanisms of light perception, signal transduction and gene regulation; Biological clocks and their genetic and molecular determinants. 14 hours

Essential Readings: Turnbull, C.G. (2005) Plant architecture and its manipulation. Barcelona: Blackwell, Chapter 1 (Cellular architecture: Regulation of cell size, cell shape and organ initiation); Buchanan, B.B. et al. (2015) Biochemistry and Molecular Biology of Plants. 2nd edition, John Wiley & Sons Ltd., UK, ISBN:9780470714218, Chapter 18 (Signal Transduction); De Rybel, B., et al. (2016) Plant vascular development: from early specification to differentiation. Nature Reviews Molecular Cell Biology, 17(1):30–40, DOI:10.1038/nrm.2015.6; Jones, R., et al. (2012) The molecular life of plants. ASPB and Wiley-Blackwell, ISBN:9781118315989, Chapter 8 (Light perception and transduction); Cheng, M. C., et al. (2021) Phytochrome signaling networks. Annual Review of Plant Biology, 72:217–244, DOI:10.1146/annurev-arplant-080620-024221.

Unit 2: Leaf and Root Development -- Molecular basis of leaf development and polarity establishment; Venation patterns in leaves; Shoot branching and architecture; Hormonal control of leaf development; Stomatal development and movement; Phyllotaxy; Root apical

meristem (RAM), primary and secondary root development, root hair and root system architecture (RSA); hormonal control of root development. **12 hours**

Essential Readings: Wolpert, L., et al. (2015) Principles of Development. Oxford Publishers, UK, ISBN: 9780198709886, Chapter 13 (Plant Development); Taiz, L., et al. (2015) Plant Physiology and Development. Sinauer Associates Inc. Publishers, USA, ISBN:9781605352558, Chapter 19 (Vegetative Growth and Organogenesis).

Unit 3: Floral Induction and Regulation of Gametogenesis and Embryogenesis -- Photoperiodism and its significance; Vernalization and hormonal control; Inflorescence and floral determination; Molecular genetics of floral development and floral organ differentiation: floral development in *Arabidopsis* and *Antirrhinum*; Formation of male and female gametes, pollination and fertilization; Self incompatibility; Cytoplasmic inheritance; Epigenetic imprinting; Embryo formation and cell lineage development in *Arabidopsis* and Maize. **8 hours**

Essential Readings: Buchanan, B.B. et al. (2015) Biochemistry and Molecular Biology of Plants. 2nd edition, John Wiley & Sons, Ltd, UK, ISBN:9780470714218, Chapter 19 (Molecular Regulation of Reproductive Development); Gilbert, S.F. (2000) Developmental Biology. INC Publishers, USA, ISBN:9780197699782, Chapter 20 (An overview of plant development); Wolpert, L. et al. (2015) Principles of Development. Oxford Publishers, UK, ISBN: 9780198709886, Chapter 13 (Plant Development).

Unit 4: Seed Development, Dormancy, Germination, and Programmed Cell Death (PCD) -- Seed maturation and dormancy; Hormonal control of seed germination, development, and seedling growth; Mobilization of food reserves during seed germination; Cell death, PCD, and apoptosis; Senescence in plants and its regulation; PCD during seed development, leaf development, and reproductive development; Energy and oxidative metabolism during senescence; Hormonal and environmental control of senescence. **11 hours**

Essential Reading: Bentsink, L. and Koornneef, M. (2008) Seed dormancy and germination. The *Arabidopsis* Book, 6:e0119, American Society of Plant Biologists, DOI:10.1199/tab.0119; Sajeev, N., et al. (2024) A commitment for life: Decades of unraveling the molecular mechanisms behind seed dormancy and germination. The Plant Cell, 36(5):1358–1376, DOI:10.1093/plcell/koad328; Jones, R., et al. (2012) The molecular life of plants. ASPB and Wiley-Blackwell, ISBN:9781118315989, Chapter 6 (Seed to seedling: germination and mobilization of food reserves, Chapter 17 (Development and dormancy of resting structures); Buchanan, B.B. et al. (2015) Biochemistry and Molecular Biology of Plants. 2nd edition, John Wiley & Sons Ltd. UK, ISBN:9780470714218, Chapter 20 (Senescence and Cell Death); Domínguez, F. and Cejudo, F.J. (2014) Programmed cell death (PCD): an essential process of cereal seed development and germination. Frontiers in Plant Science, 5:366, DOI:10.3389/fpls.2014.00366.

Practicals (30 hours)

1. Study of photomorphogenesis and skotomorphogenesis (by using mutants).
2. Analysis of microspore development.
3. Study of root differentiation using cytokinin markers.
4. Estimation of chlorophyll degradation during leaf senescence.
5. Study of embryo development.

Suggested Readings:

1. Gilbert, S.F. (2000) Developmental Biology. INC Publishers, USA, ISBN:9780197699782.
2. Westhoff, P. (1998) Molecular Plant Development: from gene to plant. The Bath Press, UK, ISBN:9780198502043.
3. Wolpert, L., et al. (2015) Principles of Development. 5th edition, Oxford Publishers, UK, ISBN:9780198709886.
4. Buchanan, B.B., et al. (2015) Biochemistry & Molecular Biology of Plants. 2nd edition, John Wiley & Sons Ltd., UK, ISBN:9780470714218.

5. Taiz, L., et al. (2015) *Plant Physiology and Development*. 7th edition, Sinauer Associates Inc. Publishers, USA, ISBN:9781605352558.
6. Caño-Delgado, A., et al. (2010) Regulatory mechanisms for specification and patterning of plant vascular tissues. *Annual Review of Cell and Developmental Biology*, 26:605–637, DOI:10.1146/annurev-cellbio-100109-104107.
7. Schuetz, M., et al. (2013) Xylem tissue specification, patterning, and differentiation mechanisms. *Journal of Experimental Botany*, 64(1):11–31, DOI:10.1093/jxb/ers287.
8. Lehesranta, S.J., et al. (2010) Cell-to-cell communication in vascular morphogenesis. *Current Opinion in Plant Biology*, 13(1):59–65, DOI:10.1016/j.pbi.2009.09.004.

PBSC202: Plant Biochemistry and Metabolism

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSC202: Plant Biochemistry and Metabolism	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

Plant biochemistry and metabolism is the study of biomolecules, biochemical processes, and the pathways of chemical energy flow. This course is designed to impart critical knowledge of plant-specific primary metabolism from a more mechanistic perspective, including photosynthesis, respiration, and the metabolism of carbohydrates, lipids, amino acids, and nucleotides. The course will also provide information on the uptake, transport, and assimilation of nutrients as well as long-distance transport mechanisms in plants. Furthermore, students will also learn to appreciate the importance of secondary metabolites produced by plants.

Learning Outcomes

This paper aims to provide a comprehensive understanding of the various metabolic processes that operate within a plant system. It would provide insights into the structural diversity of various biomolecules, their movement, synthesis and turnover. It would also aid in developing an understanding of the key components in metabolic pathways, with a focus on the genetic improvement of quality traits.

Course Content (45 hours)

Unit 1: Carbon Assimilation in Photosynthesis, and Uptake and Assimilation of Nutrients

-- Light absorption and energy conversion; Calvin Cycle (C₃), Hatch-Slack pathway (C₄), Crassulacean Acid Metabolism (CAM), Reductive pentose phosphate pathway, Carbon dioxide uptake and assimilation, photorespiration, glycolate metabolism; Enhancing photosynthetic carbon assimilation by genetic engineering; Overview of essential mineral elements, molecular physiology of nutrient acquisition (Nitrogen, Potassium, Sulphur, and Phosphorus), role of essential mineral elements in plants; Nitrate uptake, assimilation and transport, nitrate reduction, pathways of ammonia assimilation, reductive amination, transamination; Regulation of transport and assimilation of essential nutrients. **17 Hours**

Essential Readings: Buchanan, B.B. et al. (2015) Biochemistry and Molecular Biology of Plants, 2nd edition, John Wiley & Sons Ltd. UK, ISBN:9780470714218, Chapter 12 (Photosynthesis); Qin, K., et al. (2025) Engineering carbon assimilation in plants. Journal of Integrative Plant Biology, 67(4):926–948, DOI:10.1111/jipb.13825; Taiz, L. and Zeiger, E. (2002) Plant Physiology, 4th edition, ISBN:9780878938568, Unit II (Biochemistry and Metabolism); Taiz, L., et al. (2023) Plant physiology and development, 7th edition, Oxford University Press, ISBN:9780197614204, Unit III (Biochemistry and Metabolism).

Unit 2: Biological Oxidation and Release of Energy -- Glycolytic pathway, Krebs's cycle, high-energy compounds; Oxidative phosphorylation; Chemiosmotic hypothesis; Pentose phosphate shunt pathway; Regulation of citric acid cycle and cytochrome pathway; Interactions between mitochondria and other cellular compartments. **10 Hours**

Essential Readings: Buchanan, B.B., et al. (2015) *Biochemistry and Molecular Biology of Plants*. 2nd edition, John Wiley & Sons Ltd. UK, ISBN:9780470714218, Chapter 14 (Respiration and Photorespiration); Nelson, L. et al. (2021) *Lehninger Principles of Biochemistry*, 8th edition. ISBN:9781319228002, Unit II (Bioenergetics and metabolism).

Unit 3: Metabolism of Biomolecules and Secondary Metabolites -- Composition, structure and function of biomolecules (carbohydrates, lipids, proteins, and nucleic acids), biosynthesis, inter-conversion and breakdown of carbohydrates and lipids, metabolism of nucleotides and amino acids; Biosynthesis of phenolic compounds, isoprenoids, alkaloids, glucosinolates and flavonoids, phenylpropanoid pathway, mevalonate (MVA) pathway, methylerythritol phosphate pathway; Importance of secondary metabolites; Metabolic engineering of secondary metabolite production; Biotechnological applications of secondary metabolites. **12 Hours**

Essential Readings: Verpoorte, R. (2000) Secondary Metabolism. In: Verpoorte, R., Alfermann, A.W. (eds) *Metabolic engineering of plant secondary metabolism*. Springer Dordrecht, DOI:10.1007/978-94-015-9423-3_1; Crozier, A., et al. (2006) Plant secondary metabolites. Occurrence, Structure and Role in the Human Diet, Blackwell-Publishers, ISBN:9781405125093; Bhatla, S.C. and Lal, M.A. (2023) Secondary metabolites. In *Plant physiology, development and metabolism*, pp.765-808. Springer Nature Singapore, ISBN:9789819957354.

Unit 4: Long-distance Transport Mechanisms in Plants -- Transport of water: long-distance transport and short-distance transport events between xylem and nonvascular cells, transport modules, specific water channels, turgor and stomatal movements, translocation of ions and solutes from soil; Ion transport and solute movement; Passive and Active transport, Short-distance transport between phloem and nonvascular cells; Source-sink relationship, mechanisms of loading and unloading of photoassimilates. **6 hours**

Essential Readings: Buchanan, B.B., et al. (2015) *Biochemistry and Molecular Biology of Plants*. 2nd edition, John Wiley & Sons Ltd. UK, ISBN:9780470714218; Taiz, L. and Zeiger, E. (2002) *Plant physiology*, 4th edition, ISBN:9780878938568, Unit II (Biochemistry and Metabolism); Taiz, L. et al. (2023) *Plant Physiology and Development*, 7th edition, Oxford University Press, ISBN:9780197614204.

Practicals (30 hours)

1. Substrate inducibility of nitrate reductase (NR) enzyme.
2. Determination of optimal pH for nitrate reductase activity.
3. Spectrophotometric assay of acid phosphatase.
4. Isolation of chloroplastic proteins and resolve them using SDS-PAGE.
5. Activity of mitochondrial marker enzyme, succinate dehydrogenase.

Suggested Readings:

1. Dey, P.M. and Harborne, J.B. (1997) *Plant Biochemistry*. Academic Press, USA, ISBN:9780122146749.
2. Metzler, D.E. (2007) *Biochemistry*. Academic Press, USA, ISBN:9780122146749.
3. Nelson D.L. and Cox, M.M. (2017) *Principles of Biochemistry*. W.H. Freeman & Co., USA, ISBN:9781319108243.
4. Stryer L., et al. (2002) *Biochemistry*. W.H. Freeman & Co., USA, ISBN:9780716746843.
5. Ashihara, H., et al. (2011) *Plant Metabolism and Biotechnology*, Wiley, ISBN:9780470747032.
6. Piechulla, B. and Hans-Walter, H. (2024) *Plant Biochemistry*, 6th edition, Elsevier, Academic Press, ISBN:9780443266164.

PBSC203: Eukaryotic Gene Expression and Regulation

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC203: Eukaryotic Gene Expression and Regulation	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course provides a detailed understanding of eukaryotic genome structure, regulation, and function. It emphasizes advancements in genome sequencing, epigenetics, and functional genomics, including CRISPR-Cas technologies, while exploring their applications in agriculture and human health. Students will develop theoretical knowledge and practical skills to analyze and manipulate genomic systems.

Learning Outcomes

Upon successful completion of this course, students will gain a comprehensive understanding of genome organization, gene regulation, and functional genomics. It will equip them to interpret high-throughput genomic data and understand regulatory mechanisms at multiple levels. Students will be able to apply this knowledge to genome editing, crop improvement, and medical research. They will also be able to propose innovative solutions to agricultural and health-related challenges by leveraging insights from transcriptional regulation, epigenetics, and emerging genomic technologies.

Course Content (45 hours)

Unit 1: Genomes and Comparative Genomics -- Genome structure and organization; Structure of chromatin and chromosomes; Genome complexity; Nuclear territories; Chromosomal Conformation studies (Hi-C); Unique and repetitive DNA; Evolution of gene families; Advances in genome sequencing technologies (Next-gen and 3rd-gen methodologies, Illumina, PacBio, Nanopore, etc.) and assembly; Optical Genome mapping; Comparative genomics of model organisms (*Arabidopsis*, rice, humans, and non-model species); Functional annotation through phylogenetic footprinting and multi-genome alignment; Impact of repetitive and transposable elements on genome evolution. **15 hours**

Essential Readings: Brown, T.A. (2023) Genomes 5. CRC Press, ISBN:9780367674076, Chapter 4 (Sequencing genomes), Chapter 5 (Genome annotation), Chapter 6 (Identifying gene functions), Chapter 7 (Eukaryotic nuclear genomes), Chapter 8 (Genomes of prokaryotes and eukaryotic organelles); Paterson, A.H., et al. (2010) Insights from the comparison of plant genome sequences. *Annual Review of Plant Biology*, 61:349–372, DOI:10.1146/annurev-arplant-042809-112235; Jayakodi, M., et al. (2025) What are we learning from plant pangenomes? *Annual Review of Plant Biology*, 76:663–686, DOI:10.1146/annurev-arplant-090823-015358; For Case Study: International Human Genome Sequencing Consortium. (2001) Initial sequencing and analysis of the human genome. *Nature*, 409:860–921, DOI:10.1038/35057062; Arabidopsis Genome Initiative. (2000) Analysis of the genome sequence of the flowering plant *Arabidopsis thaliana*. *Nature*, 408:796–815, DOI:10.1038/35048692; International Rice Genome Sequencing Project. (2005) The map-based sequence of the rice genome. *Nature*, 436:793–800, DOI:10.1038/nature03895; 3,000 Rice Genomes Project. (2014) The 3,000 Rice Genomes Project. *GigaScience*, 3:7, DOI:10.1186/2047-217X-3-7.

Unit 2: Epigenetic and Transcriptional Regulation of Gene Expression -- Mechanisms of DNA methylation and histone modifications; Role of non-coding RNAs and chromatin remodeling in transcriptional regulation; Environmental and developmental epigenetic reprogramming; Case studies: Epigenetic regulation in flowering and stress responses; Promoter and enhancer dynamics; Mechanisms of RNA polymerase recruitment and mediator complex functions; Latest insights into transcription factors, co-activators, and repressors; Chromatin looping and transcription factories. **10 hours**

Essential Readings: Alberts, B. et al. (2022) *Molecular Biology of the Cell*, 7th edition, Garland Science/W.W. Norton, ISBN:9780393884821, Chapter 4 (DNA, Chromosomes, and Genomes), Chapter 7 (Control of Gene Expression); Hemenway, E.A. and Slotkin, R.K. (2023) Epigenetic regulation during plant development and the capacity for epigenetic memory. *Annual Review of Plant Biology*, 74:347–369, DOI:10.1146/annurev-arplant-070122-025047; Marand, A.P., et al. (2023) *cis*-Regulatory elements in plant development, adaptation, and evolution. *Annual Review of Plant Biology*, 74:111–137, DOI:10.1146/annurev-arplant-070122-030236.

Unit 3: Post-transcriptional, Translational, and Post-translational Regulation -- RNA splicing mechanisms and alternative splicing; RNA editing, stability, transport, and degradation pathways; Regulatory roles of microRNAs, siRNAs, and lncRNAs; Insights into translational regulation and protein synthesis; Global proteomics and functional characterization of protein complexes; Role of post-translational modifications (e.g. phosphorylation, ubiquitination, etc.) and degradation in cellular processes. **10 hours**

Essential Readings: Lodish, H. et al. (2016/2021) *Molecular Cell Biology*, 8th /9th edition, W.H. Freeman, ISBN:9781464183393, Chapter 9 (Post-Transcriptional Gene Control); Wu, Q. and Bazzini, A.A. (2023) Translation and mRNA stability control. *Annual Review of Biochemistry*, 92:227–245, DOI:10.1146/annurev-biochem-052621-091808; Millar, A.H. et al. (2019) The scope, functions, and dynamics of posttranslational protein modifications. *Annual Review of Plant Biology* 70:119–151, DOI:10.1146/annurev-arplant-050718-100211.

Unit 4: Functional Genomics and Genome Editing and their Applications -- High-throughput RNA sequencing (single-cell transcriptomics); Spatial Transcriptomics; CRISPR-Cas technologies: principles and applications; Gene Function validation through knockouts, knockdowns, TILLING, and transposon-tagging; Engineering crops with enhanced traits (e.g., drought resistance, pest tolerance); Case studies in transcriptional regulation and its relevance to diseases (e.g., cancer, diabetes). **10 hours**

Essential Readings: Brown, T.A. (2023) *Genomes 5*. CRC Press, ISBN:9780367674076 (print) and 9781003133162 (eBook), Chapter 6 (Identifying gene functions), Chapter 17 (Agricultural genomics); Chen, K. et al. (2019) CRISPR/Cas genome editing and precision plant breeding in agriculture. *Annual Review of Plant Biology*, 70:667–697, DOI:10.1146/annurev-arplant-050718-100049; Mackelprang, R. and Lemaux, P.G. (2020) Genetic engineering and editing of plants: An analysis of new and persisting questions. *Annual Review of Plant Biology*, 71:659–687, DOI:10.1146/annurev-arplant-081519-035916.

Practicals (30 hours)

1. Plant DNA extraction and quality assessment.
2. Plant RNA isolation and quality assessment.
3. Gene expression analysis by qRT-PCR.
4. Analysis and validation of qRT-PCR dataset by Student's t-test.
5. Experimental designing of CRISPR-Cas9-mediated gene editing in plants.

Suggested Readings:

1. Berg, J.M., et al. (2012) *Biochemistry*. W.H. Freeman and Company, New York, ISBN:9781429229364.

2. Buchanan, B.B., et al. (2015) *Biochemistry and Molecular Biology of Plants*. 2nd edition, John Wiley & Sons, Ltd., ISBN:9780470714218.
3. Kahl, G. and Meksem, K. (2008) *The handbook of plant functional genomics*. Wiley-VCH Verlag, ISBN:9783527318848.
4. Krebs, J.E., et al. (2018) *Lewin's Genes XII*. 12th edition, Jones and Bartlett Learning, ISBN:9781284104493.
5. Latchman, D.S. and Cheriya, V. (2025) *Gene Control*. 3rd edition, Garland Science New York, ISBN:9781003382225, DOI:10.1201/9781003382225.
6. Lodish, H., et al. (2016) *Molecular Cell Biology*. 8th edition, WH Freeman and Company, New York, ISBN: 978-1464183393.
7. Stewart Jr., C.N, (2025) *Plant Biotechnology and Genetics: Principles, Techniques and Applications*. 3rd edition, John Wiley & Sons Inc., ISBN:9781394217236.

PBSE204: Cell Signaling and Communication

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE204: Cell Signaling and Communication	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to provide a comprehensive understanding of cellular signaling and communication in different organisms. It will cover fundamental signaling pathways, receptor mechanisms, primary and second messengers, and their roles in cellular responses. Students will explore the molecular basis of cell cycle regulation and hormone signaling, with a special focus on plant hormones and their roles in stress responses, growth, and development. The course integrates key regulatory mechanisms, emphasizing experimental insights and biological relevance.

Learning Outcomes

The candidate would learn about cellular signaling and communication, controlling a myriad of cellular processes, and coupling the cellular processes with external and internal signals/stimuli. The candidate will develop a fundamental understanding of how cells communicate with one another and respond to external stimuli, which govern all cellular functions, including growth, development, and even cell death, making it essential to comprehend complex biological processes.

Course Content (45 hours)

Unit 1: Basic Understanding of Cellular Signaling and Communication -- External and internal signals; Different signaling pathways; Analogy of signaling pathways to electronic circuitry; Stimulus response-coupling; Cellular communication through receptors and plasmodesmata; Two-component system; G-protein coupled receptors, receptor tyrosine kinase, receptor-like kinase, ion channel receptor, other cell surface receptors, intracellular hormone receptors, intracellular ligand-receptor. **10 hours**

Essential Readings: Gomperts, B.D., et al. (2009) Signal Transduction. Academic Press USA, ISBN: 9780123694416, Chapter 1 (Prologue: Signal transduction, origin and ancestors), Chapter 2 (First messengers); Buchanan, B.B., et al. (2015) Biochemistry and Molecular Biology of the Plants. American Society of Plant Biologists, ISBN:9780470714218, Chapter 18 (Signal transduction); Alberts, B., et al. (2015) Molecular Biology of the Cell. Garland Publishing, Taylor & Francis Group, USA, ISBN:9780815344322, Chapter 15 (Cell signaling).

Unit 2: Primary and Second Messengers -- Growth factors and hormones in animals (EGF, interleukins, cytokines, insulin, etc.); Plant hormones (auxins, cytokinins, gibberellins, abscisic acid, etc.); Second messengers (Ca^{2+} , ROS, IP_3 , cAMP, cGMP, DAG, etc.). **5 hours**

Essential Readings: Buchanan, B.B., et al. (2015) Biochemistry and Molecular Biology of the Plants. American Society of Plant Physiologists, USA, ISBN:9780470714218, Chapter 18 (Signal transduction); Alberts, B., et al. (2015) Molecular Biology of the Cell. Garland Publishing, Taylor & Francis Group, USA, ISBN:9780815344322,

Chapter 15 (Cell signaling); Gomperts, B.D., et al. (2009) Signal Transduction, Academic Press, USA, ISBN:9780123694416, Chapter 2 (First messengers).

Unit 3: Signaling Pathway in Prokaryotes, Animals, and Plants -- Histidine kinase-based signaling, GPCR-based signaling, receptor tyrosine kinase-based signaling, receptor kinase-based signaling, MAP-kinase-based signaling, Ca^{2+} signaling, phospholipid-based signaling, cyclic nucleotide (cAMP/cGMP)-based signaling; Role of protein kinases and phosphatases in signaling pathways. 12 hours

Essential Readings: Gomperts, B.D., et al. (2009) Signal Transduction. Academic Press, ISBN:9780123694416, Chapter 3 (Receptors), Chapter 4 (GTP-binding proteins and signal transduction), Chapter 5 (Effector enzymes coupled to GTP binding proteins: Adenylyl cyclase and phospholipase), Chapter 6 (The regulation of visual transduction and olfaction), Chapter 20 (Signaling through receptor serine/threonine kinases); Buchanan, B. B. et al. (2015) Biochemistry and Molecular Biology of the Plants. American Society of Plant Physiologists, USA, ISBN:9780470714218, Chapter 18 (Signal transduction); Alberts, B., et al. (2015) Molecular Biology of the Cell. 6th edition, Garland Publishing, ISBN:9780815344322, DOI:10.1201/9781315735368, Chapter 15 (Cell signaling).

Unit 4: Plant Hormones Signaling and Regulation of Cell Cycle -- Signal perception of auxin, ABA, GA, cytokinins, ethylene, brassinosteroids, jasmonic acid, salicylic acid, strigolactones, etc.; Regulation of gene expression during signal transduction; Role of mutants in understanding hormone action; Regulation of biotic and abiotic stresses by phytohormones. Overview of cell cycle, progression to mitosis and meiosis; Cell cycle checkpoints, role of cyclin and cyclin-dependent kinases. 18 hours

Essential Readings: Buchanan, B.B., et al. (2015) Biochemistry and Molecular Biology of the Plants. American Society of Plant Biologists, USA, ISBN:9780470714218, Chapter 18 (Signal transduction), Chapter 11 (Cell division); Alberts, B. et al. (2015) Molecular Biology of the Cell. Garland Publishing, Taylor & Francis Group, USA, ISBN:9780815344322, Chapter 15 (Cell signaling), Chapter 17 (The cell cycle); Kleinsmith, L.J. and Kish, V.M. (1996) Principles of Cell and Molecular Biology. HarperCollins College Publishers, USA, ISBN:9780065004045, Chapter 12 (Cell cycles and cell division).

Practicals (30 hours)

1. Effect of stress signals on growth kinetics of *E. coli*.
2. Analysis of a calcium sensor and its effector kinase by yeast two-hybrid growth assay.
3. Effect of stress stimuli on plant signaling mutants by analyzing the growth phenotype.
4. Localization of cellular auxin biosensor, *DR5::GFP*, in the roots of *Arabidopsis*.
5. Effect of abiotic stress signals on key signaling gene expression in *Arabidopsis thaliana*.

Suggested Readings:

1. Gomperts B.D., et al. (2009) Signal Transduction. 2nd edition, Academic Press, USA, ISBN:9780123694416, DOI:10.1016/B978-0-12-369441-6.X0001-3.
2. Alberts, B., et al. (2015) Molecular Biology of the Cell. Garland Publishing, ISBN:9780815344322.
3. Buchanan, B.B., et al. (2015) Biochemistry and molecular biology of the plants. American Society of Plant Biologists and Wiley Blackwell, ISBN:9780470714218.
4. Karp, G., et al. (2019) Cell and Molecular Biology. 9th edition, John Wiley & Sons, USA, ISBN:781119598169.
5. Kleinsmith, L.J. and Kish, V.M. (1995) Principles of Cell & Molecular Biology. 2nd edition, Harper Collins College Publishers, USA, ISBN:9780065004045.
6. Lodish, H., et al. (2016) Molecular Cell Biology. Freeman & Co., USA, ISBN:9781464183393.

PBSE205: Plant-Environment Interactions

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE205: Plant-Environment Interactions	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

Adverse environmental conditions significantly impact plant survival and productivity. The paper aims to provide an in-depth understanding of how plants perceive and interact with their environments. Students will learn about the effect of different stresses on plant growth and development, the impact of climate change on plant-environment interactions, and how plants adapt to these changing conditions. The course will introduce experimental approaches, modern techniques, and analytical tools for studying plant stress biology.

Learning Outcomes

Students will be able to understand the interactions between plants and their environment, and understand their significance in agriculture and ecology. They will be able to evaluate the changes that plants undergo under challenging conditions and differentiate between the responses to biotic and abiotic stresses. Students will design and execute experiments using physiological, biochemical, and molecular techniques to study plant responses and adaptations. Moreover, students will be able to propose innovative solutions to mitigate the adverse effects of environmental stress on crop productivity using advanced molecular biology and bioengineering approaches. Based on their knowledge, they can develop strategies for developing stress-tolerant plants and their applications in sustainable agriculture and environmental remediation.

Course Content (45 hours)

Unit 1: Plant-Environment Interactions and Plant Stress Responses -- Overview of abiotic and biotic factors and plant responses; Adaptation strategies in different ecosystems (desert, halophytes, aquatic plants, etc.); Role of plant microbiomes in environmental interactions; Stress perception; Stress signal transduction pathways; Role of phytohormones; Epigenetic modifications and non-coding RNAs in plant stress adaptation; Crosstalk between different signaling pathways; Concept of phenotypic plasticity and stress memory in plants. **8 hours**

Essential Readings: Manghwar, H., et al. (2024) Plant Biotic and Abiotic Stresses. Life (Basel), 14(3):372, DOI:10.3390/life14030372; Hao, J-R., et al. (2024) Harnessing the plant microbiome for environmental sustainability: From ecological foundations to novel applications. Science of the Total Environment, 951:175766, DOI:10.1016/j.scitotenv.2024.175766; Ali, J., et al. (2024) Harnessing phytohormones: Advancing plant growth and defence strategies for sustainable agriculture. Physiologia Plantarum, 176:e14307, DOI:10.1111/ppl.14307; Ma, L., et al. (2025) Epigenetic control of plant abiotic stress responses. Journal of Genetics and Genomics, 52(2):129–144, DOI:10.1016/j.jgg.2024.09.008; Li, P., et al. (2025) Phenotypic plasticity and stability in plants: Genetic mechanisms, environmental adaptation, evolutionary implications, and future directions. Plant, Cell and Environment, 48(8):5847–5860, DOI:10.1111/pce.15566; Siddique, A.B., et al. (2024) Revisiting plant stress memory: mechanisms and contribution to stress adaptation. Physiology and Molecular Biology of Plants, 30:349–367, DOI:10.1007/s12298-024-01422-z.

Unit 2: Abiotic Stress Responses -- Types of abiotic stress factors; Climate change and pollution; Physiological, morphological, biochemical, and molecular changes in plants against different abiotic stresses; Stress tolerance in crops through allelic variation; Genomic and transcriptomic approaches in abiotic stress research; Engineering plants for abiotic stress resilience; Phytoremediation and environmental biotechnology. **12 hours**

Essential Readings: Zhang, H., et al. (2022) Abiotic stress responses in plants. *Nature Reviews Genetics*, 23:104–119, DOI:10.1038/s41576-021-00413-0; Ahmad, P. and Prasad, M.N.V. (2011). Abiotic stress responses in plants. Springer New York, ISBN:9781461406334 (pages1–369); Varadharajan, V., et al. (2025) Multi-omics approaches against abiotic and biotic stress-A review. *Plants (Basel)*, 14(6):865, DOI: 10.3390/plants14060865; Nedjimi, B., et al. (2021) Phytoremediation: a sustainable environmental technology for heavy metals decontamination. *SN Applied Sciences*, 3:286, DOI:10.1007/s42452-021-04301-4; Sinha, A., et al. (2020) Potential of allele mining for improving drought tolerance in crops. *International Journal of Current Microbiology and Applied Sciences*, 9(5):1098–1117. DOI:10.20546/ijcmas.2020.905.121.

Unit 3: Biotic Stress Responses and Symbiotic Interactions -- Types of biotic stresses; Molecular basis of plant-pathogen interactions (compatible vs. incompatible); Plant defense mechanisms against biotic agents (PTI and ETI); Plant disease resistance and susceptibility genes; Role of Systemic Acquired Resistance (SAR), Induced Systemic Resistance (ISR), and Hypersensitive Response (HR); Role of secondary metabolites; Plant immunity and priming; Effect of climate change on biotic interactions; Genetic and molecular basis of plant-insect interaction; Diversity in parasitic plants; Molecular mechanisms of host-parasite interactions, host plant pre- and post-attachment defense responses; Role of mobile RNAs and proteins in parasitism and defense responses; Rhizobial symbiosis and molecular regulation of nodule development; Interactions with arbuscular mycorrhizal fungi (AMF); Other mutualistic associations; Genomic insights into symbiotic relationships. **18 hours**

Essential Readings: Buchanan, B.B., et al. (2015) *Biochemistry and Molecular Biology of Plants*, 2nd edition, Chapter-21 (Responses to plant pathogens), Wiley-Blackwell, ISBN:9781118502198; Wang, Y., et al. (2022) Evasion of plant immunity by microbial pathogens. *Nature Reviews Microbiology*, 20(8):449–464, DOI: 10.1038/s41579-022-00710-3; Lopez-Raez, J., et al. (2025) Molecular mechanisms modulating beneficial plant root-microbe interactions: What's common? *Plant Communications*, 101592, DOI:10.1016/j.xplc.2025.101592; Li, F., et al. (2025) Antiviral RNA interference in plants: Increasing complexity and integration with other biological processes. *Plant Communications*, 6(10):101490, DOI:10.1016/j.xplc.2025.101490; Castro, B. (2021) Stress-induced reactive oxygen species compartmentalization, perception and signalling. *Nature Plants*, 7(4):403–412, DOI:10.1038/s41477-021-00887-0; van Schie, C.C. and Takken, F.L. (2014) Susceptibility genes 101: how to be a good host. *Annual Review of Phytopathology*, 52:551–581. DOI:10.1146/annurev-phyto-102313-045854; Mahmood, M.A., et al. (2024) Methyl-salicylate (MeSA)-mediated airborne defence. *Trends in Plant Science*, 29(4):391–393, DOI:10.1016/j.tplants.2023.12.001; Zou, J., et al. (2024) Plant-nematode battle: engagement of complex signaling network. *Trends in Parasitology*, 40(9):846–857, DOI:10.1016/j.pt.2024.07.010; Wani, K.A., et al. (2025) Evolutionarily ancient functions of enzymatic TIR proteins in innate immunity. *Trends in Immunology*, 46(6):441–454, DOI:10.1016/j.it.2025.04.005; Zhang, X., et al. (2025) Networks of the symbiosis-immunity continuum in plants. *Cell Host and Microbe*, 33(8):125–1275, DOI:10.1016/j.chom.2025.06.009.

Unit 4: Experimental Approaches and Applications -- Techniques to study plant stress physiology; Utility of model plant systems (*Arabidopsis-Pseudomonas* interaction, *Rice-Magnaporthe* interaction, etc.); Advanced techniques in high-throughput phenotyping, multi-omics approaches, advanced imaging techniques; Use of bioinformatics and AI in predicting plant stress responses; Case studies for development of climate-smart crops; Applications of synthetic biology, breeding, and transgenic technology for sustainable agriculture. **7 hours**

Essential Readings: Katagiri, F., et al. (2002) The *Arabidopsis thaliana-Pseudomonas syringae* interaction. *Arabidopsis Book*, 1:e0039, DOI:10.1199/tab.0039; Ragulakollu, S., et al. (2025) Unraveling the host-pathogen relationship between rice and *Magnaporthe oryzae*. *Physiological and Molecular Plant Pathology*, 140:102928, DOI:10.1016/j.pmp.2025.102928; Angidi, S., et al. (2025) Advanced high-throughput phenotyping techniques for managing abiotic stress in agricultural crops-A comprehensive review. *Crops*, 5:8,

DOI:10.3390/crops5020008; Vishnoi, S. and Goel, R.K. (2024) Climate smart agriculture for sustainable productivity and healthy landscapes. *Environmental Science & Policy*, 151:103600, DOI:10.1016/j.envsci.2023.103600; Zhang, D., et al. (2025) Synthetic biology and artificial intelligence in crop improvement. *Plant Communications*, 6(2):101220, DOI:10.1016/j.xplc.2024.101220; Koja, Y., et al. (2024) Basic design of artificial membrane-less organelles using condensation-prone proteins in plant cells. *Communications Biology*, 7:1396, DOI:10.1038/s42003-024-07102-8.

Practicals (30 hours)

1. Effect of heat stress on seed germination of *Arabidopsis*.
2. Determination of membrane stability index (MSI) of plant tissues exposed to drought stress.
3. Detection of reactive oxygen species (ROS) in salt-stressed rice plants.
4. Detection of plant pathogen and disease diagnosis by loop-mediated isothermal amplification (LAMP).
5. Detection of hypersensitive response (HR) during R-Avr interaction in *Nicotiana benthamiana* leaves.

Suggested Readings:

1. Tuteja, N. and Gill, S.S. (2013) *Climate change and plant abiotic stress tolerance*. Wiley-VCH Verlag GmbH & Co. KGaA, eISBN:9783527675265.
2. Buchanan, B.B., et al. (2015) *Biochemistry and Molecular Biology of Plants*. 2nd edition, Wiley, USA, ISBN:9781118502198.
3. Dickinson, M. (2003) *Molecular plant pathology*.; BIOS Scientific Publishers, ISBN:9781859960448.
4. Wolpert, T., et al. (2017) *Genome-enabled analysis of plant-pathogen interactions*. APS Press, ISBN:9780890544983.
5. Hirt, H. (2009) *Plant stress biology: From genomics to systems biology*. 1st edition. Blackwell Publishers, ISBN:978352732290.
6. Hull, R. (2014) *Plant Virology*. 5th edition, Academic Press, USA, ISBN:9780123848710.
7. Jenks, M.A. and Hasegawa, P.M. (2014) *Plant abiotic stress*. 2nd edition, Wiley-Blackwell, ISBN:9781118412176.
8. Aftab, T. (2023) *New frontiers in plant-environment interactions: Innovative technologies and developments (Environmental Science and Engineering)*. Springer International Publishing AG. 1st edition, ISBN:9783031437281.
9. Huang, B. (2006) *Plant-Environment Interactions*. 3rd edition. CRC Press, ISBN: 978084933727.
10. Jhu, M.Y., et al. (2025) From hosts to parasites: hormones driving symbiosis-induced *de novo* organogenesis. *Trends in Plant Science*, DOI:10.1016/j.tplants.2025.05.015.

PBSE206: Proteomics, Metabolomics, and Elementomics

This course is open to students of other departments as a GE course.

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE206: Proteomics, Metabolomics, and Elementomics	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

Protein, metabolite, and ionic/element profiles in living systems are crucial for understanding the regulatory and metabolic capacity of the system. The primary objective of this course is to equip students with the principles of proteome, metabolome, and elementome. The course aims to develop knowledge of the application of state-of-the-art technologies to understand the proteome, metabolome, and elementome of different organisms; protein modification; and the complexities of protein-protein interactions and metabolic outcomes. There will be a strong emphasis on how these technologies are applied to the agriculture and health sectors.

Learning Outcomes

Students would develop a detailed understanding of the state-of-the-art techniques and analytical methods for studying the plant proteome, metabolome, and elementome. They will be able to design basic experiments for a given biological condition and compare methods to study proteomics, metabolomics, and elementomics. They will learn to perform data analysis and develop skills to interpret data, such as identifying peptides/proteins/metabolites and metabolites, and comparing proteomes, elementomes, and metabolomes across different groups of samples.

Course Content (45 hours)

Unit 1: Introduction to Proteomics, Metabolomics, and Elementomics -- Introduction to 'Omics'; Protein structure folding and function; Types of Proteomics: structural, functional, and expression; Basics and workflow design of proteomics technology; Comparative proteomics; Metabolites and their importance; Elements and their significance; Technological advancements in multi-omics studies; Importance in agriculture and health sciences. **6 hours**

Essential Readings: Yan, S., et al. (2022) Recent advances in proteomics and metabolomics in plants. *Molecular Horticulture*, 2(1):17, DOI:10.1186/s43897-022-00038-9; van Wijk, K.J. (2001) Challenges and prospects of plant proteomics. *Plant Physiology*, 126(2):501–508. DOI:10.1104/pp.126.2.501; Salt, D.E., et al. (2008) Ionomics and the study of the plant ionome. *Annual Review of Plant Biology*, 59(1):709–733, DOI:10.1146/annurev.arplant.59.032607.092942.

Unit 2: Tools and Techniques in Proteomics -- Principles and applications of the separation technology; 1-D and 2-D Polyacrylamide Gel Electrophoresis (PAGE), workflow, high-throughput methods, importance and applications in proteomics; Proteomic Profiling: protein sequencing, Liquid Chromatography and Mass Spectrometry (LC-MS/MS), quantitative proteomics, advanced methods in proteomics; Isotope Coded Affinity Tag based Protein

Profiling (ICAT), Isobaric Tags for Relative and Absolute Quantitation: iTRAQ, AQUA, ESI-Q-IT-MS; SELDI-TOF-MS, SWATH, database search, protein identification, and pathway analysis; Post-translational modifications and their profiling; High-throughput methods for detection of protein-protein interactions and interactions of proteins with other biomolecules; Immunoproteomics: Overview of immune systems; Utility of antibodies in routine laboratory experiments; Serological proteome analysis; Protein microarrays (analytical and functional), protein array detection methods; Antigen identification by antigen capture and mass spectrometry; Characterization of the cell-mediated immune response by cytokine detection and quantification; Immuno-PCR; Immunoproteomics for major histocompatibility complex (MHC) peptides. 18 hours

Essential Readings: Lesk, A.M. (2010) Introduction to protein science: Architecture, function and genomics. Oxford University Press, ISBN:199541302; Loo, J.A. (2003) The tools of proteomics. *Advances in protein chemistry*, 65:25–56, DOI:10.1016/S0065-3233(03)01015-5; Righetti, P.G. (2024) Quantitative proteomics: a review of different methodologies. *European Journal of Mass Spectrometry*, 10(3):335–348; Patton, W.F., et al. (2002) Two-dimensional gel electrophoresis; better than a poke in the ICAT? *Current Opinion in Biotechnology*, 13(4):321–328, DOI:10.1016/S0958-1669(02)00333-6; Wiese, S., et al. (2007) Protein labeling by iTRAQ: a new tool for quantitative mass spectrometry in proteome research. *Proteomics*, 7(3):340–350, DOI:10.1002/pmic.200600422C; Mathur, M. et al. (2021) Advances in genomics and proteomics in agriculture. In *Crop Improvement* (pp. 23–35), CRC Press, ISBN:9781003099079; Fulton, K.M., et al. (2019) Immunoproteomics methods and techniques. *Immunoproteomics: methods and protocols*. ISBN:9781493995967.

Unit 3: Metabolomics -- Types of metabolites; Definition and scope of metabolomics; Sample preparation and extraction techniques; Separation and detection methods: gas chromatography (GC), high-performance liquid chromatography (HPLC), mass spectrometry (MS) secondary ion MS (SIMS), desorption electrospray ionization (DESI), laser ablation electrospray ionization (LAESI), Nuclear Magnetic Resonance (NMR); Statistical tools for data analysis. 11 hours

Essential Readings: Liu, X. and Locasale, J.W. (2017) Metabolomics: a primer. *Trends in Biochemical Sciences*, 42(4):274–284, DOI:10.1016/j.tibs.2017.01.004; Noack, S. and Wiechert, W. (2014) Quantitative metabolomics: a phantom? *Trends in Biotechnology*, 32:238–244, DOI:10.1016/j.tibtech.2014.03.006; Cajka, T. and Fiehn, O. (2016) Toward merging untargeted and targeted methods in mass spectrometry-based metabolomics and lipidomics. *Analytical Chemistry*, 88:524–545, DOI:10.1021/acs.analchem.5b04491; Wishart, D.S. (2016) Emerging applications of metabolomics in drug discovery and precision medicine. *Nature Reviews Drug discovery*, 15(7):473–484. DOI:10.1038/nrd.2016.32.

Unit 4: Elementomics -- Relevance of mineral nutrients and trace elements; Atomic absorption spectroscopy; High-throughput elemental profiling using inductively coupled plasma-mass spectrometry (ICP-MS), inductively coupled plasma-optical emission spectroscopy (ICP-OES), Energy Dispersive X-ray Spectroscopy (EDS), X-Ray fluorescence spectroscopy, atomic neutron activation analysis; Elemental data analysis. 10 hours

Essential Readings: Kumar, V., et al. (2022) Plant nutrition and food security in the era of climate change. Academic Press, ISBN:9780128229163, Chapter 9 (Plant ionomics: toward high-throughput nutrient profiling); Huang, X.Y. and Salt, D.E. (2016) Plant Ionomics: From elemental profiling to environmental adaptation. *Molecular Plant*, 9(6):787–797, DOI:10.1016/j.molp.2016.05.003; Singh, U.M., et al. (2013) Plant Ionomics: a newer approach to study mineral transport and its regulation. *Acta Physiologiae Plantarum*, 35:2641–2653, DOI:10.1007/s11738-013-1316-8; Marguí, E. (2022) X-ray fluorescence spectrometry for environmental analysis: Basic principles, instrumentation, applications and recent trends. *Chemosphere*, 303:135006, DOI:10.1016/j.chemosphere.2022.135006; Wilschefski, S.C. and Baxter, M.R. (2019) Inductively Coupled Plasma Mass Spectrometry: Introduction to analytical aspects. *The Clinical Biochemist Reviews*, 40(3):115–133, DOI:10.33176/AACB-19-00024; Tromp, R.M. (2024) Energy-dispersive X-ray spectroscopy in a low energy electron microscope. *Ultramicroscopy*, 259:113935, DOI:10.1016/j.ultramicro.2024.113935.

Tutorials (15 hours)

- A visit to Proteomics, Metabolomics, and Elementomics facility.
- Assignment on analysis of the protein data to understand protein function, interactions, and pathways.
- Assignment on analysis of metabolite data to understand metabolic pathways, identify biomarkers, and study the effects of various factors.
- Assignment on analysis of the elemental data to understand elemental homeostasis, identify elemental imbalances, and study the role of elements in biological processes.

Suggested Readings:

1. Antonio, C. (2018) Plant Metabolomics: Methods and Protocols (Methods in Molecular Biology). Humana Press, USA, ISBN:9781493992942.
2. Branden, C.I. and Tooze, T. (1999) Introduction to protein structure. Garland Publishing, USA, ISBN:9780815323051.
3. Saito, K., et al. (2006) Plant Metabolomics (Biotechnology in Agriculture and Forestry). Springer, USA, ISBN:9783540297819.
4. Lammerhofer, M. and Weckwerth, W. (2013) Metabolomics in practice: Successful strategies to generate and analyze metabolic data. Oxford University Press, UK, ISBN:9783527330898.
5. Weckwerth, W. (2007) Metabolomics: Methods and Protocols (Methods in Molecular Biology). Humana Press, USA, ISBN:9781588295613.
6. Tan, B.C., et al. (2017) Proteomics in commercial crops: An overview. Journal of Proteomics, 169:176–188, DOI:10.1016/j.jprot.2017.05.018.

PBSEC207: Plant Tissue Culture and Transformation Methodologies

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSEC207: Plant Tissue Culture and Transformation Methodologies	2	0	0	2	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to provide hands-on training in plant biotechnology techniques, including plant tissue culture, haploid production, protoplast isolation, plant genetic transformation, and virus-induced gene silencing. Students will gain practical experience in media preparation, sterile techniques, regeneration protocols, and molecular screening for plant improvement and research applications.

Learning Outcomes

Upon completion of this course, students will develop proficiency in key plant biotechnology methods, enabling them to perform plant tissue culture, genetic transformation, and molecular validation independently. They will acquire skills in protoplast manipulation, haploid generation, plant transformation and gene silencing, preparing them for careers in plant tissue culture, crop improvement, and biotechnological innovations.

Hands-on Training (60 hours)

Unit 1: Plant Tissue Culture, Micropropagation, and Protoplast Isolation -- Media preparation, surface sterilization of leaf discs of tobacco/hypocotyls of tomato), callus induction and proliferation, shoot and root regeneration, establishment of plantlets; Haploid production through androgenesis: Selection of specific stages of anthers of tobacco/*Datura*, surface sterilization, axenic culture, haploid plant generation; Plant protoplast isolation and transfection: protoplast isolation from leaves/roots of wheat seedlings, viability check using dyes, transformation using PEG method, visualization under confocal microscope. **30 hours**

Essential Readings: Bhojwani, S.S. and Razdan, M.K. (1986) Plant tissue culture: theory and practice. Elsevier, ISBN:0444421645; Bhojwani, S.S. and Dantu, P.K. (2013) Micropropagation. In Plant tissue culture: An introductory text (pp. 245–274). Springer India, ISBN:9788132210252; Davey, M.R., et al. (2010) Plant protoplasts: isolation, culture and plant regeneration. Plant cell culture essential methods. Wiley-Blackwell, New York, 153–173, ISBN:9780470686485; Eriksson, T.R. (2018) Protoplast isolation and culture. In Plant protoplasts (pp. 1–20), CRC Press, ISBN:9781351075770.

Unit 2: Plant Genetic Transformation and Virus-induced Gene Silencing (VIGS) -- *Agrobacterium tumefaciens*-mediated transformation of Arabidopsis plants using the floral dip method, transformants screening, transgene insertion validation by PCR; Agroinfiltration of TRV-*pds* constructs in tobacco leaves, phenotyping, and screening of VIGS lines. **30 hours**

Essential Readings: Koh, H.-J., et al. (2015) Current technologies in plant molecular breeding: A guidebook of plant molecular breeding for researchers. ISBN:9789401799966, Springer Dordrecht, DOI:10.1007/978-94-017-9996-6, Chapter 9 (Plant transformation methods and applications); Birch, R.G. (1997) Plant transformation: problems and strategies for practical application. Annual Review of Plant Biology, 48(1):297–326, DOI:10.1146/annurev.arplant.48.1.297; Jeong, J.H., et al. (2025) Empowering *Agrobacterium*: Ternary vector

systems as a new arsenal for plant transformation and genome editing. *Biotechnology Advances*, 83:108631, DOI:10.1016/j.biotechadv.2025.108631; Rössner, C., et al. (2022) VIGS goes viral: How VIGS transforms our understanding of plant science. *Annual Review of Plant Biology*, 73:703–728, DOI:10.1146/annurev-arplant-102820-020542.

Suggested Readings:

1. Barresi, M.J.F. and Gilbert, S.F. (2023) *Developmental Biology*. 13th edition, Sinauer Associates, ISBN:9780197574591.
2. Westhoff, P. (1998) *Molecular plant development: from gene to plant*. The Bath Press, UK, ISBN:9780198502043.
3. Wolpert, L., et al. (2015) *Principles of Development*. Oxford Publishers, UK, ISBN:9780198709886.
4. Boisson-Dernier, A., et al. (2001) *Agrobacterium rhizogenes*-transformed roots of *Medicago truncatula* for the study of nitrogen-fixing and endomycorrhizal symbiotic associations. *Molecular Plant-Microbe Interactions*, 14(6):695–700, DOI:10.1094/MPMI.2001.14.6.695.

Structure 1 - PG with Coursework

SEMESTER 3

PBSC311: Plant Biotechnology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC311: Plant Biotechnology	4	3	0	1	B. Sc. in any branch of science	NA

Learning Objectives

This course will enable students to understand the core principles and milestones of plant biotechnology, including the molecular basis of crop domestication and Green Revolution traits, as well as concepts in tissue culture. Students will learn about the molecular toolbox for plant genetic engineering and be introduced to advanced approaches, including RNAi, genome editing, and synthetic biology, for pathway engineering. The course will build conceptual understanding of modern gene/QTL mapping, marker-assisted and genomic selection, speed breeding, and gene pyramiding, together with applications of plant biotechnology in molecular farming, biofortification, climate resilience, plant-microbe interactions, and industrial and environmental biotechnology. Finally, students will be sensitized to biosafety guidelines, GMO risk assessment, IPR, farmers’ rights, and ethical and societal issues in plant biotechnology.

Learning Outcomes

On completing the course, students will be able to explain and apply tissue culture and related technologies for crop improvement. They will be able to outline and compare plant transformation and genome editing strategies, design genetic constructs and describe workflows for the generation and characterization of transgenic and edited plants. Students will be able to select appropriate molecular markers and mapping approaches for dissecting complex traits, and integrate marker-assisted selection, genomic selection, and breeding pipelines. They will be able to critically analyse case studies such as Golden rice, Bt cotton, virus-resistant papaya, and DH mustard, among others. In addition, they will be able to interpret biosafety and regulatory frameworks, IPR/PBR/farmer’s rights provisions, and articulate ethical, social, and policy implications of deploying plant biotechnological innovations in agriculture.

Course Content (45 hours)

Unit 1: Fundamentals and Scope of Plant Biotechnology -- Concept, history, and milestones in plant biotechnology; Molecular basis of crop domestication and Green revolution; Principles of plant tissue culture, totipotency, and micropropagation; Somaclonal variation, somatic embryogenesis, and synthetic seeds; Protoplast fusion and somatic hybridization. **5 hours**

Essential Readings: Stewart Jr., C.N. (2025) Biotechnology and Genetics: Principles, Techniques, and Applications. 3rd edition, John Wiley & Sons, ISBN:9781394217236, Chapter 1 (Plant Agriculture: The impact of biotechnology); Abdin, M.Z, et al. (2017) Plant Biotechnology: Principles and Applications, Springer Verlag,

Singapore, ISBN:9789811029592, Chapter 1 (Historical perspective and basic principles of plant tissue culture), Chapter 2 (Plant tissue culture: Applications in plant improvement and conservation); Pathirana, R. and Carimi, F. (2024) Plant biotechnology-an indispensable tool for crop improvement. *Plants* (Basel), 13(8):1133, DOI:10.3390/plants13081133.

Unit 2: Molecular Tools and Techniques -- Genetic cloning strategies and vector systems; Promoters, selectable markers, and reporter genes; Gene transfer methods; Chloroplast transformation; Characterization of transgenic plants at molecular, biochemical, and phenotypic level; Case studies: Golden rice, Bt cotton, virus-resistant papaya, herbicide-tolerant crops, Dhara Mustard, any other product; Virus-induced gene silencing (VIGS) methods; Genome editing technologies [Zinc Finger Nucleases, Transcription activator-like effector nucleases, Clustered Regularly Interspaced Short Palindromic Repeats or CRISPR)/CRISPR-associated (Cas) systems, prime editing, base editing, and miniature RNA-guided endonuclease]; Generation of marker-free transgenics; RNAi interference (RNAi); Introduction of synthetic biology and metabolic pathway engineering. **15 hours**

Essential Readings: Li, B., et al. (2024) Targeted genome-modification tools and their advanced applications in crop breeding. *Nature Reviews Genetics*, 25(9):603–622, DOI:10.1038/s41576-024-00720-2; Liu, W., et al. (2013) Advanced genetic tools for plant biotechnology. *Nature Review Genetics*, 14:781–793, DOI:10.1038/nrg3583; Gupta, O.P. and Karkute, S.G. (2021) Genome editing in plants: Principles and applications, CRC Press, ISBN:9780367415907, Chapter 1 (Historical developments of genome editing in plants), Chapter 2 (Mechanism of ZFN mediated genome editing: scope and opportunities), Chapter 3 (TALEN: customizable molecular scissors for tailoring newer types of genomes in plants), Chapter 4 (Mechanism of CRISPR/Cas9 mediated genome editing: scope and opportunities); Koeppe, S., et al. (2023) RNA interference: past and future applications in plants, *International J. Molecular Science*, 24(11):9755, DOI: 10.3390/ijms24119755; Singh, R., et al. (2023) A prospective review on selectable marker-free genome engineered rice: past, present and future scientific realm, *Frontiers in Genetics*, 13:2022, DOI:10.3389/fgene.2022.882836; Aaron, S., et al. (2020) Metabolic engineering and synthetic biology of plant natural products – A minireview. *Current Plant Biology*, 24:100163, DOI:10.1016/j.cpb.2020.100163.

Unit 3: Mapping of Genes/QTLs -- High-throughput molecular markers and genotyping assays; Bulk segregant analysis (QTL-seq), Target-Sequence Enrichment and Sequencing (TESeq), Resistance gene enrichment sequencing (RenSeq), and Mutation mapping (MutMap, MutMap-Gap, etc); Genome-Wide Association Studies (GWAS); Marker-assisted plant breeding and genomic selection (GS); Speed breeding; Gene Pyramiding; Hybrid breeding and doubled haploid technologies. **15 hours**

Essential Readings: Jaganathan, D., et al. (2020) Fine mapping and gene cloning in the post-NGS era: advances and prospects. *Theoretical and Applied Genetics*, 133(5):1791–1810, DOI:10.1007/s00122-020-03560-w; Wang, X., et al. (2023) Next-generation bulked segregant analysis for Breeding 4.0. *Cell Reports*, 42(9):113039, DOI:10.1016/j.celrep.2023.113039; Uffelman, E., et al. (2021) Genome-wide association studies. *Nature Reviews Methods Primers*, 1:59, DOI:10.1038/s43586-021-00056-9; Kabade, P.G., et al. (2025) Speed breeding 3.0: mainstreaming light-driven plant breeding for sustainable genetic gains. *Trends in Biotechnology*, 43(10):2462–2478, DOI:10.1016/j.tibtech.2025.04.011; Crossa, J., et al. (2017) Genomic selection in plant breeding: methods, models, and perspectives, *Trends in Plant Science*, 22(11):961–975, DOI:10.1016/j.tplants.2017.08.011; Qu, Y., et al. (2024) Doubled haploid technology and synthetic apomixis: Recent advances and applications in future crop breeding. *Molecular Plant*, 17(7):1005–1018, DOI:10.1016/j.molp.2024.06.005.

Unit 4: Applications and Societal Aspects of Plant Biotechnology -- Molecular farming; Biofortification and nutritional enhancement; Manipulating and harnessing plant-microbe interactions: disease resistant plants, biofertilizers, biopesticides, and mycorrhizal biotechnology; Climate-resilient crops: generation of abiotic stress tolerant plants; Industrial Biotechnology: bioethanol and other products; Environmental biotechnology: phytoremediation; Regulatory frameworks: biosafety guidelines, GMO risk assessments, and

intellectual property rights (IPR); Plant breeders' rights (PBRs) and farmers' rights; Ethical, social, and policy implications of plant biotechnology. **10 hours**

Essential Readings: Shanmugaraj, B., et al. (2020) Plant molecular farming: A viable platform for recombinant biopharmaceutical production. *Plants*, 9(7):842, DOI:10.3390/plants9070842; Garg, M., et al. (2024) Biofortification for nutrient-rich crops. ISBN:9781032690636, DOI:10.1201/9781032690636; Digel, I., et al. (2025) Introduction to Industrial Biotechnology, Springer Cham, ISBN:9783032079183, DOI:10.1007/978-3-032-07918-3; Abdin, M.Z., et al. (2017) Plant Biotechnology: Principles and Applications, Springer Verlag, Singapore, ISBN:9789811029592, Chapter 14 (Biosafety, Bioethics, and IPR Issues in Plant Biotechnology); Protection of plant varieties and farmers' right act (PPV & FR), 2001, Ministry of Agriculture and Farmers Welfare, GoI; Standard Operating Procedures for regulatory review of genome edited plants under SDN-1 and SDN-2 categories 2022 and Guidelines on genetically engineered plants containing stacked events 2025 by Department of Biotechnology, MoS&T, GoI.

Practicals (30 hours)

1. Assessment of promoter activity in transgenic plants using beta-glucuronidase (GUS) reporter through histochemical staining and fluorometric (MUG) assays.
2. To perform PCR-based screening of *Arabidopsis* T-DNA insertion lines to distinguish heterozygous and homozygous plants.
3. Genome editing of a target gene in a plant (GFP/transient assay).
4. T7E1/ Surveyor mismatch cleavage assays to detect mutated/edited genomic regions.
5. Construction of a plant genetic linkage map with molecular markers.

Suggested Readings:

1. Acquaah, G. (2020) Principles of Plant Genetics and Breeding, 3rd edition, Wiley-Blackwell, ISBN:9781119626695.
2. Al-Khayri, J.M., et al. (2025) Genome Editing for Crop Improvement - Theory and Methodology. CAB International, ISBN:9781800622494.
3. Hille, F., et al. (2018) The biology of CRISPR-Cas: Backward and forward. *Cell*, 172(6):1239–1259, DOI:10.1016/j.cell.2017.11.032.
4. Singh, B.D. and Singh, A.K. (2015) Marker-Assisted Plant Breeding: Principles and Practices, Springer New Delhi, ISBN:9788132223160, DOI:10.1007/978-81-322-2316-0.
5. Clauw, P., et al. (2025) Beyond the standard GWAS-A guide for plant biologists. *Plant and Cell Physiology*, 66(4):431–443, DOI:10.1093/pcp/pcae079.
6. Quiroz, L.F., et al. (2024) Haploid rhapsody: the molecular and cellular orchestra of *in vivo* haploid induction in plants. *New Phytologist*, 241(5):1936–1949, DOI:10.1111/nph.19523.
7. Ghosh, S., et al. (2018) Speed breeding in growth chambers and glasshouses for crop breeding and model plant research. *Nature Protocols*, 13:2944–2963, DOI:10.1038/s41596-018-0072-z.
8. Chen, J.T. (2024) Plant speed breeding and high-throughput technologies, CRC Press, ISBN: 9781003434733.
9. Xiong, J., et al. (2023) Synthetic apomixis: the beginning of a new era. *Current Opinion in Biotechnology*, 79:102877, DOI:10.1016/j.copbio.2022.102877.
10. WHO (2004) Laboratory Biosafety Manual, 3rd edition
11. FAO (2018) Biosafety Primer.
12. Department of Biotechnology (DBT), MoS&T, GoI (2023) Intellectual Property Guidelines.
13. Scientific Journals: Plant Biotechnology Reports; International Journal of Plant Biotechnology; Plant Biotechnology Journal; Transgenic Research; Journal of Plant Biotechnology; Plant Cell, Tissue and Organ Culture.
14. Singh, K.K. (2014) Biotechnology and intellectual property rights-legal and social implications. ISBN:9788132220596, DOI:10.1007/978-81-322-2059-6.

PBSC312: Molecular Plant Breeding

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC312: Molecular Plant Breeding	4	3	0	1	B. Sc. in any branch of science	NA

Learning Objectives

Molecular breeding has greatly advanced human agriculture by enabling the continuous improvement of food and industrial crops. This paper introduces students to the foundations of classical breeding, quantitative genetics, and plant genetic resources, while also covering advanced molecular methods such as marker-assisted selection, QTL mapping, genomic selection, and hybrid breeding technologies. By integrating conventional and modern techniques, the course highlights how new, high-performing crop varieties are developed to meet global demands for productivity, quality, and stress resilience.

Learning Outcomes

Students will be able to understand the historical foundations and objectives of plant breeding and crop genetics beyond model plant systems. They will be able to distinguish breeding methods across reproductive systems and the application of molecular tools in enhancing crop quality at the field level. It will equip them with the capability to understand and evaluate global molecular breeding efforts, integrate genetic modification with modern breeding practices, and apply strategies to enhance yield, quality, and stress tolerance.

Course Contents (45 hours)

Unit 1: Plant breeding -- Introduction and history of breeding; Breeding objectives and crop traits; Principles of population and quantitative genetics; Plant genetic resources and crop domestication; Breeding in self-pollinated, cross-pollinated, and clonally propagated species; Concept of molecular breeding. **12 hours**

Essential Readings: Acquaah, G. (2021) Principles of Plant Genetics and Breeding, 3rd Edition, Wiley Blackwell, ISBN:9781119626329; Singh, D.P., et al. (2021) Plant Breeding and Cultivar Development, Academic Press, ISBN:9780128175637, DOI:10.1016/C2018-0-01730-2.

Unit 2: Molecular markers and their Utilisation -- Molecular markers and genotyping methods; Linkage mapping of molecular markers; Mapping populations and quantitative trait loci mapping; Association mapping; Marker-assisted selection; Training population and statistical models in genomic selection; Phylogenetic relationships and genetic diversity; Mutation mapping and breeding; Process of variety release, Seed certification, and commercial release. **12 hours**

Essential Readings: Singh, B.D. and Singh, A.K. (2015) Marker-Assisted Plant Breeding: Principles and Practices, ISBN:9788132223160, DOI:10.1007/978-81-322-2316-0; Amiteye, S. (2021) Basic concepts and methodologies of DNA marker systems in plant molecular breeding. Heliyon, 7(10):e08093, DOI: 10.1016/j.heliyon.2021.e08093; Al-Khayri, J.M., et al. (2024) Plant Molecular Breeding in Genomics Era - Concepts and Tools, Springer Cham, ISBN:9783031685866, DOI:10.1007/978-3-031-68586-6; Bhat, T.A. and Hakeem, K.R. (2023) Biotechnologies and genetics in plant mutation breeding (volume 1: Mutagenesis and Crop Improvement). Apple Academic Press, Inc., ISBN:9781003305064; Acquaah, G. (2021) Principles of Plant

Genetics and Breeding, 3rd edition, Wiley-Blackwell, ISBN:9781119626329, Section 12 (Variety release process in plant breeding).

Unit 3: Hybrid Breeding and Doubled haploid (DH) Technologies -- Genetic basis of heterosis and hybrid breeding strategies; Molecular aspects of three-line and two-line approaches (photoperiod- and thermo-sensitive genic male sterility); Transgenics in hybrid seed production; Role of DH lines in mapping and varietal improvement; Molecular mechanisms of haploid induction (maternal and paternal); Synthetic apomixis and fixing elite genotypes. 12 hours

Essential Readings: Chen, L. and Liu, Y.G. (2014) Male sterility and fertility restoration in crops. *Annual Review of Plant Biology*, 65:579–606, DOI:10.1146/annurev-arplant-050213-040119; Kim, Y.J. and Zhang, D. (2018) Molecular control of male fertility for crop hybrid breeding. *Trends in Plant Science*, 23(1):53–65, DOI: 10.1016/j.tplants.2017.10.001; Quiroz, L.F., et al. (2024) Haploid rhapsody: the molecular and cellular orchestra of *in vivo* haploid induction in plants. *New Phytologist*, 241(5):1936–1949, DOI: 10.1111/nph.19523.

Unit 4: Applications of Molecular Breeding -- International molecular breeding efforts; Improving crop yields, quality, biotic and abiotic stress tolerance; Enhancing shelf-life, nutritional value and flavor; Integration of genetic modification and molecular breeding. 9 hours

Essential Readings: Acquaah, G. (2021) *Principles of plant genetics and breeding*, 3rd edition, Wiley-Blackwell. ISBN:9781119626343, Chapter 14 (Breeding for resistance to disease and insect pests), Chapter 15 (Breeding for resistance to abiotic stresses), Chapter 35 (International plant breeding efforts); Lomax, J., et al. (2024) Multi-omic applications for understanding and enhancing tropical fruit flavour. *Plant Molecular Biology*, 114(4):83, DOI:10.1007/s11103-024-01480-7; Sharma, R., et al. (2025) Integrating molecular genetics with plant breeding to deliver impact. *Plant Physiology*, 198(3):kiaf087, DOI:10.1093/plphys/kiaf087.

Practicals (30 hours)

1. *In silico* analysis of crop genomes and identification of polymorphisms under known QTLs.
2. Designing markers and genotyping of locus-specific SNPs using CAPS and dCAPS markers.
3. Haplotype analysis from publicly available genomic data of a selected crop plant.
4. Verification of true F₁ hybrid with molecular markers in bi-parental crossed plants.
5. Association analysis of selected genotypes with their phenotype data.

Suggested Readings:

1. Koh, H.J., et al. (2015) *Current technologies in plant molecular breeding - A guidebook of plant molecular breeding for Researchers*. ISBN:9789401799966, DOI:10.1007/978-94-017-9996-6.
2. Al-Khayri, J.M., et al. (2016) *Advances in plant breeding strategies: Breeding, Biotechnology and Molecular Tools*, Springer Cham, ISBN:9783319225210, DOI:10.1007/978-3-319-22521-0.
3. Kang, M.S. (2020). *Quantitative genetics, genomics and plant breeding*, 2nd Edition, CABI, ISBN: 9781789242942.
4. Li, B., et al. (2024) Targeted genome-modification tools and their advanced applications in crop breeding. *Nature Reviews Genetics*, 25(9):603–622, DOI:10.1038/s41576-024-00720-2.
5. Bharadwaj, D.N. (2018) *Advanced Molecular Plant Breeding- Meeting the challenge of food security*. CRC Press. ISBN:9780203710654, DOI:10.1201/b22473.
6. Crossa, J., et al. (2017) Genomic selection in plant breeding: Methods, models, and perspectives. *Trends in Plant Science*, 22(11):961–975, DOI:10.1016/j.tplants.2017.08.011.
7. Alemu, A., et al. (2024) Genomic selection in plant breeding: Key factors shaping two decades of progress. *Molecular Plant*, 17(4):552–578, DOI:10.1016/j.molp.2024.03.007.
8. Chaudhary, N. and Sandhu, R. (2024) A comprehensive review on speed breeding methods and applications. *Euphytica*, 220:42, DOI:10.1007/s10681-024-03300-x.

9. Rajan, R., et al. (2025) Innovations in climate resilient agriculture, Springer Cham, ISBN:9783031848025, DOI:10.1007/978-3-031-84802-5.
10. Klee, H.J. and Tieman, D.M. (2018) The genetics of fruit flavour preferences. *Nature Reviews Genetics*, 19(6):347–356, DOI:10.1038/s41576-018-0002-5.
11. Kamaluddin, et al. (2022) Technologies in Plant biotechnology and breeding of field Crops. Springer Singapore, ISBN:9789811657672, DOI:10.1007/978-981-16-5767-2.

PBSE313: Metagenomics of Plant-associated Microbes

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE313: Metagenomics of Plant-associated Microbes	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to introduce students to the fundamental concepts of metagenomics and the plant holobiont, with a focus on rhizosphere and aquatic microbiomes using environmental DNA (eDNA). It seeks to develop an understanding of sampling strategies and to familiarize students with the basics of metagenomic data analysis. This would help students appreciate how metagenomic approaches are applied in biodiversity assessment, plant pathology, environmental surveillance, and emerging areas such as space biology, integration of breeding and precision agriculture.

Learning Outcomes

By the end of the course, students should be able to explain key concepts of metagenomics and plant microbiomes and outline appropriate strategies for sampling and sequencing rhizosphere and aquatic environmental samples. They should be able to understand the components of the metagenomic analysis pipeline, interpret community and functional profiles, and critically read metagenomic datasets. Students will be able to relate metagenomic findings to practical applications in plant health, ecosystem monitoring, and sustainable agriculture.

Course Contents (45 hours)

Unit 1: Introduction to Metagenomics -- Concepts of microbiome, metagenome, holobiont, hologenome; Plant-associated microbiomes: Rhizosphere, phyllosphere, endosphere, etc.; Overview of metagenomics and integration with metatranscriptomics, metaproteomics, and metabolomics; Marker genes and DNA barcoding; Overview of workflow and sample preparation methodologies. 15 hours

Essential Readings: Nelson, K.E. (2020) Encyclopedia of metagenomics. Springer, New York, ISBN: 9781461464181, DOI:10.1007/978-1-4614-6418-1; Simon, J.C., et al. (2019) Host-microbiota interactions: from holobiont theory to analysis. Microbiome, 7:5, DOI:10.1186/s40168-019-0619-4; Vorholt, J. (2012) Microbial life in the phyllosphere. Nature Reviews Microbiology, 10:828–840, DOI:10.1038/nrmicro2910; Compant, S., et al. (2021) The plant endosphere world - bacterial life within plants. Environmental Microbiology, 23(4):1812–1829, DOI:10.1111/1462-2920.15240; Christopher, C.M., et al. (2016) Dissecting host-associated communities with DNA barcodes. Philosophical Transactions of the Royal Society Biological Sciences, 371(1702):20150328, DOI:10.1098/rstb.2015.0328.

Unit 2: Rhizosphere and Aquatic Metagenomics -- Environmental DNA (eDNA): sources, stability, sampling, limitations; Rhizosphere: structure, gradients, root exudates and microsome assembly; Aquatic plants-associated microbes; case studies. 10 hours

Essential Readings: Liu, S., et al. (2025) Analysis of metagenomic data. Nature Reviews Methods Primers, 5:5, DOI:10.1038/s43586-024-00376-6; Behera, B.K., et al. (2024) Metagenomics study in aquatic resource management: Recent trends, applied methodologies and future needs. Gene Reports, 25:101371, DOI:

10.1016/j.genrep.2021.101372; Wang, B., et al. (2021) Metagenomic insights into the effects of submerged plants on functional potential of microbial communities in wetland sediments. *Marine Life Science & Technology*, 3(4):405–415, DOI:10.1007/s42995-021-00100-3; Sahu, A., et al. (2023) Environmental DNA (eDNA): Powerful technique for biodiversity conservation. *Journal for Nature Conservation*, 71:126325, DOI: 10.1016/j.jnc.2022.126325; Pudake, R.N. et al. (2021) *Omics science for rhizosphere biology*. Springer Singapore, ISBN:9789811608896, DOI:10.1007/978-981-16-0889-6; Wani, A.K., et al. (2024) Metagenomic profiling of rhizosphere microbiota: Unravelling the plant-soil dynamics. *Physiology and Molecular Plant Pathology*, 133:10238, DOI:10.1016/j.pmpp.2024.102381.

Unit 3: Overview of Metagenomic Data Generation and Analysis -- Workflow overview, Selection of appropriate sequencing technologies (short and long-read); Demultiplexing, adapter and quality trimming, removal of contaminating DNA (host) sequences, metagenomic data assembly, taxonomic characterization (alignment based, alignment-free k-mer based, hybrid strategy); Gene prediction and functional analysis; Metagenomic data repositories.

10 hours

Essential Readings: Thomas T., et al. (2012) *Metagenomics - a guide from sampling to data analysis*. Microbial Informatics and Experimentation, 2:3, DOI:10.1186/2042-5783-2-3; Navgire, G.S., et al. (2022) Analysis and Interpretation of metagenomics data: an approach. *Biological Procedures Online*, 24:18, DOI:10.1186/s12575-022-00179-7; Aplakidou, E., et al. (2024) Visualizing metagenomic and metatranscriptomic data: A comprehensive review. *Computational and Structural Biotechnology Journal*, 23:2011–33, DOI:10.1016/j.csbj.2024.04.060.

Unit 4: Applications of Metagenomics -- Biodiversity assessment of plant-associated ecosystems; Plant pathology; Metagenomics in bioremediation and agro-ecosystem health; Metagenomics in controlled plant growth systems; Space biology; Future perspectives: integrating metagenomics with breeding and agriculture.

10 hours

Essential Readings: Charles, T.C., et al. (2017) *Functional Metagenomics: Tools and Applications*. Springer Cham, ISBN:9783319615103, DOI:10.1007/978-3-319-61510-3; Nagarajan, M. (2024) *Metagenomics - Perspectives, Methods, and Applications*. 2nd edition, Academic Press, ISBN:9780323917124; Roman-Reyna, V. and Crandall, S.G. (2024) Seeing in the dark: a metagenomic approach can illuminate the drivers of plant disease. *Frontiers in Plant Science*, 15:140502, DOI:10.3389/fpls.2024.1405042; Kumar, V. and Iram, S. (2024) *Microbial Technology for Agro-Ecosystems*. Academic Press, ISBN:9780443184468, Chapter 15 (Metagenomics: An approach for understanding microbe-microbe and plant-microbiome-interactions); Compant, S., et. al. (2025) Harnessing the plant microbiome for sustainable crop production. *Nature Reviews Microbiology*, 23(1):9–23, DOI:10.1038/s41579-024-01079-1.

Tutorials (15 hours)

1. Case study: Sargasso Sea.
2. Designing a rhizosphere metagenomics experiment.
3. Case study on how eDNA is used to track microbial biodiversity.
4. Survey of metagenomic databases.

Suggested Readings:

1. Chopra, R.S., et al. (2020) *Metagenomics: techniques, applications, challenges and opportunities*. Springer Singapore, ISBN:9789811565298, DOI:10.1007/978-981-15-6529-8.
2. Streit, W.R. and Daniel, R. (2017) *Metagenomics: Methods and Protocols*. Humana NY, ISBN: 9781493966912, DOI:10.1007/978-1-4939-6691-2.
3. Vacher, C., et al. (2016) The phyllosphere: microbial jungle at the plant–climate interface. *Annual Review of Ecology, Evolution, and Systematics*, 47:1–24, DOI:10.1146/annurev-ecolsys-121415-032238
4. Pudake, R.N., et al. (2021) *Omics science for rhizosphere biology*. Springer Singapore, ISBN:9789811608896, DOI:10.1007/978-981-16-0889-6.
5. Carter, D.O., et al. (2017) *Forensic Microbiology*. Wiley, ISBN:9781119062578, Chapter 5 (An introduction to metagenomic data generation, analysis, visualization, and interpretation).

PBSE314: Frontiers in Plant Molecular Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE314: Frontiers in Plant Molecular Biology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course has been designed to introduce students to state-of-the-art concepts, technologies, and experimental systems that define modern plant molecular biology and its translational applications. It aims to develop a rigorous understanding of plant signaling architectures, multi-omics driven functional genomics, structural advances in genome biology, and emerging domains such as epitranscriptomics, nanobiotechnology, and space biology. Furthermore, it aims to enable students to relate primary discoveries in calcium, ROS, hormone and retrograde signaling to crop improvement, biosensing, and stress resilience through synthetic and genome engineering approaches, supported by current literature in plant signaling and systems biology.

Learning Outcomes

After successful completion of the course, students will be able to critically interpret and integrate datasets from transcriptomic, proteomic, metabolomic, epigenomic, and phenomics platforms to elucidate gene function and regulatory networks in plants. They should be able to design and conceptualize CRISPR-based functional analyses, visualize and analyse gene interaction networks, and evaluate gene function prediction, stress-tolerance forecasting, and genome-assisted breeding. Students will also be able to assess emerging tools, such as optogenetics, targeted epigenome editing, and plant nanotechnology, for their feasibility in research or application in crops, thereby demonstrating their research readiness.

Course Content (45 hours)

Unit 1: Forefront of Plant Signaling -- Mechanosensing and electrosensing; Receptor dynamics and nanodomains; Phosphoswitches and dynamic network mapping; Organelle-to-nucleus signaling (retrograde signaling); Optogenetics and chemical biology tools; Live-cell imaging of Ca²⁺ and ROS dynamics; Phytohormone dynamics studies; Engineering synthetic receptors or signaling circuits for stress tolerance or biosensing. **11 hours**

Essential Readings: Hamilton, E.S., et al. (2015) United in diversity: mechanosensitive ion channels in plants, *Annual Review of Plant Biology*, 66:113–37, DOI:10.1146/annurev-arplant-043014-114700; Fromm, J. and Lautner, S. (2007) Electrical signals and their physiological significance in plants. *Plant Cell and Environment*, 30(3):249–257, DOI:10.1111/j.1365-3040.2006.01614.x; Wang, L., et al. (2018) Exploring the spatiotemporal organization of membrane proteins in living plant cells. *Annual Review of Plant Biology*, 69:525–551, DOI:10.1146/annurev-arplant-042817-040233; Zhang, J., et al. (2023) Protein phosphorylation: A molecular switch in plant signaling. *Cell Reports*, 42(7):112729, DOI:10.1016/j.celrep.2023.112729; Tatjana, K. and Dario, L. (2016) Retrograde signaling: Organelles go networking. *Biochimica et Biophysica Acta (BBA)–Bioenergetics*, 1857(8):1313–1325, DOI:10.1016/j.bbabi.2016.03.017; Hiromasa, S. and Philipp, D. (2022) Plant optogenetics: Applications and perspectives. *Current Opinion in Plant Biology*, 68:102256, DOI:10.1016/j.pbi.2022.102256; Sarah, J., et al. (2011) *In vivo* imaging of Ca²⁺, pH, and reactive oxygen species using fluorescent probes in plants. *Annual Review of Plant Biology*, 62:273–297, DOI:10.1146/annurev-arplant-042110-103832; Rainer, W. (2020) Phytohormone signaling mechanisms and genetic methods for their

modulation and detection, *Current Opinion in Plant Biology*, 57:31–40, DOI:10.1016/j.pbi.2020.05.011; Ondřej N., et al. (2017) Zooming in on plant hormone analysis: Tissue- and cell-specific approaches. *Annual Review of Plant Biology*, 68:323–348, DOI:10.1146/annurev-arplant-042916-040812; Alexander, R.L., et al. (2020) Engineering synthetic signaling in plants. *Annual Review of Plant Biology*, 71:767–788, DOI:10.1146/annurev-arplant-081519-035852.

Unit 2: Structural and Functional Genomics -- Third- and fourth-generation sequencing platforms and their applications in plant genome analysis, principles of transcriptomics and proteomics, including experimental design and data interpretation; Case study-based functional genomics strategies such as large-scale mutagenesis (T-DNA, CRISPR/Cas), RNAi, VIGS and activation tagging to elucidate gene function; Understanding advanced layers of regulation through RNA-seq, ribosome profiling, single-nucleus RNA-seq, and epigenomic assays such as ATAC-seq, ChIP-seq and DNA methylome analysis.

12 hours

Essential Readings: Brown, T.A. (2023) *Genomes 5*. CRC Press, ISBN:9781003133162, Chapter 4 (Sequencing Genomes), Chapter 9 (Transcriptomes and Proteomes), Chapter 10 (Genome Regulation); Mardis, E.R. (2008) Next-generation DNA sequencing methods. *Annual Review of Genomics and Human Genetics*, 9:387–402, DOI:10.1146/annurev.genom.9.081307.164359; Chappell, L., et al. (2018) Single-Cell (Multi)omics Technologies. *Annual Review of Genomics and Human Genetics*, 19:15–41, DOI: 10.1146/annurev-genom-091416-035324.

Unit 3: Applied Aspects of Plant-Environment Interactions -- Overview of plant responses to abiotic and biotic stresses; Molecular signaling pathways; Omics-driven discovery of stress tolerance genes; Engineering the plant microbiome; Spatial and integrative omics for stress biology: single cell vs. tissue level omics, transcriptomics and metabolite mapping of root-soil interface; Inter-kingdom communication; AI and ML in prediction of stress-tolerant genotypes.

11 hours

Essential Readings: Tuteja, N. and Gill, S.S. (2016) *Abiotic stress responses in plants*. ISBN:9783527339181, Wiley-VCH Verlag GmbH & Co., Chapter 1 (Abiotic stress signaling in plants: an overview); Zhang H., et al. (2022) Abiotic stress responses in plants. *Nature Review Genetics*, 23:104–119, DOI:10.1038/s41576-021-00413-0; Jiang Z., et al. (2025) Mechanisms of plant acclimation to multiple abiotic stresses. *Communications Biology*, 8:655, DOI:10.1038/s42003-025-08077-w; Mochida, K., et al. (2020) Decoding plant–environment interactions that influence crop agronomic traits. *Plant and Cell Physiology*, 61(8):1408–1418, DOI:10.1093/pcp/pcaa064; Du, B., et al. (2024) Strategies of plants to overcome abiotic and biotic stresses. *Biological Reviews*, 99(4):1524–1536, DOI: 10.1111/brv.13079; Varadharajan, V., et al. (2025) Multi-omics approaches against abiotic and biotic stress-A review. *Plants*, 14(6):865, DOI:10.3390/plants14060865; Afridi M.S., et al. (2022) New opportunities in plant microbiome engineering for increasing agricultural sustainability under stressful conditions. *Frontiers in Plant Sciences*, 13:899464, DOI:10.3389/fpls.2022.899464; Special issue on “Use of single cell and spatial multiomics for uncovering cellular and molecular mechanisms underlying plant stress responses”. *Stress Biology*, 2025; Salem M.A., et al. (2022) Metabolomics of plant root exudates: From sample preparation to data analysis, *Frontiers in Plant Sciences*, 13:1062982, DOI:10.3389/fpls.2022.1062982; Singhal, R., et al. (2025) Using supervised machine-learning approaches to understand abiotic stress tolerance and design resilient crops. *Philosophical Transactions of the Royal Society B*, 380:2024.0252, DOI:10.1098/rstb.2024.0252.

Unit 4: Emerging Tools and Techniques -- Epitranscriptomics; Targeted epigenome editing: development of specific DNA-targeting systems, next-generation CRISPR activators, applications in agriculture; Nanotechnology and its applications in plant biology: types of nanomaterials, uptake and translocation, biological impact, applications of nanoparticles (NPs) in plant biology (biosensors, nutrient delivery, nanomaterials in plant genetic engineering (DNA / RNA delivery)); Plant biology in space: growth and monitoring, effects of microgravity and ionizing radiations, applications, and benefits.

11 hours

Essential Readings: Kumari, A., et. al. (2023) Nanotechnology as a powerful tool in plant sciences: Recent developments, challenges and perspectives. *Plant Nano Biology*, 5:100046, DOI:10.1016/j.plana.2023.100046; Sanzari, I., et. al. (2019) Nanotechnology in plant science: To make a long story short. *Frontiers in Bioengineering and Biotechnology*, 7:120, DOI:10.3389/fbioe.2019.00120; Sharma, B., et al. (2023) The diversity and functions

of plant RNA modifications: what we know and where we go from here. *Annual Review of Plant Biology*, 74(1):53–85, DOI:10.1146/annurev-arplant-071122-085813; Shen, L., et al. (2019) Messenger RNA modifications in plants. *Trends in Plant Science*, 24(4):328–41, DOI:10.1016/j.tplants.2019.01.005; McCutcheon, S.R., et al. (2024) Epigenome editing technologies for discovery and medicine. *Nature Biotechnology*, 42:1199–1217, DOI:10.1038/s41587-024-02320-1; Kungulovski, G. and Jeltsch, A. (2016) Epigenome editing: state of the art, concepts, and perspectives. *Trends in Genetics*, 32(2):101–13, DOI:10.1016/j.tig.2015.12.001.

Practicals (30 hours)

1. To investigate the phenotypic responses in the calcium signaling mutants.
2. To investigate the transactivation or transrepression activity of a transcription factor.
3. To design CRISPR guide RNA primers using online tools (e.g., CHOPCHOP, CRISPOR).
4. Molecular probe-based pathogen detection.
5. To design functional genomics approaches for specific gene/phenotype questions and compare the strengths and limitations of different methods.

Suggested Readings:

1. Kramer, L.M. (2015) *Signal Transduction*. 3rd edition, Academic Press, ISBN:9780123948199.
2. Heldin, C.H. and Purton, M. (1996) *Signal transduction: Modular texts in molecular and cell biology*, Chapman & Hall, ISBN:0412708108.
3. Alberts, B., et al. (2022) *Molecular Biology of the Cell*. 7th edition, W.W. Norton & Company, ISBN:9780393884630.
4. Buchanan, B.B., et al. (2015) *Biochemistry & Molecular Biology of the Plants*. 2nd edition, Wiley Blackwell, ISBN:9781118502198.
5. Kleinsmith, L.J. and Kish, V.M. (1997) *Principles of Cell & Molecular Biology*. Harper Collins College Publishers, ISBN:9780065004045.
6. Taiz, L., et al. (2023). *Plant Physiology and Development*. 7th edition, Sinauer Associates, ISBN:9780197614204.
7. Glick, B.R. and Pasternak, J.J. (2022) *Molecular Biotechnology: Principles and Applications of recombinant DNA*. 6th edition, ASM Press, ISBN:9781683673668.
8. Brown, T.A. (2023) *Genomes 5*. 5th edition, CRC Press, ISBN:9781003133162.
9. Piechulla, B. (2025) *Plant Biochemistry*. 6th edition, Academic Press, ISBN:9780443266164.
10. Abd-Elsalam, K.A. and Prasad, R. (2018) *Nanobiotechnology applications in plant protection*. Springer Cham, ISBN:9783319911601, DOI:10.1007/978-3-319-91161-8.
11. Chen, J.T. (2024) *Advanced Nanotechnology in Plants: Methods and Applications*. CRC Press, ISBN:9781003368571.
12. Jeltsch, A., and Rots, M.G. (2018) *Epigenome editing: Methods and Protocols*. Humana New York, ISBN:9781493977741, DOI:10.1007/978-1-4939-7774-1.
13. Jurga, S. and Barciszewski, J. (2021) *Epitranscriptomics*. Springer Cham, ISBN:9783030716127, DOI:10.1007/978-3-030-71612-7.
14. Online Databases and Resources: NCBI, TAIR, Phytozome, EnsemblPlants and others, KEGG, STRING, Gene Ontology, CRISPR-Cas toolkits and others.

PBSE315: Introduction to Bioinformatics

This course is open to students of other departments as a GE course.

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE315: Introduction to Bioinformatics	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

The paper is devised to introduce the students to the field of bioinformatics and data analysis. The content is designed for students from any stream of life sciences. The course imparts basic and essential knowledge regarding the nature of life science data, including data formats, international databases and data repositories. It also helps to understand how different biological file formats facilitate storage, retrieval and analysis of biological sequences and structures. Furthermore, the unit is designed to familiarize the learner with the landscape of major international nucleotide and protein databases, understanding their scope, interrelationships, and specific applications (universal and organism-specific databases). Additionally, understand the structure, interoperability, and collaborative role of INSDC, and its importance in maintaining the global genomic data ecosystem. Furthermore, it will explain the fundamental principles of local and global alignment (pairwise sequence comparison) and the biological rationale behind scoring systems, including substitution matrices and gap penalties. It also focuses on interpreting results of Clustal-W, Clustal Omega, T-Coffee, and MultiAlign BLAST tools and how to optimize their parameters to draw biologically meaningful conclusions. The last unit of the course presents the fundamentals of RNA/ Protein secondary and tertiary structure prediction. It will be helpful to learn the basic principles of docking analysis and drug design workflows.

Learning Outcomes

After successfully completing the course, students will be able to identify and describe various biological data formats and their respective applications. They will be able to access and retrieve sequences and structural data from major databases, data repositories, and browsers like UCSC Genome Browser, linking data formats to visual genomic analysis. Furthermore, students will be able to utilize tools like BLAST for sequence comparison and evolutionary significance, as well as understand the conceptual difference between various substitution matrices and pairwise algorithms. They can perform and interpret the MSA of different biological sequences using different computational software and also visualize phylogenetic trees using various algorithms. Upon completing the last unit, students will be able to use computational tools for RNA and protein prediction, evaluate them, and analyse protein-ligand interaction and outcomes of docking.

Course Content (45 hours)

Unit 1: Biological Data Formats and Databases -- Overview of database management system, concept of 'structured' and 'semi-structured/unstructured' data, concept of 'flat-file' formats; Various file formats used in bioinformatics such as 'fasta', 'fastq', Phylip format, Newick, PDB file format, 'GFF3', SAM/BAM/CRAM formats; Universal nucleotide data repositories: NCBI-GenBank, EMBL-ENA, DDBJ; Details of the International Nucleotide Sequence Data Collaboration (INSDC); Universal Protein databases: UniprotKB, PDB. Organism specific databases (Flybase, Wormbase etc), UCSC Human Genome Browser; Molecular interaction databases such as KEGG and STRING. **10 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 1 (Historical Introduction and Overview), Chapter 2 (Collecting and Storing Sequences in the Laboratory); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 1 (The nucleic world) and chapter 3 (Dealing with databases); Sayers, E.W., et al. (2022) Database resources of the National Center for Biotechnology Information. Nucleic Acids Research, 50(D1):D20–D26, DOI:10.1093/nar/gkab1112; Cochrane, G., et al. (2016). The European Nucleotide Archive in 2016. Nucleic Acids Research, 44(D1):D32–D37, DOI:10.1093/nar/gkw1106; The UniProt Consortium (2023) UniProt: the Universal Protein Knowledgebase in 2023. Nucleic Acids Research, 51(D1):D523–D531, DOI:10.1093/nar/gkac1052; Berman, H.M., et al. (2000) The Protein Data Bank. Nucleic Acids Research, 28(1):235–242, DOI:10.1093/nar/28.1.235; Li, H., et al. (2009) The Sequence Alignment/Map format and SAMtools. Bioinformatics, 25(16):2078–2079, DOI:10.1093/bioinformatics/btp352; Cock, P.J.A., et al. (2010) The Sanger FASTQ file format for sequences with quality scores, and the Solexa/Illumina FASTQ variants. Nucleic Acids Research, 38(6):1767–1771, DOI:10.1093/nar/gkp1137; Kanehisa, M., et al. (2023) KEGG for taxonomy-based analysis of pathways and genomes. Nucleic Acids Research, 51(D1):D587–D592, DOI:10.1093/nar/gkac997; Szklarczyk, D., et al. (2023) The STRING database in 2023: protein–protein association networks and functional enrichment analyses for any sequenced genome. Nucleic Acids Research, 51(D1):D638–D646, DOI:10.1093/nar/gkac1000; The FlyBase Consortium. (2022). FlyBase: updates to the *Drosophila melanogaster* knowledge base. Nucleic Acids Research, 50(D1):D1014–D1020, DOI:10.1093/nar/gkab1099; Haeussler, M., et al. (2019) The UCSC Genome Browser database: 2019 update. Nucleic Acids Research, 47(D1):D853–D858, DOI:10.1093/nar/gky1095.

Unit 2: Pairwise Sequence Alignment -- Concept of local and global sequence alignment; Pairwise sequence alignment algorithms such as Needleman and Wunsch, Smith-Waterman, scoring an alignment, linear and affine gap penalty, amino acid substitution scoring matrices (PAM and BLOSUM); Sequence alignment-based database search, BLAST and its variants, BLAST parameters (word size, E-value, scoring scheme, gap-penalty), bit/raw score. **10 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 3 (Alignment of pairs of sequences), Chapter 6 (Sequence database searching for similar sequences); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 4 (Producing and analyzing sequence alignments), Chapter 5 (Pairwise sequence alignment and database searching); Morrison, D.A. (2006). Multiple sequence alignment for phylogenetic purposes. Australian Systematic Botany, 19(6):479–539, DOI:10.1071/SB06020.

Unit 3: Multiple Sequence Alignment and Phylogenetic Analysis -- Global and local multiple sequence alignment, multiple sequence alignment algorithms (progressive and iterative algorithms), profile and block analysis; Softwares: Clustal-X, Clustal-W, Clustal-Omega, T-Coffee, MultiAlign; Basic concept of phylogenetic analysis, rooted and unrooted trees, approaches for phylogenetic tree construction; Basics of algorithm for UPGMA, neighbour joining (NJ), maximum parsimony, and maximum likelihood phylogenetic analysis. **15 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 5 (Multiple sequence alignment), Chapter 7 (Phylogenetic prediction); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 4 (Producing and analyzing sequence alignments), Chapter 5 (Pairwise sequence alignment and database searching), Chapter 6 (Patterns, profiles, and multiple alignments).

Unit 4: Structure Predictions for Nucleic Acids and Proteins -- Approaches for prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models; Basic approaches for protein structure predictions, comparative modeling, fold recognition/‘threading’, and *ab-initio* prediction; Introduction to AlfaFold database; Docking analysis and drug designing. **10 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 8 (Prediction of RNA secondary structure), Chapter 10 (Protein classification and structure prediction); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 8 (Recovering evolutionary history), Chapter 11 (Obtaining secondary structure from sequence), Chapter 12 (Predicting secondary structures).

Tutorials (15 hours)

1. To perform ‘text-based’ database search
2. Sequence alignment-based database search.
3. Multiple sequence alignment and phylogenetic analysis.
4. Analysis of gene/protein interaction networks.

Suggested Readings:

1. Baxevanis, A.D., et al. (2020) Bioinformatics: A practical guide to the analysis of genes and proteins. 4th edition. John Wiley & Sons, Inc., ISBN:9781119335962.
2. Tramontano, A. (2018) Introduction to Bioinformatics. Chapman and Hall/CRC, ISBN:9781315276014, DOI:10.1201/9781420010886.
3. Lee, E. Tan, T.W. (2018) Beginners guide to bioinformatics for high throughput sequencing. World Scientific, ISBN:9789813231665, DOI:10.1142/10720.
4. Thompson, J.D., et al. (1994) CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice. Nucleic Acids Research, 22(22):4673–4680, DOI:10.1093/nar/22.22.4673.
5. Notredame, C., et al., (2000) T-Coffee: A novel method for fast and accurate multiple sequence alignment. Journal of Molecular Biology, 302(1):205–217, DOI:10.1006/jmbi.2000.4042.
6. Saitou, N. and Nei, M. (1987) The neighbor-joining method: a new method for reconstructing phylogenetic trees. Molecular Biology and Evolution, 4(4):406–425, DOI:10.1093/oxfordjournals.molbev.a040454.
7. Felsenstein, J. (1981) Evolutionary trees from DNA sequences: a maximum likelihood approach. Journal of Molecular Evolution, 17(6):368–376, DOI:10.1007/BF01734359.
8. JJumper, J., et al. (2021) Highly accurate protein structure prediction with AlphaFold2. Nature, 596:583–589, DOI:10.1038/s41586-021-03819-2.
9. Zhang, Y. (2008) Progress and challenges in protein structure prediction. Current Opinion in Structural Biology, 18(3):342–348, DOI:10.1016/j.sbi.2008.02.004.
10. Kryshchuk, A., et al. (2021) Critical assessment of methods of protein structure prediction (CASP)—Round XIV. Proteins: Structure, Function, and Bioinformatics, 89(12):1607–1617, DOI:10.1002/prot.26237.
11. Zuker, M. (2003) Mfold web server for nucleic acid folding and hybridization prediction. Nucleic Acids Research, 31(13):3406–3415, DOI:10.1093/nar/gkg595.
12. Kitchen, D.B., et al. (2004) Docking and scoring in virtual screening for drug discovery: methods and applications. Nature Reviews Drug Discovery, 3(11):935–949, DOI:10.1038/nrd1549.

PBSE316: Molecular Plant Evolution and Biodiversity

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE316: Molecular Plant Evolution and Biodiversity	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

The course aims to establish a foundational understanding of the core principles of evolutionary biology from a plant-centric perspective. It explores how mechanisms like polyploidy and lateral gene transfer shape plant diversity, and covers the evolution of key plant structures, developmental processes, and metabolic pathways. The learner will investigate how abiotic (climate, soil) and biotic (herbivores, pollinators, microbes) interactions act as selective pressures, driving adaptation and diversification. The final unit introduces methods for assessing biodiversity using genomics (multi-omics data), phylogenomics, and environmental DNA (eDNA), and discusses global efforts in biodiversity data sharing and the Access and Benefit Sharing (ABS) mechanism.

Learning Outcomes

The course enables learners to describe the evolutionary biology of plants through genetic mechanisms, including mutation, drift, and natural selection. Upon completion, students will be able to explain homologies and analogies in plant phenotypes, metabolic evolution, and various evolutionary trends relevant to modern plant physiology and adaptation. Learners are able to discuss the roles of abiotic and biotic factors in shaping plant diversity and analyze the impact of domestication on genetic diversity. Furthermore, scholars are equipped to conduct analyses using whole-genome, pan-genome, and environmental DNA approaches. They also gain an understanding of the importance of FAIR data principles, Access and Benefit-Sharing (ABS) in biodiversity management, and the policy dimensions of Digital Sequence Information (DSI).

Course Contents (45 hours)

Unit 1: Basics of Evolution -- Overview of plant evolution; Natural selection, adaptation, lateral gene transfer, genetic drift, speciation, adaptive potential, polyploidy; Multicellularity in plants; Molecular basis of evolution. **5 hours**

Essential Readings: Willis, K.J. and McElwain, J.C. (2021) The evolution of plants. 3rd edition, Oxford University Press, ISBN:9780199292233; Soltis, D.E. and Soltis, P.S. (2009) The role of hybridization in plant speciation. Annual Review of Plant Biology, 60:561–588, DOI:10.1146/annurev.arplant.043008.092039.

Unit 2: Introduction to Plant Evolution -- Evolution of land plants and plant stress response networks (terrestrialization), plant development and vasculature, homology and evolution of key phenotypic novelties of land plants, plant sexual diversity; Evolution of plant metabolism, photosynthesis, energy metabolism, and specialised metabolites. **15 hours**

Essential Readings: Niklas, K.J. and Kutschera, U. (2022) The evolution of the land plants. University of Chicago Press, Chicago, ISBN:9780226784635; Raven, P.H., et al. (2016) Biology of Plants, 8th edition, W.H.

Freeman New York, ISBN:9781429219617; Bowman, J.L., et. al. (2019) Evolution and co-option of developmental regulatory pathways in early land plants. *Current Topics in Developmental Biology*, 131:35–53, DOI:10.1016/bs.ctdb.2018.10.001; Muggia, L., et. al. (2020) An Overview of genomics, phylogenomics and proteomics approaches in Ascomycota. *Life (Basel)*. 10(12):356, DOI:10.3390/life10120356.

Unit 3: Drivers of Plant Evolution -- Impact of environmental factors on plant evolution and distribution; Role of biotic factors such as herbivores, pollinators, and microbes in plant evolution; Domestication; Impact of plant evolution on Earth's climate; Drivers of biodiversity loss. 10 hours

Essential Readings: Briggs, D. (2020) *Plant Microevolution and Conservation in Human-Influenced Ecosystems*, Cambridge University Press, ISBN:9780521818353; Doebley, J.F., et. al. (2006) The molecular genetics of crop domestication. *Cell*, 127(7):1309–1321, DOI:10.1016/j.cell.2006.12.006; Ehrlich, P.R. and Raven, P.H. (1964) Butterflies and plants: a study in coevolution. *Evolution*, 18(4):586–608, DOI:10.1111/j.1558-5646.1964.tb01674.x; Larson, G. and Fuller, D.Q. (2014) The evolution of animal domestication. *Annual Review of Ecology, Evolution, and Systematics*, 45:115-136, DOI:10.1146/annurev-ecolsys-110512-135813; Niklas, K.J. and Kutschera, U. (2022) *The evolution of the land plants*. University of Chicago Press, Chicago, ISBN:9780226784635; Willis, K.J. and McElwain, J.C. (2021) *The Evolution of Plants*. 3rd edition, Oxford University Press, ISBN:9780199292233; Ruiz, V.V., et. al., (2025). A new era in the discovery of biological control bacteria: Omics-driven bioprospecting. *Soil Systems*, 9(4):108, DOI:10.3390/soilsystems9040108.

Unit 4: Multi-omic Assessment of Plant Evolutionary Biodiversity -- Biodiversity hot-spots, monitoring and assessment of biodiversity, Whole genome sequencing; Phylogenomics; environmental DNA (eDNA) sequencing for diversity assessment, advantage of pangenome datasets, biodiversity cell atlas, global efforts to characterize plant molecular diversity; Metabolomics; Concept of digital forests; Implications of the Convention on Biological Diversity, concept of Digital Sequence Information (DSI) and Access Benefit Sharing mechanisms (ABS). 15 hours

Essential Readings: Deiner, K., et al. (2017) Environmental DNA metabarcoding: Transforming how we survey animal and plant communities. *Molecular Ecology*, 26(21):5872–95, DOI:10.1111/mec.14350; Exposito-Alonso, M., et al. (2022) The Earth BioGenome project: opportunities and challenges for plant genomics and conservation. *The Plant Journal*, 102(2):222–229, DOI:10.1111/tpj.14631; Golicz, A.A., et.al. (2016) The pangenome of an agronomically important crop plant *Brassica oleracea*. *Nature Communications*, 7:13390, DOI:10.1038/ncomms13390; Laird, S. and Wynberg, R. (2018) A fact-finding and scoping study on digital sequence information on genetic resources in the context of the Convention on Biological Diversity and the Nagoya Protocol, CBD/DSI/AHTEG/2018/1/3, Secretariat of the Convention on Biological Diversity, Montreal; Zhou, L., et. al. (2025) Estimating carbon biomass using DNA: Phytoplankton as a case study. *DNA*, 5(1):13, DOI:10.3390/dna5010013; Achieng, A.O., et al. (2023) Monitoring biodiversity loss in rapidly changing Afrotropical ecosystems: an emerging imperative for governance and research. *Philosophical Transactions of the Royal Society B*. 378:20220271, DOI:10.1098/rstb.2022.0271.

Tutorials (15 hours)

Case studies on:

1. Impact of horizontal gene transfer on plant evolution.
2. Evolution of 3D growth patterns in plants.
3. Plant biodiversity and modern drug discovery.
4. Insights into plant biodiversity of India.

Suggested Readings:

1. Doyle, J.J. and Gaut, B.S. (2000) *Plant molecular evolution*. Springer Dordrecht, ISBN:9780792360964, DOI:10.1007/978-94-011-4221-2.
2. Kenrick, P. and Crane, P.R. (1997) The origin and early evolution of plants on land. *Nature*, 389:33–39, DOI:10.1038/37918.
3. Weng, J.K., et al. (2012). The rise of chemodiversity in plants. *Science*, 336:1667–70, DOI:10.1126/science.1217411.

PBSEC317: Emerging Techniques in Plant Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSEC317: Emerging Techniques in Plant Biology	2	1	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The objective of this paper is to familiarize students with the latest advancements and methodologies in the field. The course offers insight into diverse imaging approaches and methodologies used to study plant systems at the cellular level. This course provides an in-depth understanding of emerging and state-of-the-art techniques used in contemporary research and applications.

Learning Outcomes

Students would acquire specific practical skills regarding various sample preparations and imaging techniques, which are essential for conducting advanced plant science research. They will acquire knowledge of the principles and applications of cutting-edge techniques relevant to modern research and innovation, and will learn to apply appropriate state-of-the-art tools and technologies to investigate complex scientific problems.

Course Content (15 hours)

Unit 1: Imaging Techniques -- Fundamental principles of microscope design, image formation, magnification, numerical aperture, resolution, and contrast; Components and optics of light microscopy; Transmitted light techniques: bright-field, phase contrast, and DIC; Fundamentals of fluorescence, excitation-emission principles, fluorescent probes and biosensors, photobleaching, and quenching; Confocal laser scanning microscopy–optical sectioning, Z-stack reconstruction, and 3D imaging, super-resolution microscopy (STED, SIM, PALM/STORM), and cryo-electron microscopy (Cryo-EM); Digital image recording, cameras, signal-to-noise ratio, and quantitative image analysis; Applications in plant cell and developmental biology using fluorescence-based imaging approaches. **7.5 hours**

Essential Readings: Murphy, D.B. and Davidson, M.W. (2012) Fundamentals of light microscopy and electronic imaging, 2nd edition, Wiley-Blackwell, ISBN:9781118382905, Chapter 1 (Introduction to Microscopy), Chapter 2 (The Optical Microscope), Chapter 3 (Image Formation in the Microscope), Chapter 4 (Fluorescence Microscopy): Principles, Chapter 5 (Fluorescence Microscopy: Instrumentation), Chapter 6 (Digital Imaging Fundamentals), Chapter 9 (Confocal Microscopy), Chapter 13 (Electron Microscopy Fundamentals); Huang, B., et al. (2009) Super-resolution fluorescence microscopy. Annual Review of Biochemistry, 78:993–1016, DOI: 10.1146/annurev.biochem.77.061906.092014; Nogales, E. and Scheres, S.H.W. (2015) Cryo-EM: A unique tool for the visualization of macromolecular complexity. Molecular Cell, 58:677–689, DOI: 10.1016/j.molcel.2015.02.019.

Unit 2: Single Cell Biology -- Isolation and handling of single cells: Fluorescence-activated cell sorting (FACS); Microfluidics, Laser Capture Microdissection (LCM); Single-cell multi-omics analysis: Single-cell genomics (scDNA-seq), transcriptomics (scRNA-seq), proteomics (scProteomics), metabolomics (scMetabolomics); Multi-omics integration; Temporal and Spatial analysis: Spatial Transcriptomics, *in situ* subcellular localization of a metabolite;

Chromosomal immunostaining; Applications of single cell biology in plant molecular biology.

7.5 hours

Essential Readings: Hu, P., et al. (2016) Single cell isolation and analysis. *Frontiers in Cell and Developmental Biology*, 4:116, DOI:10.3389/fcell.2016.00116; Wang, D. and Bodovitz, S. (2010) Single-cell analysis: the new frontier in 'omics'. *Trends in Biotechnology*, 28(6):281–290, DOI:10.1016/j.tibtech.2010.03.002; Jackson, C.A., et al. (2022) New horizons in the stormy sea of multimodal single-cell data integration *Molecular Cell*, 82(2):248–259, DOI:10.1016/j.molcel.2021.12.012; Rahman, M.S., et al. (2024) Opportunities and challenges in advancing plant research with single-cell omics. *Genomics, Proteomics & Bioinformatics*, 22(2):qzae026, DOI:10.1093/gpbjnl/qzae026; Clark, N.M., et al. (2022) To the proteome and beyond: advances in single-cell omics profiling for plant systems. *Plant Physiology*, 188(2):726–737, DOI:10.1093/plphys/kiab429; Nobori, T. (2025) Exploring the untapped potential of single-cell and spatial omics in plant biology. *The New Phytologist*, 247(3):1098, DOI:10.1111/nph.70220; Chau, T.N., et al. (2024) Advancing plant single-cell genomics with foundation models. *Current Opinion in Plant Biology*, 82:102666, DOI:10.1016/j.pbi.2024.102666.

Practicals (30 hours)

1. To visualize a living plant specimen using bright-field, phase contrast, and (if available) DIC, and understand how each enhances different features.
2. Preparation of publication-quality microscopy figures: Brightfield–Fluorescence overlays and scale bars.
3. To navigate and annotate multi-dimensional images for preparing a figure using Image J.
4. Data analysis of targeted metabolite profiling.
5. Analysis of cell cycle stages using FACS.

Suggested Readings:

1. Wu, X., et al. (2024) Single-cell sequencing to multi-omics: technologies and applications. *Biomarker Research*, 12:110, DOI:10.1186/s40364-024-00643-4.
2. Zhu, M., et al. (2025) Single-cell transcriptomics reveal how root tissues adapt to soil stress. *Nature*, 642:721–729, DOI:10.1038/s41586-025-08941-z.
3. Lee, T.A., et al. (2025) A single-cell, spatial transcriptomic atlas of the *Arabidopsis* life cycle. *Nature Plants*, 11:1960–75, DOI:10.1038/s41477-025-02072-z.
4. Cold Spring Harbour Protocols- Imaging/Microscopy, general weblink: (https://cshprotocols.cshlp.org/cgi/collection/imaging_microscopy_general)
5. Paddock, S.W. (2014) *Confocal Microscopy: Methods and Protocols*. Humana New York, NY, eISBN:9781607618478, DOI:10.1007/978-1-60761-847-8.
6. Ruzin, S.E. (1999) *Plant Microtechnique and Microscopy*. Oxford University Press, USA, ISBN:9780195089561.
7. Pawley, J.B. (2006) *Handbook of Biological Confocal Microscopy*. 3rd Edition, Springer New York, NY, ISBN:9780387455242, DOI:10.1007/978-0-387-45524-2.
8. Markaki, Y. and Harz, H. (2017) *Light microscopy: Methods and Protocols*. Humana New York, NY, DOI:10.1007/978-1-4939-6810-7.
9. Yin, Z. et al. (2023) Mass spectrometry imaging techniques: a versatile toolbox for plant metabolomics. *Trends in Plant Science*, 289(2):250–251, DOI:10.1016/j.tplants.2022.10.009.
10. Pawlowski, W.P., et al. (2013) *Plant Meiosis: Methods and Protocols*. Humana Totowa, NJ, Chapter (Immunolocalization of meiotic proteins in *Brassicaceae*: method 1), ISBN:9781627033336, DOI:10.1007/978-1-62703-333-6_9.
11. Petrova, B. and Guler, A.T. (2025) Recent developments in single-cell metabolomics by mass Spectrometry- A perspective. *Journal of Proteome Research*, 24(4):1493–1518, DOI:10.1021/acs.jproteome.4c00646.
12. Shaw, R., et al. (2021) Single-cell transcriptome analysis in plants: advances and challenges. *Molecular Plant*, 14(1):115–126, DOI:10.1016/j.molp.2020.10.012.

SEMESTER 4

PBSC411: Advances in Crop Biotechnology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC411: Advances in Crop Biotechnology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to provide learners with an advanced and integrative understanding of modern crop biotechnology and its role in sustainable agriculture. Students will engage with emerging molecular tools, the development and significance of crop pan-genomes, and cutting-edge concepts such as *de novo* domestication and innovations in *in-planta* transformation. The course will also provide in-depth insights into translational strategies to enhance crop nutrition and improve resilience to biotic and abiotic stresses through sustainable, environmentally friendly approaches. Overall, learners will develop the scientific foundation and biotechnology skills required to address challenges in crop improvement.

Learning Outcomes

Upon completing this course, participants will be able to critically analyze crop genomes for domestication signatures and evaluate germplasm diversity for trait improvement. They will demonstrate practical knowledge of state-of-the-art plant transformation techniques and emerging delivery platforms for gene and RNA manipulation. Students will be able to assess and design strategies for enhancing stress tolerance, yield, and nutritional value in crop plants. They will also gain competence in applying biostimulants and other biofortification approaches.

Course Contents (45 hours)

Unit 1: Introduction to Crop Biotechnology -- Emerging tools and techniques in biotechnology; Crop pan-genomes and signatures of crop domestication; Germplasm diversity analysis; Concept of *de novo* crop domestication; Agro-morphological traits enhancement; Environmental challenges and food security; Plants as biofactories. **10 hours**

Essential Readings: Mascher, M., et al. (2024) Promises and challenges of crop translational genomics. *Nature*, 636:585–593, DOI:10.1038/s41586-024-07713-5; Shi, J., et al. (2023) Plant pan-genomics and its applications. *Molecular Plant*, 16(1):168–186, DOI:10.1016/j.molp.2022.12.009; Curtin, S., et al. (2022) Pathways to *de novo* domestication of crop wild relatives. *Plant Physiology*, 188(4):1746–1756, DOI:10.1093/plphys/kiab554.

Unit 2: Genetic Transformation Techniques -- Ternary vector systems; Improved *in planta* transformation - *de novo* meristems induction, morphogenic regulators, particle bombardment of shoot apical meristem, composite plants, etc; Use of magnetic nanoparticles; Organelle genome transformation. **10 hours**

Essential Readings: Chen, Z., et al. (2022) Recent advances in crop transformation technologies. *Nature Plants*, 8(12):1343–1351, DOI:10.1038/s41477-022-01295-8; Bélanger, J.G., et al. (2024) A comprehensive review of *in planta* stable transformation strategies. *Plant Methods*, 20(1):79, DOI:10.1186/s13007-024-01200-8.

Unit 3: Climate Resilience and Yield Enhancement -- Case studies on abiotic and biotic stress tolerance; RNA delivery against fungal pathogens; Probiotic-based gene silencing in polyphagous pests; Biofertilizers, Biopesticides; Cell-penetrating peptides; Concept of chronoculture; Synthetic circuits and rewiring for plant improvement; Enhancement of photosynthetic capacity; Carbon dots in plant (epi)genomics. **15 hours**

Essential Readings: González Guzmán, M., et al. (2022) New approaches to improve crop tolerance to biotic and abiotic stresses. *Physiologia Plantarum*, 174(1):e13547, DOI:10.1111/ppl.13547; Al-Dossary, O., et al. (2025) Crop management to enhance plant resilience to abiotic stress using nanotechnology: towards more efficient and sustainable agriculture. *Frontiers in Plant Science*, 16:1626624, DOI:10.3389/fpls.2025.1626624; Afridi, M.S., et al. (2022) New opportunities in plant microbiome engineering for increasing agricultural sustainability under stressful conditions. *Frontiers in Plant Science* 13:899464, DOI:10.3389/fpls.2022.899464; Shahwar, D., et al. (2023) Role of microbial inoculants as bio fertilizers for improving crop productivity: A review. *Heliyon*, 9(6):e16134, DOI:10.1016/j.heliyon.2023.e16134; Lloyd, J.P.B., et al. (2025) The switch-liker's guide to plant synthetic gene circuits. *Plant Journal*, 121(5):e70090, DOI: 10.1111/tpj.70090.

Unit 4: Enhancement of Nutrients -- Improved nutritional profile of crops; Enhancement of mineral nutrient uptake and distribution; Biofortification (Fe, Zn, Ca, K, Vitamins, proteins, essential oils, etc.), micronutrient-dense crops; Anti-nutrient reduction; Concept of Biostimulants. **10 hours**

Essential Readings: Napier, J.A., et al. (2019) The challenges of delivering genetically modified crops with nutritional enhancement traits. *Nature Plants*, 5(6):563–567, DOI:10.1038/s41477-019-0430-z; Zhu, Q., et al. (2019) Plant synthetic metabolic engineering for enhancing crop nutritional quality. *Plant Communications*, 1(1):100017, DOI:10.1016/j.xplc.2019.100017; White, P.J. and Broadley, M.R. (2005) Biofortifying crops with essential mineral elements. *Trends in Plant Science*, 10(12):586–593, DOI:10.1016/j.tplants.2005.10.001.

Practicals (30 hours)

1. Transient gene expression using the particle bombardment method.
2. Measurement of photosynthetic efficiency using fluorescence-based system.
3. *In vivo* plant imaging under stress conditions.
4. Mineral nutrient profiling of plants.
5. Molecular detection of *Rhizobium* in root nodules of leguminous plants.

Suggested Readings:

1. Li, X., et al. (2025) The next Green Revolution: integrating crop architecture and phenotype. *Trends in Biotechnology*, 43(10):2479–2493, DOI:10.1016/j.tibtech.2025.04.002.
2. Della Coletta, R., et al. (2021) How the pan-genome is changing crop genomics and improvement. *Genome Biology*, 22(1):3, DOI:10.1186/s13059-020-02224-8.
3. Li, S., et al. (2021) Advancing organelle genome transformation and editing for crop improvement. *Plant Communications*, 2(2):100141, DOI:10.1016/j.xplc.2021.100141.
4. Jeong, J.H., et al. (2025). Empowering *Agrobacterium*: Ternary vector systems as a new arsenal for plant transformation and genome editing. *Biotechnology Advances*, 83:108631, DOI: 10.1016/j.biotechadv.2025.108631.
5. Shrawat, A., et al. (2018) Engineering nitrogen utilization in crop plants. Springer Cham, DOI: 10.1007/978-3-319-92958-3.
6. Basar, N.U., et al. (2025) Synergies between biostimulants and plant nutrients: a review of ecofriendly nutrient management in crop production. *Discover Agriculture*, 3:150, DOI:10.1007/s44279-025-00345-x.
7. Patel, P., et al. (2024) Cell-penetrating peptides for sustainable agriculture. *Trends in Plant Science*, 29(10):1131–44, DOI:10.1016/j.tplants.2024.05.011.
8. Jaswal, S., et al. (2025) Chloroplast engineering for enhancing photosynthetic efficiency and agronomic traits. *Trends in Biotechnology*, DOI:10.1016/j.tibtech.2025.09.011.
9. Tavakoli, M., et al. (2025) Emerging applications of carbon dots in plant (epi)genomics. *Trends in Biotechnology*, DOI:10.1016/j.tibtech.2025.09.005.

10. Hawkesford, M.J., et al. (2016) Nutrient use efficiency in plants. Springer Cham, ISBN:9783319106342, DOI:10.1007/978-3-319-10635-9.
11. Li, G., et al. (2025) Integrated biotechnological and AI innovations for crop improvement. *Nature*, 643:925–937, DOI:10.1038/s41586-025-09122-8.
12. Bartlett, M.E., et al. (2023) The power and perils of *De Novo* domestication using genome editing. *Annual Review of Plant Biology*, 74:727–750, DOI:10.1146/annurev-arplant-053122-030653.
13. Jian, L., et al. (2022) *De novo* domestication in the multi-omics era. *Plant and Cell Physiology*, 63(11): 1592–1606, DOI:10.1093/pcp/pcac077.
14. Altpeter, F., et al. (2016) Advancing crop transformation in the era of genome editing. *The Plant cell*, 28(7):1510–1520, DOI:10.1105/tpc.16.00196.
15. Olsen, K.M., and Wendel, J.F. (2013) A bountiful harvest: genomic insights into crop domestication phenotypes. *Annual Review of Plant Biology*, 64:47–70, DOI:10.1146/annurev-arplant-050312-120048.
16. Ayenew, B.M. et al. (2024) A review on the production of nanofertilizers and its application in agriculture. *Heliyon*, 11(1):e41243, DOI:10.1016/j.heliyon.2024.e41243.
17. Steed, G., et al. (2021) Chronoculture, harnessing the circadian clock to improve crop yield and sustainability. *Science*, 372:eabc9141, DOI:10.1126/science.abc9141.
18. Borowsky, A.T. and Bailey-Serres, J. (2024) Rewiring gene circuitry for plant improvement. *Nature Genetics*, 56(8):1574–1582, DOI:10.1038/s41588-024-01806-7.
19. Naik, B., et al. (2024) Biofortification as a solution for addressing nutrient deficiencies and malnutrition. *Heliyon*, 10(9):e30595, DOI:10.1016/j.heliyon.2024.e30595.

PBSC412: Plant Secondary Metabolism and Applications

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSC412: Plant Secondary Metabolism and Applications	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to provide students with a comprehensive understanding of plant secondary metabolites, focusing on their biosynthesis, regulation, detection, and diverse applications. It is designed to equip students with knowledge in analytical techniques, molecular tools, and biotechnological approaches used to study and manipulate secondary metabolite pathways. The course also emphasizes the ecological significance and medicinal potential of these compounds, preparing students to apply metabolic engineering for research and development in areas such as plant defense, drug discovery, and sustainable bioproduction.

Learning Outcomes

Upon completing this course, students will understand the biosynthesis, regulation, and classification of key plant secondary metabolites, as well as their significance in molecular biology and biotechnology. Students will also learn to apply genetic and metabolic engineering tools, such as CRISPR/Cas and RNAi, to manipulate biosynthetic pathways to enhance the production of metabolites. Additionally, students will explore the ecological functions of these compounds in plant defense and pollination, including the role of VOCs. Through this course, students will be prepared for research and applied careers in plant molecular biology, biotechnology, and phytopharmaceuticals.

Course Content (45 hours)

Unit 1: Fundamentals of Plant Secondary Metabolism -- Overview of Primary vs. Secondary Metabolites; Different classes of secondary metabolites: Alkaloids, Terpenoids, Flavonoids, Phenolics, Glucosinolates; Regulation of secondary metabolism (transcriptional, post-transcriptional, epigenetic). 12 hours

Essential Readings: Dixon, R.A. (2001) Natural products and plant disease resistance. *Nature*, 411:843–847, DOI:10.1038/35081178; Rabeh, K., et al. (2025) A comprehensive review of transcription factor-mediated regulation of secondary metabolites in plants under environmental stress. *Stress Biology*, 5(1):15, DOI:10.1007/s44154-024-00201-w; Buchanan, B.B., et al. (2015) *Biochemistry and Molecular Biology of Plants*. John Wiley & Sons, ISBN:9780470714218, Chapter 24 (Natural Products); Strauss, J. and Reyes-Dominguez, Y. (2011) Regulation of secondary metabolism by chromatin structure and epigenetic codes. *Fungal Genetics and Biology*, 48(1):62–69, DOI:10.1016/j.fgb.2010.07.009.

Unit 2: Isolation, Detection, and Characterization of Secondary Metabolites -- Extraction techniques: Solvent extraction, hydrodistillation, supercritical CO₂; Detection techniques (Chromatographic and Spectroscopic methods); Large-scale metabolite profiling and data analysis. 10 hours

Essential Reading: Dettmer, K., et al. (2007) Mass spectrometry-based metabolomics. *Mass Spectrometry Reviews*, 26(1):51–78, DOI:10.1002/mas.20108; Sukumaran, S.T., et al. (2020) Plant metabolites: methods, applications and prospects. Springer, ISBN:9789811551352, DOI:10.1007/978-981-15-5136-9.

Unit 3: Metabolic Engineering of Secondary Metabolites -- Concepts and techniques in metabolic engineering; Understanding of Synthetic biology and pathway engineering; Large-scale production of metabolites; Case studies in *E. coli*, *Saccharomyces*, and *Nicotiana*.

12 hours

Essential Readings: Zhu, X., et al. (2021) Synthetic biology of plant natural products: from pathway elucidation to engineered biosynthesis in plant cells. *Plant Communications*, 2(5):100229, DOI:10.1016/j.xplc.2021.100229; Karaca, H., et al. (2024) Metabolic engineering of *Saccharomyces cerevisiae* for enhanced taxadiene production. *Microbial Cell Factories*, 23(1):241, DOI:10.1186/s12934-024-02512-z; Zhao, S., et al. (2024) The metabolic engineering of *Escherichia coli* for the high-yield production of hypoxanthine. *Microbial Cell Factories*, 23(1):309, DOI:10.1186/s12934-024-02576-x.

Unit 4: Applications in Plant Defense, Human Health, and Ecology -- Role of secondary metabolites in plant defense (phytoalexins, VOCs, allelopathy); Ecological significance: VOCs in pollination, plant-insect interactions; Secondary metabolites in human health: antimicrobial, anticancer, antioxidant; Secondary metabolites in nutraceuticals and pharmaceuticals. 11 hours

Essential Readings: George, B.P., et al. (2021) Role of phytochemicals in cancer chemoprevention: Insights. *Antioxidants*, 10(9):1455, DOI:10.3390/antiox10091455; Divekar, P.A., et al. (2022) Plant secondary metabolites as defense tools against herbivores for sustainable crop protection. *International Journal of Molecular Sciences*, 23(5):2690, DOI:10.3390/ijms23052690.

Practicals (30 hours)

1. Extraction and qualitative analysis of plant secondary metabolites-saponins, phenolics, lignin.
2. Induction of secondary metabolite production in callus culture.
3. Demonstration of antimicrobial activity of plant extracts.
4. Detection of flavonoids during pollen development.
5. Effect of glucosinolate-derived compound, indole-3-carbinol, in plant root growth and development.

Suggested Readings:

1. Crozier, A., et al. (2006) Plant secondary metabolites: Occurrence, structure and role in the human diet. Blackwell Publishing, ISBN:9780470988558, DOI:10.1002/9780470988558.
2. Wink, M. (2010) Annual Plant Reviews Vol. 39: Functions and biotechnology of plant secondary metabolites. Blackwell Publishing, ISBN:9781444318876, DOI:10.1002/9781444318876.
3. Verpoorte, R. and Memelink, J. (2002) Engineering secondary metabolite production in plants. *Current Opinion in Biotechnology*, 13(2):181–187, DOI:10.1016/S0958-1669(02)00308-7.
4. Dewick, P.M. (2009) Medicinal Natural Products: A Biosynthetic Approach. John Wiley & Sons, ISBN:9780470742761, DOI:10.1002/9780470742761.
5. Katz, E., et al. (2015) The glucosinolate breakdown product indole-3-carbinol acts as an auxin antagonist in roots of *Arabidopsis thaliana*. *The Plant Journal*, 82(4):547–555, DOI: 10.1111/tpj.12824.

PBSE413: Epigenetics and Small RNA Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE413: Epigenetics and Small RNA Biology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The epigenetic landscape (including both DNA methylation and histone modifications) of an organism has a significant bearing in regulating various developmental and metabolic processes at the global level. Similarly, small RNAs (sRNAs) have emerged as major modulators of global gene expression patterns. Therefore, this course is designed to provide students with a clear understanding of key epigenetic mechanisms, including chromatin modelling, DNA methylation, and histone modifications, and how these processes regulate plant development and physiology. Students will learn how epigenetic regulation contributes to environmental responses, stress adaptation, and inheritance, as well as its relevance in human systems, including immunity, cancer, and cardiovascular diseases. The course also introduces the diversity, biogenesis, and regulatory roles of non-coding RNAs across organisms, including their mechanisms of action and trans-kingdom interactions. Additionally, students will become familiar with experimental and computational tools for detecting, predicting, and validating small RNAs, and will explore the applications of RNA-based technologies and CRISPR-Cas systems in crop improvement, diagnostics, and therapeutic development.

Learning Outcomes

By the end of this course, students will be able to understand major epigenetic mechanisms and evaluate their roles in plant development, environmental responses, and human diseases. They will be able to understand DNA methylation and histone modifications, classify non-coding RNAs, and describe how small RNAs regulate gene expression. Students will also be equipped to use molecular and bioinformatic approaches for small RNA analyses and apply RNA-based tools. Overall, they will be able to integrate epigenetics and small RNA biology concepts to address research problems and understand their practical applications in agriculture, biotechnology, and human health.

Course Content (45 hours)

Unit 1: Epigenetic Regulation -- Chromatin modeling and remodeling: polycomb complexes, SWI/SNF1 complexes and other chromatin modifiers; DNA methylation and its interpretation: methylated DNA-binding proteins, their structure and function; techniques of altering and analyzing DNA methylation; Histone modifications: types, modifying enzymes, histone deacetylase inhibitors; Chromatin modification and its influence on plant development: somatic embryogenesis, leaf development, photosynthesis, flowering, and ageing. **12 hours**

Essential Readings: Jenuwein, T. and Allis, C.D. (2001) Translating the histone code. *Science*, 293(5532):1074-1080, DOI:10.1126/science.1063127; Zhang, H., et al. (2018). Dynamics and function of DNA methylation in plants. *Nature Reviews Molecular Cell Biology*, 19(8):489-506, DOI:10.1038/s41580-018-0016-z; Rajewsky, N., et al. (2018) *Plant epigenetics*. Springer International, ISBN:9783319555195, DOI:10.1007/978-3-319-55520-1;

Huang, Y., et al., (2025) Chromatin remodeling in plants: Complex composition, mechanistic diversity, and biological functions. *Molecular Plant*, 18(9):1436–1457, DOI:10.1016/j.molp.2025.08.004.

Unit 2: Environmental and Evolutionary Epigenetics -- Role of epigenetic regulation in plant stress responses and epigenetic memory; Epigenetic inheritance and adaptive responses to environmental cues; Epigenetics in human systems: regulation of immune responses, cancer, and cardiovascular diseases. 10 hours

Essential Readings: Chinnusamy, V. and Zhu, J.K. (2009) Epigenetic regulation of stress responses in plants. *Current Opinion in Plant Biology*, 12(2):133–139, DOI:10.1016/j.pbi.2008.12.006; Avramova, Z. (2015) Transcriptional ‘memory’ of a stress: transient chromatin and memory (epigenetic) marks at stress-response genes. *The Plant Journal*, 83(1):149–159, DOI:10.1111/tpj.12832; Ma, L., et al., (2025) Epigenetic control of plant abiotic stress responses. *Journal of Genetics and Genomics*, 52(2):129–44, DOI:10.1016/j.jgg.2024.09.008; Janson, P.C. and Winqvist, O. (2011) Epigenetics—the key to understand immune responses in health and disease. *American Journal of Reproductive Immunology*, 66:72–74, DOI:10.1111/j.1600-0897.2011.01050.x; Zoghbi, H.Y. and Beaudet, A.L. (2016) Epigenetics and human disease. *Cold Spring Harbor Perspectives in Biology*, 8(2): a019497, DOI:10.1101/cshperspect.a019497.

Unit 3: Biology of Non-coding RNAs -- Discovery, types, occurrence, and diversity of non-coding RNAs; Small RNA pathways in bacteria, plants, and animal systems; Biogenesis and functional components of different classes of small RNAs; Regulation of gene expression by small RNAs: transcriptional gene silencing (TGS), post-transcriptional gene silencing (PTGS), gene activation, and evolutionary transitions in RNA-target interactions; Functional roles of small RNAs in different organisms; Trans-kingdom cross-talk mediated by small RNAs. 13 hours

Essential Readings: Guleria, P. and Kumar, V. (2020) *Plant Small RNA- Biogenesis, Regulation and Application*. Academic Press, ISBN:9780128171127, DOI:10.1016/C2018-0-01900-3; Alquethamy S., et al. (2025). What makes a small RNA work. *Nucleic Acids Research*, 53(12):gkaf563, DOI:10.1093/nar/gkaf563; Mattick, J. and Amaral, P. (2022) *RNA, the epicenter of genetic information*. ISBN:9781003109242, CRC Press, DOI:10.1201/9781003109242; Wierzbiki, A.T., et al. (2021) Long non-coding RNAs in plants. *Annual Review of Plant Biology*, 72:245–271, DOI:10.1146/annurev-arplant-093020-035446; Zhan, J. and Meyers, B.C. (2023) Plant small RNAs: their biogenesis, Regulatory roles, and functions. *Annual Review of Plant Biology*, 74:21–51, DOI:10.1146/annurev-arplant-070122-035226; Barquist, L. and Vogel, J. (2015) Accelerating discovery and functional analysis of small RNAs with new technologies. *Annual Review of Genetics*, 49:367–394, DOI:10.1146/annurev-genet-112414-054804.

Unit 4: Tools, Applications, and Emerging Technologies -- Discovery, detection, and validation of small RNAs; Target prediction and validation approaches; Databases and bioinformatic tools for small RNA analysis; Applications: artificial miRNA (amiRNA) technology, siRNA and virus-induced gene silencing (VIGS); RNAi interference (RNAi), RNA activation (RNAa), target mimicry and STTM technologies; CRISPR-Cas-based genome editing guided by small RNAs; Applications in crop improvement, diagnostics, and therapeutics. 10 hours

Essential Readings: Tang, G., et al. (2021) RNA-based technologies for functional genomics in plants. Springer Cham, ISBN:9783030649937, DOI:10.1007/978-3-030-64994-4; Ting, P., et al. (2018) A resource for inactivation of microRNAs using short tandem target mimic technology in model and crop plants. *Molecular Plant*, 11(11):1400–1417, DOI:10.1016/j.molp.2018.09.003; Halloy, F., et al. (2022) Innovative developments and emerging technologies in RNA therapeutics. *19(1):313–332*, DOI:10.1080/15476286.2022.2027150.

Practicals (30 hours)

1. To resolve and visualize low molecular weight RNAs by denaturing urea-PAGE.
2. To perform expression analysis of selected miRNAs using the quantitative PCR method.

3. To isolate, sonicate, and observe cross-linked chromatin to study histone modifications.
4. To enzymatically cleave and assess DNA to detect methylation patterns.
5. To predict and analyze the secondary structure and thermodynamic stability of the miRNA precursor sequence (pre-miRNA) using Mfold.

Suggested Readings:

1. Esteller, M. (2009) Epigenetics in biology and medicine. CRC Press, eISBN:9780429124921.
2. Workman, J.L. and Abmayr, S.M. (2014) Fundamentals of chromatin. Springer New York, ISBN:9781461486237, DOI:10.1007/978-1-4614-8624-4.
3. Dinkar, V., et al. (2024) Epigenetic regulations under plant stress: a cereals perspective. *Environmental and Experimental Botany*, 220:105688, DOI:10.1016/j.envexpbot.2024.105688.
4. He, L. (2025) The interplay between chromatin remodeling and DNA double-strand break repair: Implications for cancer biology and therapeutics. *DNA Repair*, 146:103811, DOI:10.1016/j.dnarep.2025.103811.
5. Muka, T., et al. (2016) The role of epigenetic modifications in cardiovascular disease: a systematic review. *International Journal of Cardiology*, 212:174–183, DOI:10.1016/j.ijcard.2016.03.062.
6. Mallick, B. and Ghosh, Z. (2012) Regulatory RNAs: Basics, Methods and Applications. Springer Berlin, Heidelberg, ISBN:9783642225161, DOI:10.1007/978-3-642-22517-8.
7. Nellan, W. and Hammann, C. (2007) Small RNAs: analysis and regulatory functions. Springer Berlin, Heidelberg, ISBN:9783540281306, DOI:10.1007/978-3-540-28130-6.
8. Gaur, R.K. and Rossi, J.J. (2009) Regulation of gene expression by small RNAs. CRC Press, USA, eISBN:9780429121692, DOI:10.1201/9781420008708.
9. Alquethamy, S., et al. (2025) What makes a small RNA work? *Nucleic Acids Research*, 53(12):gkaf563, DOI:10.1093/nar/gkaf563.
10. Rederstorff, M. (2021) Small non-coding RNAs: Methods and Protocols. Humana New York. eISBN:9781071613863, DOI:10.1007/978-1-0716-1386-3.

PBSE414: Data Analytics and Biocuration

This course is open to students of other departments as a GE course.

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE414: Data Analytics and Biocuration	4	3	1	0	B.Sc. in any branch of Science	

Learning Objectives

The paper aims to empower learners with foundational data analytics skills essential for modern bioinformatics by exposing them to the fundamentals of advanced operating systems, including the Linux command-line interface (CLI), file handling, permissions, and data manipulation. It also provides a brief exposure to the R programming environment, syntax, and functions for data analysis and packages available in the Bioconductor repository for statistical computing, data visualization, and genomic data analysis. It also provides a comprehensive overview of the primary computational workflows for analyzing next-generation sequencing (NGS) data. The learner will explore the concepts, applications, and key steps involved in major "big data" bioinformatics domains, including genome assembly, variant calling, pangenomics, metagenomics, transcriptomics (RNA-seq) and epigenomics (ChIP-seq, Bisulfite-seq). Besides, it also focuses on the behind-the-scenes work of biocuration that powers biological databases through processes of extracting, standardizing, and organizing biological data from literature and experiments. It provides an overview of BioDbCore, FAIRsharing, and ethical principles of open data management. The student will be able to interpret Gene Ontology and biomedical ontologies using OBO formats. In the last unit, there is a brief overview of foundational concepts of AI and machine learning (ML), along with the utility of domain-specific LLMs, their applications in genomics, drug design, and systems biology.

Learning Outcomes

The completion of the course will give expertise in essential Linux commands and in setting up and running 'R' scripts for statistical analysis and plotting. The learner can apply Bioconductor tools for biological data exploration, such as DESeq2, edgeR, and limma. Furthermore, students can analyse NGS data for variant calling, transcriptome quantification, and epigenomic data integration. They also understand the FAIR data principles, ontologies, and the curation of biological data from published sources. Moreover, students can work with LLMs, ML, and AI tools across domains such as genomic prediction, phenotype classification, drug discovery, and structure-based screening.

Course Content (45 hours)

Unit 1: Basic of Linux and 'R' -- Computer architecture, types of operating systems (Windows, Mac-OS and Linux), concept of networking (IP address); Basic fundamentals of working with Unix/Linux on CLI (Command Line Interface), Unix/Linux directory structure, file permissions, remote login; Linux commands (whoami, pwd, cd, ls, man, mkdir, rm, cat

copy, mv, chmod, grep, sed, sep, sort, head, tail, wc); Introduction to the ‘R’ data analysis package, basic work environment, syntax, introduction to the ‘Bioconductor’ packages for data analysis. **15 hours**

Essential Readings: Blum, R. and Bresnahan, A. (2021) Linux Command Line and Shell Scripting Bible. 4th edition, John Wiley & Sons, Inc., ISBN:9781119700913; Kabacoff, R.I. (2022) R in action: Data analysis and graphics with R. 3rd edition, Manning Publications, ISBN:9781617296055; Gentleman, R.C., et al. (2004) Bioconductor: open software development for computational biology and bioinformatics. Genome Biology, 5:R80, DOI:10.1186/gb-2004-5-10-r80.

Unit 2: Big Data Analysis -- Whole genome reference-based assembly, de-novo genome analysis, variant call analysis, Pangenomes, Metagenomic analysis, RNA-seq data analysis, ChIP (Chromatin Immunoprecipitation) data analysis; Whole genome bisulphite sequencing data analysis. **10 hours**

Essential Readings: Compeau, P. and Pevzner, P. (2018) Bioinformatics algorithms: An active learning approach. 3rd edition, Active Learning Publishers, ISBN:9780990374633; Shendure, J. and Aiden, E.L. (2012) The expanding scope of DNA sequencing. Nature Biotechnology, 30(11):1084–1094, DOI:10.1038/nbt.2421; Conesa, A., et al. (2016) A survey of best practices for RNA-seq data analysis. Genome Biology, 17:13, DOI:10.1186/s13059-016-0881-8; Landt, S.G., et al. (2012) ChIP-seq guidelines and practices of the ENCODE and modENCODE consortia. Genome Research, 22(9):1813–31, DOI:10.1101/gr.136184.111.

Unit 3: Data Integration and Biocuration -- Overview of Biocuration, various approaches for biocuration, BioDbCore guidelines, FAIRsharing and ethics in data sharing, Text/Literature-based curation, text mining approaches, and an introduction to tools such as Textpresso. Basics and importance of ontology development, OBO (Open Biological and Biomedical Ontology) format, OBO foundry, biomedical and plant-based ontologies. **10 hours**

Essential Readings: Gaudet, P., et al. (2011) Towards BioDBcore: a community-defined information specification for biological databases. Nucleic Acids Research, 39(s1):D7–D10, DOI:10.1093/nar/gkq1173; Open Biological and Biomedical Ontology Foundry: Community development of interoperable ontologies for the biological sciences, <https://obofoundry.org/about-OBO-Foundry.html>; FAIRsharing: A curated, informative and educational resource on data and metadata standards, inter-related to databases and data policies, <https://fairsharing.org>, DOI:10.1038/s41587-019-0080-8; Howe, D., et al. (2008) The future of biocuration. Nature, 455:47–50, DOI:10.1038/455047a; Wilkinson, M.D., et al. (2016) The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data, 3:160018, DOI:10.1038/sdata.2016.18.

Unit 4: Artificial Intelligence in Life Sciences -- Introduction to Machine-Learning (ML) and Artificial Intelligence (AI); Supervised and unsupervised learning approaches in data integration, interpretation, and predictive modelling; Applications in genomic prediction, drug discovery, ecosystem modelling; Domain-specific Large Language Models (LLMs). **10 hours**

Essential Readings: Cannataro, M., et al. (2022) Artificial Intelligence in Bioinformatics: from omics analysis to deep learning and network mining, 1st edition, Elsevier, eISBN:9780128229293; Jumper, J., et al. (2021) Highly accurate protein structure prediction with AlphaFold. Nature, 596:583–589, DOI:10.1038/s41586-021-03819-2.

Tutorials (15 hours)

1. Practice of working with Linux commands on the Command Line Interface (CLI).
2. Analysis of RNA-seq data:
 - a. Quality and adapter trimming of Next Generation Sequencing (NGS) data.
 - b. Reference-based genome mapping of NGS data.
 - c. Identification of differentially expressed genes.
3. Use of Gene Ontology for gene function analysis.

Suggested Readings:

1. Bessant, C., et al. (2014) Building bioinformatics solutions with Perl, R, and SQL. 2nd edition, Oxford University Press, UK, ISBN:978019965855.
2. Buffalo, V. (2015) Bioinformatics data skills: Reproducible and robust research with open-source tools. O'Reilley Media, ISBN:9781449367374.
3. Quince, C., et al. (2017) Shotgun metagenomics, from sampling to analysis. Nature Biotechnology, 35(9):833–844, DOI:10.1038/nbt.3935.
4. Sansone, S.A., et al. (2019) FAIRsharing as a community approach to standards, repositories and policies, Nature Biotechnology, 37(4):358–367, DOI:10.1038/s41587-019-0080-8.
5. Smith, B., et al. (2007) The OBO Foundry: coordinated evolution of ontologies to support biomedical data integration, Nature Biotechnology, 25(11):1251–1255, DOI:10.1038/nbt1346.
6. Müller, H.M., et al. (2018) Textpresso Central: a customizable platform for searching, text mining, viewing, and curating biological literature. BMC Bioinformatics, 19:94, DOI:10.1186/s12859-018-2103-8.
7. Web link: www.bioconductor.org
8. Web link: www.obofoundry.org; www.oboedit.org
9. Web link: www.biocuration.org

PBSE415: Plant Phenomics

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE415: Plant Phenomics	4	3	1	0	B.Sc. in any branch of science	

Course Objectives

This course aims to introduce students to the conceptual and methodological foundations of plant phenomics, spanning trait ontology, G×E×M frameworks, and robust experimental design. It seeks to familiarise students with controlled-environment and field phenotyping platforms, diverse imaging modalities, and 3D architectural reconstruction. A further objective is to develop competence in end-to-end phenomics data pipelines, from image acquisition to quantitative trait extraction and machine-learning-based modelling, enabling critical engagement with current literature and applications in crop improvement and stress biology.

Learning Outcomes

Upon successful completion, students will be able to define and differentiate plant phenomics from classical phenotyping, design basic phenotyping experiments with appropriate traits, platforms and metadata, and justify these choices. They will interpret and compare outputs from RGB, fluorescence, thermal, spectral and 3D imaging in controlled and field settings. Students will execute simple image-analysis workflows, apply elementary machine learning for phenotypic data, critically evaluate published phenomics studies, and articulate how phenomics informs breeding, resilience and systems-level plant biology.

Course Content (45 hours)

Unit 1: Foundations of Plant Phenomics and Trait Biology -- Definition and scope of plant phenomics; Distinction between classical phenotyping and high-throughput phenomics; Links to functional genomics, systems biology, and crop improvement; Trait ontology (morphological, physiological, developmental, functional traits); G×E×M (genotype×environment×management) framework; Principles of experimental design (replication, randomisation, blocking, temporal sampling); Metadata standards and FAIR (Findable, Accessible, Interoperable, and Reusable) data; Evolution of phenotyping platforms and international phenomics networks; Ideotype concepts and gene-to-phenotype mapping.

12 hours

Essential Readings: Chen, J.T. (2025) Plant high-throughput phenotyping and functional phenomics. CRC Press, eISBN:9781003505631, DOI:10.1201/9781003505631, Chapter 2 (Plant high-throughput phenotyping and phenomics for accelerating crop breeding), Chapter 9 (High-throughput phenotyping and phenomics for exploration of plant growth and development), Chapter 13 (High-throughput plant phenotyping and phenomics: Advances and prospects); Fiorani, F. and Schurr, U. (2013) Future scenarios for plant phenotyping. Annual Review of Plant Biology, 64:267–291, DOI:10.1146/annurev-arplant-050312-120137; Papoutsoglou, E.A., et al. (2023) The benefits and struggles of FAIR data: the case of reusing plant phenotyping data. Scientific Data, 10(1):595, DOI:10.1038/s41597-023-02364-z.

Unit 2: Controlled-Environment Phenomics and Imaging Modalities -- Growth chamber and greenhouse phenotyping platforms; conveyor- and chamber-based systems; Longitudinal monitoring of growth and development; RGB (Red, Green, and Blue) imaging for morphology, colour indices, and growth curves; Chlorophyll fluorescence imaging (PSII efficiency, stress signatures); Thermal imaging (canopy temperature, transpiration proxies); Multispectral and hyperspectral imaging for pigment and biochemical traits; Controlled root phenotyping [rhizotrons, gel systems, CT (Computed Tomography)/MRI (Magnetic Resonance Imaging) concepts]; Calibration, illumination control, reference standards; Time-series design for controlled-environment stress and treatment experiments. **10 hours**

Essential Readings: Lorence, A. and Jimenez, K.M. (2022) High-throughput plant phenotyping: Methods and Protocols. Methods in Molecular Biology. Humana New York, ISBN:9781071625361, DOI:10.1007/978-1-0716-2537-8, Chapter 5 (A straightforward high-throughput aboveground phenotyping platform for small- to medium-sized plants), Chapter 6 (Wireless fixed camera network for greenhouse-based plant phenotyping), Chapter 7 (Experimental design for controlled environment high-throughput plant phenotyping); Zhang, Y. and Zhang, N. (2018) Imaging technologies for plant high-throughput phenotyping: a review. *Frontiers of Agricultural Science and Engineering*, 5(4):406–419, DOI:10.15302/J-FASE-2018242; Mahlein, A.K., et al. (2018) Hyperspectral sensors and imaging technologies in phytopathology: state of the art. *Annual Review of Phytopathology*, 56:535–558, DOI:10.1146/annurev-phyto-080417-050100.

Unit 3: Field Phenomics, Remote Sensing, and 3D Architecture -- Fixed gantry, tractor-/robot-mounted and handheld phenotyping systems; UAV(Unmanned Aerial Vehicle)-based phenotyping with RGB, multispectral, and hyperspectral sensors; Vegetation indices (NDVI (Normalized Difference Vegetation Index), NDRE (Normalized Difference Red Edge Index), etc. for growth, water and nutrient status; Canopy temperature mapping; LiDAR and stereo vision for 3D reconstruction; Point clouds and structural traits; Integration of environmental data with phenotypic measurements; Spatial heterogeneity and experimental layout; Applications in breeding across diverse field environments. **12 hours**

Essential Readings: Chen, J.T. (2025) Plant high-throughput phenotyping and functional phenomics. CRC Press, eISBN:9781003505631, DOI:10.1201/9781003505631, Chapter 3 (Remote sensing technologies for high-throughput in-field crop phenotyping, Chapter 4 (High-Throughput field phenotyping: Enhancing crop monitoring for food security), Chapter 10 (Root phenotyping for breeding of climate-resilient crops), Chapter 16 (Robotics and aerial vehicle for high-throughput phenotyping: technologies and prospects); Araus, J.L. and Cairns, J.E. (2014) Field high-throughput phenotyping: the new crop breeding frontier. *Trends in Plant Science*, 19(1):52–61, DOI:10.1016/j.tplants.2013.09.008; Guo, W., et al. (2021) UAS-based plant phenotyping for research and breeding applications. *Plant Phenomics*, 2021:9840192, DOI:10.34133/2021/9840192.

Unit 4: Data Pipelines, Image Analysis, and Machine Learning in Phenomics -- End-to-end phenomics data pipeline (acquisition, pre-processing, segmentation, feature extraction, trait computation); Use of ImageJ/Fiji, PlantCV and related open-source tools; Machine learning for phenotyping; Deep learning and CNNs for segmentation, Classification and regression; Model training, validation and evaluation; Phenomic features in GWAS, genomic prediction and phenomic selection; Data management, reproducibility, model transferability and interpretability. **11 hours**

Essential Readings: Chen, J.T. (2025) Plant high-throughput phenotyping and functional phenomics. CRC Press, eISBN:9781003505631, DOI:10.1201/9781003505631, Chapter 1 (Bioinformatics tools and deep learning for plant high-throughput phenotyping and phenomics), Chapter 15 (Statistical tools and data analysis for organizing plant high-throughput phenomics); Murphy, K.M., et al. (2024) Deep learning in image-based plant phenotyping. *Annual Review of Plant Biology*, 75:771–795, DOI:10.1146/annurev-arplant-070523-042828; Danilevicz, M.F., et al. (2021) Resources for image-based high-throughput phenotyping in crops and data sharing challenges. *Plant Physiology*, 187(2):699–715, DOI:10.1093/plphys/kiab301.

Tutorials (15 hours)

1. Short presentations on landmark phenomics papers.
2. Designing a basic phenotyping experiment (traits, platform, experimental design, metadata sheet).
3. Hands-on demonstrations with sample image datasets.
4. Analysis of PSII efficiency (Fv/Fm) and photosynthetic activity [fluorescence decline ratio in steady state (Rfd_Lss)] in control and stressed plants.

Suggested Readings:

1. Chen, J.T. (2025) Plant high-throughput phenotyping and functional phenomics. CRC Press, ISBN:9781003505631, DOI:10.1201/9781003505631.
2. Lorence, A. and Jimenez, K.M. (2022) High-throughput plant phenotyping: Methods and Protocols. Methods in Molecular Biology, Humana New York, DOI:10.1007/978-1-0716-2537-8.
3. Awada, L., et al. (2024) The evolution of plant phenomics: Global insights, trends, and collaborations (2000-2021). Frontiers in Plant Science, 15:1410738, DOI:10.3389/fpls.2024.1410738.
4. Großkinsky, D.K., et al. (2023) The potential of integrative phenomics to harness underutilized crops for improving stress resilience. Frontiers in Plant Science, 14:1216337, DOI:10.3389/fpls.2023.1216337.
5. Singh, A., et al. (2016) Machine learning for high-throughput stress phenotyping in plants. Trends in Plant Science, 21(2):110–124, DOI:10.1016/j.tplants.2015.10.015.
6. Abebe, A.M., et al. (2023) Image-based high-throughput phenotyping in horticultural crops. Plants, 12(10):2061, DOI:10.3390/plants12102061.
7. Xu, R. and Li, C. (2022) A review of high-throughput field phenotyping systems: Focusing on ground robots. Plant Phenomics, 2022:9760269, DOI:10.34133/2022/9760269.
8. Gano, B., et al. (2024) Drone-based imaging sensors, techniques, and applications in plant phenotyping for crop breeding: A comprehensive review. The Plant Phenome Journal, 7(1): e20100, DOI:10.1002/ppj2.20100.
9. Li, S., et al. (2025) A review of optical-based three-dimensional reconstruction and multi-source fusion for plant phenotyping. Sensors, 25(11):3401, DOI:10.3390/s25113401.
10. Su, M., et al. (2025) Design and implementation of high-throughput field phenotyping robot for acquiring multisensory data in wheat. Plant Phenomics, 7(2):100014, DOI:10.1016/j.plaphe.2025.100014.
11. Adak, A., et al. (2023) Phenomic data-driven biological prediction of maize through field-base high-throughput phenotyping integration with genomic data. Journal of Experimental Botany, 74(17):5307–5326, DOI: 0.1093/jxb/erad216.
12. Zavafer, A., et al. (2023) Phenomics: conceptualization and importance for plant physiology. Trends in Plant Science, 28(9):1004–1013, DOI:10.1016/j.tplants.2023.03.023.
13. Lichtenthaler, H.K. and Miehe, J.A. (1997) Fluorescence imaging as a diagnostic tool for plant stress. Trends in Plant Science, 2(8):316–320, DOI:10.1016/S1360-1385(97)89954-2.

PBSE416: Synthetic Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE416: Synthetic Biology	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

This course introduces the foundational and applied aspects of synthetic biology with a focus on plants and microbial chassis used in plant biotechnology. It integrates principles of genetic circuit design, genome refactoring, metabolic engineering, and synthetic ecosystems. Special emphasis is placed on synthetic *E. coli* as a design chassis and on plant-based biohybrid systems, such as photovoltaic cells, that merge biological and artificial components for sustainable energy and agricultural innovation.

Learning Outcomes

Students will understand theoretical and design principles of synthetic biology across systems. They will be able to apply genetic circuit and metabolic pathway engineering to plants and microbes. They will evaluate *E. coli* as a chassis for producing plant metabolites, explore biohybrid innovations like plant photovoltaic cells and synthetic photosynthesis, and recognize biosafety, ethical, and policy issues in synthetic biology research.

Course Content (45 hours)

Unit 1: Principles and Foundations of Synthetic Biology -- Definition, concept, and evolution of synthetic biology; Historical milestones; Comparison with conventional genetic engineering; Minimal genomes and synthetic cells; Jargons of Synbio: parts, devices, systems, modules, chassis, orthogonality, retroactivity; Modularity and chassis optimization for plants and microbes.

8 hours

Essential Readings: Brenner, S.A. and Sismour, A.M. (2005) Synthetic biology. *Nature Reviews Genetics* 6(7):533–543, DOI:10.1038/nrg1637; Andrianantoandro, E., et al. (2006) Synthetic biology: new engineering rules for an emerging discipline. *Molecular Systems Biology*, 2:MSB4100073, DOI:10.1038/msb4100073; Garner, K.L. (2021) Principles of synthetic biology. *Essays in Biochemistry*, 65(5):791–811, DOI:10.1042/EBC20200059; Wang, Y. and Demirer, G.S. (2023) Synthetic biology for plant genetic engineering and molecular farming. *Trends in Biotechnology* 41(9):1182–1198, DOI:10.1016/j.tibtech.2023.03.007; Nemhauser, J.L., and Torii, K.U. (2016) Plant synthetic biology for molecular engineering of signalling and development. *Nature Plants*, 2:16010, DOI:10.1038/nplants.2016.10; Kocaoglan, E.G., et al. (2023) Synthetic developmental biology: molecular tools to re-design plant shoots and roots. *Journal of Experimental Botany*, 74(13):3864–3876, DOI:10.1093/jxb/erad169.

Unit 2: Synthetic *E. coli* as a Model Chassis -- Genome refactoring and minimal *E. coli* genomes; Design and assembly of synthetic operons for metabolite production; Genetic circuits; Synthetic biosensors and quorum-sensing modules; Heterologous expression of plant pathways in *E. coli* for establishing biomanufacturing platform

10 hours

Essential Readings: Chi, H., et al. (2019) Engineering and modification of microbial chassis for systems and synthetic biology. *Synthetic and Systems Biotechnology*, 4(1):25–33, DOI:10.1016/j.synbio.2018.12.001; Reiter, M.A., et al. (2024) A synthetic methylotrophic *Escherichia coli* as a chassis for bioproduction from methanol. *Nature Catalysis*, 7:560–573, DOI:10.1038/s41929-024-01137-0.

Unit 3: Biological Circuits and Network Engineering -- Design of genetic circuits: requirements, tools, and techniques; Modelling of gene circuits (basic ODE modelling of biological systems with MATLAB, introduction to Cello: genetic circuit design automation software); Creating large-scale biological circuits and regulatory networks; Multi-gene network construction and *in silico* simulations. 12 hours

Essential Readings: Elnaggar, K.S., et al. (2025) A guide in synthetic biology: Designing genetic circuits and their applications in stem cells. *SynBio* 3(3):11. DOI:10.3390/synbio3030011; Müller, M.M., et al. (2025) Genetic circuits in synthetic biology: broadening the toolbox of regulatory devices. *Frontiers in Synthetic Biology*, 3:1548572. DOI:10.3389/fsybi.2025.1548572.

Unit 4: Plant Synthetic Biology and Biohybrid Systems -- Gene circuit design in plants: requirements, tools, and techniques; Engineering photosynthesis, photorespiration, and carbon fixation pathways; Chloroplast genome engineering and minimal plastomes; Metabolic engineering for nutraceuticals, industrial products, etc.; Plant-based photovoltaic cells; Case studies on Spinach leaf photovoltaic (PV) devices, cytochrome-based photoanodes; Synthetic nitrogen fixation and carbon sequestration in plants; Machine learning and AI-assisted circuit optimization; Biocontainment and genetic firewalls; Ethical, legal, and biosafety frameworks; Future prospects: cell-free systems, synthetic organelles. 15 hours

Essential Readings: Goshisht, M.K. (2024) Machine learning and deep learning in synthetic biology: Key architectures, applications, and challenges. *ACS Omega*, 9:9921–45, DOI:10.1021/acsomega.3c05913; Kurtoğlu, A., et al. (2024) The view of synthetic biology in the field of ethics: a thematic systematic review. *Frontiers in Bioengineering and Biotechnology*, 12:1397796, DOI:10.3389/fbioe.2024.1397796; Hynek, N. (2025) Synthetic biology/AI convergence (SynBioAI): security threats in frontier science and regulatory challenges. *AI & Society*, DOI:10.1007/s00146-025-02576-4; Arya, R., et al. (2025) New techniques of genetic engineering in agriculture: Innovations, applications, and future prospects. *International Journal of Advanced Biochemistry Research*, 9(4):166–174, DOI:10.33545/26174693.2025.v9.i4c.4066; Zhang, D., et al. (2025) Synthetic biology and artificial intelligence in crop improvement. *Plant Communications*, 6(2):101220, DOI:10.1007/s00146-025-02576-4.

Tutorials (15 hours)

Case studies of:

- a. *Escherichia coli* as a chassis for the production of plant metabolites.
- b. Synthetic photosynthesis.
- c. Synthetic cell.
- d. Carbon sequestration.

Suggested Readings:

1. Davies, J.A. (2018) *Synthetic Biology: A very short introduction*. Oxford University Press, ISBN:9780198803492, DOI:10.1093/actrade/9780198803492.001.0001.
2. Zhang, W. and Nielsen, D.R. (2014) Synthetic biology applications in industrial microbiology. *Frontiers in Microbiology*, 5(313):451, DOI:10.3389/fmicb.2014.00451.
3. Zhao, H. (2013) *Synthetic biology: tools and applications*. Academic Press, ISBN:9780123944306, DOI:10.1016/C2011-0-06857-6.
4. Freemont, P.S. and Kitney, R.I. (2015) *Synthetic Biology - A Primer*. Imperial College Press, ISBN:9781783268795.
5. Voigt, C.A. (2020) Synthetic biology 2020–2030: six commercially-available products that are changing our world. *Nature Communications*, 11:6379, DOI:10.1038/s41467-020-20122-2.

PBSEC417: Advanced Research Methodology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSEC417: Advanced Research Methodology	2	1	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to provide students with an in-depth conceptual understanding of advanced research methodologies applied in molecular plant sciences. It emphasizes experimental design, interpretation, and analysis in the context of gene function, regulatory networks, and crop improvement. The course also aims to establish a solid foundation for critically evaluating experimental data, formulating hypotheses, and communicating scientific findings in plant biology research.

Learning Outcomes

Upon successful completion of this course, students will develop a comprehensive understanding of advanced research methodologies in plant molecular biology. They will be able to conceptualize and design theoretical frameworks for gene function analysis, regulatory network mapping, and crop improvement experiments. Students will gain the ability to integrate bioinformatics insights with molecular and genetic approaches to interpret gene and protein function. Furthermore, they will gain an understanding of the conceptual underpinnings of genome editing, regulatory pathway analysis, and experimental data validation. The course will enhance their skills in critical thinking and experimental design in plant molecular biology research.

Course Content (15 hours)

Unit 1: Experimental Design for Gene Function Analysis -- Experimental frameworks for dissecting gene function and regulatory cascade in plants; Conceptual foundations of gene/protein function prediction, principles of homology, conserved domain identification, integration networks and database search; Principles of experimental design for gene over-expression and knock-out/knock-down studies, mutant analysis, and genetic mapping; Protein localization studies; Elucidation of genetic regulatory cascades. 10 hours

Essential Readings: Robles, J.A., et al. (2012) Efficient experimental design and analysis strategies for the detection of differential expression using RNA-Sequencing. BMC Genomics, 13:484, DOI:10.1186/1471-2164-13-484; Grondin, A., et al. (2024) A case study from the overexpression of OsTZF5, encoding a CCCH tandem zinc finger protein, in rice plants across nineteen yield trials. Rice, 17(1):25, DOI:10.1186/s12284-024-00705-z; Tang, M., et al. (2021) A genome-scale TF–DNA interaction network of transcriptional regulation of *Arabidopsis* primary and specialized metabolism. Molecular Systems Biology, 17(11):e10625, DOI:10.15252/msb.202110625; <https://www.goldenhelix.com/blog/stop-ignoring-experimental-design-or-my-head-will-explode/>; <https://www.ncbi.nlm.nih.gov/books/NBK26818/>; Wagner, M.R., and Kleiner, M. (2025) How thoughtful experimental design can empower biologists in the omics era. Nature Communications, 16(1):7263, DOI:10.1038/s41467-025-62616-x; Boadu, F., (2025) Deep learning methods for protein function prediction. Proteomics, 25(1-2):e2300471, DOI:10.1002/pmic.202300471; Goodin, M.M. (2018) Advances in virus research. 100:117-144, DOI:10.1016/bs.aivir.2017.10.004, Chapter 6 (Protein localization and interaction studies in plants: Toward defining complete proteomes by visualization).

Unit 2: Experimental Frameworks for Crop Improvement by Genome Editing --

Experimental frameworks for designing molecular and genetic strategies for crop improvement; CRISPR-based strategies for gain-of-function and loss-of-function of genes for enhanced agronomic traits; Validation of transgene-free plants, Field trials and regulations regarding the release of genome-edited crops. 5 hours

Essential Readings: Graham, D.B. and Root, D.E. (2015) Resources for the design of CRISPR gene editing experiments. *Genome Biology*, 16:260, DOI:10.1186/s13059-015-0823-x; Zhou, J., et al. (2023) An efficient CRISPR–Cas12a promoter editing system for crop improvement. *Nature Plants*, 9(4):588–604, DOI:10.1038/s41477-023-01384-2; Han, X., et al. (2025) Genetic engineering, including genome editing, for enhancing broad-spectrum disease resistance in crops. *Plant Communications*, 6(2):101195, DOI:10.1016/j.xplc.2024.101195; Hanna, R.E. and Doench, J.G. (2020) Design and analysis of CRISPR-Cas experiments. *Nature Biotechnology*, 38(7):813–823, DOI:10.1038/s41587-020-0490-7.

Practicals (30 hours)

1. Analysis of conserved protein motifs using WebLogo and interpreting functional domains of a protein family.
2. Development of transgenic hairy roots using RNAi or promoter–*uidA* binary vector constructs.
3. Analysis of stress-induced promoter activity *in planta* using non-destructive methods.
4. *In silico* design of a vector for transgene-free plant genome editing using TnpB.
5. Design and application of CAPS/dCAPS markers to identify and validate single-base substitutions or targeted genome edits.

Suggested Readings:

1. Buchanan, B.B. et al. (2015) *Biochemistry and molecular biology of the plants*. 2nd edition, WILEY Blackwell, ISBN:9780470714218.
2. Singh, P.P., and Benayoun, B.A. (2023) Considerations for reproducible omics in aging research. *Nature Aging*, 3(8):921–930, DOI:10.1038/s43587-023-00448-4;
3. Conesa, A., et al. (2016) A survey of best practices for RNA-seq data analysis. *Genome Biology*, 17:13, DOI:10.1186/s13059-016-0881-8.
4. Haas, R., et al. (2017) Designing and interpreting 'multi-omic' experiments that may change our understanding of biology. *Current Opinion in Systems Biology*, 6:37–45, DOI:10.1016/j.coisb.2017.08.009.
5. Strotmann, V.I. and Stahl, Y. (2022) Visualization of *in vivo* protein-protein interactions in plants. *Journal of Experimental Botany*, 73(12):3866–3880, DOI:10.1093/jxb/erac139.
6. Quattrocchio, F.M., et al. (2013) Transgenes and protein localization: myths and legends. *Trends in Plant Science*, 18(9):473–476, DOI:10.1016/j.tplants.2013.07.003.
7. Lichocka, M. and Schmelzer, E. (2014) Subcellular localization experiments and FRET-FLIM measurements in plants. *Bio-Protocol*, 4(1):e1018, DOI:10.21769/BioProtoc.1018.
8. Zhang, Y., et al. (2023) Investigating the dynamics of protein-protein interactions in plants. *The Plant Journal*, 114(4):965–983, DOI:10.1111/tpj.16182.
9. Teng, C. (2024) Killing two birds with one stone: A breakthrough in transgene-free gene editing in soybean. *Plant Physiology*, 196(4):2263–2265, DOI:10.1093/plphys/kiae526.
10. Riccroch, A., et al. (2024) Worldwide study on field trials of biotechnological crops: new promises but old policy hurdles. *Frontiers in Plant Science*, 15:1452767, DOI:10.3389/fpls.2024.1452767.
11. https://dbtindia.gov.in/sites/default/files/Final_%2011052022_Annexure-1%2C%20Genome_Edited_Plants_2022_Hyperlink.pdf

Structure 2 - PG with Coursework & Research

SEMESTER 3

PBSC321: Plant Biotechnology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC321: Plant Biotechnology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course will enable students to understand the core principles and milestones of plant biotechnology, including the molecular basis of crop domestication and Green Revolution traits, as well as concepts in tissue culture. Students will learn about the molecular toolbox for plant genetic engineering and be introduced to advanced approaches, including RNAi, genome editing, and synthetic biology, for pathway engineering. The course will build conceptual understanding of modern gene/QTL mapping, marker-assisted and genomic selection, speed breeding, and gene pyramiding, together with applications of plant biotechnology in molecular farming, biofortification, climate resilience, plant-microbe interactions, and industrial and environmental biotechnology. Finally, students will be sensitized to biosafety guidelines, GMO risk assessment, IPR, farmers’ rights, and ethical and societal issues in plant biotechnology.

Learning Outcomes

On completing the course, students will be able to explain and apply tissue culture and related technologies for crop improvement. They will be able to outline and compare plant transformation and genome editing strategies, design genetic constructs and describe workflows for the generation and characterization of transgenic and edited plants. Students will be able to select appropriate molecular markers and mapping approaches for dissecting complex traits, and integrate marker-assisted selection, genomic selection, and breeding pipelines. They will be able to critically analyse case studies such as Golden rice, Bt cotton, virus-resistant papaya, and DH mustard, among others. In addition, they will be able to interpret biosafety and regulatory frameworks, IPR/PBR/farmer’s rights provisions, and articulate ethical, social, and policy implications of deploying plant biotechnological innovations in agriculture.

Course Content (45 hours)

Unit 1: Fundamentals and Scope of Plant Biotechnology -- Concept, history, and milestones in plant biotechnology; Molecular basis of crop domestication and Green revolution; Principles of plant tissue culture, totipotency, and micropropagation; Somaclonal variation, somatic embryogenesis, and synthetic seeds; Protoplast fusion and somatic hybridization. **5 hours**

Essential Readings: Stewart Jr., C.N. (2025) Biotechnology and Genetics: Principles, Techniques, and Applications. 3rd edition, John Wiley & Sons, ISBN:9781394217236, Chapter 1 (Plant Agriculture: The impact of biotechnology); Abdin, M.Z, et al. (2017) Plant Biotechnology: Principles and Applications, Springer Verlag,

Singapore, ISBN:9789811029592, Chapter 1 (Historical perspective and basic principles of plant tissue culture), Chapter 2 (Plant tissue culture: Applications in plant improvement and conservation); Pathirana, R. and Carimi, F. (2024) Plant biotechnology-an indispensable tool for crop improvement. *Plants (Basel)*, 13(8):1133, DOI:10.3390/plants13081133.

Unit 2: Molecular Tools and Techniques -- Genetic cloning strategies and vector systems; Promoters, selectable markers, and reporter genes; Gene transfer methods; Chloroplast transformation; Characterization of transgenic plants at molecular, biochemical, and phenotypic level; Case studies: Golden rice, Bt cotton, virus-resistant papaya, herbicide-tolerant crops, Dhara Mustard, any other product; Virus-induced gene silencing (VIGS) methods; Genome editing technologies [Zinc Finger Nucleases, Transcription activator-like effector nucleases, Clustered Regularly Interspaced Short Palindromic Repeats or CRISPR)/CRISPR-associated (Cas) systems, prime editing, base editing, and miniature RNA-guided endonuclease]; Generation of marker-free transgenics; RNAi interference (RNAi); Introduction of synthetic biology and metabolic pathway engineering. **15 hours**

Essential Readings: Li, B., et al. (2024) Targeted genome-modification tools and their advanced applications in crop breeding. *Nature Reviews Genetics*, 25(9):603–622, DOI:10.1038/s41576-024-00720-2; Liu, W., et al. (2013) Advanced genetic tools for plant biotechnology. *Nature Review Genetics*, 14:781–793, DOI:10.1038/nrg3583; Gupta, O.P. and Karkute, S.G. (2021) Genome editing in plants: Principles and applications, CRC Press, ISBN:9780367415907, Chapter 1 (Historical developments of genome editing in plants), Chapter 2 (Mechanism of ZFN mediated genome editing: scope and opportunities), Chapter 3 (TALEN: customizable molecular scissors for tailoring newer types of genomes in plants), Chapter 4 (Mechanism of CRISPR/Cas9 mediated genome editing: scope and opportunities); Koeppe, S., et al. (2023) RNA interference: past and future applications in plants, *International J. Molecular Science*, 24(11):9755, DOI: 10.3390/ijms24119755; Singh, R., et al. (2023) A prospective review on selectable marker-free genome engineered rice: past, present and future scientific realm, *Frontiers in Genetics*, 13:2022, DOI:10.3389/fgene.2022.882836; Aaron, S., et al. (2020) Metabolic engineering and synthetic biology of plant natural products – A minireview. *Current Plant Biology*, 24:100163, DOI:10.1016/j.cpb.2020.100163.

Unit 3: Mapping of Genes/QTLs -- High-throughput molecular markers and genotyping assays; Bulk segregant analysis (QTL-seq), Target-Sequence Enrichment and Sequencing (TESeq), Resistance gene enrichment sequencing (RenSeq), and Mutation mapping (MutMap, MutMap-Gap, etc); Genome-Wide Association Studies (GWAS); Marker-assisted plant breeding and genomic selection (GS); Speed breeding; Gene Pyramiding; Hybrid breeding and doubled haploid technologies. **15 hours**

Essential Readings: Jaganathan, D., et al. (2020) Fine mapping and gene cloning in the post-NGS era: advances and prospects. *Theoretical and Applied Genetics*, 133(5):1791–1810, DOI:10.1007/s00122-020-03560-w; Wang, X., et al. (2023) Next-generation bulked segregant analysis for Breeding 4.0. *Cell Reports*, 42(9):113039, DOI:10.1016/j.celrep.2023.113039; Uffelman, E., et al. (2021) Genome-wide association studies. *Nature Reviews Methods Primers*, 1:59, DOI:10.1038/s43586-021-00056-9; Kabade, P.G., et al. (2025) Speed breeding 3.0: mainstreaming light-driven plant breeding for sustainable genetic gains. *Trends in Biotechnology*, 43(10):2462–2478, DOI:10.1016/j.tibtech.2025.04.011; Crossa, J., et al. (2017) Genomic selection in plant breeding: methods, models, and perspectives, *Trends in Plant Science*, 22(11):961–975, DOI:10.1016/j.tplants.2017.08.011; Qu, Y., et al. (2024) Doubled haploid technology and synthetic apomixis: Recent advances and applications in future crop breeding. *Molecular Plant*, 17(7):1005–1018, DOI:10.1016/j.molp.2024.06.005.

Unit 4: Applications and Societal Aspects of Plant Biotechnology -- Molecular farming; Biofortification and nutritional enhancement; Manipulating and harnessing plant-microbe interactions: disease resistant plants, biofertilizers, biopesticides, and mycorrhizal biotechnology; Climate-resilient crops: generation of abiotic stress tolerant plants; Industrial Biotechnology: bioethanol and other products; Environmental biotechnology: phytoremediation; Regulatory frameworks: biosafety guidelines, GMO risk assessments, and

intellectual property rights (IPR); Plant breeders' rights (PBRs) and farmers' rights; Ethical, social, and policy implications of plant biotechnology. **10 hours**

Essential Readings: Shanmugaraj, B., et al. (2020) Plant molecular farming: A viable platform for recombinant biopharmaceutical production. *Plants*, 9(7):842, DOI:10.3390/plants9070842; Garg, M., et al. (2024) Biofortification for nutrient-rich crops. ISBN:9781032690636, DOI:10.1201/9781032690636; Digel, I., et al. (2025) Introduction to Industrial Biotechnology, Springer Cham, ISBN:9783032079183, DOI:10.1007/978-3-032-07918-3; Abdin, M.Z., et al. (2017) Plant Biotechnology: Principles and Applications, Springer Verlag, Singapore, ISBN:9789811029592, Chapter 14 (Biosafety, Bioethics, and IPR Issues in Plant Biotechnology); Protection of plant varieties and farmers' right act (PPV & FR), 2001, Ministry of Agriculture and Farmers Welfare, GoI; Standard Operating Procedures for regulatory review of genome edited plants under SDN-1 and SDN-2 categories 2022 and Guidelines on genetically engineered plants containing stacked events 2025 by Department of Biotechnology, MoS&T, GoI.

Practicals (30 hours)

1. Assessment of promoter activity in transgenic plants using beta-glucuronidase (GUS) reporter through histochemical staining and fluorometric (MUG) assays.
2. To perform PCR-based screening of *Arabidopsis* T-DNA insertion lines to distinguish heterozygous and homozygous plants.
3. Genome editing of a target gene in a plant (GFP/transient assay).
4. T7E1/ Surveyor mismatch cleavage assays to detect mutated/edited genomic regions.
5. Construction of a plant genetic linkage map with molecular markers.

Suggested Readings:

1. Acquaah, G. (2020) Principles of Plant Genetics and Breeding, 3rd edition, Wiley-Blackwell, ISBN:9781119626695.
2. Al-Khayri, J.M., et al. (2025) Genome Editing for Crop Improvement - Theory and Methodology. CAB International, ISBN:9781800622494.
3. Hille, F., et al. (2018) The biology of CRISPR-Cas: Backward and forward. *Cell*, 172(6):1239–1259, DOI:10.1016/j.cell.2017.11.032.
4. Singh, B.D. and Singh, A.K. (2015) Marker-Assisted Plant Breeding: Principles and Practices, Springer New Delhi, ISBN:9788132223160, DOI:10.1007/978-81-322-2316-0.
5. Clauw, P., et al. (2025) Beyond the standard GWAS-A guide for plant biologists. *Plant and Cell Physiology*, 66(4):431–443, DOI:10.1093/pcp/pcae079.
6. Quiroz, L.F., et al. (2024) Haploid rhapsody: the molecular and cellular orchestra of *in vivo* haploid induction in plants. *New Phytologist*, 241(5):1936–1949, DOI:10.1111/nph.19523.
7. Ghosh, S., et al. (2018) Speed breeding in growth chambers and glasshouses for crop breeding and model plant research. *Nature Protocols*, 13:2944–2963, DOI:10.1038/s41596-018-0072-z.
8. Chen, J.T. (2024) Plant speed breeding and high-throughput technologies, CRC Press, ISBN: 9781003434733.
9. Xiong, J., et al. (2023) Synthetic apomixis: the beginning of a new era. *Current Opinion in Biotechnology*, 79:102877, DOI:10.1016/j.copbio.2022.102877.
10. WHO (2004) Laboratory Biosafety Manual, 3rd edition
11. FAO (2018) Biosafety Primer.
12. Department of Biotechnology (DBT), MoS&T, GoI (2023) Intellectual Property Guidelines.
13. Scientific Journals: Plant Biotechnology Reports; International Journal of Plant Biotechnology; Plant Biotechnology Journal; Transgenic Research; Journal of Plant Biotechnology; Plant Cell, Tissue and Organ Culture.
14. Singh, K.K. (2014) Biotechnology and intellectual property rights-legal and social implications. ISBN:9788132220596, DOI:10.1007/978-81-322-2059-6.

PBSC322: Molecular Plant Breeding

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC322: Molecular Plant Breeding	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

Molecular breeding has greatly advanced human agriculture by enabling the continuous improvement of food and industrial crops. This paper introduces students to the foundations of classical breeding, quantitative genetics, and plant genetic resources, while also covering advanced molecular methods, including marker-assisted selection, QTL mapping, genomic selection, and hybrid breeding technologies. By integrating conventional and modern techniques, the course highlights how new, high-performing crop varieties are developed to meet global demands for productivity, quality, and stress resilience.

Learning Outcomes

Students will be able to understand the historical foundations and objectives of plant breeding and crop genetics beyond model plant systems. They will be able to distinguish between breeding methods across reproductive systems and the application of molecular tools to enhance crop quality at the field level. It will equip them to understand and evaluate global molecular breeding efforts, integrate genetic modification with modern breeding practices, and apply strategies to enhance yield, quality, and stress tolerance.

Course Contents (45 hours)

Unit 1: Plant breeding -- Introduction and history of breeding; Breeding objectives and crop traits; Principles of population and quantitative genetics; Plant genetic resources and crop domestication; Breeding in self-pollinated, cross-pollinated, and clonally propagated species; Concept of molecular breeding. **12 hours**

Essential Readings: Acquaah, G. (2021) Principles of Plant Genetics and Breeding, 3rd Edition, Wiley Blackwell, ISBN:9781119626329; Singh, D.P., et al. (2021) Plant Breeding and Cultivar Development, Academic Press, ISBN:9780128175637, DOI:10.1016/C2018-0-01730-2.

Unit 2: Molecular markers and their Utilisation -- Molecular markers and genotyping methods; Linkage mapping of molecular markers; Mapping populations and quantitative trait loci mapping; Association mapping; Marker-assisted selection; Training population and statistical models in genomic selection; Phylogenetic relationships and genetic diversity; Mutation mapping and breeding; Process of variety release, Seed certification, and commercial release. **12 hours**

Essential Readings: Singh, B.D. and Singh, A.K. (2015) Marker-Assisted Plant Breeding: Principles and Practices, ISBN:9788132223160, DOI:10.1007/978-81-322-2316-0; Amiteye, S. (2021) Basic concepts and methodologies of DNA marker systems in plant molecular breeding. Heliyon, 7(10):e08093, DOI: 10.1016/j.heliyon.2021.e08093; Al-Khayri, J.M., et al. (2024) Plant Molecular Breeding in Genomics Era - Concepts and Tools, Springer Cham, ISBN:9783031685866, DOI:10.1007/978-3-031-68586-6; Bhat, T.A. and Hakeem, K.R. (2023) Biotechnologies and genetics in plant mutation breeding (volume 1: Mutagenesis and Crop Improvement). Apple Academic Press, Inc., ISBN:9781003305064; Acquaah, G. (2021) Principles of Plant

Genetics and Breeding, 3rd edition, Wiley-Blackwell, ISBN:9781119626329, Section 12 (Variety release process in plant breeding).

Unit 3: Hybrid Breeding and Doubled haploid (DH) Technologies -- Genetic basis of heterosis and hybrid breeding strategies; Molecular aspects of three-line and two-line approaches (photoperiod- and thermo-sensitive genic male sterility); Transgenics in hybrid seed production; Role of DH lines in mapping and varietal improvement; Molecular mechanisms of haploid induction (maternal and paternal); Synthetic apomixis and fixing elite genotypes. 12 hours

Essential Readings: Chen, L. and Liu, Y.G. (2014) Male sterility and fertility restoration in crops. *Annual Review of Plant Biology*, 65:579–606, DOI:10.1146/annurev-arplant-050213-040119; Kim, Y.J. and Zhang, D. (2018) Molecular control of male fertility for crop hybrid breeding. *Trends in Plant Science*, 23(1):53–65, DOI: 10.1016/j.tplants.2017.10.001; Quiroz, L.F., et al. (2024) Haploid rhapsody: the molecular and cellular orchestra of *in vivo* haploid induction in plants. *New Phytologist*, 241(5):1936–1949, DOI: 10.1111/nph.19523.

Unit 4: Applications of Molecular Breeding -- International molecular breeding efforts; Improving crop yields, quality, biotic and abiotic stress tolerance; Enhancing shelf-life, nutritional value and flavor; Integration of genetic modification and molecular breeding. 9 hours

Essential Readings: Acquaah, G. (2021) *Principles of plant genetics and breeding*, 3rd edition, Wiley-Blackwell. ISBN:9781119626343, Chapter 14 (Breeding for resistance to disease and insect pests), Chapter 15 (Breeding for resistance to abiotic stresses), Chapter 35 (International plant breeding efforts); Lomax, J., et al. (2024) Multi-omic applications for understanding and enhancing tropical fruit flavour. *Plant Molecular Biology*, 114(4):83, DOI:10.1007/s11103-024-01480-7; Sharma, R., et al. (2025) Integrating molecular genetics with plant breeding to deliver impact. *Plant Physiology*, 198(3):kiaf087, DOI:10.1093/plphys/kiaf087.

Practicals (30 hours)

1. *In silico* analysis of crop genomes and identification of polymorphisms under known QTLs.
2. Designing markers and genotyping of locus-specific SNPs using CAPS and dCAPS markers.
3. Haplotype analysis from publicly available genomic data of a selected crop plant.
4. Verification of true F₁ hybrid with molecular markers in bi-parental crossed plants.
5. Association analysis of selected genotypes with their phenotype data.

Suggested Readings:

1. Koh, H.J., et al. (2015) *Current technologies in plant molecular breeding - A guidebook of plant molecular breeding for Researchers*. ISBN:9789401799966, DOI:10.1007/978-94-017-9996-6.
2. Al-Khayri, J.M., et al. (2016) *Advances in plant breeding strategies: Breeding, Biotechnology and Molecular Tools*, Springer Cham, ISBN:9783319225210, DOI:10.1007/978-3-319-22521-0.
3. Kang, M.S. (2020). *Quantitative genetics, genomics and plant breeding*, 2nd Edition, CABI, ISBN: 9781789242942.
4. Li, B., et al. (2024) Targeted genome-modification tools and their advanced applications in crop breeding. *Nature Reviews Genetics*, 25(9):603–622, DOI:10.1038/s41576-024-00720-2.
5. Bharadwaj, D.N. (2018) *Advanced Molecular Plant Breeding- Meeting the challenge of food security*. CRC Press. ISBN:9780203710654, DOI:10.1201/b22473.
6. Crossa, J., et al. (2017) Genomic selection in plant breeding: Methods, models, and perspectives. *Trends in Plant Science*, 22(11):961–975, DOI:10.1016/j.tplants.2017.08.011.
7. Alemu, A., et al. (2024) Genomic selection in plant breeding: Key factors shaping two decades of progress. *Molecular Plant*, 17(4):552–578, DOI:10.1016/j.molp.2024.03.007.
8. Chaudhary, N. and Sandhu, R. (2024) A comprehensive review on speed breeding methods and applications. *Euphytica*, 220:42, DOI:10.1007/s10681-024-03300-x.

9. Rajan, R., et al. (2025) Innovations in climate resilient agriculture, Springer Cham, ISBN:9783031848025, DOI:10.1007/978-3-031-84802-5.
10. Klee, H.J. and Tieman, D.M. (2018) The genetics of fruit flavour preferences. *Nature Reviews Genetics*, 19(6):347–356, DOI:10.1038/s41576-018-0002-5.
11. Kamaluddin, et al. (2022) Technologies in Plant biotechnology and breeding of field Crops. Springer Singapore, ISBN:9789811657672, DOI:10.1007/978-981-16-5767-2.

PBSE323: Metagenomics of Plant-associated Microbes

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE323: Metagenomics of Plant-associated Microbes	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to introduce students to the fundamental concepts of metagenomics and the plant holobiont, with a focus on rhizosphere and aquatic microbiomes using environmental DNA (eDNA). It seeks to develop an understanding of sampling strategies and to familiarize students with the basics of metagenomic data analysis. This would help students appreciate how metagenomic approaches are applied in biodiversity assessment, plant pathology, environmental surveillance, and emerging areas such as space biology, integration of breeding and precision agriculture.

Learning Outcomes

By the end of the course, students should be able to explain key concepts of metagenomics and plant microbiomes and outline appropriate strategies for sampling and sequencing rhizosphere and aquatic environmental samples. They should be able to understand the components of the metagenomic analysis pipeline, interpret community and functional profiles, and critically read metagenomic datasets. Students will be able to relate metagenomic findings to practical applications in plant health, ecosystem monitoring, and sustainable agriculture.

Course Contents (45 hours)

Unit 1: Introduction to Metagenomics -- Concepts of microbiome, metagenome, holobiont, hologenome; Plant-associated microbiomes: Rhizosphere, phyllosphere, endosphere, etc.; Overview of metagenomics and integration with metatranscriptomics, metaproteomics, and metabolomics; Marker genes and DNA barcoding; Overview of workflow and sample preparation methodologies. **15 hours**

Essential Readings: Nelson, K.E. (2020) Encyclopedia of metagenomics. Springer, New York, ISBN: 9781461464181, DOI:10.1007/978-1-4614-6418-1; Simon, J.C., et al. (2019) Host-microbiota interactions: from holobiont theory to analysis. Microbiome, 7:5, DOI:10.1186/s40168-019-0619-4; Vorholt, J. (2012) Microbial life in the phyllosphere. Nature Reviews Microbiology, 10:828–840, DOI:10.1038/nrmicro2910; Compant, S., et al. (2021) The plant endosphere world - bacterial life within plants. Environmental Microbiology, 23(4):1812–1829, DOI:10.1111/1462-2920.15240; Christopher, C.M., et al. (2016) Dissecting host-associated communities with DNA barcodes. Philosophical Transactions of the Royal Society Biological Sciences, 371(1702):20150328, DOI:10.1098/rstb.2015.0328.

Unit 2: Rhizosphere and Aquatic Metagenomics -- Environmental DNA (eDNA): sources, stability, sampling, limitations; Rhizosphere: structure, gradients, root exudates and microsome assembly; Aquatic plants-associated microbes; case studies. **10 hours**

Essential Readings: Liu, S., et al. (2025) Analysis of metagenomic data. Nature Reviews Methods Primers, 5:5, DOI:10.1038/s43586-024-00376-6; Behera, B.K., et al. (2024) Metagenomics study in aquatic resource management: Recent trends, applied methodologies and future needs. Gene Reports, 25:101371, DOI:

10.1016/j.genrep.2021.101372; Wang, B., et al. (2021) Metagenomic insights into the effects of submerged plants on functional potential of microbial communities in wetland sediments. *Marine Life Science & Technology*, 3(4):405–415, DOI:10.1007/s42995-021-00100-3; Sahu, A., et al. (2023) Environmental DNA (eDNA): Powerful technique for biodiversity conservation. *Journal for Nature Conservation*, 71:126325, DOI: 10.1016/j.jnc.2022.126325; Pudake, R.N. et al. (2021) *Omics science for rhizosphere biology*. Springer Singapore, ISBN:9789811608896, DOI:10.1007/978-981-16-0889-6; Wani, A.K., et al. (2024) Metagenomic profiling of rhizosphere microbiota: Unravelling the plant-soil dynamics. *Physiology and Molecular Plant Pathology*, 133:10238, DOI:10.1016/j.pmpp.2024.102381.

Unit 3: Overview of Metagenomic Data Generation and Analysis -- Workflow overview, Selection of appropriate sequencing technologies (short and long-read); Demultiplexing, adapter and quality trimming, removal of contaminating DNA (host) sequences, metagenomic data assembly, taxonomic characterization (alignment based, alignment-free k-mer based, hybrid strategy); Gene prediction and functional analysis; Metagenomic data repositories.

10 hours

Essential Readings: Thomas T., et al. (2012) *Metagenomics - a guide from sampling to data analysis*. Microbial Informatics and Experimentation, 2:3, DOI:10.1186/2042-5783-2-3; Navgire, G.S., et al. (2022) Analysis and Interpretation of metagenomics data: an approach. *Biological Procedures Online*, 24:18, DOI:10.1186/s12575-022-00179-7; Aplakidou, E., et al. (2024) Visualizing metagenomic and metatranscriptomic data: A comprehensive review. *Computational and Structural Biotechnology Journal*, 23:2011–33, DOI:10.1016/j.csbj.2024.04.060.

Unit 4: Applications of Metagenomics -- Biodiversity assessment of plant-associated ecosystems; Plant pathology; Metagenomics in bioremediation and agro-ecosystem health; Metagenomics in controlled plant growth systems; Space biology; Future perspectives: integrating metagenomics with breeding and agriculture.

10 hours

Essential Readings: Charles, T.C., et al. (2017) *Functional Metagenomics: Tools and Applications*. Springer Cham, ISBN:9783319615103, DOI:10.1007/978-3-319-61510-3; Nagarajan, M. (2024) *Metagenomics - Perspectives, Methods, and Applications*. 2nd edition, Academic Press, ISBN:9780323917124; Roman-Reyna, V. and Crandall, S.G. (2024) Seeing in the dark: a metagenomic approach can illuminate the drivers of plant disease. *Frontiers in Plant Science*, 15:140502, DOI:10.3389/fpls.2024.1405042; Kumar, V. and Iram, S. (2024) *Microbial Technology for Agro-Ecosystems*. Academic Press, ISBN:9780443184468, Chapter 15 (Metagenomics: An approach for understanding microbe-microbe and plant-microbiome-interactions); Compant, S., et al. (2025) Harnessing the plant microbiome for sustainable crop production. *Nature Reviews Microbiology*, 23(1):9–23, DOI:10.1038/s41579-024-01079-1.

Tutorials (15 hours)

1. Case study: Sargasso Sea.
2. Designing a rhizosphere metagenomics experiment.
3. Case study on how eDNA is used to track microbial biodiversity.
4. Survey of metagenomic databases.

Suggested Readings:

1. Chopra, R.S., et al. (2020) *Metagenomics: techniques, applications, challenges and opportunities*. Springer Singapore, ISBN:9789811565298, DOI:10.1007/978-981-15-6529-8.
2. Streit, W.R. and Daniel, R. (2017) *Metagenomics: Methods and Protocols*. Humana NY, ISBN: 9781493966912, DOI:10.1007/978-1-4939-6691-2.
3. Vacher, C., et al. (2016) The phyllosphere: microbial jungle at the plant–climate interface. *Annual Review of Ecology, Evolution, and Systematics*, 47:1–24, DOI:10.1146/annurev-ecolsys-121415-032238
4. Pudake, R.N., et al. (2021) *Omics science for rhizosphere biology*. Springer Singapore, ISBN:9789811608896, DOI:10.1007/978-981-16-0889-6.
5. Carter, D.O., et al. (2017) *Forensic Microbiology*. Wiley, ISBN:9781119062578, Chapter 5 (An introduction to metagenomic data generation, analysis, visualization, and interpretation).

PBSE324: Frontiers in Plant Molecular Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE324: Frontiers in Plant Molecular Biology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course has been designed to introduce students to state-of-the-art concepts, technologies, and experimental systems that define modern plant molecular biology and its translational applications. It aims to develop a rigorous understanding of plant signaling architectures, multi-omics driven functional genomics, structural advances in genome biology, and emerging domains such as epitranscriptomics, nanobiotechnology, and space biology. Furthermore, it aims to enable students to relate primary discoveries in calcium, ROS, hormone and retrograde signaling to crop improvement, biosensing, and stress resilience through synthetic and genome engineering approaches, supported by current literature in plant signaling and systems biology.

Learning Outcomes

After successful completion of the course, students will be able to critically interpret and integrate datasets from transcriptomic, proteomic, metabolomic, epigenomic, and phenomics platforms to elucidate gene function and regulatory networks in plants. They should be able to design and conceptualize CRISPR-based functional analyses, visualize and analyse gene interaction networks, and evaluate gene function prediction, stress-tolerance forecasting, and genome-assisted breeding. Students will also be able to assess emerging tools, such as optogenetics, targeted epigenome editing, and plant nanotechnology, for their feasibility for research or crop applications, thereby demonstrating their research readiness.

Course Content (45 hours)

Unit 1: Forefront of Plant Signaling -- Mechanosensing and electrosensing; Receptor dynamics and nanodomains; Phosphoswitches and dynamic network mapping; Organelle-to-nucleus signaling (retrograde signaling); Optogenetics and chemical biology tools; Live-cell imaging of Ca²⁺ and ROS dynamics; Phytohormone dynamics studies; Engineering synthetic receptors or signaling circuits for stress tolerance or biosensing. 11 hours

Essential Readings: Hamilton, E.S., et al. (2015) United in diversity: mechanosensitive ion channels in plants, *Annual Review of Plant Biology*, 66:113–37, DOI:10.1146/annurev-arplant-043014-114700; Fromm, J. and Lautner, S. (2007) Electrical signals and their physiological significance in plants. *Plant Cell and Environment*, 30(3):249–257, DOI:10.1111/j.1365-3040.2006.01614.x; Wang, L., et al. (2018) Exploring the spatiotemporal organization of membrane proteins in living plant cells. *Annual Review of Plant Biology*, 69:525–551, DOI:10.1146/annurev-arplant-042817-040233; Zhang, J., et al. (2023) Protein phosphorylation: A molecular switch in plant signaling. *Cell Reports*, 42(7):112729, DOI:10.1016/j.celrep.2023.112729; Tatjana, K. and Dario, L. (2016) Retrograde signaling: Organelles go networking. *Biochimica et Biophysica Acta (BBA)–Bioenergetics*, 1857(8):1313–1325, DOI:10.1016/j.bbabi.2016.03.017; Hiromasa, S. and Philipp, D. (2022) Plant optogenetics: Applications and perspectives. *Current Opinion in Plant Biology*, 68:102256, DOI:10.1016/j.pbi.2022.102256; Sarah, J., et al. (2011) *In vivo* imaging of Ca²⁺, pH, and reactive oxygen species using fluorescent probes in plants. *Annual Review of Plant Biology*, 62:273–297, DOI:10.1146/annurev-arplant-042110-103832; Rainer, W. (2020) Phytohormone signaling mechanisms and genetic methods for their

modulation and detection, *Current Opinion in Plant Biology*, 57:31–40, DOI:10.1016/j.pbi.2020.05.011; Ondřej N., et al. (2017) Zooming in on plant hormone analysis: Tissue- and cell-specific approaches. *Annual Review of Plant Biology*, 68:323–348, DOI:10.1146/annurev-arplant-042916-040812; Alexander, R.L., et al. (2020) Engineering synthetic signaling in plants. *Annual Review of Plant Biology*, 71:767–788, DOI:10.1146/annurev-arplant-081519-035852.

Unit 2: Structural and Functional Genomics -- Third- and fourth-generation sequencing platforms and their applications in plant genome analysis, principles of transcriptomics and proteomics, including experimental design and data interpretation; Case study-based functional genomics strategies such as large-scale mutagenesis (T-DNA, CRISPR/Cas), RNAi, VIGS and activation tagging to elucidate gene function; Understanding advanced layers of regulation through RNA-seq, ribosome profiling, single-nucleus RNA-seq, and epigenomic assays such as ATAC-seq, ChIP-seq and DNA methylome analysis.

12 hours

Essential Readings: Brown, T.A. (2023) *Genomes 5*. CRC Press, ISBN:9781003133162, Chapter 4 (Sequencing Genomes), Chapter 9 (Transcriptomes and Proteomes), Chapter 10 (Genome Regulation); Mardis, E.R. (2008) Next-generation DNA sequencing methods. *Annual Review of Genomics and Human Genetics*, 9:387–402, DOI:10.1146/annurev.genom.9.081307.164359; Chappell, L., et al. (2018) Single-Cell (Multi)omics Technologies. *Annual Review of Genomics and Human Genetics*, 19:15–41, DOI: 10.1146/annurev-genom-091416-035324.

Unit 3: Applied Aspects of Plant-Environment Interactions -- Overview of plant responses to abiotic and biotic stresses; Molecular signaling pathways; Omics-driven discovery of stress tolerance genes; Engineering the plant microbiome; Spatial and integrative omics for stress biology: single cell vs. tissue level omics, transcriptomics and metabolite mapping of root-soil interface; Inter-kingdom communication; AI and ML in prediction of stress-tolerant genotypes.

11 hours

Essential Readings: Tuteja, N. and Gill, S.S. (2016) *Abiotic stress responses in plants*. ISBN:9783527339181, Wiley-VCH Verlag GmbH & Co., Chapter 1 (Abiotic stress signaling in plants: an overview); Zhang H., et al. (2022) Abiotic stress responses in plants. *Nature Review Genetics*, 23:104–119, DOI:10.1038/s41576-021-00413-0; Jiang Z., et al. (2025) Mechanisms of plant acclimation to multiple abiotic stresses. *Communications Biology*, 8:655, DOI:10.1038/s42003-025-08077-w; Mochida, K., et al. (2020) Decoding plant–environment interactions that influence crop agronomic traits. *Plant and Cell Physiology*, 61(8):1408–1418, DOI:10.1093/pcp/pcaa064; Du, B., et al. (2024) Strategies of plants to overcome abiotic and biotic stresses. *Biological Reviews*, 99(4):1524–1536, DOI: 10.1111/brv.13079; Varadharajan, V., et al. (2025) Multi-omics approaches against abiotic and biotic stress-A review. *Plants*, 14(6):865, DOI:10.3390/plants14060865; Afridi M.S., et al. (2022) New opportunities in plant microbiome engineering for increasing agricultural sustainability under stressful conditions. *Frontiers in Plant Sciences*, 13:899464, DOI:10.3389/fpls.2022.899464; Special issue on “Use of single cell and spatial multiomics for uncovering cellular and molecular mechanisms underlying plant stress responses”. *Stress Biology*, 2025; Salem M.A., et al. (2022) Metabolomics of plant root exudates: From sample preparation to data analysis, *Frontiers in Plant Sciences*, 13:1062982, DOI:10.3389/fpls.2022.1062982; Singhal, R., et al. (2025) Using supervised machine-learning approaches to understand abiotic stress tolerance and design resilient crops. *Philosophical Transactions of the Royal Society B*, 380:2024.0252, DOI:10.1098/rstb.2024.0252.

Unit 4: Emerging Tools and Techniques -- Epitranscriptomics; Targeted epigenome editing: development of specific DNA-targeting systems, next-generation CRISPR activators, applications in agriculture; Nanotechnology and its applications in plant biology: types of nanomaterials, uptake and translocation, biological impact, applications of nanoparticles (NPs) in plant biology (biosensors, nutrient delivery, nanomaterials in plant genetic engineering (DNA / RNA delivery); Plant biology in space: growth and monitoring, effects of microgravity and ionizing radiations, applications, and benefits.

11 hours

Essential Readings: Kumari, A., et. al. (2023) Nanotechnology as a powerful tool in plant sciences: Recent developments, challenges and perspectives. *Plant Nano Biology*, 5:100046, DOI:10.1016/j.plana.2023.100046; Sanzari, I., et. al. (2019) Nanotechnology in plant science: To make a long story short. *Frontiers in Bioengineering and Biotechnology*, 7:120, DOI:10.3389/fbioe.2019.00120; Sharma, B., et al. (2023) The diversity and functions

of plant RNA modifications: what we know and where we go from here. *Annual Review of Plant Biology*, 74(1):53–85, DOI:10.1146/annurev-arplant-071122-085813; Shen, L., et al. (2019) Messenger RNA modifications in plants. *Trends in Plant Science*, 24(4):328–41, DOI:10.1016/j.tplants.2019.01.005; McCutcheon, S.R., et al. (2024) Epigenome editing technologies for discovery and medicine. *Nature Biotechnology*, 42:1199–1217, DOI:10.1038/s41587-024-02320-1; Kungulovski, G. and Jeltsch, A. (2016) Epigenome editing: state of the art, concepts, and perspectives. *Trends in Genetics*, 32(2):101–13, DOI:10.1016/j.tig.2015.12.001.

Practicals (30 hours)

1. To investigate the phenotypic responses in the calcium signaling mutants.
2. To investigate the transactivation or trans-repression activity of a transcription factor.
3. To design CRISPR guide RNA primers using online tools (e.g., CHOPCHOP, CRISPOR).
4. Molecular probe-based pathogen detection.
5. To design functional genomics approaches for specific gene/phenotype questions and compare the strengths and limitations of different methods.

Suggested Readings:

1. Kramer, L.M. (2015) *Signal Transduction*. 3rd edition, Academic Press, ISBN:9780123948199.
2. Heldin, C.H. and Purton, M. (1996) *Signal transduction: Modular texts in molecular and cell biology*, Chapman & Hall, ISBN:0412708108.
3. Alberts, B., et al. (2022) *Molecular Biology of the Cell*. 7th edition, W.W. Norton & Company, ISBN:9780393884630.
4. Buchanan, B.B., et al. (2015) *Biochemistry & Molecular Biology of the Plants*. 2nd edition, Wiley Blackwell, ISBN:9781118502198.
5. Kleinsmith, L.J. and Kish, V.M. (1997) *Principles of Cell & Molecular Biology*. Harper Collins College Publishers, ISBN:9780065004045.
6. Taiz, L., et al. (2023). *Plant Physiology and Development*. 7th edition, Sinauer Associates, ISBN:9780197614204.
7. Glick, B.R. and Pasternak, J.J. (2022) *Molecular Biotechnology: Principles and Applications of recombinant DNA*. 6th edition, ASM Press, ISBN:9781683673668.
8. Brown, T.A. (2023) *Genomes 5*. 5th edition, CRC Press, ISBN:9781003133162.
9. Piechulla, B. (2025) *Plant Biochemistry*. 6th edition, Academic Press, ISBN:9780443266164.
10. Abd-Elsalam, K.A. and Prasad, R. (2018) *Nanobiotechnology applications in plant protection*. Springer Cham, ISBN:9783319911601, DOI:10.1007/978-3-319-91161-8.
11. Chen, J.T. (2024) *Advanced Nanotechnology in Plants: Methods and Applications*. CRC Press, ISBN:9781003368571.
12. Jeltsch, A., and Rots, M.G. (2018) *Epigenome editing: Methods and Protocols*. Humana New York, ISBN:9781493977741, DOI:10.1007/978-1-4939-7774-1.
13. Jurga, S. and Barciszewski, J. (2021) *Epitranscriptomics*. Springer Cham, ISBN:9783030716127, DOI:10.1007/978-3-030-71612-7.
14. Online Databases and Resources: NCBI, TAIR, Phytozome, EnsemblPlants and others, KEGG, STRING, Gene Ontology, CRISPR-Cas toolkits and others.

PBSE325: Introduction to Bioinformatics

This course is open to students of other departments as a GE course.

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE325: Introduction to Bioinformatics	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

The paper is devised to introduce the students to the field of bioinformatics and data analysis. The content is designed for students from any stream of life sciences. The course imparts basic and essential knowledge regarding the nature of life science data, including data formats, international databases and data repositories. It also helps to understand how different biological file formats facilitate storage, retrieval and analysis of biological sequences and structures. Furthermore, the unit is designed to familiarize the learner with the landscape of major international nucleotide and protein databases, understanding their scope, interrelationships, and specific applications (universal and organism-specific databases). Additionally, understand the structure, interoperability, and collaborative role of INSDC, as well as its importance in maintaining the global genomic data ecosystem. Furthermore, it will explain the fundamental principles of local and global alignment (pairwise sequence comparison) and the biological rationale behind scoring systems, including substitution matrices and gap penalties. It also focuses on interpreting results of Clustal-W, Clustal Omega, T-Coffee, and MultiAlign BLAST tools and how to optimize their parameters to draw biologically meaningful conclusions. The last unit of the course presents the fundamentals of RNA/ Protein secondary and tertiary structure prediction. It will be helpful to learn the basic principles of docking analysis and drug design workflows.

Learning Outcomes

After successfully completing the course, students will be able to identify and describe various biological data formats and their respective applications. They will be able to access and retrieve sequences and structural data from major databases, data repositories, and browsers such as the UCSC Genome Browser, linking these data formats to visual genomic analysis. Furthermore, students will be able to utilize tools like BLAST for sequence comparison and evolutionary significance, as well as understand the conceptual difference between various substitution matrices and pairwise algorithms. They can perform and interpret the MSA of different biological sequences using different computational software and also visualize phylogenetic trees using various algorithms. Upon completing the last unit, students will be able to use computational tools for RNA and protein prediction, evaluate them, and analyse protein-ligand interaction and outcomes of docking.

Course Content (45 hours)

Unit 1: Biological Data Formats and Databases -- Overview of database management system, concept of 'structured' and 'semi-structured/unstructured' data, concept of 'flat-file' formats; Various file formats used in bioinformatics such as 'fasta', 'fastq', Phylip format, Newick, PDB file format, 'GFF3', SAM/BAM/CRAM formats; Universal nucleotide data repositories: NCBI-GenBank, EMBL-ENA, DDBJ; Details of the International Nucleotide Sequence Data Collaboration (INSDC); Universal Protein databases: UniprotKB, PDB. Organism specific databases (Flybase, Wormbase etc), UCSC Human Genome Browser; Molecular interaction databases such as KEGG and STRING. **10 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 1 (Historical Introduction and Overview), Chapter 2 (Collecting and Storing Sequences in the Laboratory); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 1 (The nucleic world) and chapter 3 (Dealing with databases); Sayers, E.W., et al. (2022) Database resources of the National Center for Biotechnology Information. Nucleic Acids Research, 50(D1):D20–D26, DOI:10.1093/nar/gkab1112; Cochrane, G., et al. (2016). The European Nucleotide Archive in 2016. Nucleic Acids Research, 44(D1):D32–D37, DOI:10.1093/nar/gkw1106; The UniProt Consortium (2023) UniProt: the Universal Protein Knowledgebase in 2023. Nucleic Acids Research, 51(D1):D523–D531, DOI:10.1093/nar/gkac1052; Berman, H.M., et al. (2000) The Protein Data Bank. Nucleic Acids Research, 28(1):235–242, DOI:10.1093/nar/28.1.235; Li, H., et al. (2009) The Sequence Alignment/Map format and SAMtools. Bioinformatics, 25(16):2078–2079, DOI:10.1093/bioinformatics/btp352; Cock, P.J.A., et al. (2010) The Sanger FASTQ file format for sequences with quality scores, and the Solexa/Illumina FASTQ variants. Nucleic Acids Research, 38(6):1767–1771, DOI:10.1093/nar/gkp1137; Kanehisa, M., et al. (2023) KEGG for taxonomy-based analysis of pathways and genomes. Nucleic Acids Research, 51(D1):D587–D592, DOI:10.1093/nar/gkac997; Szklarczyk, D., et al. (2023) The STRING database in 2023: protein–protein association networks and functional enrichment analyses for any sequenced genome. Nucleic Acids Research, 51(D1):D638–D646, DOI:10.1093/nar/gkac1000; The FlyBase Consortium. (2022). FlyBase: updates to the *Drosophila melanogaster* knowledge base. Nucleic Acids Research, 50(D1):D1014–D1020, DOI:10.1093/nar/gkab1099; Haeussler, M., et al. (2019) The UCSC Genome Browser database: 2019 update. Nucleic Acids Research, 47(D1):D853–D858, DOI:10.1093/nar/gky1095.

Unit 2: Pairwise Sequence Alignment -- Concept of local and global sequence alignment; Pairwise sequence alignment algorithms such as Needleman and Wunsch, Smith-Waterman, scoring an alignment, linear and affine gap penalty, amino acid substitution scoring matrices (PAM and BLOSUM); Sequence alignment-based database search, BLAST and its variants, BLAST parameters (word size, E-value, scoring scheme, gap-penalty), bit/raw score. **10 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 3 (Alignment of pairs of sequences), Chapter 6 (Sequence database searching for similar sequences); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 4 (Producing and analyzing sequence alignments), Chapter 5 (Pairwise sequence alignment and database searching); Morrison, D.A. (2006). Multiple sequence alignment for phylogenetic purposes. Australian Systematic Botany, 19(6):479–539, DOI:10.1071/SB06020.

Unit 3: Multiple Sequence Alignment and Phylogenetic Analysis -- Global and local multiple sequence alignment, multiple sequence alignment algorithms (progressive and iterative algorithms), profile and block analysis; Softwares: Clustal-X, Clustal-W, Clustal-Omega, T-Coffee, MultiAlign; Basic concept of phylogenetic analysis, rooted and unrooted trees, approaches for phylogenetic tree construction; Basics of algorithm for UPGMA, neighbour joining (NJ), maximum parsimony, and maximum likelihood phylogenetic analysis. **15 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 5 (Multiple sequence alignment), Chapter 7 (Phylogenetic prediction); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 4 (Producing and analyzing sequence alignments), Chapter 5 (Pairwise sequence alignment and database searching), Chapter 6 (Patterns, profiles, and multiple alignments).

Unit 4: Structure Predictions for Nucleic Acids and Proteins -- Approaches for prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models; Basic approaches for protein structure predictions, comparative modeling, fold recognition/‘threading’, and *ab-initio* prediction; Introduction to AlfaFold database; Docking analysis and drug designing. **10 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 8 (Prediction of RNA secondary structure), Chapter 10 (Protein classification and structure prediction); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 8 (Recovering evolutionary history), Chapter 11 (Obtaining secondary structure from sequence), Chapter 12 (Predicting secondary structures).

Tutorials (15 hours)

1. To perform ‘text-based’ database search.
2. Sequence alignment-based database search.
3. Multiple sequence alignment and phylogenetic analysis.
4. Analysis of gene/protein interaction networks.

Suggested Readings:

1. Baxevanis, A.D., et al. (2020) Bioinformatics: A practical guide to the analysis of genes and proteins. 4th edition. John Wiley & Sons, Inc., ISBN:9781119335962.
2. Tramontano, A. (2018) Introduction to Bioinformatics. Chapman and Hall/CRC, ISBN:9781315276014, DOI:10.1201/9781420010886.
3. Lee, E. Tan, T.W. (2018) Beginners guide to bioinformatics for high throughput sequencing. World Scientific, ISBN:9789813231665, DOI:10.1142/10720.
4. Thompson, J.D., et al. (1994) CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice. Nucleic Acids Research, 22(22):4673–4680, DOI:10.1093/nar/22.22.4673.
5. Notredame, C., et al., (2000) T-Coffee: A novel method for fast and accurate multiple sequence alignment. Journal of Molecular Biology, 302(1):205–217, DOI:10.1006/jmbi.2000.4042.
6. Saitou, N. and Nei, M. (1987) The neighbor-joining method: a new method for reconstructing phylogenetic trees. Molecular Biology and Evolution, 4(4):406–425, DOI:10.1093/oxfordjournals.molbev.a040454.
7. Felsenstein, J. (1981) Evolutionary trees from DNA sequences: a maximum likelihood approach. Journal of Molecular Evolution, 17(6):368–376, DOI:10.1007/BF01734359.
8. JJumper, J., et al. (2021) Highly accurate protein structure prediction with AlphaFold2. Nature, 596:583–589, DOI:10.1038/s41586-021-03819-2.
9. Zhang, Y. (2008) Progress and challenges in protein structure prediction. Current Opinion in Structural Biology, 18(3):342–348, DOI:10.1016/j.sbi.2008.02.004.
10. Kryshchuk, A., et al. (2021) Critical assessment of methods of protein structure prediction (CASP)—Round XIV. Proteins: Structure, Function, and Bioinformatics, 89(12):1607–1617, DOI:10.1002/prot.26237.
11. Zuker, M. (2003) Mfold web server for nucleic acid folding and hybridization prediction. Nucleic Acids Research, 31(13):3406–3415, DOI:10.1093/nar/gkg595.
12. Kitchen, D.B., et al. (2004) Docking and scoring in virtual screening for drug discovery: methods and applications. Nature Reviews Drug Discovery, 3(11):935–949, DOI:10.1038/nrd1549.

PBRE326: Dissertation-I

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBRE326: Dissertation-I	6	0	0	6	B.Sc. in any branch of science	NA

Learning Objectives

The students will identify and select a relevant research problem in consultation with the faculty members, ensuring alignment with current advances in Plant Molecular Biology and Biotechnology. They will conduct a thorough and critical appraisal of the existing literature on the problem, enabling them to understand the depth of current knowledge. Students will learn to formulate well-defined research questions and develop testable hypotheses in the context of scientific reasoning. Under faculty mentorship, they will design an experimentally feasible and scientifically structured research plan, complete with realistic timelines, appropriate methodologies, and anticipated outcomes. In addition, the students will gain training in scientific writing through preparation of a detailed literature review, and they will enhance their communication skills by effectively presenting and discussing their research survey in laboratory group discussions and structured oral presentations.

Learning Outcomes

Upon successful completion of the course, the student will be able to independently conduct a comprehensive survey of scientific literature and critically analyse it to identify significant knowledge gaps within the research field. They will demonstrate the ability to justify the importance and relevance of selected research problems using evidence-based reasoning. Students will prepare a well-structured synopsis that includes an in-depth literature review, clearly articulated research questions, hypotheses, and a coherent experimental plan to be executed in Semester 4. Additionally, they will acquire proficiency in scientific writing, including organization, clarity, and synthesis of complex information, and will develop strong oral communication skills necessary for presenting research findings and engaging in scientific discourse. Overall, the students will hone their ability to think independently, plan research systematically, and communicate their work confidently in both written and verbal formats.

Suggested Readings:

1. Latest research and review articles from scientific journals and book chapters on a chosen research problem.

SEMESTER 4

PBSC421: Advances in Crop Biotechnology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSC421: Advances in Crop Biotechnology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to provide learners with an advanced and integrative understanding of modern crop biotechnology and its role in sustainable agriculture. Students will engage with emerging molecular tools, the development and significance of crop pan-genomes, and cutting-edge concepts such as *de novo* domestication and innovations in *in-planta* transformation. The course will also provide in-depth insights into translational strategies to enhance crop nutrition and improve resilience to biotic and abiotic stresses through sustainable, environmentally friendly approaches. Overall, learners will develop the scientific foundation and biotechnology skills required to address challenges in crop improvement.

Learning Outcomes

Upon completing this course, participants will be able to critically analyze crop genomes for domestication signatures and evaluate germplasm diversity for trait improvement. They will demonstrate practical knowledge of state-of-the-art plant transformation techniques and emerging delivery platforms for gene and RNA manipulation. Students will be able to assess and design strategies for enhancing stress tolerance, yield, and nutritional value in crop plants. They will also gain competence in applying biostimulants and other biofortification approaches.

Course Contents (45 hours)

Unit 1: Introduction to Crop Biotechnology -- Emerging tools and techniques in biotechnology; Crop pan-genomes and signatures of crop domestication; Germplasm diversity analysis; Concept of *de novo* crop domestication; Agro-morphological traits enhancement; Environmental challenges and food security; Plants as biofactories. 10 hours

Essential Readings: Mascher, M., et al. (2024) Promises and challenges of crop translational genomics. *Nature*, 636:585–593, DOI:10.1038/s41586-024-07713-5; Shi, J., et al. (2023) Plant pan-genomics and its applications. *Molecular Plant*, 16(1):168–186, DOI:10.1016/j.molp.2022.12.009; Curtin, S., et al. (2022) Pathways to *de novo* domestication of crop wild relatives. *Plant Physiology*, 188(4):1746–1756, DOI:10.1093/plphys/kiab554.

Unit 2: Genetic Transformation Techniques -- Ternary vector systems; Improved *in planta* transformation - *de novo* meristems induction, morphogenic regulators, particle bombardment of shoot apical meristem, composite plants, etc; Use of magnetic nanoparticles; Organelle genome transformation. 10 hours

Essential Readings: Chen, Z., et al. (2022) Recent advances in crop transformation technologies. *Nature Plants*, 8(12):1343–1351, DOI:10.1038/s41477-022-01295-8; Bélanger, J.G., et al. (2024) A comprehensive review of *in planta* stable transformation strategies. *Plant Methods*, 20(1):79, DOI:10.1186/s13007-024-01200-8.

Unit 3: Climate Resilience and Yield Enhancement -- Case studies on abiotic and biotic stress tolerance; RNA delivery against fungal pathogens; Probiotic-based gene silencing in polyphagous pests; Biofertilizers, Biopesticides; Cell-penetrating peptides; Concept of chronoculture; Synthetic circuits and rewiring for plant improvement; Enhancement of photosynthetic capacity; Carbon dots in plant (epi)genomics. **15 hours**

Essential Readings: González Guzmán, M., et al. (2022) New approaches to improve crop tolerance to biotic and abiotic stresses. *Physiologia Plantarum*, 174(1):e13547, DOI:10.1111/ppl.13547; Al-Dossary, O., et al. (2025) Crop management to enhance plant resilience to abiotic stress using nanotechnology: towards more efficient and sustainable agriculture. *Frontiers in Plant Science*, 16:1626624, DOI:10.3389/fpls.2025.1626624; Afridi, M.S., et al. (2022) New opportunities in plant microbiome engineering for increasing agricultural sustainability under stressful conditions. *Frontiers in Plant Science* 13:899464, DOI:10.3389/fpls.2022.899464; Shahwar, D., et al. (2023) Role of microbial inoculants as bio fertilizers for improving crop productivity: A review. *Heliyon*, 9(6):e16134, DOI:10.1016/j.heliyon.2023.e16134; Lloyd, J.P.B., et al. (2025) The switch-liker's guide to plant synthetic gene circuits. *Plant Journal*, 121(5):e70090, DOI: 10.1111/tpj.70090.

Unit 4: Enhancement of Nutrients -- Improved nutritional profile of crops; Enhancement of mineral nutrient uptake and distribution; Biofortification (Fe, Zn, Ca, K, Vitamins, proteins, essential oils, etc.), micronutrient-dense crops; Anti-nutrient reduction; Concept of Biostimulants. **10 hours**

Essential Readings: Napier, J.A., et al. (2019) The challenges of delivering genetically modified crops with nutritional enhancement traits. *Nature Plants*, 5(6):563–567, DOI:10.1038/s41477-019-0430-z; Zhu, Q., et al. (2019) Plant synthetic metabolic engineering for enhancing crop nutritional quality. *Plant Communications*, 1(1):100017, DOI:10.1016/j.xplc.2019.100017; White, P.J. and Broadley, M.R. (2005) Biofortifying crops with essential mineral elements. *Trends in Plant Science*, 10(12):586–593, DOI:10.1016/j.tplants.2005.10.001.

Practicals (30 hours)

1. Transient gene expression using the particle bombardment method.
2. Measurement of photosynthetic efficiency using fluorescence-based system.
3. *In vivo* plant imaging under stress conditions.
4. Mineral nutrient profiling of plants.
5. Molecular detection of *Rhizobium* in root nodules of leguminous plants.

Suggested Readings:

1. Li, X., et al. (2025) The next Green Revolution: integrating crop architecture and phenotype. *Trends in Biotechnology*, 43(10):2479–2493, DOI:10.1016/j.tibtech.2025.04.002.
2. Della Coletta, R., et al. (2021) How the pan-genome is changing crop genomics and improvement. *Genome Biology*, 22(1):3, DOI:10.1186/s13059-020-02224-8.
3. Li, S., et al. (2021) Advancing organelle genome transformation and editing for crop improvement. *Plant Communications*, 2(2):100141, DOI:10.1016/j.xplc.2021.100141.
4. Jeong, J.H., et al. (2025). Empowering *Agrobacterium*: Ternary vector systems as a new arsenal for plant transformation and genome editing. *Biotechnology Advances*, 83:108631, DOI: 10.1016/j.biotechadv.2025.108631.
5. Shrawat, A., et al. (2018) Engineering nitrogen utilization in crop plants. Springer Cham, DOI: 10.1007/978-3-319-92958-3.
6. Basar, N.U., et al. (2025) Synergies between biostimulants and plant nutrients: a review of ecofriendly nutrient management in crop production. *Discover Agriculture*, 3:150, DOI:10.1007/s44279-025-00345-x.
7. Patel, P., et al. (2024) Cell-penetrating peptides for sustainable agriculture. *Trends in Plant Science*, 29(10):1131–44, DOI:10.1016/j.tplants.2024.05.011.
8. Jaswal, S., et al. (2025) Chloroplast engineering for enhancing photosynthetic efficiency and agronomic traits. *Trends in Biotechnology*, DOI:10.1016/j.tibtech.2025.09.011.
9. Tavakoli, M., et al. (2025) Emerging applications of carbon dots in plant (epi)genomics. *Trends in Biotechnology*, DOI:10.1016/j.tibtech.2025.09.005.

10. Hawkesford, M.J., et al. (2016) Nutrient use efficiency in plants. Springer Cham, ISBN:9783319106342, DOI:10.1007/978-3-319-10635-9.
11. Li, G., et al. (2025) Integrated biotechnological and AI innovations for crop improvement. *Nature*, 643:925–937, DOI:10.1038/s41586-025-09122-8.
12. Bartlett, M.E., et al. (2023) The power and perils of *De Novo* domestication using genome editing. *Annual Review of Plant Biology*, 74:727–750, DOI:10.1146/annurev-arplant-053122-030653.
13. Jian, L., et al. (2022) *De novo* domestication in the multi-omics era. *Plant and Cell Physiology*, 63(11): 1592–1606, DOI:10.1093/pcp/pcac077.
14. Altpeter, F., et al. (2016) Advancing crop transformation in the era of genome editing. *The Plant cell*, 28(7):1510–1520, DOI:10.1105/tpc.16.00196.
15. Olsen, K.M., and Wendel, J.F. (2013) A bountiful harvest: genomic insights into crop domestication phenotypes. *Annual Review of Plant Biology*, 64:47–70, DOI:10.1146/annurev-arplant-050312-120048.
16. Ayenew, B.M. et al. (2024) A review on the production of nanofertilizers and its application in agriculture. *Heliyon*, 11(1):e41243, DOI:10.1016/j.heliyon.2024.e41243.
17. Steed, G., et al. (2021) Chronoculture, harnessing the circadian clock to improve crop yield and sustainability. *Science*, 372:eabc9141, DOI:10.1126/science.abc9141.
18. Borowsky, A.T. and Bailey-Serres, J. (2024) Rewiring gene circuitry for plant improvement. *Nature Genetics*, 56(8):1574–1582, DOI:10.1038/s41588-024-01806-7.
19. Naik, B., et al. (2024) Biofortification as a solution for addressing nutrient deficiencies and malnutrition. *Heliyon*, 10(9):e30595, DOI:10.1016/j.heliyon.2024.e30595.

PBSC422: Plant Secondary Metabolism and Applications

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC422: Plant Secondary Metabolism and Applications	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to provide students with a comprehensive understanding of plant secondary metabolites, focusing on their biosynthesis, regulation, detection, and diverse applications. It is designed to equip students with knowledge in analytical techniques, molecular tools, and biotechnological approaches used to study and manipulate secondary metabolite pathways. The course also emphasizes the ecological significance and medicinal potential of these compounds, preparing students to apply metabolic engineering for research and development in areas such as plant defense, drug discovery, and sustainable bioproduction.

Learning Outcomes

Upon completing this course, students will understand the biosynthesis, regulation, and classification of key plant secondary metabolites, as well as their significance in molecular biology and biotechnology. Students will also learn to apply genetic and metabolic engineering tools, such as CRISPR/Cas and RNAi, to manipulate biosynthetic pathways and enhance metabolite production. Additionally, students will explore the ecological functions of these compounds in plant defense and pollination, including the role of VOCs. Through this course, students will be prepared for research and applied careers in plant molecular biology, biotechnology, and phytopharmaceuticals.

Course Content (45 hours)

Unit 1: Fundamentals of Plant Secondary Metabolism -- Overview of Primary vs. Secondary Metabolites; Different classes of secondary metabolites: Alkaloids, Terpenoids, Flavonoids, Phenolics, Glucosinolates; Regulation of secondary metabolism (transcriptional, post-transcriptional, epigenetic). 12 hours

Essential Readings: Dixon, R.A. (2001) Natural products and plant disease resistance. *Nature*, 411:843–847, DOI:10.1038/35081178; Rabeh, K., et al. (2025) A comprehensive review of transcription factor-mediated regulation of secondary metabolites in plants under environmental stress. *Stress Biology*, 5(1):15, DOI:10.1007/s44154-024-00201-w; Buchanan, B.B., et al. (2015) *Biochemistry and Molecular Biology of Plants*. John Wiley & Sons, ISBN:9780470714218, Chapter 24 (Natural Products); Strauss, J. and Reyes-Dominguez, Y. (2011) Regulation of secondary metabolism by chromatin structure and epigenetic codes. *Fungal Genetics and Biology*, 48(1):62–69, DOI:10.1016/j.fgb.2010.07.009.

Unit 2: Isolation, Detection, and Characterization of Secondary Metabolites -- Extraction techniques: Solvent extraction, hydrodistillation, supercritical CO₂; Detection techniques (Chromatographic and Spectroscopic methods); Large-scale metabolite profiling and data analysis. 10 hours

Essential Reading: Dettmer, K., et al. (2007) Mass spectrometry-based metabolomics. *Mass Spectrometry Reviews*, 26(1):51–78, DOI:10.1002/mas.20108; Sukumaran, S.T., et al. (2020) *Plant metabolites: methods, applications and prospects*. Springer, ISBN:9789811551352, DOI:10.1007/978-981-15-5136-9.

Unit 3: Metabolic Engineering of Secondary Metabolites -- Concepts and techniques in metabolic engineering; Understanding of Synthetic biology and pathway engineering; Large-scale production of metabolites; Case studies in *E. coli*, *Saccharomyces*, and *Nicotiana*.

12 hours

Essential Readings: Zhu, X., et al. (2021) Synthetic biology of plant natural products: from pathway elucidation to engineered biosynthesis in plant cells. *Plant Communications*, 2(5):100229, DOI:10.1016/j.xplc.2021.100229; Karaca, H., et al. (2024) Metabolic engineering of *Saccharomyces cerevisiae* for enhanced taxadiene production. *Microbial Cell Factories*, 23(1):241, DOI:10.1186/s12934-024-02512-z; Zhao, S., et al. (2024) The metabolic engineering of *Escherichia coli* for the high-yield production of hypoxanthine. *Microbial Cell Factories*, 23(1):309, DOI:10.1186/s12934-024-02576-x.

Unit 4: Applications in Plant Defense, Human Health, and Ecology -- Role of secondary metabolites in plant defense (phytoalexins, VOCs, allelopathy); Ecological significance: VOCs in pollination, plant-insect interactions; Secondary metabolites in human health: antimicrobial, anticancer, antioxidant; Secondary metabolites in nutraceuticals and pharmaceuticals. 11 hours

Essential Readings: George, B.P., et al. (2021) Role of phytochemicals in cancer chemoprevention: Insights. *Antioxidants*, 10(9):1455, DOI:10.3390/antiox10091455; Divekar, P.A., et al. (2022) Plant secondary metabolites as defense tools against herbivores for sustainable crop protection. *International Journal of Molecular Sciences*, 23(5):2690, DOI:10.3390/ijms23052690.

Practicals (30 hours)

1. Extraction and qualitative analysis of plant secondary metabolites-saponins, phenolics, lignin.
2. Induction of secondary metabolite production in callus culture.
3. Demonstration of antimicrobial activity of plant extracts.
4. Detection of flavonoids during pollen development.
5. Effect of glucosinolate-derived compound, indole-3-carbinol, in plant root growth and development.

Suggested Readings:

1. Crozier, A., et al. (2006) *Plant secondary metabolites: Occurrence, structure and role in the human diet*. Blackwell Publishing, ISBN:9780470988558, DOI:10.1002/9780470988558.
2. Wink, M. (2010) *Annual Plant Reviews Vol. 39: Functions and biotechnology of plant secondary metabolites*. Blackwell Publishing, ISBN:9781444318876, DOI:10.1002/9781444318876.
3. Verpoorte, R. and Memelink, J. (2002) Engineering secondary metabolite production in plants. *Current Opinion in Biotechnology*, 13(2):181–187, DOI:10.1016/S0958-1669(02)00308-7.
4. Dewick, P.M. (2009) *Medicinal Natural Products: A Biosynthetic Approach*. John Wiley & Sons, ISBN:9780470742761, DOI:10.1002/9780470742761.
5. Katz, E., et al. (2015) The glucosinolate breakdown product indole-3-carbinol acts as an auxin antagonist in roots of *Arabidopsis thaliana*. *The Plant Journal*, 82(4):547–555, DOI: 10.1111/tpj.12824.

PBSE423: Epigenetics and Small RNA Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE423: Epigenetics and Small RNA Biology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The epigenetic landscape (including both DNA methylation and histone modifications) of an organism has a significant bearing in regulating various developmental and metabolic processes at the global level. Similarly, small RNAs (sRNAs) have emerged as major modulators of global gene expression patterns. Therefore, this course is designed to provide students with a clear understanding of key epigenetic mechanisms, including chromatin modeling, DNA methylation, and histone modifications, and how these processes regulate plant development and physiology. Students will learn how epigenetic regulation contributes to environmental responses, stress adaptation, and inheritance, and its relevance in human systems, including immunity, cancer, and cardiovascular diseases. The course also introduces the diversity, biogenesis, and regulatory roles of non-coding RNAs across organisms, including their mechanisms of action and trans-kingdom interactions. Additionally, students will become familiar with experimental and computational tools for detecting, predicting, and validating small RNAs, and will explore the applications of RNA-based technologies and CRISPR-Cas systems in crop improvement, diagnostics, and therapeutic development.

Learning Outcomes

By the end of this course, students will be able to understand major epigenetic mechanisms and evaluate their roles in plant development, environmental responses, and human diseases. They will be able to understand DNA methylation and histone modifications, classify non-coding RNAs, and describe how small RNAs regulate gene expression. Students will also be equipped to use molecular and bioinformatic approaches for small RNA analyses and apply RNA-based tools. Overall, they will be able to integrate epigenetics and small RNA biology concepts to address research problems and understand their practical applications in agriculture, biotechnology, and human health.

Course Content (45 hours)

Unit 1: Epigenetic Regulation -- Chromatin modeling and remodeling: polycomb complexes, SWI/SNF1 complexes and other chromatin modifiers; DNA methylation and its interpretation: methylated DNA-binding proteins, their structure and function; techniques of altering and analyzing DNA methylation; Histone modifications: types, modifying enzymes, histone deacetylase inhibitors; Chromatin modification and its influence on plant development: somatic embryogenesis, leaf development, photosynthesis, flowering, and ageing. **12 hours**

Essential Readings: Jenuwein, T. and Allis, C.D. (2001) Translating the histone code. *Science*, 293(5532):1074-1080, DOI:10.1126/science.1063127; Zhang, H., et al. (2018). Dynamics and function of DNA methylation in plants. *Nature Reviews Molecular Cell Biology*, 19(8):489-506, DOI:10.1038/s41580-018-0016-z; Rajewsky, N., et al. (2018) *Plant epigenetics*. Springer International, ISBN:9783319555195, DOI:10.1007/978-3-319-55520-1;

Huang, Y., et al., (2025) Chromatin remodeling in plants: Complex composition, mechanistic diversity, and biological functions. *Molecular Plant*, 18(9):1436–1457, DOI:10.1016/j.molp.2025.08.004.

Unit 2: Environmental and Evolutionary Epigenetics -- Role of epigenetic regulation in plant stress responses and epigenetic memory; Epigenetic inheritance and adaptive responses to environmental cues; Epigenetics in human systems: regulation of immune responses, cancer, and cardiovascular diseases. 10 hours

Essential Readings: Chinnusamy, V. and Zhu, J.K. (2009) Epigenetic regulation of stress responses in plants. *Current Opinion in Plant Biology*, 12(2):133–139, DOI:10.1016/j.pbi.2008.12.006; Avramova, Z. (2015) Transcriptional ‘memory’ of a stress: transient chromatin and memory (epigenetic) marks at stress-response genes. *The Plant Journal*, 83(1):149–159, DOI:10.1111/tpj.12832; Ma, L., et al., (2025) Epigenetic control of plant abiotic stress responses. *Journal of Genetics and Genomics*, 52(2):129–44, DOI:10.1016/j.jgg.2024.09.008; Janson, P.C. and Winqvist, O. (2011) Epigenetics—the key to understand immune responses in health and disease. *American Journal of Reproductive Immunology*, 66:72–74, DOI:10.1111/j.1600-0897.2011.01050.x; Zoghbi, H.Y. and Beaudet, A.L. (2016) Epigenetics and human disease. *Cold Spring Harbor Perspectives in Biology*, 8(2): a019497, DOI:10.1101/cshperspect.a019497.

Unit 3: Biology of Non-coding RNAs -- Discovery, types, occurrence, and diversity of non-coding RNAs; Small RNA pathways in bacteria, plants, and animal systems; Biogenesis and functional components of different classes of small RNAs; Regulation of gene expression by small RNAs: transcriptional gene silencing (TGS), post-transcriptional gene silencing (PTGS), gene activation, and evolutionary transitions in RNA-target interactions; Functional roles of small RNAs in different organisms; Trans-kingdom cross-talk mediated by small RNAs. 13 hours

Essential Readings: Guleria, P. and Kumar, V. (2020) *Plant Small RNA- Biogenesis, Regulation and Application*. Academic Press, ISBN:9780128171127, DOI:10.1016/C2018-0-01900-3; Alquethamy S., et al. (2025). What makes a small RNA work. *Nucleic Acids Research*, 53(12):gkaf563, DOI:10.1093/nar/gkaf563; Mattick, J. and Amaral, P. (2022) *RNA, the epicenter of genetic information*. ISBN:9781003109242, CRC Press, DOI:10.1201/9781003109242; Wierzbiki, A.T., et al. (2021) Long non-coding RNAs in plants. *Annual Review of Plant Biology*, 72:245–271, DOI:10.1146/annurev-arplant-093020-035446; Zhan, J. and Meyers, B.C. (2023) Plant small RNAs: their biogenesis, Regulatory roles, and functions. *Annual Review of Plant Biology*, 74:21–51, DOI:10.1146/annurev-arplant-070122-035226; Barquist, L. and Vogel, J. (2015) Accelerating discovery and functional analysis of small RNAs with new technologies. *Annual Review of Genetics*, 49:367–394, DOI:10.1146/annurev-genet-112414-054804.

Unit 4: Tools, Applications, and Emerging Technologies -- Discovery, detection, and validation of small RNAs; Target prediction and validation approaches; Databases and bioinformatic tools for small RNA analysis; Applications: artificial miRNA (amiR) technology, siRNA and virus-induced gene silencing (VIGS); RNAi interference (RNAi), RNA activation (RNAa), target mimicry and STTM technologies; CRISPR-Cas-based genome editing guided by small RNAs; Applications in crop improvement, diagnostics, and therapeutics. 10 hours

Essential Readings: Tang, G., et al. (2021) *RNA-based technologies for functional genomics in plants*. Springer Cham, ISBN:9783030649937, DOI:10.1007/978-3-030-64994-4; Ting, P., et al. (2018) A resource for inactivation of microRNAs using short tandem target mimic technology in model and crop plants. *Molecular Plant*, 11(11):1400–1417, DOI:10.1016/j.molp.2018.09.003; Halloy, F., et al. (2022) Innovative developments and emerging technologies in RNA therapeutics. *19(1):313–332*, DOI:10.1080/15476286.2022.2027150.

Practicals (30 hours)

1. To resolve and visualize low molecular weight RNAs by denaturing urea-PAGE.
2. To perform expression analysis of selected miRNAs using the quantitative PCR method.

3. To isolate, sonicate, and observe cross-linked chromatin to study histone modifications.
4. To enzymatically cleave and assess DNA to detect methylation patterns.
5. To predict and analyze the secondary structure and thermodynamic stability of the miRNA precursor sequence (pre-miRNA) using Mfold.

Suggested Readings:

1. Esteller, M. (2009) Epigenetics in biology and medicine. CRC Press, eISBN:9780429124921.
2. Workman, J.L. and Abmayr, S.M. (2014) Fundamentals of chromatin. Springer New York, ISBN:9781461486237, DOI:10.1007/978-1-4614-8624-4.
3. Dinkar, V., et al. (2024) Epigenetic regulations under plant stress: a cereals perspective. *Environmental and Experimental Botany*, 220:105688, DOI:10.1016/j.envexpbot.2024.105688.
4. He, L. (2025) The interplay between chromatin remodeling and DNA double-strand break repair: Implications for cancer biology and therapeutics. *DNA Repair*, 146:103811, DOI:10.1016/j.dnarep.2025.103811.
5. Muka, T., et al. (2016) The role of epigenetic modifications in cardiovascular disease: a systematic review. *International Journal of Cardiology*, 212:174–183, DOI:10.1016/j.ijcard.2016.03.062.
6. Mallick, B. and Ghosh, Z. (2012) Regulatory RNAs: Basics, Methods and Applications. Springer Berlin, Heidelberg, ISBN:9783642225161, DOI:10.1007/978-3-642-22517-8.
7. Nellan, W. and Hammann, C. (2007) Small RNAs: analysis and regulatory functions. Springer Berlin, Heidelberg, ISBN:9783540281306, DOI:10.1007/978-3-540-28130-6.
8. Gaur, R.K. and Rossi, J.J. (2009) Regulation of gene expression by small RNAs. CRC Press, USA, eISBN:9780429121692, DOI:10.1201/9781420008708.
9. Alquethamy, S., et al. (2025) What makes a small RNA work? *Nucleic Acids Research*, 53(12):gkaf563, DOI:10.1093/nar/gkaf563.
10. Rederstorff, M. (2021) Small non-coding RNAs: Methods and Protocols. Humana New York. eISBN:9781071613863, DOI:10.1007/978-1-0716-1386-3.

PBSE424: Data Analytics and Biocuration

This course is open to students of other departments as a GE course.

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE424: Data Analytics and Biocuration	4	3	1	0	B.Sc. in any branch of science	

Learning Objectives

The paper aims to empower learners with foundational data analytics skills essential to modern bioinformatics by exposing them to the fundamentals of advanced operating systems, including the Linux command-line interface (CLI), file handling, permissions, and data manipulation. It also provides a brief exposure to the R programming environment, syntax, and functions for data analysis and packages available in the Bioconductor repository for statistical computing, data visualization, and genomic data analysis. It also provides a comprehensive overview of the primary computational workflows for analyzing next-generation sequencing (NGS) data. The learner will explore the concepts, applications, and key steps involved in major "big data" bioinformatics domains, including genome assembly, variant calling, pangenomics, metagenomics, transcriptomics (RNA-seq) and epigenomics (ChIP-seq, Bisulfite-seq). Besides, it also focuses on the behind-the-scenes work of biocuration that powers biological databases through processes of extracting, standardizing, and organizing biological data from literature and experiments. It provides an overview of BioDbCore, FAIRsharing, and ethical principles of open data management. The student will be able to interpret Gene Ontology and biomedical ontologies using OBO formats. In the last unit, there is a brief overview of foundational concepts of AI and machine learning (ML), along with the utility of domain-specific LLMs, their applications in genomics, drug design, and systems biology.

Learning Outcomes

The completion of the course will give expertise in essential Linux commands, set up and run 'R' scripts for statistical analysis and plotting. The learner can apply Bioconductor tools for biological data exploration, such as DESeq2, edgeR, and limma. Furthermore, students can analyse NGS data for variant calling, transcriptome quantification, and epigenomic data integration. They also now understand the FAIR data principles, ontologies, and the curation of biological data from published sources. Moreover, students can work with LLMs, ML, and AI tools across domains such as genomic prediction, phenotype classification, drug discovery, and structure-based screening.

Course Content (45 hours)

Unit 1: Basic of Linux and 'R' -- Computer architecture, types of operating systems (Windows, Mac-OS and Linux), concept of networking (IP address); Basic fundamentals of working with Unix/Linux on CLI (Command Line Interface), Unix/Linux directory structure, file permissions, remote login; Linux commands (whoami, pwd, cd, ls, man, mkdir, rm, cat copy, mv, chmod, grep, sed, sep, sort, head, tail, wc); Introduction to the 'R' data analysis

package, basic work environment, syntax, introduction to the ‘Bioconductor’ packages for data analysis. **15 hours**

Essential Readings: Blum, R. and Bresnahan, A. (2021) Linux Command Line and Shell Scripting Bible. 4th edition, John Wiley & Sons, Inc., ISBN:9781119700913; Kabacoff, R.I. (2022) R in action: Data analysis and graphics with R. 3rd edition, Manning Publications, ISBN:9781617296055; Gentleman, R.C., et al. (2004) Bioconductor: open software development for computational biology and bioinformatics. Genome Biology, 5:R80, DOI:10.1186/gb-2004-5-10-r80.

Unit 2: Big Data Analysis -- Whole genome reference-based assembly, de-novo genome analysis, variant call analysis, Pangenomes, Metagenomic analysis, RNA-seq data analysis, ChIP (Chromatin Immunoprecipitation) data analysis; Whole genome bisulphite sequencing data analysis. **10 hours**

Essential Readings: Compeau, P. and Pevzner, P. (2018) Bioinformatics algorithms: An active learning approach. 3rd edition, Active Learning Publishers, ISBN:9780990374633; Shendure, J. and Aiden, E.L. (2012) The expanding scope of DNA sequencing. Nature Biotechnology, 30(11):1084–1094, DOI:10.1038/nbt.2421; Conesa, A., et al. (2016) A survey of best practices for RNA-seq data analysis. Genome Biology, 17:13, DOI:10.1186/s13059-016-0881-8; Landt, S.G., et al. (2012) ChIP-seq guidelines and practices of the ENCODE and modENCODE consortia. Genome Research, 22(9):1813–31, DOI:10.1101/gr.136184.111.

Unit 3: Data Integration and Biocuration -- Overview of Biocuration, various approaches for biocuration, BioDbCore guidelines, FAIRsharing and ethics in data sharing, Text/Literature-based curation, text mining approaches, introduction to tools such as Textpresso. Basics and importance of ontology development, OBO (Open Biological and Biomedical Ontology) format, OBO foundry, biomedical and plant-based ontologies. **10 hours**

Essential Readings: Gaudet, P., et al. (2011) Towards BioDBcore: a community-defined information specification for biological databases. Nucleic Acids Research, 39(s1):D7–D10, DOI:10.1093/nar/gkq1173; Open Biological and Biomedical Ontology Foundry: Community development of interoperable ontologies for the biological sciences, <https://obofoundry.org/about-OBO-Foundry.html>; FAIRsharing: A curated, informative and educational resource on data and metadata standards, inter-related to databases and data policies, <https://fairsharing.org>, DOI:10.1038/s41587-019-0080-8; Howe, D., et al. (2008) The future of biocuration. Nature, 455:47–50, DOI:10.1038/455047a; Wilkinson, M.D., et al. (2016) The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data, 3:160018, DOI:10.1038/sdata.2016.18.

Unit 4: Artificial Intelligence in Life Sciences -- Introduction to Machine-Learning (ML) and Artificial Intelligence (AI); Supervised and un-supervised learning approaches in data integration, interpretation, and predictive modelling; Applications in genomic prediction, drug discovery, ecosystem modelling; Domain-specific Large Language Models (LLMs). **10 hours**

Essential Readings: Cannataro, M., et al. (2022) Artificial Intelligence in Bioinformatics: from omics analysis to deep learning and network mining, 1st edition, Elsevier, eISBN:9780128229293; Jumper, J., et al. (2021) Highly accurate protein structure prediction with AlphaFold. Nature, 596:583–589, DOI:10.1038/s41586-021-03819-2.

Tutorials (15 hours)

1. Practice of working with Linux commands on the Command Line Interface (CLI).
2. Analysis of RNA-seq data:
 - a. Quality and adapter trimming of Next Generation Sequencing (NGS) data.
 - b. Reference-based genome mapping of NGS data.
 - c. Identification of differentially expressed genes.
3. Use of Gene Ontology for gene function analysis.

Suggested Readings:

1. Bessant, C., et al. (2014) Building bioinformatics solutions with Perl, R, and SQL. 2nd edition, Oxford University Press, UK, ISBN:978019965855.
2. Buffalo, V. (2015) Bioinformatics data skills: Reproducible and robust research with open-source tools. O'Reilley Media, ISBN:9781449367374.
3. Quince, C., et al. (2017) Shotgun metagenomics, from sampling to analysis. Nature Biotechnology, 35(9):833–844, DOI:10.1038/nbt.3935.
4. Sansone, S.A., et al. (2019) FAIRsharing as a community approach to standards, repositories and policies, Nature Biotechnology, 37(4):358–367, DOI:10.1038/s41587-019-0080-8.
5. Smith, B., et al. (2007) The OBO Foundry: coordinated evolution of ontologies to support biomedical data integration, Nature Biotechnology, 25(11):1251–1255, DOI:10.1038/nbt1346.
6. Müller, H.M., et al. (2018) Textpresso Central: a customizable platform for searching, text mining, viewing, and curating biological literature. BMC Bioinformatics, 19:94, DOI:10.1186/s12859-018-2103-8.
7. Web link: www.bioconductor.org
8. Web link: www.obofoundry.org; www.oboedit.org
9. Web link: www.biocuration.org

PBSE425: Plant Phenomics

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE425: Plant Phenomics	4	3	1	0	B.Sc. in any branch of science	

Course Objectives

This course aims to introduce students to the conceptual and methodological foundations of plant phenomics, spanning trait ontology, G×E×M frameworks, and robust experimental design. It seeks to familiarise students with controlled-environment and field phenotyping platforms, diverse imaging modalities, and 3D architectural reconstruction. A further objective is to develop competence in end-to-end phenomics data pipelines, from image acquisition to quantitative trait extraction and machine-learning-based modelling, enabling critical engagement with current literature and applications in crop improvement and stress biology.

Learning Outcomes

Upon successful completion, students will be able to define and differentiate plant phenomics from classical phenotyping, design basic phenotyping experiments with appropriate traits, platforms and metadata, and justify these choices. They will interpret and compare outputs from RGB, fluorescence, thermal, spectral and 3D imaging in controlled and field settings. Students will execute simple image-analysis workflows, apply elementary machine learning for phenotypic data, critically evaluate published phenomics studies, and articulate how phenomics informs breeding, resilience and systems-level plant biology.

Course Content (45 hours)

Unit 1: Foundations of Plant Phenomics and Trait Biology -- Definition and scope of plant phenomics; Distinction between classical phenotyping and high-throughput phenomics; Links to functional genomics, systems biology, and crop improvement; Trait ontology (morphological, physiological, developmental, functional traits); G×E×M (genotype×environment×management) framework; Principles of experimental design (replication, randomisation, blocking, temporal sampling); Metadata standards and FAIR (Findable, Accessible, Interoperable, and Reusable) data; Evolution of phenotyping platforms and international phenomics networks; Ideotype concepts and gene-to-phenotype mapping.

12 hours

Essential Readings: Chen, J.T. (2025) Plant high-throughput phenotyping and functional phenomics. CRC Press, eISBN:9781003505631, DOI:10.1201/9781003505631, Chapter 2 (Plant high-throughput phenotyping and phenomics for accelerating crop breeding), Chapter 9 (High-throughput phenotyping and phenomics for exploration of plant growth and development), Chapter 13 (High-throughput plant phenotyping and phenomics: Advances and prospects); Fiorani, F. and Schurr, U. (2013) Future scenarios for plant phenotyping. Annual Review of Plant Biology, 64:267–291, DOI:10.1146/annurev-arplant-050312-120137; Papoutsoglou, E.A., et al. (2023) The benefits and struggles of FAIR data: the case of reusing plant phenotyping data. Scientific Data, 10(1):595, DOI:10.1038/s41597-023-02364-z.

Unit 2: Controlled-Environment Phenomics and Imaging Modalities -- Growth chamber and greenhouse phenotyping platforms; conveyor- and chamber-based systems; Longitudinal monitoring of growth and development; RGB (Red, Green, and Blue) imaging for morphology, colour indices, and growth curves; Chlorophyll fluorescence imaging (PSII efficiency, stress signatures); Thermal imaging (canopy temperature, transpiration proxies); Multispectral and hyperspectral imaging for pigment and biochemical traits; Controlled root phenotyping [rhizotrons, gel systems, CT (Computed Tomography)/MRI (Magnetic Resonance Imaging) concepts]; Calibration, illumination control, reference standards; Time-series design for controlled-environment stress and treatment experiments. **10 hours**

Essential Readings: Lorence, A. and Jimenez, K.M. (2022) High-throughput plant phenotyping: Methods and Protocols. Methods in Molecular Biology. Humana New York, ISBN:9781071625361, DOI:10.1007/978-1-0716-2537-8, Chapter 5 (A straightforward high-throughput aboveground phenotyping platform for small- to medium-sized plants), Chapter 6 (Wireless fixed camera network for greenhouse-based plant phenotyping), Chapter 7 (Experimental design for controlled environment high-throughput plant phenotyping); Zhang, Y. and Zhang, N. (2018) Imaging technologies for plant high-throughput phenotyping: a review. Frontiers of Agricultural Science and Engineering, 5(4):406–419, DOI:10.15302/J-FASE-2018242; Mahlein, A.K., et al. (2018) Hyperspectral sensors and imaging technologies in phytopathology: state of the art. Annual Review of Phytopathology, 56:535–558, DOI:10.1146/annurev-phyto-080417-050100.

Unit 3: Field Phenomics, Remote Sensing, and 3D Architecture -- Fixed gantry, tractor-/robot-mounted and handheld phenotyping systems; UAV (Unmanned Aerial Vehicle)-based phenotyping with RGB, multispectral, and hyperspectral sensors; Vegetation indices (NDVI (Normalized Difference Vegetation Index), NDRE (Normalized Difference Red Edge Index), etc. for growth, water and nutrient status; Canopy temperature mapping; LiDAR and stereo vision for 3D reconstruction; Point clouds and structural traits; Integration of environmental data with phenotypic measurements; Spatial heterogeneity and experimental layout; Applications in breeding across diverse field environments. **12 hours**

Essential Readings: Chen, J.T. (2025) Plant high-throughput phenotyping and functional phenomics. CRC Press, eISBN:9781003505631, DOI:10.1201/9781003505631, Chapter 3 (Remote sensing technologies for high-throughput in-field crop phenotyping, Chapter 4 (High-Throughput field phenotyping: Enhancing crop monitoring for food security), Chapter 10 (Root phenotyping for breeding of climate-resilient crops), Chapter 16 (Robotics and aerial vehicle for high-throughput phenotyping: technologies and prospects); Araus, J.L. and Cairns, J.E. (2014) Field high-throughput phenotyping: the new crop breeding frontier. Trends in Plant Science, 19(1):52–61, DOI:10.1016/j.tplants.2013.09.008; Guo, W., et al. (2021) UAS-based plant phenotyping for research and breeding applications. Plant Phenomics, 2021:9840192, DOI:10.34133/2021/9840192.

Unit 4: Data Pipelines, Image Analysis, and Machine Learning in Phenomics -- End-to-end phenomics data pipeline (acquisition, pre-processing, segmentation, feature extraction, trait computation); Use of ImageJ/Fiji, PlantCV and related open-source tools; Machine learning for phenotyping; Deep learning and CNNs for segmentation, Classification and regression; Model training, validation and evaluation; Phenomic features in GWAS, genomic prediction and phenomic selection; Data management, reproducibility, model transferability and interpretability. **11 hours**

Essential Readings: Chen, J.T. (2025) Plant high-throughput phenotyping and functional phenomics. CRC Press, eISBN:9781003505631, DOI:10.1201/9781003505631, Chapter 1 (Bioinformatics tools and deep learning for plant high-throughput phenotyping and phenomics), Chapter 15 (Statistical tools and data analysis for organizing plant high-throughput phenomics); Murphy, K.M., et al. (2024) Deep learning in image-based plant phenotyping. Annual Review of Plant Biology, 75:771–795, DOI:10.1146/annurev-arplant-070523-042828; Danilevicz, M.F., et al. (2021) Resources for image-based high-throughput phenotyping in crops and data sharing challenges. Plant Physiology, 187(2):699–715, DOI:10.1093/plphys/kiab301.

Tutorials (15 hours)

1. Short presentations on landmark phenomics papers.
2. Designing a basic phenotyping experiment (traits, platform, experimental design, metadata sheet).
3. Hands-on demonstrations with sample image datasets.
4. Analysis of PSII efficiency (Fv/Fm) and photosynthetic activity [fluorescence decline ratio in steady state (Rfd_Lss)] in control and stress plants.

Suggested Readings:

1. Chen, J.T. (2025) Plant high-throughput phenotyping and functional phenomics. CRC Press, ISBN:9781003505631, DOI:10.1201/9781003505631.
2. Lorence, A. and Jimenez, K.M. (2022) High-throughput plant phenotyping: Methods and Protocols. Methods in Molecular Biology, Humana New York, DOI:10.1007/978-1-0716-2537-8.
3. Awada, L., et al. (2024) The evolution of plant phenomics: Global insights, trends, and collaborations (2000-2021). Frontiers in Plant Science, 15:1410738, DOI:10.3389/fpls.2024.1410738.
4. Großkinsky, D.K., et al. (2023) The potential of integrative phenomics to harness underutilized crops for improving stress resilience. Frontiers in Plant Science, 14:1216337, DOI:10.3389/fpls.2023.1216337.
5. Singh, A., et al. (2016) Machine learning for high-throughput stress phenotyping in plants. Trends in Plant Science, 21(2):110–124, DOI:10.1016/j.tplants.2015.10.015.
6. Abebe, A.M., et al. (2023) Image-based high-throughput phenotyping in horticultural crops. Plants, 12(10):2061, DOI:10.3390/plants12102061.
7. Xu, R. and Li, C. (2022) A review of high-throughput field phenotyping systems: Focusing on ground robots. Plant Phenomics, 2022:9760269, DOI:10.34133/2022/9760269.
8. Gano, B., et al. (2024) Drone-based imaging sensors, techniques, and applications in plant phenotyping for crop breeding: A comprehensive review. The Plant Phenome Journal, 7(1): e20100, DOI:10.1002/ppj2.20100.
9. Li, S., et al. (2025) A review of optical-based three-dimensional reconstruction and multi-source fusion for plant phenotyping. Sensors, 25(11):3401, DOI:10.3390/s25113401.
10. Su, M., et al. (2025) Design and implementation of high-throughput field phenotyping robot for acquiring multisensory data in wheat. Plant Phenomics, 7(2):100014, DOI:10.1016/j.plaphe.2025.100014.
11. Adak, A., et al. (2023) Phenomic data-driven biological prediction of maize through field-base high-throughput phenotyping integration with genomic data. Journal of Experimental Botany, 74(17):5307–5326, DOI: 0.1093/jxb/erad216.
12. Zavafer, A., et al. (2023) Phenomics: conceptualization and importance for plant physiology. Trends in Plant Science, 28(9):1004–1013, DOI:10.1016/j.tplants.2023.03.023.
13. Lichtenthaler, H.K. and Miehe, J.A. (1997) Fluorescence imaging as a diagnostic tool for plant stress. Trends in Plant Science, 2(8):316–320, DOI:10.1016/S1360-1385(97)89954-2.

PBRE426: Dissertation-II

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBRE426: Dissertation-II	6	0	0	6	B.Sc. in any branch of science	NA

Learning Objectives

The students will work independently on the research problem chosen in Semester 3 and will apply appropriate molecular, biochemical, physiological and/or computational approaches to address the defined objectives and hypotheses. They will learn to design and execute experiments with suitable controls and replicates, systematically collect, document, and analyse data using relevant statistical and bioinformatic tools, and interpret the results in the context of existing knowledge. They will further strengthen their skills in scientific writing by updating and refining the literature review and by preparing a well-organized dissertation adhering to standard formats, citation styles, and ethical guidelines. The student will also develop competencies in scientific communication by regularly discussing their work in lab meetings and presenting their findings through formal oral presentations.

Learning Outcomes

On successful completion of the dissertation, the student will be able to independently plan and conduct the experiments with appropriate controls, optimize and adapt protocols, and troubleshoot technical problems in response to experimental challenges. They will maintain systematic and complete laboratory records, generate reproducible datasets, and carry out quantitative/qualitative analyses, including appropriate statistical tests and data visualization. They will be able to critically interpret and integrate their experimental findings with published literature to draw logical, evidence-based conclusions, identify limitations, and suggest future directions. The student will be able to prepare a coherent dissertation that includes an updated literature review, methodology, results, discussion, and references in a standard format. They will exhibit professional research attitudes, including scientific rigor, ethical conduct, teamwork, and responsible data and time management in the laboratory to meet defined timelines and submission deadlines.

Suggested Readings:

Latest research and review articles on the chosen research topic.

Structure 3 - PG with Research

SEMESTER 3

PBSC331: Plant Biotechnology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSC331: Plant Biotechnology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course will enable students to understand the core principles and milestones of plant biotechnology, including the molecular basis of crop domestication and Green Revolution traits, as well as concepts in tissue culture. Students will learn about the molecular toolbox for plant genetic engineering and be introduced to advanced approaches, including RNAi, genome editing, and synthetic biology, for pathway engineering. The course will build conceptual understanding of modern gene/QTL mapping, marker-assisted and genomic selection, speed breeding, and gene pyramiding, together with applications of plant biotechnology in molecular farming, biofortification, climate resilience, plant-microbe interactions, and industrial and environmental biotechnology. Finally, students will be sensitized to biosafety guidelines, GMO risk assessment, IPR, farmers’ rights, and ethical and societal issues in plant biotechnology.

Learning Outcomes

On completing the course, students will be able to explain and apply tissue culture and related technologies for crop improvement. They will be able to outline and compare plant transformation and genome editing strategies, design genetic constructs and describe workflows for the generation and characterization of transgenic and edited plants. Students will be able to select appropriate molecular markers and mapping approaches for dissecting complex traits, and integrate marker-assisted selection, genomic selection, and breeding pipelines. They will be able to critically analyse case studies such as Golden rice, Bt cotton, virus-resistant papaya, and DH mustard, among others. In addition, they will be able to interpret biosafety and regulatory frameworks, IPR/PBR/farmer’s rights provisions, and articulate ethical, social, and policy implications of deploying plant biotechnological innovations in agriculture.

Course Content (45 hours)

Unit 1: Fundamentals and Scope of Plant Biotechnology -- Concept, history, and milestones in plant biotechnology; Molecular basis of crop domestication and Green revolution; Principles of plant tissue culture, totipotency, and micropropagation; Somaclonal variation, somatic embryogenesis, and synthetic seeds; Protoplast fusion and somatic hybridization. **5 hours**

Essential Readings: Stewart Jr., C.N. (2025) Biotechnology and Genetics: Principles, Techniques, and Applications. 3rd edition, John Wiley & Sons, ISBN:9781394217236, Chapter 1 (Plant Agriculture: The impact of biotechnology); Abdin, M.Z, et al. (2017) Plant Biotechnology: Principles and Applications, Springer Verlag,

Singapore, ISBN:9789811029592, Chapter 1 (Historical perspective and basic principles of plant tissue culture), Chapter 2 (Plant tissue culture: Applications in plant improvement and conservation); Pathirana, R. and Carimi, F. (2024) Plant biotechnology-an indispensable tool for crop improvement. *Plants (Basel)*, 13(8):1133, DOI:10.3390/plants13081133.

Unit 2: Molecular Tools and Techniques -- Genetic cloning strategies and vector systems; Promoters, selectable markers, and reporter genes; Gene transfer methods; Chloroplast transformation; Characterization of transgenic plants at molecular, biochemical, and phenotypic level; Case studies: Golden rice, Bt cotton, virus-resistant papaya, herbicide-tolerant crops, Dhara Mustard, any other product; Virus-induced gene silencing (VIGS) methods; Genome editing technologies [Zinc Finger Nucleases, Transcription activator-like effector nucleases, Clustered Regularly Interspaced Short Palindromic Repeats or CRISPR)/CRISPR-associated (Cas) systems, prime editing, base editing, and miniature RNA-guided endonuclease]; Generation of marker-free transgenics; RNAi interference (RNAi); Introduction of synthetic biology and metabolic pathway engineering. **15 hours**

Essential Readings: Li, B., et al. (2024) Targeted genome-modification tools and their advanced applications in crop breeding. *Nature Reviews Genetics*, 25(9):603–622, DOI:10.1038/s41576-024-00720-2; Liu, W., et al. (2013) Advanced genetic tools for plant biotechnology. *Nature Review Genetics*, 14:781–793, DOI:10.1038/nrg3583; Gupta, O.P. and Karkute, S.G. (2021) Genome editing in plants: Principles and applications, CRC Press, ISBN:9780367415907, Chapter 1 (Historical developments of genome editing in plants), Chapter 2 (Mechanism of ZFN mediated genome editing: scope and opportunities), Chapter 3 (TALEN: customizable molecular scissors for tailoring newer types of genomes in plants), Chapter 4 (Mechanism of CRISPR/Cas9 mediated genome editing: scope and opportunities); Koeppe, S., et al. (2023) RNA interference: past and future applications in plants, *International J. Molecular Science*, 24(11):9755, DOI: 10.3390/ijms24119755; Singh, R., et al. (2023) A prospective review on selectable marker-free genome engineered rice: past, present and future scientific realm, *Frontiers in Genetics*, 13:2022, DOI:10.3389/fgene.2022.882836; Aaron, S., et al. (2020) Metabolic engineering and synthetic biology of plant natural products – A minireview. *Current Plant Biology*, 24:100163, DOI:10.1016/j.cpb.2020.100163.

Unit 3: Mapping of Genes/QTLs -- High-throughput molecular markers and genotyping assays; Bulk segregant analysis (QTL-seq), Target-Sequence Enrichment and Sequencing (TESeq), Resistance gene enrichment sequencing (RenSeq), and Mutation mapping (MutMap, MutMap-Gap, etc); Genome-Wide Association Studies (GWAS); Marker-assisted plant breeding and genomic selection (GS); Speed breeding; Gene Pyramiding; Hybrid breeding and doubled haploid technologies. **15 hours**

Essential Readings: Jaganathan, D., et al. (2020) Fine mapping and gene cloning in the post-NGS era: advances and prospects. *Theoretical and Applied Genetics*, 133(5):1791–1810, DOI:10.1007/s00122-020-03560-w; Wang, X., et al. (2023) Next-generation bulked segregant analysis for Breeding 4.0. *Cell Reports*, 42(9):113039, DOI:10.1016/j.celrep.2023.113039; Uffelman, E., et al. (2021) Genome-wide association studies. *Nature Reviews Methods Primers*, 1:59, DOI:10.1038/s43586-021-00056-9; Kabade, P.G., et al. (2025) Speed breeding 3.0: mainstreaming light-driven plant breeding for sustainable genetic gains. *Trends in Biotechnology*, 43(10):2462–2478, DOI:10.1016/j.tibtech.2025.04.011; Crossa, J., et al. (2017) Genomic selection in plant breeding: methods, models, and perspectives, *Trends in Plant Science*, 22(11):961–975, DOI:10.1016/j.tplants.2017.08.011; Qu, Y., et al. (2024) Doubled haploid technology and synthetic apomixis: Recent advances and applications in future crop breeding. *Molecular Plant*, 17(7):1005–1018, DOI:10.1016/j.molp.2024.06.005.

Unit 4: Applications and Societal Aspects of Plant Biotechnology -- Molecular farming; Biofortification and nutritional enhancement; Manipulating and harnessing plant-microbe interactions: disease resistant plants, biofertilizers, biopesticides, and mycorrhizal biotechnology; Climate-resilient crops: generation of abiotic stress tolerant plants; Industrial Biotechnology: bioethanol and other products; Environmental biotechnology: phytoremediation; Regulatory frameworks: biosafety guidelines, GMO risk assessments, and

intellectual property rights (IPR); Plant breeders' rights (PBRs) and farmers' rights; Ethical, social, and policy implications of plant biotechnology. **10 hours**

Essential Readings: Shanmugaraj, B., et al. (2020) Plant molecular farming: A viable platform for recombinant biopharmaceutical production. *Plants*, 9(7):842, DOI:10.3390/plants9070842; Garg, M., et al. (2024) Biofortification for nutrient-rich crops. ISBN:9781032690636, DOI:10.1201/9781032690636; Digel, I., et al. (2025) Introduction to Industrial Biotechnology, Springer Cham, ISBN:9783032079183, DOI:10.1007/978-3-032-07918-3; Abdin, M.Z., et al. (2017) Plant Biotechnology: Principles and Applications, Springer Verlag, Singapore, ISBN:9789811029592, Chapter 14 (Biosafety, Bioethics, and IPR Issues in Plant Biotechnology); Protection of plant varieties and farmers' right act (PPV & FR), 2001, Ministry of Agriculture and Farmers Welfare, GoI; Standard Operating Procedures for regulatory review of genome edited plants under SDN-1 and SDN-2 categories 2022 and Guidelines on genetically engineered plants containing stacked events 2025 by Department of Biotechnology, MoS&T, GoI.

Practicals (30 hours)

1. Assessment of promoter activity in transgenic plants using beta-glucuronidase (GUS) reporter through histochemical staining and fluorometric (MUG) assays.
2. To perform PCR-based screening of *Arabidopsis* T-DNA insertion lines to distinguish heterozygous and homozygous plants.
3. Genome editing of a target gene in a plant (GFP/transient assay).
4. T7E1/ Surveyor mismatch cleavage assays to detect mutated/edited genomic regions.
5. Construction of a plant genetic linkage map with molecular markers.

Suggested Readings:

1. Acquaah, G. (2020) Principles of Plant Genetics and Breeding, 3rd edition, Wiley-Blackwell, ISBN:9781119626695.
2. Al-Khayri, J.M., et al. (2025) Genome Editing for Crop Improvement - Theory and Methodology. CAB International, ISBN:9781800622494.
3. Hille, F., et al. (2018) The biology of CRISPR-Cas: Backward and forward. *Cell*, 172(6):1239–1259, DOI:10.1016/j.cell.2017.11.032.
4. Singh, B.D. and Singh, A.K. (2015) Marker-Assisted Plant Breeding: Principles and Practices, Springer New Delhi, ISBN:9788132223160, DOI:10.1007/978-81-322-2316-0.
5. Clauw, P., et al. (2025) Beyond the standard GWAS-A guide for plant biologists. *Plant and Cell Physiology*, 66(4):431–443, DOI:10.1093/pcp/pcae079.
6. Quiroz, L.F., et al. (2024) Haploid rhapsody: the molecular and cellular orchestra of *in vivo* haploid induction in plants. *New Phytologist*, 241(5):1936–1949, DOI:10.1111/nph.19523.
7. Ghosh, S., et al. (2018) Speed breeding in growth chambers and glasshouses for crop breeding and model plant research. *Nature Protocols*, 13:2944–2963, DOI:10.1038/s41596-018-0072-z.
8. Chen, J.T. (2024) Plant speed breeding and high-throughput technologies, CRC Press, ISBN: 9781003434733.
9. Xiong, J., et al. (2023) Synthetic apomixis: the beginning of a new era. *Current Opinion in Biotechnology*, 79:102877, DOI:10.1016/j.copbio.2022.102877.
10. WHO (2004) Laboratory Biosafety Manual, 3rd edition
11. FAO (2018) Biosafety Primer.
12. Department of Biotechnology (DBT), MoS&T, GoI (2023) Intellectual Property Guidelines.
13. Scientific Journals: Plant Biotechnology Reports; International Journal of Plant Biotechnology; Plant Biotechnology Journal; Transgenic Research; Journal of Plant Biotechnology; Plant Cell, Tissue and Organ Culture.
14. Singh, K.K. (2014) Biotechnology and intellectual property rights-legal and social implications. ISBN:9788132220596, DOI:10.1007/978-81-322-2059-6.

PBSE334: Frontiers in Plant Molecular Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE334: Frontiers in Plant Molecular Biology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course has been designed to introduce students to state-of-the-art concepts, technologies, and experimental systems that define modern plant molecular biology and its translational applications. It aims to develop a rigorous understanding of plant signaling architectures, multi-omics-driven functional genomics, structural advances in genome biology, and emerging domains such as epitranscriptomics, nanobiotechnology, and space biology. Furthermore, it aims to enable students to relate primary discoveries in calcium, ROS, hormone and retrograde signaling to crop improvement, biosensing, and stress resilience through synthetic and genome engineering approaches, supported by current literature in plant signaling and systems biology.

Learning Outcomes

After successful completion of the course, students will be able to critically interpret and integrate datasets from transcriptomic, proteomic, metabolomic, epigenomic, and phenomics platforms to elucidate gene function and regulatory networks in plants. They should be able to design and conceptualize CRISPR-based functional analyses, visualize and analyse gene interaction networks, and evaluate gene function prediction, stress-tolerance forecasting, and genome-assisted breeding. Students will also be able to assess emerging tools, such as optogenetics, targeted epigenome editing, and plant nanotechnology, for their feasibility for research or crop applications, thereby demonstrating their research readiness.

Course Content (45 hours)

Unit 1: Forefront of Plant Signaling -- Mechanosensing and electrosensing; Receptor dynamics and nanodomains; Phosphoswitches and dynamic network mapping; Organelle-to-nucleus signaling (retrograde signaling); Optogenetics and chemical biology tools; Live-cell imaging of Ca²⁺ and ROS dynamics; Phytohormone dynamics studies; Engineering synthetic receptors or signaling circuits for stress tolerance or biosensing. **11 hours**

Essential Readings: Hamilton, E.S., et al. (2015) United in diversity: mechanosensitive ion channels in plants, *Annual Review of Plant Biology*, 66:113–37, DOI:10.1146/annurev-arplant-043014-114700; Fromm, J. and Lautner, S. (2007) Electrical signals and their physiological significance in plants. *Plant Cell and Environment*, 30(3):249–257, DOI:10.1111/j.1365-3040.2006.01614.x; Wang, L., et al. (2018) Exploring the spatiotemporal organization of membrane proteins in living plant cells. *Annual Review of Plant Biology*, 69:525–551, DOI:10.1146/annurev-arplant-042817-040233; Zhang, J., et al. (2023) Protein phosphorylation: A molecular switch in plant signaling. *Cell Reports*, 42(7):112729, DOI:10.1016/j.celrep.2023.112729; Tatjana, K. and Dario, L. (2016) Retrograde signaling: Organelles go networking. *Biochimica et Biophysica Acta (BBA)–Bioenergetics*, 1857(8):1313–1325, DOI:10.1016/j.bbabi.2016.03.017; Hiromasa, S. and Philipp, D. (2022) Plant optogenetics: Applications and perspectives. *Current Opinion in Plant Biology*, 68:102256, DOI:10.1016/j.pbi.2022.102256; Sarah, J., et al. (2011) *In vivo* imaging of Ca²⁺, pH, and reactive oxygen species using fluorescent probes in plants. *Annual Review of Plant Biology*, 62:273–297, DOI:10.1146/annurev-arplant-042110-103832; Rainer, W. (2020) Phytohormone signaling mechanisms and genetic methods for their

modulation and detection, *Current Opinion in Plant Biology*, 57:31–40, DOI:10.1016/j.pbi.2020.05.011; Ondřej N., et al. (2017) Zooming in on plant hormone analysis: Tissue- and cell-specific approaches. *Annual Review of Plant Biology*, 68:323–348, DOI:10.1146/annurev-arplant-042916-040812; Alexander, R.L., et al. (2020) Engineering synthetic signaling in plants. *Annual Review of Plant Biology*, 71:767–788, DOI:10.1146/annurev-arplant-081519-035852.

Unit 2: Structural and Functional Genomics -- Third- and fourth-generation sequencing platforms and their applications in plant genome analysis, principles of transcriptomics and proteomics, including experimental design and data interpretation; Case study-based functional genomics strategies such as large-scale mutagenesis (T-DNA, CRISPR/Cas), RNAi, VIGS and activation tagging to elucidate gene function; Understanding advanced layers of regulation through RNA-seq, ribosome profiling, single-nucleus RNA-seq, and epigenomic assays such as ATAC-seq, ChIP-seq and DNA methylome analysis. 12 hours

Essential Readings: Brown, T.A. (2023) *Genomes 5*. CRC Press, ISBN:9781003133162, Chapter 4 (Sequencing Genomes), Chapter 9 (Transcriptomes and Proteomes), Chapter 10 (Genome Regulation); Mardis, E.R. (2008) Next-generation DNA sequencing methods. *Annual Review of Genomics and Human Genetics*, 9:387–402, DOI:10.1146/annurev.genom.9.081307.164359; Chappell, L., et al. (2018) Single-Cell (Multi)omics Technologies. *Annual Review of Genomics and Human Genetics*, 19:15–41, DOI: 10.1146/annurev-genom-091416-035324.

Unit 3: Applied Aspects of Plant-Environment Interactions -- Overview of plant responses to abiotic and biotic stresses; Molecular signaling pathways; Omics-driven discovery of stress tolerance genes; Engineering the plant microbiome; Spatial and integrative omics for stress biology: single cell vs. tissue level omics, transcriptomics and metabolite mapping of root-soil interface; Inter-kingdom communication; AI and ML in prediction of stress-tolerant genotypes. 11 hours

Essential Readings: Tuteja, N. and Gill, S.S. (2016) *Abiotic stress responses in plants*. ISBN:9783527339181, Wiley-VCH Verlag GmbH & Co., Chapter 1 (Abiotic stress signaling in plants: an overview); Zhang H., et al. (2022) Abiotic stress responses in plants. *Nature Review Genetics*, 23:104–119, DOI:10.1038/s41576-021-00413-0; Jiang Z., et al. (2025) Mechanisms of plant acclimation to multiple abiotic stresses. *Communications Biology*, 8:655, DOI:10.1038/s42003-025-08077-w; Mochida, K., et al. (2020) Decoding plant–environment interactions that influence crop agronomic traits. *Plant and Cell Physiology*, 61(8):1408–1418, DOI:10.1093/pcp/pcaa064; Du, B., et al. (2024) Strategies of plants to overcome abiotic and biotic stresses. *Biological Reviews*, 99(4):1524–1536, DOI: 10.1111/brv.13079; Varadharajan, V., et al. (2025) Multi-omics approaches against abiotic and biotic stress-A review. *Plants*, 14(6):865, DOI:10.3390/plants14060865; Afridi M.S., et al. (2022) New opportunities in plant microbiome engineering for increasing agricultural sustainability under stressful conditions. *Frontiers in Plant Sciences*, 13:899464, DOI:10.3389/fpls.2022.899464; Special issue on “Use of single cell and spatial multiomics for uncovering cellular and molecular mechanisms underlying plant stress responses”. *Stress Biology*, 2025; Salem M.A., et al. (2022) Metabolomics of plant root exudates: From sample preparation to data analysis, *Frontiers in Plant Sciences*, 13:1062982, DOI:10.3389/fpls.2022.1062982; Singhal, R., et al. (2025) Using supervised machine-learning approaches to understand abiotic stress tolerance and design resilient crops. *Philosophical Transactions of the Royal Society B*, 380:2024.0252, DOI:10.1098/rstb.2024.0252.

Unit 4: Emerging Tools and Techniques -- Epitranscriptomics; Targeted epigenome editing: development of specific DNA-targeting systems, next-generation CRISPR activators, applications in agriculture; Nanotechnology and its applications in plant biology: types of nanomaterials, uptake and translocation, biological impact, applications of nanoparticles (NPs) in plant biology (biosensors, nutrient delivery, nanomaterials in plant genetic engineering (DNA / RNA delivery); Plant biology in space: growth and monitoring, effects of microgravity and ionizing radiations, applications, and benefits. 11 hours

Essential Readings: Kumari, A., et. al. (2023) Nanotechnology as a powerful tool in plant sciences: Recent developments, challenges and perspectives. *Plant Nano Biology*, 5:100046, DOI:10.1016/j.plana.2023.100046; Sanzari, I., et. al. (2019) Nanotechnology in plant science: To make a long story short. *Frontiers in Bioengineering and Biotechnology*, 7:120, DOI:10.3389/fbioe.2019.00120; Sharma, B., et al. (2023) The diversity and functions

of plant RNA modifications: what we know and where we go from here. *Annual Review of Plant Biology*, 74(1):53–85, DOI:10.1146/annurev-arplant-071122-085813; Shen, L., et al. (2019) Messenger RNA modifications in plants. *Trends in Plant Science*, 24(4):328–41, DOI:10.1016/j.tplants.2019.01.005; McCutcheon, S.R., et al. (2024) Epigenome editing technologies for discovery and medicine. *Nature Biotechnology*, 42:1199–1217, DOI:10.1038/s41587-024-02320-1; Kungulovski, G. and Jeltsch, A. (2016) Epigenome editing: state of the art, concepts, and perspectives. *Trends in Genetics*, 32(2):101–13, DOI:10.1016/j.tig.2015.12.001.

Practicals (30 hours)

1. To investigate the phenotypic responses in the calcium signaling mutants.
2. To investigate the transactivation or transrepression activity of a transcription factor.
3. To design CRISPR guide RNA primers using online tools (e.g., CHOPCHOP, CRISPOR).
4. Molecular probe-based pathogen detection.
5. To design functional genomics approaches for specific gene/phenotype questions and compare the strengths and limitations of different methods.

Suggested Readings:

1. Kramer, L.M. (2015) *Signal Transduction*. 3rd edition, Academic Press, ISBN:9780123948199.
2. Heldin, C.H. and Purton, M. (1996) *Signal transduction: Modular texts in molecular and cell biology*, Chapman & Hall, ISBN:0412708108.
3. Alberts, B., et al. (2022) *Molecular Biology of the Cell*. 7th edition, W.W. Norton & Company, ISBN:9780393884630.
4. Buchanan, B.B., et al. (2015) *Biochemistry & Molecular Biology of the Plants*. 2nd edition, Wiley Blackwell, ISBN:9781118502198.
5. Kleinsmith, L.J. and Kish, V.M. (1997) *Principles of Cell & Molecular Biology*. Harper Collins College Publishers, ISBN:9780065004045.
6. Taiz, L., et al. (2023). *Plant Physiology and Development*. 7th edition, Sinauer Associates, ISBN:9780197614204.
7. Glick, B.R. and Pasternak, J.J. (2022) *Molecular Biotechnology: Principles and Applications of recombinant DNA*. 6th edition, ASM Press, ISBN:9781683673668.
8. Brown, T.A. (2023) *Genomes 5*. 5th edition, CRC Press, ISBN:9781003133162.
9. Piechulla, B. (2025) *Plant Biochemistry*. 6th edition, Academic Press, ISBN:9780443266164.
10. Abd-Elsalam, K.A. and Prasad, R. (2018) *Nanobiotechnology applications in plant protection*. Springer Cham, ISBN:9783319911601, DOI:10.1007/978-3-319-91161-8.
11. Chen, J.T. (2024) *Advanced Nanotechnology in Plants: Methods and Applications*. CRC Press, ISBN:9781003368571.
12. Jeltsch, A., and Rots, M.G. (2018) *Epigenome editing: Methods and Protocols*. Humana New York, ISBN:9781493977741, DOI:10.1007/978-1-4939-7774-1.
13. Jurga, S. and Barciszewski, J. (2021) *Epitranscriptomics*. Springer Cham, ISBN:9783030716127, DOI:10.1007/978-3-030-71612-7.
14. Online Databases and Resources: NCBI, TAIR, Phytozome, EnsemblPlants and others, KEGG, STRING, Gene Ontology, CRISPR-Cas toolkits and others.

PBSE335: Introduction to Bioinformatics

This course is open to students of other departments as a GE course.

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE335: Introduction to Bioinformatics	4	3	1	0	B.Sc. in any branch of science	NA

Learning Objectives

The paper is devised to introduce the students to the field of bioinformatics and data analysis. The content is designed for students from any stream of life sciences. The course imparts basic and essential knowledge regarding the nature of life science data, including data formats, international databases and data repositories. It also helps to understand how different biological file formats facilitate storage, retrieval and analysis of biological sequences and structures. Furthermore, the unit is designed to familiarize the learner with the landscape of major international nucleotide and protein databases, understanding their scope, interrelationships, and specific applications (universal and organism-specific databases). Additionally, understand the structure, interoperability, and collaborative role of INSDC, as well as its importance in maintaining the global genomic data ecosystem. Furthermore, it will explain the fundamental principles of local and global alignment (pairwise sequence comparison) and the biological rationale behind scoring systems, including substitution matrices and gap penalties. It also focuses on interpreting results of Clustal-W, Clustal Omega, T-Coffee, and MultiAlign BLAST tools and how to optimize their parameters to draw biologically meaningful conclusions. The last unit of the course presents the fundamentals of RNA/ Protein secondary and tertiary structure prediction. It will be helpful to learn the basic principles of docking analysis and drug design workflows.

Learning Outcomes

After successfully completing the course, students will be able to identify and describe various biological data formats and their respective applications. They will be able to access and retrieve sequences and structural data from major databases, data repositories, and browsers like UCSC Genome Browser, linking data formats to visual genomic analysis. Furthermore, students will be able to utilize tools like BLAST for sequence comparison and evolutionary significance, as well as understand the conceptual difference between various substitution matrices and pairwise algorithms. They can perform and interpret the MSA of different biological sequences using different computational software and also visualize phylogenetic trees using various algorithms. Upon completing the last unit, students will be able to use computational tools for RNA and protein prediction, evaluate them, and analyse protein-ligand interaction and outcomes of docking.

Course Content (45 hours)

Unit 1: Biological Data Formats and Databases -- Overview of database management system, concept of 'structured' and 'semi-structured/unstructured' data, concept of 'flat-file' formats; Various file formats used in bioinformatics such as 'fasta', 'fastq', Phylip format, Newick, PDB file format, 'GFF3', SAM/BAM/CRAM formats; Universal nucleotide data repositories: NCBI-GenBank, EMBL-ENA, DDBJ; Details of the International Nucleotide Sequence Data Collaboration (INSDC); Universal Protein databases: UniprotKB, PDB. Organism specific databases (Flybase, Wormbase etc), UCSC Human Genome Browser; Molecular interaction databases such as KEGG and STRING. **10 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 1 (Historical Introduction and Overview), Chapter 2 (Collecting and Storing Sequences in the Laboratory); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 1 (The nucleic world) and chapter 3 (Dealing with databases); Sayers, E.W., et al. (2022) Database resources of the National Center for Biotechnology Information. Nucleic Acids Research, 50(D1):D20–D26, DOI:10.1093/nar/gkab1112; Cochrane, G., et al. (2016). The European Nucleotide Archive in 2016. Nucleic Acids Research, 44(D1):D32–D37, DOI:10.1093/nar/gkw1106; The UniProt Consortium (2023) UniProt: the Universal Protein Knowledgebase in 2023. Nucleic Acids Research, 51(D1):D523–D531, DOI:10.1093/nar/gkac1052; Berman, H.M., et al. (2000) The Protein Data Bank. Nucleic Acids Research, 28(1):235–242, DOI:10.1093/nar/28.1.235; Li, H., et al. (2009) The Sequence Alignment/Map format and SAMtools. Bioinformatics, 25(16):2078–2079, DOI:10.1093/bioinformatics/btp352; Cock, P.J.A., et al. (2010) The Sanger FASTQ file format for sequences with quality scores, and the Solexa/Illumina FASTQ variants. Nucleic Acids Research, 38(6):1767–1771, DOI:10.1093/nar/gkp1137; Kanehisa, M., et al. (2023) KEGG for taxonomy-based analysis of pathways and genomes. Nucleic Acids Research, 51(D1):D587–D592, DOI:10.1093/nar/gkac997; Szklarczyk, D., et al. (2023) The STRING database in 2023: protein–protein association networks and functional enrichment analyses for any sequenced genome. Nucleic Acids Research, 51(D1):D638–D646, DOI:10.1093/nar/gkac1000; The FlyBase Consortium. (2022). FlyBase: updates to the *Drosophila melanogaster* knowledge base. Nucleic Acids Research, 50(D1):D1014–D1020, DOI:10.1093/nar/gkab1099; Haeussler, M., et al. (2019) The UCSC Genome Browser database: 2019 update. Nucleic Acids Research, 47(D1):D853–D858, DOI:10.1093/nar/gky1095.

Unit 2: Pairwise Sequence Alignment -- Concept of local and global sequence alignment; Pairwise sequence alignment algorithms such as Needleman and Wunsch, Smith-Waterman, scoring an alignment, linear and affine gap penalty, amino acid substitution scoring matrices (PAM and BLOSUM); Sequence alignment-based database search, BLAST and its variants, BLAST parameters (word size, E-value, scoring scheme, gap-penalty), bit/raw score. **10 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 3 (Alignment of pairs of sequences), Chapter 6 (Sequence database searching for similar sequences); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 4 (Producing and analyzing sequence alignments), Chapter 5 (Pairwise sequence alignment and database searching); Morrison, D.A. (2006). Multiple sequence alignment for phylogenetic purposes. Australian Systematic Botany, 19(6):479–539, DOI:10.1071/SB06020.

Unit 3: Multiple Sequence Alignment and Phylogenetic Analysis -- Global and local multiple sequence alignment, multiple sequence alignment algorithms (progressive and iterative algorithms), profile and block analysis; Softwares: Clustal-X, Clustal-W, Clustal-Omega, T-Coffee, MultiAlign; Basic concept of phylogenetic analysis, rooted and unrooted trees, approaches for phylogenetic tree construction; Basics of algorithm for UPGMA, neighbour joining (NJ), maximum parsimony, and maximum likelihood phylogenetic analysis. **15 hours**

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 5 (Multiple sequence alignment), Chapter 7 (Phylogenetic prediction); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 4 (Producing and analyzing sequence alignments), Chapter 5 (Pairwise sequence alignment and database searching), Chapter 6 (Patterns, profiles, and multiple alignments).

Unit 4: Structure Predictions for Nucleic Acids and Proteins -- Approaches for prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models; Basic approaches for protein structure predictions, comparative modeling, fold recognition/‘threading’, and *ab-initio* prediction; Introduction to AlfaFold database; Docking analysis and drug designing. 10 hours

Essential Readings: Mount, D.W. (2004) Bioinformatics: Sequence and Genome Analysis. 2nd edition, Cold Spring Harbor Laboratory Press, ISBN:9780879697129, Chapter 8 (Prediction of RNA secondary structure), Chapter 10 (Protein classification and structure prediction); Zvelebil, M. and Baum, J.O. (2008) Understanding Bioinformatics. Garland Science, ISBN:9780815340249, Chapter 8 (Recovering evolutionary history), Chapter 11 (Obtaining secondary structure from sequence), Chapter 12 (Predicting secondary structures).

Tutorials (15 hours)

1. To perform ‘text-based’ database search.
2. Sequence alignment-based database search.
3. Multiple sequence alignment and phylogenetic analysis.
4. Analysis of gene/protein interaction networks.

Suggested Readings:

1. Baxevanis, A.D., et al. (2020) Bioinformatics: A practical guide to the analysis of genes and proteins. 4th edition. John Wiley & Sons, Inc., ISBN:9781119335962.
2. Tramontano, A. (2018) Introduction to Bioinformatics. Chapman and Hall/CRC, ISBN:9781315276014, DOI:10.1201/9781420010886.
3. Lee, E. Tan, T.W. (2018) Beginners guide to bioinformatics for high throughput sequencing. World Scientific, ISBN:9789813231665, DOI:10.1142/10720.
4. Thompson, J.D., et al. (1994) CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice. Nucleic Acids Research, 22(22):4673–4680, DOI:10.1093/nar/22.22.4673.
5. Notredame, C., et al., (2000) T-Coffee: A novel method for fast and accurate multiple sequence alignment. Journal of Molecular Biology, 302(1):205–217, DOI:10.1006/jmbi.2000.4042.
6. Saitou, N. and Nei, M. (1987) The neighbor-joining method: a new method for reconstructing phylogenetic trees. Molecular Biology and Evolution, 4(4):406–425, DOI:10.1093/oxfordjournals.molbev.a040454.
7. Felsenstein, J. (1981) Evolutionary trees from DNA sequences: a maximum likelihood approach. Journal of Molecular Evolution, 17(6):368–376, DOI:10.1007/BF01734359.
8. JJumper, J., et al. (2021) Highly accurate protein structure prediction with AlphaFold2. Nature, 596:583–589, DOI:10.1038/s41586-021-03819-2.
9. Zhang, Y. (2008) Progress and challenges in protein structure prediction. Current Opinion in Structural Biology, 18(3):342–348, DOI:10.1016/j.sbi.2008.02.004.
10. Kryshchuk, A., et al. (2021) Critical assessment of methods of protein structure prediction (CASP)—Round XIV. Proteins: Structure, Function, and Bioinformatics, 89(12):1607–1617, DOI:10.1002/prot.26237.
11. Zuker, M. (2003) Mfold web server for nucleic acid folding and hybridization prediction. Nucleic Acids Research, 31(13):3406–3415, DOI:10.1093/nar/gkg595.
12. Kitchen, D.B., et al. (2004) Docking and scoring in virtual screening for drug discovery: methods and applications. Nature Reviews Drug Discovery, 3(11):935–949, DOI:10.1038/nrd1549.

PBRM332: Advanced Research Methodology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBRM332: Advanced Research Methodology	2	1	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to provide students with an in-depth conceptual understanding of advanced research methodologies applied in molecular plant sciences. It emphasizes experimental design, interpretation, and analysis in the context of gene function, regulatory networks, and crop improvement. The course also aims to establish a solid foundation for critically evaluating experimental data, formulating hypotheses, and communicating scientific findings in plant biology research.

Learning Outcomes

Upon successful completion of this course, students will develop a comprehensive understanding of advanced research methodologies in plant molecular biology. They will be able to conceptualize and design theoretical frameworks for gene function analysis, regulatory network mapping, and crop improvement experiments. Students will gain the ability to integrate bioinformatics insights with molecular and genetic approaches to interpret gene and protein functions. Furthermore, they will gain an understanding of the conceptual underpinnings of genome editing, regulatory pathway analysis, and experimental data validation. The course will enhance their skills in critical thinking and experimental design in plant molecular biology research.

Course Content (15 hours)

Unit 1: Experimental Design for Gene Function Analysis -- Experimental frameworks for dissecting gene function and regulatory cascade in plants; Conceptual foundations of gene/protein function prediction, principles of homology, conserved domain identification, integration networks and database search; Principles of experimental design for gene over-expression and knock-out/knock-down studies, mutant analysis, and genetic mapping; Protein localization studies; Elucidation of genetic regulatory cascades. **10 hours**

Essential Readings: Robles, J.A., et al. (2012) Efficient experimental design and analysis strategies for the detection of differential expression using RNA-Sequencing. *BMC Genomics*, 13:484, DOI:10.1186/1471-2164-13-484; Grondin, A., et al. (2024) A case study from the overexpression of OsTZF5, encoding a CCCH tandem zinc finger protein, in rice plants across nineteen yield trials. *Rice*, 17(1):25, DOI:10.1186/s12284-024-00705-z; Tang, M., et al. (2021) A genome-scale TF–DNA interaction network of transcriptional regulation of *Arabidopsis* primary and specialized metabolism. *Molecular Systems Biology*, 17(11):e10625, DOI:10.15252/msb.202110625; <https://www.goldenhelix.com/blog/stop-ignoring-experimental-design-or-my-head-will-explode/>; <https://www.ncbi.nlm.nih.gov/books/NBK26818/>; Wagner, M.R., and Kleiner, M. (2025) How thoughtful experimental design can empower biologists in the omics era. *Nature Communications*, 16(1):7263, DOI:10.1038/s41467-025-62616-x; Boadu, F., (2025) Deep learning methods for protein function prediction. *Proteomics*, 25(1-2):e2300471, DOI:10.1002/pmic.202300471; Goodin, M.M. (2018) Advances in virus research. 100:117-144, DOI:10.1016/bs.aivir.2017.10.004, Chapter 6 (Protein localization and interaction studies in plants: Toward defining complete proteomes by visualization).

Unit 2: Experimental Frameworks for Crop Improvement by Genome Editing --

Experimental frameworks for designing molecular and genetic strategies for crop improvement; CRISPR-based strategies for gain-of-function and loss-of-function of genes for enhanced agronomic traits; Validation of transgene-free plants, Field trials and regulations regarding the release of genome-edited crops. 5 hours

Essential Readings: Graham, D.B. and Root, D.E. (2015) Resources for the design of CRISPR gene editing experiments. *Genome Biology*, 16:260, DOI:10.1186/s13059-015-0823-x; Zhou, J., et al. (2023) An efficient CRISPR–Cas12a promoter editing system for crop improvement. *Nature Plants*, 9(4):588–604, DOI:10.1038/s41477-023-01384-2; Han, X., et al. (2025) Genetic engineering, including genome editing, for enhancing broad-spectrum disease resistance in crops. *Plant Communications*, 6(2):101195, DOI:10.1016/j.xplc.2024.101195; Hanna, R.E. and Doench, J.G. (2020) Design and analysis of CRISPR-Cas experiments. *Nature Biotechnology*, 38(7):813–823, DOI:10.1038/s41587-020-0490-7.

Practicals (30 hours)

1. Analysis of conserved protein motifs using WebLogo and interpreting functional domains of a protein family.
2. Development of transgenic hairy roots using RNAi or promoter–*uidA* binary vector constructs.
3. Analysis of stress-induced promoter activity *in planta* using non-destructive methods.
4. *In silico* design of a vector for transgene-free plant genome editing using TnpB.
5. Design and application of CAPS/dCAPS markers to identify and validate single base substitutions or targeted genome edits.

Suggested Readings:

1. Buchanan, B.B. et al. (2015) *Biochemistry and molecular biology of the plants*. 2nd edition, WILEY Blackwell, ISBN:9780470714218.
2. Singh, P.P., and Benayoun, B.A. (2023) Considerations for reproducible omics in aging research. *Nature Aging*, 3(8):921–930, DOI:10.1038/s43587-023-00448-4;
3. Conesa, A., et al. (2016) A survey of best practices for RNA-seq data analysis. *Genome Biology*, 17:13, DOI:10.1186/s13059-016-0881-8.
4. Haas, R., et al. (2017) Designing and interpreting 'multi-omic' experiments that may change our understanding of biology. *Current Opinion in Systems Biology*, 6:37–45, DOI:10.1016/j.coisb.2017.08.009.
5. Strotmann, V.I. and Stahl, Y. (2022) Visualization of *in vivo* protein-protein interactions in plants. *Journal of Experimental Botany*, 73(12):3866–3880, DOI:10.1093/jxb/erac139.
6. Quattrocchio, F.M., et al. (2013) Transgenes and protein localization: myths and legends. *Trends in Plant Science*, 18(9):473–476, DOI:10.1016/j.tplants.2013.07.003.
7. Lichocka, M. and Schmelzer, E. (2014) Subcellular localization experiments and FRET-FLIM measurements in plants. *Bio-Protocol*, 4(1):e1018, DOI:10.21769/BioProtoc.1018.
8. Zhang, Y., et al. (2023) Investigating the dynamics of protein-protein interactions in plants. *The Plant Journal*, 114(4):965–983, DOI:10.1111/tpj.16182.
9. Teng, C. (2024) Killing two birds with one stone: A breakthrough in transgene-free gene editing in soybean. *Plant Physiology*, 196(4):2263–2265, DOI:10.1093/plphys/kiae526.
10. Riccroch, A., et al. (2024) Worldwide study on field trials of biotechnological crops: new promises but old policy hurdles. *Frontiers in Plant Science*, 15:1452767, DOI:10.3389/fpls.2024.1452767.
11. https://dbtindia.gov.in/sites/default/files/Final_%2011052022_Annexure-1%2C%20Genome_Edited_Plants_2022_Hyperlink.pdf

PBRM333: Emerging Techniques in Plant Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBRM333: Emerging Techniques in Plant Biology	2	1	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The objective of this paper is to familiarize students with the latest advancements and methodologies in the field. The course offers insight into diverse imaging approaches and methodologies used to study plant systems at the cellular level. This course provides an in-depth understanding of emerging and state-of-the-art techniques used in contemporary research and applications.

Learning Outcomes

Students would acquire specific practical skills regarding various sample preparations and imaging techniques, which are essential for conducting advanced plant science research. They will acquire knowledge of the principles and applications of cutting-edge techniques relevant to modern research and innovation, and will learn to apply appropriate state-of-the-art tools and technologies to investigate complex scientific problems.

Course Content (15 hours)

Unit 1: Imaging Techniques -- Fundamental principles of microscope design, image formation, magnification, numerical aperture, resolution, and contrast; Components and optics of light microscopy; Transmitted light techniques: bright-field, phase contrast, and DIC; Fundamentals of fluorescence, excitation-emission principles, fluorescent probes and biosensors, photobleaching, and quenching; Confocal laser scanning microscopy–optical sectioning, Z-stack reconstruction, and 3D imaging, super-resolution microscopy (STED, SIM, PALM/STORM), and cryo-electron microscopy (Cryo-EM); Digital image recording, cameras, signal-to-noise ratio, and quantitative image analysis; Applications in plant cell and developmental biology using fluorescence-based imaging approaches. **7.5 hours**

Essential Readings: Murphy, D.B. and Davidson, M.W. (2012) Fundamentals of light microscopy and electronic imaging, 2nd edition, Wiley-Blackwell, ISBN:9781118382905, Chapter 1 (Introduction to Microscopy), Chapter 2 (The Optical Microscope), Chapter 3 (Image Formation in the Microscope), Chapter 4 (Fluorescence Microscopy): Principles, Chapter 5 (Fluorescence Microscopy: Instrumentation), Chapter 6 (Digital Imaging Fundamentals), Chapter 9 (Confocal Microscopy), Chapter 13 (Electron Microscopy Fundamentals); Huang, B., et al. (2009) Super-resolution fluorescence microscopy. Annual Review of Biochemistry, 78:993–1016, DOI: 10.1146/annurev.biochem.77.061906.092014; Nogales, E. and Scheres, S.H.W. (2015) Cryo-EM: A unique tool for the visualization of macromolecular complexity. Molecular Cell, 58:677–689, DOI: 10.1016/j.molcel.2015.02.019.

Unit 2: Single Cell Biology -- Isolation and handling of single cells: Fluorescence-activated cell sorting (FACS); Microfluidics, Laser Capture Microdissection (LCM); Single-cell multi-omics analysis: Single-cell genomics (scDNA-seq), transcriptomics (scRNA-seq), proteomics (scProteomics), metabolomics (scMetabolomics); Multi-omics integration; Temporal and Spatial analysis: Spatial Transcriptomics, *in situ* subcellular localization of a metabolite;

Chromosomal immunostaining; Applications of single cell biology in plant molecular biology.

7.5 hours

Essential Readings: Hu, P., et al. (2016) Single cell isolation and analysis. *Frontiers in Cell and Developmental Biology*, 4:116, DOI:10.3389/fcell.2016.00116; Wang, D. and Bodovitz, S. (2010) Single-cell analysis: the new frontier in 'omics'. *Trends in Biotechnology*, 28(6):281–290, DOI:10.1016/j.tibtech.2010.03.002; Jackson, C.A., et al. (2022) New horizons in the stormy sea of multimodal single-cell data integration *Molecular Cell*, 82(2):248–259, DOI:10.1016/j.molcel.2021.12.012; Rahman, M.S., et al. (2024) Opportunities and challenges in advancing plant research with single-cell omics. *Genomics, Proteomics & Bioinformatics*, 22(2):qzae026, DOI:10.1093/gpbjnl/qzae026; Clark, N.M., et al. (2022) To the proteome and beyond: advances in single-cell omics profiling for plant systems. *Plant Physiology*, 188(2):726–737, DOI:10.1093/plphys/kiab429; Nobori, T. (2025) Exploring the untapped potential of single-cell and spatial omics in plant biology. *The New Phytologist*, 247(3):1098, DOI:10.1111/nph.70220; Chau, T.N., et al. (2024) Advancing plant single-cell genomics with foundation models. *Current Opinion in Plant Biology*, 82:102666, DOI:10.1016/j.pbi.2024.102666.

Practicals (30 hours)

1. To visualize a living plant specimen using bright-field, phase contrast, and (if available) DIC, and understand how each enhances different features.
2. Preparation of publication-quality microscopy figures: Brightfield–Fluorescence overlays and scale bars.
3. To navigate and annotate multi-dimensional images for preparing a figure using Image J.
4. Data analysis of targeted metabolite profiling.
5. Analysis of cell cycle stages using FACS.

Suggested Readings:

1. Wu, X., et al. (2024) Single-cell sequencing to multi-omics: technologies and applications. *Biomarker Research*, 12:110, DOI:10.1186/s40364-024-00643-4.
2. Zhu, M., et al. (2025) Single-cell transcriptomics reveal how root tissues adapt to soil stress. *Nature*, 642:721–729, DOI:10.1038/s41586-025-08941-z.
3. Lee, T.A., et al. (2025) A single-cell, spatial transcriptomic atlas of the *Arabidopsis* life cycle. *Nature Plants*, 11:1960–75, DOI:10.1038/s41477-025-02072-z.
4. Cold Spring Harbour Protocols- Imaging/Microscopy, general weblink: (https://cshprotocols.cshlp.org/cgi/collection/imaging_microscopy_general)
5. Paddock, S.W. (2014) *Confocal Microscopy: Methods and Protocols*. Humana New York, NY, eISBN:9781607618478, DOI:10.1007/978-1-60761-847-8.
6. Ruzin, S.E. (1999) *Plant Microtechnique and Microscopy*. Oxford University Press, USA, ISBN:9780195089561.
7. Pawley, J.B. (2006) *Handbook of Biological Confocal Microscopy*. 3rd edition, Springer New York, NY, ISBN:9780387455242, DOI:10.1007/978-0-387-45524-2.
8. Markaki, Y. and Harz, H. (2017) *Light microscopy: Methods and Protocols*. Humana New York, NY, DOI:10.1007/978-1-4939-6810-7.
9. Yin, Z. et al. (2023) Mass spectrometry imaging techniques: a versatile toolbox for plant metabolomics. *Trends in Plant Science*, 289(2):250–251, DOI:10.1016/j.tplants.2022.10.009.
10. Pawlowski, W.P., et al. (2013) *Plant Meiosis: Methods and Protocols*. Humana Totowa, NJ, Chapter (Immunolocalization of meiotic proteins in *Brassicaceae*: method 1), ISBN:9781627033336, DOI:10.1007/978-1-62703-333-6_9.
11. Petrova, B. and Guler, A.T. (2025) Recent developments in single-cell metabolomics by mass Spectrometry- A perspective. *Journal of Proteome Research*, 24(4):1493–1518, DOI:10.1021/acs.jproteome.4c00646.
12. Shaw, R., et al. (2021) Single-cell transcriptome analysis in plants: advances and challenges. *Molecular Plant*, 14(1):115–126, DOI:10.1016/j.molp.2020.10.012.

PBRE336: Dissertation-I

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBRE336: Dissertation-I	6	0	0	6	B.Sc. in any branch of science	NA

Learning Objectives

The students will identify and select a relevant research problem in consultation with the faculty members, ensuring alignment with current advances in Plant Molecular Biology and Biotechnology. They will conduct a thorough and critical appraisal of the existing literature on the problem, enabling them to understand the depth of current knowledge. Students will learn to formulate well-defined research questions and develop testable hypotheses in the context of scientific reasoning. Under faculty mentorship, they will design an experimentally feasible and scientifically structured research plan, complete with realistic timelines, appropriate methodologies, and anticipated outcomes. In addition, the students will gain training in scientific writing through preparation of a detailed literature review, and they will enhance their communication skills by effectively presenting and discussing their research survey in laboratory group discussions and structured oral presentations.

Learning Outcomes

Upon successful completion of the course, the student will be able to independently conduct a comprehensive survey of scientific literature and critically analyse it to identify significant knowledge gaps within the research field. They will demonstrate the ability to justify the importance and relevance of selected research problems using evidence-based reasoning. Students will prepare a well-structured synopsis that includes an in-depth literature review, clearly articulated research questions, hypotheses, and a coherent experimental plan to be executed in Semester 4. Additionally, they will acquire proficiency in scientific writing, including organization, clarity, and synthesis of complex information, and will develop strong oral communication skills necessary for presenting research findings and engaging in scientific discourse. Overall, the students will hone their ability to think independently, plan research systematically, and communicate their work confidently in both written and verbal formats.

Suggested Readings:

1. Latest research and review articles from scientific journals and book chapters on a chosen research problem.

SEMESTER 4

PBSE433: Epigenetics and Small RNA Biology

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBSE433: Epigenetics and Small RNA Biology	4	3	0	1	B.Sc. in any branch of science	NA

Learning Objectives

The epigenetic landscape (including both DNA methylation and histone modifications) of an organism has a significant bearing in regulating various developmental and metabolic processes at the global level. Similarly, small RNAs (sRNAs) have emerged as major modulators of global gene expression patterns. Therefore, this course is designed to provide students with a clear understanding of key epigenetic mechanisms, including chromatin modeling, DNA methylation, and histone modifications, and how these processes regulate plant development and physiology. Students will learn how epigenetic regulation contributes to environmental responses, stress adaptation, and inheritance, as well as its relevance in human systems, including immunity, cancer, and cardiovascular diseases. The course also introduces the diversity, biogenesis, and regulatory roles of non-coding RNAs across organisms, including their mechanisms of action and trans-kingdom interactions. Additionally, students will become familiar with experimental and computational tools for detecting, predicting, and validating small RNAs, and will explore the applications of RNA-based technologies and CRISPR-Cas systems in crop improvement, diagnostics, and therapeutic development.

Learning Outcomes

By the end of this course, students will be able to understand major epigenetic mechanisms and evaluate their roles in plant development, environmental responses, and human diseases. They will be able to understand DNA methylation and histone modifications, classify non-coding RNAs, and describe how small RNAs regulate gene expression. Students will also be equipped to use molecular and bioinformatic approaches for small RNA analyses and apply RNA-based tools. Overall, they will be able to integrate epigenetics and small RNA biology concepts to address research problems and understand their practical applications in agriculture, biotechnology, and human health.

Course Content (45 hours)

Unit 1: Epigenetic Regulation -- Chromatin modeling and remodeling: polycomb complexes, SWI/SNF1 complexes and other chromatin modifiers; DNA methylation and its interpretation: methylated DNA-binding proteins, their structure and function; techniques of altering and analyzing DNA methylation; Histone modifications: types, modifying enzymes, histone deacetylase inhibitors; Chromatin modification and its influence on plant development: somatic embryogenesis, leaf development, photosynthesis, flowering, and ageing. **12 hours**

Essential Readings: Jenuwein, T. and Allis, C.D. (2001) Translating the histone code. *Science*, 293(5532):1074-1080, DOI:10.1126/science.1063127; Zhang, H., et al. (2018). Dynamics and function of DNA methylation in plants. *Nature Reviews Molecular Cell Biology*, 19(8):489-506, DOI:10.1038/s41580-018-0016-z; Rajewsky, N., et al. (2018) *Plant epigenetics*. Springer International, ISBN:9783319555195, DOI:10.1007/978-3-319-55520-1; Huang, Y., et al., (2025) Chromatin remodeling in plants: Complex composition, mechanistic diversity, and biological functions. *Molecular Plant*, 18(9):1436–1457, DOI:10.1016/j.molp.2025.08.004.

Unit 2: Environmental and Evolutionary Epigenetics -- Role of epigenetic regulation in plant stress responses and epigenetic memory; Epigenetic inheritance and adaptive responses to environmental cues; Epigenetics in human systems: regulation of immune responses, cancer, and cardiovascular diseases. 10 hours

Essential Readings: Chinnusamy, V. and Zhu, J.K. (2009) Epigenetic regulation of stress responses in plants. *Current Opinion in Plant Biology*, 12(2):133–139, DOI:10.1016/j.pbi.2008.12.006; Avramova, Z. (2015) Transcriptional ‘memory’ of a stress: transient chromatin and memory (epigenetic) marks at stress-response genes. *The Plant Journal*, 83(1):149–159, DOI:10.1111/tbj.12832; Ma, L., et al., (2025) Epigenetic control of plant abiotic stress responses. *Journal of Genetics and Genomics*, 52(2):129–44, DOI:10.1016/j.jgg.2024.09.008; Janson, P.C. and Winqvist, O. (2011) Epigenetics—the key to understand immune responses in health and disease. *American Journal of Reproductive Immunology*, 66:72–74, DOI:10.1111/j.1600-0897.2011.01050.x; Zoghbi, H.Y. and Beaudet, A.L. (2016) Epigenetics and human disease. *Cold Spring Harbor Perspectives in Biology*, 8(2): a019497, DOI:10.1101/cshperspect.a019497.

Unit 3: Biology of Non-coding RNAs -- Discovery, types, occurrence, and diversity of non-coding RNAs; Small RNA pathways in bacteria, plants, and animal systems; Biogenesis and functional components of different classes of small RNAs; Regulation of gene expression by small RNAs: transcriptional gene silencing (TGS), post-transcriptional gene silencing (PTGS), gene activation, and evolutionary transitions in RNA-target interactions; Functional roles of small RNAs in different organisms; Trans-kingdom cross-talk mediated by small RNAs. 13 hours

Essential Readings: Guleria, P. and Kumar, V. (2020) *Plant Small RNA- Biogenesis, Regulation and Application*. Academic Press, ISBN:9780128171127, DOI:10.1016/C2018-0-01900-3; Alquethamy S., et al. (2025). What makes a small RNA work. *Nucleic Acids Research*, 53(12):gkaf563, DOI:10.1093/nar/gkaf563; Mattick, J. and Amaral, P. (2022) *RNA, the epicenter of genetic information*. ISBN:9781003109242, CRC Press, DOI:10.1201/9781003109242; Wierzbiki, A.T., et al. (2021) Long non-coding RNAs in plants. *Annual Review of Plant Biology*, 72:245–271, DOI:10.1146/annurev-arplant-093020-035446; Zhan, J. and Meyers, B.C. (2023) Plant small RNAs: their biogenesis, Regulatory roles, and functions. *Annual Review of Plant Biology*, 74:21–51, DOI:10.1146/annurev-arplant-070122-035226; Barquist, L. and Vogel, J. (2015) Accelerating discovery and functional analysis of small RNAs with new technologies. *Annual Review of Genetics*, 49:367–394, DOI:10.1146/annurev-genet-112414-054804.

Unit 4: Tools, Applications, and Emerging Technologies -- Discovery, detection, and validation of small RNAs; Target prediction and validation approaches; Databases and bioinformatic tools for small RNA analysis; Applications: artificial miRNA (amiR) technology, siRNA and virus-induced gene silencing (VIGS); RNAi interference (RNAi), RNA activation (RNAa), target mimicry and STTM technologies; CRISPR-Cas-based genome editing guided by small RNAs; Applications in crop improvement, diagnostics, and therapeutics. 10 hours

Essential Readings: Tang, G., et al. (2021) RNA-based technologies for functional genomics in plants. Springer Cham, ISBN:9783030649937, DOI:10.1007/978-3-030-64994-4; Ting, P., et al. (2018) A resource for inactivation of microRNAs using short tandem target mimic technology in model and crop plants. *Molecular Plant*, 11(11):1400–1417, DOI:10.1016/j.molp.2018.09.003; Halloy, F., et al. (2022) Innovative developments and emerging technologies in RNA therapeutics. *19(1):313–332*, DOI:10.1080/15476286.2022.2027150.

Practicals (30 hours)

1. To resolve and visualize low molecular weight RNAs by denaturing urea-PAGE.

2. To perform expression analysis of selected miRNAs using the quantitative PCR method.
3. To isolate, sonicate, and observe cross-linked chromatin to study histone modifications.
4. To enzymatically cleave and assess DNA to detect methylation patterns.
5. To predict and analyze the secondary structure and thermodynamic stability of the miRNA precursor sequence (pre-miRNA) using Mfold.

Suggested Readings:

1. Esteller, M. (2009) Epigenetics in biology and medicine. CRC Press, eISBN:9780429124921.
2. Workman, J.L. and Abmayr, S.M. (2014) Fundamentals of chromatin. Springer New York, ISBN:9781461486237, DOI:10.1007/978-1-4614-8624-4.
3. Dinkar, V., et al. (2024) Epigenetic regulations under plant stress: a cereals perspective. *Environmental and Experimental Botany*, 220:105688, DOI:10.1016/j.envexpbot.2024.105688.
4. He, L. (2025) The interplay between chromatin remodeling and DNA double-strand break repair: Implications for cancer biology and therapeutics. *DNA Repair*, 146:103811, DOI:10.1016/j.dnarep.2025.103811.
5. Muka, T., et al. (2016) The role of epigenetic modifications in cardiovascular disease: a systematic review. *International Journal of Cardiology*, 212:174–183, DOI:10.1016/j.ijcard.2016.03.062.
6. Mallick, B. and Ghosh, Z. (2012) Regulatory RNAs: Basics, Methods and Applications. Springer Berlin, Heidelberg, ISBN:9783642225161, DOI:10.1007/978-3-642-22517-8.
7. Nellan, W. and Hammann, C. (2007) Small RNAs: analysis and regulatory functions. Springer Berlin, Heidelberg, ISBN:9783540281306, DOI:10.1007/978-3-540-28130-6.
8. Gaur, R.K. and Rossi, J.J. (2009) Regulation of gene expression by small RNAs. CRC Press, USA, eISBN:9780429121692, DOI:10.1201/9781420008708.
9. Alquethamy, S., et al. (2025) What makes a small RNA work? *Nucleic Acids Research*, 53(12):gkaf563, DOI:10.1093/nar/gkaf563.
10. Rederstorff, M. (2021) Small non-coding RNAs: Methods and Protocols. Humana New York. eISBN:9781071613863, DOI:10.1007/978-1-0716-1386-3.

PBSE434: Data Analytics and Biocuration

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBSE434: Data Analytics and Biocuration	4	3	1	0	B.Sc. in any branch of science	

Learning Objectives

The paper aims to empower learners with foundational data analytics skills essential to modern bioinformatics by exposing them to the fundamentals of advanced operating systems, including the Linux command-line interface (CLI), file handling, permissions, and data manipulation. It also provides a brief exposure to the R programming environment, syntax, and functions for data analysis and packages available in the Bioconductor repository for statistical computing, data visualization, and genomic data analysis. It also provides a comprehensive overview of the primary computational workflows for analyzing next-generation sequencing (NGS) data. The learner will explore the concepts, applications, and key steps involved in major "big data" bioinformatics domains, including genome assembly, variant calling, pangenomics, metagenomics, transcriptomics (RNA-seq) and epigenomics (ChIP-seq, Bisulfite-seq). Besides, it also focuses on the behind-the-scenes work of biocuration that powers biological databases through processes of extracting, standardizing, and organizing biological data from literature and experiments. It provides an overview of BioDbCore, FAIRsharing, and ethical principles of open data management. The student will be able to interpret Gene Ontology and biomedical ontologies using OBO formats. In the last unit, there is a brief overview of foundational concepts in AI and machine learning (ML), along with the utility of domain-specific LLMs and their applications in genomics, drug design, and systems biology.

Learning Outcomes

The completion of the course will give expertise in essential Linux commands and in setting up and running 'R' scripts for statistical analysis and plotting. The learner can apply Bioconductor tools for biological data exploration, such as DESeq2, edgeR, and limma. Furthermore, students can analyse NGS data for variant calling, transcriptome quantification, and epigenomic data integration. They also now understand the FAIR data principles, ontologies, and the curation of biological data from published sources. Moreover, students can work with LLMs, ML, and AI tools across domains such as genomic prediction, phenotype classification, drug discovery, and structure-based screening.

Course Content (45 hours)

Unit 1: Basic of Linux and 'R' -- Computer architecture, types of operating systems (Windows, Mac-OS and Linux), concept of networking (IP address); Basic fundamentals of working with Unix/Linux on CLI (Command Line Interface), Unix/Linux directory structure, file permissions, remote login; Linux commands (whoami, pwd, cd, ls, man, mkdir, rm, cat copy, mv, chmod, grep, sed, sep, sort, head, tail, wc); Introduction to the 'R' data analysis

package, basic work environment, syntax, introduction to the ‘Bioconductor’ packages for data analysis. **15 hours**

Essential Readings: Blum, R. and Bresnahan, A. (2021) Linux Command Line and Shell Scripting Bible. 4th edition, John Wiley & Sons, Inc., ISBN:9781119700913; Kabacoff, R.I. (2022) R in action: Data analysis and graphics with R. 3rd edition, Manning Publications, ISBN:9781617296055; Gentleman, R.C., et al. (2004) Bioconductor: open software development for computational biology and bioinformatics. Genome Biology, 5:R80, DOI:10.1186/gb-2004-5-10-r80.

Unit 2: Big Data Analysis -- Whole genome reference-based assembly, de-novo genome analysis, variant call analysis, Pangenomes, Metagenomic analysis, RNA-seq data analysis, ChIP (Chromatin Immunoprecipitation) data analysis; Whole genome bisulphite sequencing data analysis. **10 hours**

Essential Readings: Compeau, P. and Pevzner, P. (2018) Bioinformatics algorithms: An active learning approach. 3rd edition, Active Learning Publishers, ISBN:9780990374633; Shendure, J. and Aiden, E.L. (2012) The expanding scope of DNA sequencing. Nature Biotechnology, 30(11):1084–1094, DOI:10.1038/nbt.2421; Conesa, A., et al. (2016) A survey of best practices for RNA-seq data analysis. Genome Biology, 17:13, DOI:10.1186/s13059-016-0881-8; Landt, S.G., et al. (2012) ChIP-seq guidelines and practices of the ENCODE and modENCODE consortia. Genome Research, 22(9):1813–31, DOI:10.1101/gr.136184.111.

Unit 3: Data Integration and Biocuration -- Overview of Biocuration, various approaches to biocuration, BioDbCore guidelines, FAIRsharing and ethics in data sharing, Text/Literature-based curation, text mining approaches, and an introduction to tools such as Textpresso. Basics and importance of ontology development, OBO (Open Biological and Biomedical Ontology) format, OBO foundry, biomedical and plant-based ontologies. **10 hours**

Essential Readings: Gaudet, P., et al. (2011) Towards BioDBcore: a community-defined information specification for biological databases. Nucleic Acids Research, 39(s1):D7–D10, DOI:10.1093/nar/gkq1173; Open Biological and Biomedical Ontology Foundry: Community development of interoperable ontologies for the biological sciences, <https://obofoundry.org/about-OBO-Foundry.html>; FAIRsharing: A curated, informative and educational resource on data and metadata standards, inter-related to databases and data policies, <https://fairsharing.org>, DOI:10.1038/s41587-019-0080-8; Howe, D., et al. (2008) The future of biocuration. Nature, 455:47–50, DOI:10.1038/455047a; Wilkinson, M.D., et al. (2016) The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data, 3:160018, DOI:10.1038/sdata.2016.18.

Unit 4: Artificial Intelligence in Life Sciences -- Introduction to Machine-Learning (ML) and Artificial Intelligence (AI); Supervised and un-supervised learning approaches in data integration, interpretation, and predictive modelling; Applications in genomic prediction, drug discovery, ecosystem modelling; Domain-specific Large Language Models (LLMs). **10 hours**

Essential Readings: Cannataro, M., et al. (2022) Artificial Intelligence in Bioinformatics: from omics analysis to deep learning and network mining, 1st edition, Elsevier, eISBN:9780128229293; Jumper, J., et al. (2021) Highly accurate protein structure prediction with AlphaFold. Nature, 596:583–589, DOI:10.1038/s41586-021-03819-2.

Tutorials (15 hours)

1. Practice of working with Linux commands on the Command Line Interface (CLI).
2. Analysis of RNA-seq data:
 - a. Quality and adapter trimming of Next Generation Sequencing (NGS) data.
 - b. Reference-based genome mapping of NGS data.
 - c. Identification of differentially expressed genes.
3. Use of Gene Ontology for gene function analysis.

Suggested Readings:

1. Bessant, C., et al. (2014) Building bioinformatics solutions with Perl, R, and SQL. 2nd edition, Oxford University Press, UK, ISBN:978019965855.
2. Buffalo, V. (2015) Bioinformatics data skills: Reproducible and robust research with open-source tools. O'Reilley Media, ISBN:9781449367374.
3. Quince, C., et al. (2017) Shotgun metagenomics, from sampling to analysis. *Nature Biotechnology*, 35(9):833–844, DOI:10.1038/nbt.3935.
4. Sansone, S.A., et al. (2019) FAIRsharing as a community approach to standards, repositories and policies, *Nature Biotechnology*, 37(4):358–367, DOI:10.1038/s41587-019-0080-8.
5. Smith, B., et al. (2007) The OBO Foundry: coordinated evolution of ontologies to support biomedical data integration, *Nature Biotechnology*, 25(11):1251–1255, DOI:10.1038/nbt1346.
6. Müller, H.M., et al. (2018) Textpresso Central: a customizable platform for searching, text mining, viewing, and curating biological literature. *BMC Bioinformatics*, 19:94, DOI:10.1186/s12859-018-2103-8.
7. Web link: www.bioconductor.org
8. Web link: www.obofoundry.org; www.oboedit.org
9. Web link: www.biocuration.org

PBRM431: Research Presentation and Communication

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/Lecture	Tutorial	Practical		
PBRM431: Research Presentation and Communication	2	1	0	1	B.Sc. in any branch of science	NA

Learning Objectives

This course aims to outline the key principles and approaches in science communication. The course will blend theoretical insights with practical exercises to ensure that learners are prepared for the real-world challenges of science communication. The curriculum is structured to ensure that students gain the skills needed to communicate science accurately, compellingly, and responsibly.

Learning Outcomes

This course equips students with the skills to effectively communicate scientific concepts to diverse groups of audiences including experts as well as non-experts in the field. Students will learn to craft clear, engaging, and accurate messages and interact confidently with the media. They will learn to apply effective visual and verbal communication strategies to enhance the impact of the message and will also understand the role of science in society, policy, and public engagement.

Course Content (15 hours)

Unit 1: Foundations of Effective Science Communication -- Key principles of Science Communication (clarity, simplicity, accuracy, and engagement); History and evolution of science communication; Role of Science in Society (science policy, public perception, and media; Importance of science communication in shaping public understanding and policy), audience analysis, role of visuals in enhancing understanding (e.g., graphs, infographics, videos), evaluating the impact of Science Communication; Ethics in Science Communication.

7.5 hours

Essential Readings: National Academies of Sciences, Engineering, and Medicine (2017). Communicating Science Effectively: A Research Agenda. Washington, DC: National Academies Press, ISBN:0309451035, DOI:10.17226/23674, Chapter 1 (Using science to improve science communication), Chapter 2 (The complexities of communicating science), Chapter 3 (The nature of science-related public controversies), Chapter 4 (Communicating science in a complex, competitive communication environment); Bucchi, M. and Trench, B. (2021) Routledge handbook of public communication of science and technology. 3rd edition, Routledge, ISBN:9781003039242, Chapter 1 (Introduction: science communication as the social conversation around science), Chapter 9 (Risk, science and public communication: Third-order thinking about scientific culture).

Unit 2: Writing and Oral Communication -- Scientific and Technical Writing (scientific articles, thesis, project report, and research proposal, abstracts, preparing CVs, and research statements), Popular Science Writing; Presentation Skills (infographics, animation and slide design and organization); Public Speaking, Q&A Management; Digital Media and Social

Media in Science Communication: Science Blogging, Creative Video Production, Science Journalism, Science Communication for Crisis Management. **7.5 hours**

Essential Readings: Hofmann, A.H. (2022) Scientific writing and communication. 5th edition, Oxford University Press, ISBN:9780197613795; Okwemba, R.K. (2022) Introduction to scientific writing A Review. International Journal of Scientific Research in Science and Technology, 9(1):56–63, DOI:10.32628/IJSRST218631; Vogel, W.H. and Viale, P.H. (2018) Presenting with confidence. Journal of the Advanced Practitioner in Oncology, 9(5):545–548, DOI:10.6004/jadpro.2018.9.5.9; Wallwork, A. and Southern, A. (2020) 100 Tips to avoid mistakes in academic writing and presenting. Springer Cham, eISBN:9783030442149, DOI:10.1007/978-3-030-44214-9, Chapter 9 (Presentations); Traboco, L., et al. (2022) Designing infographics: visual representations for enhancing education, communication, and scientific research. Journal of Korean Medical Science, 37(27):e214, DOI:10.3346/jkms.2022.37.e214; Wang, Y., et al. (2021) Animated presentation of static infographics with InfoMotion. Computer Graphics Forum, 40(3):507–518, DOI:10.1111/cgf.14325; León, B. and Bourk, M. (2018) Communicating science and technology through online video. Routledge, eISBN:9781351054584, DOI:10.4324/9781351054584, Chapter 3 (Producing science online video, by Erviti, M.C.); Bucchi, M. and Trench, B. (2021) Routledge handbook of public communication of science and technology. Routledge, eISBN:9781003039242, DOI:10.4324/9781003039242, Chapter 2 (Science journalism); Vadapalli, R., et al. (2018) Sci-Blogger: A step towards automated science journalism. Proceedings of the 27th ACM International Conference on Information and Knowledge Management, 1787–90, DOI: 10.1145/3269206.3269303.

Practicals (30 hours)

1. Conceptualization, designing, and assembly of a scientific poster presenting research objectives, methodology, results, and conclusions.
2. To design and develop a documentary-style video presenting the mission, key projects, and scientific contributions of a research group.
3. To prepare and publish a science blog.

Suggested Readings:

1. van Dam, F., et al. (2020) Science Communication- An Introduction. World Scientific, ISBN:9789811209871, DOI:10.1142/11541.
2. Kim, Y.S.G., et al. (2025) The science of teaching reading is incomplete without the science of writing: A randomized control trial of integrated teaching of reading and writing. Scientific Studies of Reading, 29(1):32–54, DOI:10.1080/10888438.2024.2380272.
3. Bowater, L. and Yeoman, K. (2012) Science communication: A practical guide for scientists. Wiley-Blackwell, ISBN:978111840666-3.
4. Plaxco, K.W. (2010) The art of writing science. Protein Science, 19(12):2261–66, DOI: 10.1002/pro.514.
5. Adair, J. (2011) John Adair's 100 Greatest Ideas for Brilliant Communication. John Wiley & Sons, ISBN:9780857082244.
6. Bewersdorff, A., et al. (2025) Taking the next step with generative artificial intelligence: The transformative role of multimodal large language models in science education. Learning and Individual Differences, 118:102601, DOI:10.1016/j.lindif.2024.102601.
7. Monavarian, M. (2021) Basics of scientific and technical writing. MRS Bulletin, 46:284–286, DOI:10.1557/s43577-021-00070-y.
8. Reid, C.P.P. (2000) Handbook for preparing and writing research proposals. IUFRO Special Programme for Developing Countries. ISBN:3901347232.
9. Brown, P. (2014) An explosion of alternatives: considering the future of science journalism. EMBO Reports, 15(8):827–832, DOI:10.15252/embr.201439130.

PBRE432: Dissertation-II

Course code & title	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Theory/ Lecture	Tutorial	Practical		
PBRE432: Dissertation-II	16	0	0	16	B.Sc. in any branch of science	NA

Learning Objectives

The students will work independently on the research problem chosen in Semester 3 and will apply appropriate molecular, biochemical, physiological and/or computational approaches to address the defined objectives and hypotheses. They will learn to design and execute experiments with suitable controls and replicates, systematically collect, document, and analyse data using relevant statistical and bioinformatic tools, and interpret the results in the context of existing knowledge. They will further strengthen their skills in scientific writing by updating and refining the literature review and by preparing a well-organized dissertation adhering to standard formats, citation styles, and ethical guidelines. The student will also develop competencies in scientific communication by regularly discussing their work in lab meetings and presenting their findings through formal oral presentations.

Learning Outcomes

On successful completion of the dissertation, the student will be able to independently plan and conduct the experiments with appropriate controls, optimize and adapt protocols, and troubleshoot technical problems in response to experimental challenges. They will maintain systematic and complete laboratory records, generate reproducible datasets, and carry out quantitative/qualitative analyses, including appropriate statistical tests and data visualization. They will be able to critically interpret and integrate their experimental findings with published literature to draw logical, evidence-based conclusions, identify limitations, and suggest future directions. The student will be able to prepare a coherent dissertation that includes an updated literature review, methodology, results, discussion, and references in a standard format. They will exhibit professional research attitudes, including scientific rigor, ethical conduct, teamwork, and responsible data and time management in the laboratory to meet defined timelines and submission deadlines.

Suggested Readings:

Latest research and review articles on the chosen research topic.

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