UNIVERSITY OF DELHI

MASTER OF SCIENCE

IN

PLANT MOLECULAR BIOLOGY AND BIOTECHNOLOGY

(Effective from Academic Year 2018-19)

TWO YEAR FULL TIME PROGRAMME

PROGRAMME BROCHURE

Approved in the meeting of the FIAS held on **3rd July 2018**

PMBB Revised Syllabus as approved by Academic Council on _____, 2018 and Executive Council on _____, 2018

DEPARTMENT OF PLANT MOLECULAR BIOLOGY

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

Contents

I. About the Department

The Department of Plant Molecular Biology was established in 1988 under the Faculty of Interdisciplinary and Applied Sciences to cater to the needs of students in frontier areas of plant biology and to carry out research on Molecular Aspects of Plant Biology and Biotechnology. The Department was enriched by merger of the Unit for Plant Cell and Molecular Biology in 1988 (originally established by the DST), and award of COSIST grant by the UGC (1990-1995). The Department has been recognized for Special Assistance Programme (DRS Phase I to Phase III) by the UGC (2002-2018) to strengthen research/teaching in the area of Functional Genomics. Since its establishment in 1988, Professor S.C. Maheshwari (1988- 1992), Professor Akhilesh K. Tyagi (1988, 1992-95, 1998-2001), Professor Jitendra P. Khurana (1995-1998, 2001- 2004, 2014 - 2016), Professor Paramjit Khurana (2004 - 2007, 2016- till date), Professor Anil Grover (2007-2010), Professor Indranil Dasgupta (2010 - 2013), and Professor Madan Mohan (2013 - 2014) have served as Heads of the Department.

Faculty members of the Department have undertaken several prestigious projects, many of which were funded by the Rockefeller Rice Biotechnology Program, between the years 1990 and 2000, which helped the Department make significant strides in acquiring expertise in transgenics and structural and functional analysis of genes. With the beginning of the new millennium, faculty members of the Department took up challenges of large-scale genome sequencing and analysis, which resulted in the landmark achievement of generating the complete sequence of the rice genome, as part of an international consortium of scientists, in the year 2005. This was followed by a similar achievement for the completion of the tomato genome in the year 2012. Currently, the departmental faculty is part of International Wheat Genome Sequencing Consortium. The research has also been supported by major grants in the form of “Centre for Plant Molecular Biology” and “Genome Initiatives on Sequencing, Gene Discovery and Function” by DBT, in addition to other competitive grants from DST, UGC, European Commission and the Rockefeller Foundation. The faculty is involved in multi–institutional as well as international projects. The research has yielded about 750 publications in journals of repute, such as Nature, Genome Research, Nucleic Acids Research, Trends in Biotechnology, Plant Physiology, New Phytologist, Journal of Experimental Botany, Plant Cell & Environment and Bioessays alongwith several patents as well. Efforts of the faculty have been recognized in the form of fellowships to national/international scientific academies and national/international awards. While providing due emphasis for basic research and training, the Department endeavors to convert knowledge into application for human welfare.

The alumni of this Department have spread out all over the World and occupy several important positions in well-known universities and research institutes (including Washington State University, Pullman, USA; University of Nebraska, Lincoln, USA; Texas Tech University Health Sciences Centre, USA; Rothamstead Research Station, Hertfordshire, UK) or are working as post-doctoral fellows in research establishments across the World. Several of our alumni are leading their active research groups and have already established themselves as distinguished scientists in India, in both academia and industry including E. I. DuPont (Hyderabad), Guru Jambheshwar University (Hisar), Bioseed Research (Hyderabad), IARI, ICGEB, NIPGR, JNU, IIT Delhi, NII, Indraprastha University, IISER (Bhopal), TERI University, CIMAP (Lucknow), Birsa Agricultural University (Ranchi) and Assam Agricultural University (Jorhat).

II. Introduction to CBCS (Choice Based Credit System)

Choice Based Credit System:

The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill-based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Grading system provides uniformity in the evaluation and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations which enables the student to move across institutions of higher learning. The uniformity in evaluation system also enable the potential employers in assessing the performance of the candidates.

Definitions:

(i) '*Academic Programme'* means an entire course of study comprising its programme structure, course details, evaluation schemes etc. designed to be taught and evaluated in a teaching Department/Centre or jointly under more than one such Department/ Centre

(ii) '*Course'* means a segment of a subject that is part of an Academic Programme

(iii) '*Programme Structure'* means a list of courses (Core, Elective, Open Elective) that makes up an Academic Programme, specifying the syllabus, Credits, hours of teaching, evaluation and examination schemes, minimum number of credits required for successful completion of the programme etc. prepared in conformity to University Rules, eligibility criteria for admission

(iv) '*Core Course'* 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

(v) '*Elective Course'* means an optional course to be selected by a student out of such courses offered in the same or any other Department/Centre

(vi) *'Open Elective'* means an elective course which is available for students of all programmes, including students of same department. Students of other Department will opt these courses subject to fulfilling of eligibility of criteria as laid down by the Department offering the course.

(vii) '*Credit*' means the value assigned to a course which indicates the level of instruction; One-hour lecture per week equals 1 Credit, 2 hours practical class per week equals 1 credit. Credit for a practical could be proposed as part of a course or as a separate practical course

(viii) '*SGPA*' means Semester Grade Point Average calculated for individual semester.

(ix) '*CGPA*' is Cumulative Grade Points Average calculated for all courses completed by the students at any point of time. CGPA is calculated each year for both the semesters clubbed together.

(x) '*Grand CGPA'* is calculated in the last year of the course by clubbing together of CGPA of two years, i.e., four semesters. Grand CGPA is being given in Transcript form. To benefit the student a formula for conversation of Grand CGPA into %age marks is given in the Transcript.

I. PMBB Programme Details

a. **Programme Objectives (POs)**: The M. Sc. Course in Plant Molecular Biology and Biotechnology at the Department of Plant Molecular Biology (PMB), UDSC has been designed to expose students to the latest developments in the exciting and burgeoning areas of modern Plant Sciences. This course will prepare students to take research in Plant Molecular Biology and allied areas as a possible career option as well as will enable generation of manpower for the emerging Plant Biotechnology industry.

b. **Programme Specific Outcomes (PSOs):** After successfully completing the program, the students would have developed in-depth understanding of the plant systems at molecular level. They would have a very clear understanding about how plant systems respond at molecular level to various environmental and developmental cues. Students would develop a very strong theoretical background on the subject as well as practical skills, including both wet-lab and computational analysis, rendering them competent enough to undertake major research programs later in their career. They would also understand the intricacies of how one can engineer various molecular components in order to develop better crop varieties, in an environmentally sustainable manner, to address the ever-growing demands of the population.

c. **Programme Structure :** The M.Sc. in Plant Molecular Biology and Biotechnology (PMBB) is a two years programme and offers a total of ten core theory papers (4 credits each), one open elective (4 credits), four internal elective papers (4 credits each), three practical papers (two 8 credits and one 4 credits) and dissertation (24 credits). In general, while the core theory papers provide basic and updated information about the subject, the internal electives theory papers have been designed to provide much more detailed and advance information on the subject whose basics have been covered in the core papers. They would also have a fair share of hands-on training aimed to better the understanding of the subject. The open elective paper has been designed to provide in-depth and advanced training to a wider community of life science students in an emerging field of biological sciences. Candidate can select **any one** internal elective paper per semester. Similarly, an open elective paper can be selected from the ones offered by either the parent department or by any of the sister departments within the Faculty of Interdisciplinary and Applied Sciences (FIAS), UDSC. A minimum of 4 students must opt for a particular elective paper to be offered in any semester.

The entire course is divided in two parts i.e. Part I (sem. I & II) and Part II (sem. III and IV), each having two semesters.

Part I	First Year	Semester-1	Semester-2

Part II	Second Year	Semester-3	Semester-4

Semester-1 has four core theory papers of 4 credits each (100 marks each) and one practical paper of 8 credits (200 marks) based on theory papers. Semester-2 has three core theory and two internal elective theory papers of 4 credits each (100 marks each), one open elective paper of 4 credits (100 marks), and one practical paper of 4 credits (100 marks). Semester-3 has three core theory and two internal elective theory papers of 4 credits each (100 marks each), and one practical paper of 8 credits (200 marks). The entire semester-4 would have dissertation work of 24 credits (600 marks). In both semester 2 and 3, candidates can chose any one of the internal elective theory papers.

Course Credit Scheme

- Total credits of the course = 96
- Number of papers = 16
- Theory = 13
  - No. of core theory papers = 10 (4 credits)
  - Number of internal elective papers = 02 (4 credits each)
  - Number of open elective paper = 01 (4 credits)
- Practical = 3 (8+4+8 = 20 credits)

Semester	**Core Courses**			**Internal Elective Course**			**Open Elective Course**			**Total Credits**
	No. of papers	Credits (L+T/P)	Total Credits	No. of papers	Credits (L+T)	Total Credits	No. of papers	Credits (L+T)	Total Credits	
I	5	16/8	24	0	0	0	0	0	0	**24**
II	4	12/4	16	1	4	4	1	4	4	**24**
III	4	12/8	20	1	4	4				**24**
IV	Dissertation		24	0	0	0	0	0	0	**24**
									Total Credits	**96**

- Dissertation = 1 (24 credits)

Semester wise Details of PMBB Course

The schedule of papers prescribed for various semesters shall be as follows:

PART I : Semester-1	
Core Courses	Credits

PBCC 101 - Genetics and Molecular Biology of Prokaryotes	4
PBCC 102 - Molecular Cell Biology	4
PBCC 103 – Recombinant DNA technology: concepts, techniques and applications	4
PBCC 104 - Introduction to Bioinformatics	4
PBCC 105 - Practicals	8
Total Credits in core courses	**24**
Total Credits in Semester I	***24***
PART I : Semester-2	
Core Courses	Credits
PBCC 201 - Molecular Basis of Plant Growth and Development	4
PBCC 202 - Plant Biochemistry and Metabolism	4
PBCC 203 - Proteomics and Metabolomics	4
PBCC 205 - Practicals	4
Total Credits in core courses	**16**
Elective Courses	Credits
PBEC 206 - Biotechnological Approaches in Control of Plant Form and Function**	4
PBEC 207 - Advanced Plant Imaging Techniques **	4
Total Credits in Elective courses	**4**
Open Elective Courses	Credits
PBOE 204 - Data Analytics and Biocuration*	4
Total Credits in Open Elective courses	**4**
Total Credits in Semester 2	***24***
PART II : Semester-3	
Core Courses	Credits
PBCC 301 - Structure and Function of Eukaryotic Genome	4
PBCC 302 - Concepts of Pattern Formation and Differentiation	4
PBCC 303 - Agricultural Biotechnology	4
PBCC 305 - Practicals	8

Total Credits in core courses	**20**
Elective Courses	Credits
PBEC 304 - Plant Stress Biology**	4
PBEC 306 - Small RNA Biology and Epigenetics**	4
Total Credits in Elective courses	**4**
Total Credits in Semester 3	***24***
PART II: Semester-4	
PBCC 401 - Dissertation	24
Total Credits in Semester 4	***24***

*Open Elective theory paper (student can chose either PBOE 204 or any other open elective paper offered by any the sister departments within the Faculty of Interdisciplinary and Applied Sciences (FIAS), UDSC). A minimum of 4 students must opt for the elective to be offered during the semester. The maximum number of students for the course is 24.

**Internal Elective theory paper (Students have to opt for any one in a semester). A minimum of 4 students must opt for any particular elective to be offered during the semester.

List of Elective courses

PBEC 206 - Biotechnological Approaches in Control of Plant Form and Function
PBEC 207 - Advanced Plant Imaging Techniques
PBOE 204 - Data Analytics and Biocuration
PBEC 304 - Plant Stress Biology
PBEC 306 - Small RNA Biology and Epigenetics

Selection of Elective Courses

Students have to opt for any one Elective theory paper in semester 2 and 3. A minimum of 4 students must opt for any particular elective to be offered during the semester. Similarly, with regard to 'Open Elective Paper', student can chose either PMBB 0804 or any other open elective paper offered by any of the sister departments within the Faculty of Interdisciplinary and Applied Sciences (FIAS), UDSC. A minimum of 4 students must opt for the elective to be offered during the semester. The maximum number of students for the course is 24.

Teaching

The course comprises classroom teaching, laboratory practicals, tutorials in the form of seminars and a Dissertation. All theory, practicals and dissertation will have 30% marks reserved for Internal Assessment (IA). Each theory examination will be of three hours durations and practical examination will be for 12 hours (8+4 hours) spread on two days. Dissertation will carry marks for continuous assessment, dissertation/thesis, presentation and viva-voce. The detailed syllabus for each paper is appended with a list of suggested readings, which would be further supplemented with other books/papers and be modified as new material becomes available. While the students will be advised to refer to older editions of books for some of the topics, the books generally prescribed would consist of the latest editions. To reflect the same, edition numbers have not been mentioned in the suggested readings.

d. Eligibility for Admissions

Eligibility

- A student seeking admission to this course must have passed bachelor in biological, chemical or physical sciences with at least 60% marks in the main subject (in case of Hons. Courses) or in aggregate (for other courses).
- The candidates must also have completed the 10+2+3 years of formal education.
- Candidates whose results have not been declared but are expecting to pass in the first division can also appear in the entrance test.
- Appropriate relaxation for candidates belonging to reserved category is applicable as per the university norms.

Admission Procedure: Admission to M.Sc. Program in Plant Molecular Biology and Biotechnology (PMBB) is through a written entrance examination. A total of 12 students are selected from general and reserved categories (reservation as per University rules).

All admissions are made in the order of merit in each category, which is based on the marks secured in the written entrance examination.

e. Assessment of Students' Performance and Scheme of Examinations

1. English shall be the medium of instruction and examination.
2. Examinations shall be conducted at the end of each semester as per the academic calendar notified by the University of Delhi.
3. The summary of the examinations shall be as follows:

PART I: SEMESTER-1			
		Duration (hrs)	Max. marks
PBCC 101	Genetics and Molecular Biology of Prokaryotes	3	100
PBCC 102	Molecular Cell Biology	3	100
PBCC 103	Recombinant DNA technology: concepts, techniques and applications	3	100
PBCC 104	Introduction to Bioinformatics	3	100
PBCC 105	Practicals	12	200
	Total Maximum Marks		**600**
PART I: SEMESTER-2			
PBCC 201	Molecular Basis of Plant Growth and Development	3	100
PBCC 202	Plant Biochemistry and Metabolism	3	100
PBCC 203	Proteomics and Metabolomics	3	100
PBOE 204*	Data Analytics and Biocuration	3	100
PBCC 205	Practicals	12	100
PBEC 206**	Biotechnological Approaches in Control of Plant Form and Function	3	100
PBEC 207**	Advanced Plant Imaging Techniques	3	100
	Total Maximum Marks		**600**
PART II: SEMESTER-3			
PBCC 301	Structure and Function of Eukaryotic Genome	3	100
PBCC 302	Concepts of Pattern Formation and Differentiation	3	100
PBCC 303	Agricultural Biotechnology	3	100
PBEC 304**	Plant Stress Biology	3	100
PBCC 305	Practicals	12	200
PBEC 306**	Small RNA Biology and Epigenetics	3	100
	Total Maximum Marks		**600**
PART II: SEMESTER-4			
PBCC 401***	Dissertation		
	Total Maximum Marks		**600**

*Open Elective theory paper

** Internal Elective theory paper (Students have to opt for any one in a semester)

Each core and elective theory paper will consist of written examination (70 marks) and internal assessment (30 marks). Internal assessment will consist of seminar presentations (12 marks), class-tests (12 marks) and attendance (6 marks).

The open elective theory paper will have a written examination (70 marks) and internal assessment (30 marks). Internal assessment of the open elective paper will consist of class-test (12 marks) and attendance (6 marks).

The practical examinations in sem. 1 and 3 will consist of attendance (10 marks), Practical records (50 marks), Viva-voce/internal assessment (40 marks) and Practical examination (100 marks). However, practical examination in sem. 2 will consist of attendance (5 marks), Practical records (25 marks), Viva-voce/internal assessment (20 marks) and Practical examination (50 marks)

*** Dissertation work will consist of internal evaluation by the concerned supervisor based on general performance during the Project work as internal assessment (180 marks), and project work (320 marks) and seminar/viva-voce (100 marks) evaluated by a Board comprising all teachers in the Department.

The detailed description of the examination process is as follows:

All core and internal elective theory paper will carry 100 marks of which 30% marks shall be reserved for internal assessment based on classroom participation, seminar, term courses, tests, viva-voce and laboratory work and attendance. The open elective paper will carry 50 marks of which 30% marks shall be reserved for internal assessment based on classroom participation, tests and attendance The weightage given to each of these components shall be decided and announced at the beginning of the semester by the individual teacher responsible for the course. Any student who fails to participate in classes, seminars, term courses, test, viva-voce, practical and laboratory work will be debarred from appearing in the end-semester examination in the specific course and no internal Assessment marks will be awarded. His/her Internal Assessment marks will be awarded as and when he/she attends regular classes in the courses in the next applicable semester. No special classes will be conducted for him/her during other semesters.

Practical paper in sem. 1 and 3 will be of 200 marks of which 30% marks will be reserved for internal assessment. However, practical paper in sem. 3 will be of 100 marks with 30% marks reserved for internal

assessment. The duration of written examination for each paper shall be three hours and Practical examination shall be for 12 hours spread over two days (8+4 hours).

As regards Project Work/Dissertation (PMBB 1001), the scheme of evaluation shall be as follows:

- Project Work/Dissertation shall be in Semester-4. It will be evaluated at the end of Semester-4.

- The candidate has to submit dissertation in a bound form at the end of Semester-4. Total marks for dissertation shall be 600 and evaluation will be as follows:

Continuous evaluation	=	400 marks
Dissertation	=	100 marks
Presentation and viva-voce	=	100 marks
Total	**=**	**600 marks**

Examinations for courses shall be conducted only in the respective odd and even Semesters as per the Scheme of Examination. Regular as well as Ex-Students shall be permitted to appear/reappear/improve in courses of odd semesters only at the end of odd semesters and for even semester with the even.

f. Pass Percentage and Promotion Criteria

Students are required to pass separately in theory, practical and dissertation examinations. Minimum marks for passing the examination shall be 45% in aggregate in theory courses, 45% in practical courses and 45% marks in dissertation by scoring at least 40% in each theory paper.

Semester to Semester

Within the same Part, the candidate will be promoted from a Semester to the next Semester (Semester-1 to Semester-2 and Semester-3 to Semester-4), provided the candidate has passed at least two of the papers of the current semester by securing **at least 40% marks** in each paper.

Note: 1. A candidate who does not appear in a theory paper will be allowed **ONLY ONE** more attempt to pass the paper. No further attempts for improvement will be allowed.

2. A candidate will not be allowed to reappear (even if he/she is absent) in the practicals .

Part I to Part II Progression

Admission to Part II of the program shall be open to only those students who have fulfilled the following criteria:

1. have scored at least 45% marks in the practical papers of both Semester-1 and -2 taken together,
2. have passed at least 75% of the theory papers (6 papers) offered in courses of Part I comprising of Semester-1 and Semester-2 by securing at least 40% marks in each of these six papers and
3. have secured at least 45% in aggregate of all theory papers of Part I.

Note: The candidate however will have to clear the remaining papers while studying in Part II of the programme.

g. Conversion of Marks into Grades:

(specify the formula for conversion of marks into grades)

h. Grade Points:

Grade point table as per University Examination rule

i. CGPA Calculation:

As per University Examination rule.

j. SGPA Calculation:

As per University Examination rule.

k. Grand SGPA Calculation:

As per University Examination rule.

l. Conversion of Grand CGPA into Marks

As notified by competent authority the formula for conversion of Grand CGPA into marks is: Final %age of marks = CGPA based on all four semesters × 9.5

m. Division of Degree into Classes:

Post Graduate degree to be classified based on CGPA obtained into various classes as notified into Examination policy.

n. Attendance Requirement:

No student shall be considered to have pursued a regular course of study and be eligible to take examination unless he/she has attended 75% of the total number of lectures, tutorials, seminars and practicals conducted in each semester, during his/her course of study. Under special circumstances, the Head of the Department may allow students with at least 65% attendance to take the examination.

o. Span Period:

No student shall be admitted as a candidate for the examination for any of the Parts/Semesters after the lapse of **four** years from the date of admission to the Part-I/Semester-I of the XXX Programme.

p. Guidelines for the Award of Internal Assessment Marks in PMBB Programme (Semester Wise)

All core and internal elective theory paper will carry 100 marks of which 30% marks shall be reserved for internal assessment based on classroom participation, seminar, term courses, tests, viva-voce and laboratory work and attendance. The open elective paper will carry 100 marks of which 30% marks shall be reserved for internal assessment based on classroom participation, tests and attendance The weightage given to each of these components shall be decided and announced at the beginning of the semester by the individual teacher responsible for the course. Any student who fails to participate in classes, seminars, term courses, test, viva-voce, practical and laboratory work will be debarred from appearing in the end-semester examination in the specific course and no internal Assessment marks will be awarded. His/her Internal Assessment marks will be awarded as and when he/she attends regular classes in the courses in the next applicable semester. No special classes will be conducted for him/her during other semesters.

Practical paper in sem. 1 and 3 will be of 200 marks of which 30% marks will be reserved for internal assessment. However, practical paper in sem. 3 will be of 100 marks with 30% marks reserved for internal assessment.

Award of Degree

A candidate will be awarded M.Sc. degree at the end of Semester-4 provided he/she has:

1. passed all the theory papers of Part I (Semester-1&-2) and Part II (Semester-3&-4) by securing at least 40% marks in each paper and has also obtained at least 45% in aggregate of Part I & Part II,
2. passed the practical examination by securing at least 45% in aggregate of Part I and Part II, separately and
3. passed dissertation by securing at least 45% marks.

Candidates who have fulfilled criteria 2 and 3 (wherever applicable) but not criteria 1:

1. Can reappear for theory papers as per University rules.

   A candidate must pass the M.Sc. examination within span period.
2. No candidate shall be allowed to reappear for practical or dissertation.

Scope For Improvement

As per University rules

Division Criteria

Successful candidates will be classified on the basis of the combined results of Part I and Part II examinations as follows:

Candidates securing 60% and above	:	1st Division
Candidates securing 50% and above but less than 60%	:	2nd Division
Candidates securing 45% and above but less than 50%	:	Pass

IV: Course Wise Content Details for PMBB Programme:

Masters of Plant Molecular Biology and Biotechnology

Semester 1

PBCC 101: Genetics And Molecular Biology of Prokaryotes

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

Prokaryotic systems are regularly used as tools for various molecular biology investigations. Further, plant-microbe interactions are important aspects of plant biology. Thus, this course is designed to provide expertise in prokaryotic biology and gene expression, which is essential to lay a strong foundation for understanding the molecular biology of plant systems.

Course outcome

The candidate would have learnt the details of the various molecular processes involved in the growth and development microbial systems.

Content

- **Unit 1: Historical and General Aspects** -- Important discoveries on the genetic material; Relationship between genotype and phenotype; Introduction to Mendelian Genetics; Gene mapping in prokaryotes.
- **Unit 2: DNA Replication** -- Biochemical and genetic tools to study replication; DNA polymerases and accessory proteins; Proteins at the replication origin and the replication fork; Concept of replicon; Linear replicons and their maintenance; Control of replication of chromosomes and extra-chromosomal elements; Telomeres.
- **Unit 3: Maintenance of Genomic Flexibility and Integrity** -- Spontaneous and induced mutations; Mutagens; Mechanisms of homologous and site-specific recombinations; DNA repair and retrieval systems; Transposons and retro-transposons.
- **Unit 4: Regulation of Transcription** -- Discovery of RNA; Promoters and other control elements; RNA polymerases and accessory factors; Sigma factors and their interactions with promoters; Transcriptional controls; Concept of operons; Controls at transcription termination; *Rho* factor and polar mutations.
- **Unit 5: Bacteriophages as Models for Gene Regulation** -- Bacteriophage lambda; Lysogenic and lytic cycles; gene expression circuits; Bacteriophage T_4 and T_7; Temporal control of gene expression in bacteriophages.

- **Unit 6: Translation and its Mechanism** -- Initiation, elongation and termination of translation and the accessory proteins; Structural and functional studies on ribosome; Ribosomal RNAs; Ribosomal proteins; Mapping the decoding and peptidyl transferase sites of ribosome; Accuracy during translation.
- **Unit 7: Transfer RNAs and Genetic Code** -- Biogenesis, structure and function of transfer RNAs; Suppressor mutations; Post-translational control; Genetic code and its characteristics; Wobble phenomenon; Codon bias.

Suggested Readings

1. Clarke, D. and Pazdernik, N. (2013) Molecular Biology. Academic Cell, USA
2. Griffiths, A. J., Gelbart, W. M., Lewontin, R. C. and Miller, J. H. (2002) Modern Genetic Analysis. W. H. Freeman, USA.
3. Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. (2013) Lewin's Genes XI. Jones and Bartlett Publishers, Inc., USA.
4. Tropp, B. E. (2014) Principles of Molecular Biology, Jones and Bartlett, USA.
5. Weaver, R. F. (2012) Molecular Biology. McGraw Hill, UK.

Masters of Plant Molecular Biology and Biotechnology

Semester 1

PBCC 102 Molecular Cell Biology

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This paper is devised to provide a detailed knowledge of the cell biology, which is important to understand various molecular and biochemical processes operating at cellular level.

Course outcome

The candidate would learn about the structure and functioning of various macromolecular and sub-cellular components. The candidate would also learn about the various imaging techniques used to study these sub-cellular components.

Content

- **Unit 1: Investigating the Cell** -- Cell theory; Fundamentals of microscopy and imaging.
- **Unit 2: Cell Wall** -- Cell wall composition and architecture; Biogenesis and assembly; Dynamic aspects of cell wall during growth and differentiation
- **Unit 3:Membrane Systems** -- Structural models; Composition and dynamics; Transport of ions and macromolecules; Pumps, carriers and channels; Sensory physiology; Endo- and exo-cytosis; Membrane proteins & carbohydrates and their significance in cellular recognition.
- **Unit 4:Mitochondria** -- Structure; Organization; Structure-function relationship; Mitochondrial genetic machinery and male sterility; Biogenesis, origin and evolution.
- **Unit 5:Chloroplast and Photosynthetic Systems** -- Structure; Organization; Structure-function relationship; Chloroplast genetic machinery and its significance; Chloroplast biogenesis, origin and evolution.
- **Unit 6:Nucleus** -- Structure and function (architecture); Chromatin organization and packaging,; chromosome organization, nucleosomes, euchromatin; heterochromatin, centeromere, telomere; chromosome territories; 3D genome; Macromolecular trafficking.
- **Unit 7:Endomembrane Systems** -- Structure and function of Golgi apparatus, lysosomes and endoplasmic reticulum and microbodies; Membrane maturation and specialization.
- **Unit 8:Cytoskeleton and Cellular Motility** -- Organization and role of microtubules and microfilaments; Actin-binding proteins and their significance; Molecular motors; Intermediate filaments.

Suggested readings

1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P. (2015) Molecular Biology of the Cell. Garland Publishing, Taylor & Francis Group, USA.
2. Karp, J. G. (2013). Cell and Molecular Biology. John Wiley & Sons, USA.
3. Kleinsmith, L. J. and Kish, V. M. (1996) Principles of Cell & Molecular Biology. Harper Collins College Publishers, USA.
4. Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretsher, A., Ploegh, H., Amon, A., Martin, K. (2016) Molecular Cell Biology. Freeman & Co., USA.
5. Ruzin, S. E. (1999) Plant Microtechnique and Microscopy. Oxford University Press, USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 1

PBCC 103:Recombinant DNA Technology: Concepts, Techniques and Applications

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course Objectives

The course is designed with an aim to develop technical skills in recombinant DNA technology. It will also provide a foundation that would help students to understand the advanced courses in the succeeding semesters.

Course outcome

The candidate will develop an in-depth knowledge on principles and applications of the versatile instrumentation, basic and cutting-edge tools and techniques in recombinant DNA technology. Students will get acquainted with designing/conducting and analysing experiments and experimental data, respectively. Integration of theory and problem-solving exercises will motivate students to take keen interest in research and enhance their understanding in the topics they are taught.

Contents

- **Unit 1: Basics of Nucleic Acids** -- Types, occurrence, structure, topology and dynamics, functions; Methods for isolation and purification of nucleic acids.
- **Unit 2: Physicochemical and Separation Techniques** -- Principles and biological applications of spectrometry, centrifugation, chromatography, electrophoresis, radioactivity measurements.
- **Unit 3: Basics of DNA Cloning** -- Gene cloning methodologies, restriction enzymes and nucleic acid modifying enzymes, TA cloning, topoisomerase-based cloning, ligation independent cloning, GATEWAY technology; Vectors for gene cloning - plasmids, phages, phagemids, cosmids, shuttle vectors, artificial chromosomes, plant viruses and other advanced vectors; Methods for selection and screening of recombinant clones, selection and screening of clones (marker genes, reporter genes, positive and negative selection, insertion inactivation, alpha-complementation); Bacterial transformation methods.
- **Unit 4: Isolation of Gene(s) 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.
- **Unit 5: Polymerase Chain Reaction** -- Concept and enzymes employed, optimization of PCR, types of PCR (touch-down, hot-start, inverse, nested, gradient, RACE, semi-quantitative and quantitative, overlapping and multiplex), applications of PCR.

- **Unit 6: Methods to Study Gene Expression** -- Gene expression analyses at transcriptional level (Northern blotting and its variants, real-time PCR, S1 nuclease mapping, *in situ* hybridization, RNase protection, nuclear run-on assays, DNA microarrays), translational level (Western blotting, ELISA and immunofluorescence assays).
- **Unit 7: Methods to Study Biomolecular Interactions** -- DNA-protein (EMSA, DNase I footprinting, ChIP, Y-1-H), RNA-protein (Y-3-H, north western, RIP) and protein-protein interaction (Y-2-H, pull down, CoIP, FRET, BiFC) method; Real-time label-free detection by Surface Plasmon Resonance (SPR).
- **Unit 8: Basics of Genome Sequencing** -- DNA sequencing methods (Maxam-Gilbert, Sanger, automated sequencing, Next Generation Sequencing or NGS platforms); Introduction to mapping and sequencing of genomes (whole genome shotgun and clone-by-clone approach of genome sequencing).
- **Unit 9: 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.
- **Unit 10: Applications and ethics of Recombinant DNA Technology** -- Production of useful recombinant molecules, improving agronomic traits, diagnostic and therapeutic applications in human diseases; Impact and safety, moral, social, regulatory & ethical issues associated with recombinant DNA technology.

Suggested readings

1. Brown, T. A. (2016) Gene Cloning and Analysis: An Introduction. Wiley-Blackwell Publishing, UK.
2. Dale J. W., Schantz M. V. and Plant N. (2011) From Genes to Genomes: Concepts and Applications of DNA Technology. John Wiley & Sons, UK.
3. Glick B. R., Pasternak J. J. and Patten C. L. (2010) Molecular Biotechnology: Principles and Applications of Recombinant DNA. ASM Press, USA.
4. Green M. R. and Sambrook J. (2012) Molecular Cloning: A Laboratory Manual. CSHL Press, USA.
5. Metzler, D. E. (2003) Biochemistry. Academic Press, USA.
6. Primrose, S. B. and Twyman, R. M. (2006) Principles of Genetic Manipulation and Genomics. Blackwell Publishing, UK.
7. Voet, D., Voet, J. G. and Pratt C. W. (2012) Principles of Biochemistry. John Wiley & Sons, UK.
8. Wilson, K. and Walker, J. (2010) Principles and Techniques of Biochemistry and Molecular Biology. Cambridge University Press,USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 1

PBCC 104: Introduction to Bioinformatics

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This paper is designed to provide the basic skills required to perform computational analysis of biological data at various levels.

Course outcome

The candidates would learn the basic fundamentals of various bioinformatic analysis approaches. They would also generate and in-depth understanding on the usage of various tools for computational analysis.

Contents

- **Unit 1: Introduction to Computers and Bioinformatics** -- Types of operating systems, concept of networking and remote login, basic fundamentals of working with unix.
- **Unit 2: Biological Databases** -- Overview, modes of database search, mode of data storage (Flat file format, db-tables), flat-file formats of GenBank, EMBL, DDBJ, PDB.
- **Unit 3: Sequence Alignment** -- Concept of local and global sequence alignment; Pairwise sequence alignment, scoring an alignment, substitution matrices, multiple sequence alignment.
- **Unit 4: Phylogenetic Analysis** -- Basic concept of phylogenetic analysis, rooted/uprooted trees, approaches for phylogenetic tree construction (UPGMA, neighbour joining, maximum parsimony, maximum likelihood).
- **Unit 5: Analysis of High Throughput Sequence Data** -- Assembly pipeline for clustering of HTGS data, introduction to NGS data analysis, de-novo vs genome reference assembly, analysis file formats (BAM, SAM, ACE, BED), quality assessment of genomic assemblies; International norms for sequence data quality.
- **Unit 6: Functional Annotation and Molecular Metworks** -- Identification of various genomic elements (protein coding genes, repeat elements); Strategies for annotation of whole genome; gene ontology (GO) consortium, molecular networks, 'systems' biology approach.
- **Unit 7: 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.

Suggested readings

1. Baxevanis, A. D. and Ouellette, B. F. F. (2005) Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins. John Wiley and Son Inc., USA.

2. Mount, D. W. (2004) Bioinformatics Sequence and Genome Analysis. CSHL Press, USA.

3. Tramontano, A. (2007) Introduction to Bioinformatics. Chapman & Hall/CRC, USA.

4. T. W., Tan and Lee, E. (2018) Beginners guide to Bioinformatics for High Throughput Sequencing. World Scientific Publishing Co Pte. Ltd, USA.

5. Zvelebil, M. and Baum, J. O. (2008) Understanding Bioinformatics. Taylor and Francis, USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 1

PBCC 105: Practicals

Marks = 200 *Teaching Hrs. = 120 (Credits= 8)*

Course objectives

The paper is designed to provide practical training on various molecular techniques.

Course outcome

The candidate would get hands-on experience about how to conduct various molecular techniques as well as about the usage of various instruments.

List of Practicals

1. Isolate chloroplasts from the given plant material, quantitate proteins using dot blot assay, and resolve the proteins by SDS-PAGE to identify major chloroplast proteins.
2. Isolate mitochondria from the given plant material and demonstrate the activity of its marker enzyme, succinate dehydrogenase.
3. To study the effect of physical and chemical permeabilizing agents on membrane permeability.
4. To isolate protoplasts from flower petals and leaves of different plants and demonstrate protoplast fusion via PEG.
5. Perform (i) Desalting of proteins and (ii) resolve proteins of various molecular weights (between 20 to 200 kDa) using gel filtration chromatography.
6. To extract proteins from the given plant material and estimate soluble protein content by Bradford method.
7. To resolve soluble proteins by discontinuous, SDS-gel electrophoresis under denaturing conditions followed by staining with Coomassie Brilliant Blue R-250.
8. To resolve soluble proteins by gradient gel electrophoresis under denaturing conditions, for optimal separation of proteins followed by staining with silver staining method.
9. To isolate native proteins for resolving isozymes using native, non-denaturing polyacrylamide gel electrophoresis.
10. To prepare electro-competent cells of *E. coli* and transform them by plasmid using electroporator.
11. To study the growth characteristics of *E. coli* by turbidometry and plating methods.
12. Effect of nutrient starvation (Nitrogen, Sulphur, phosphate) on growth kinetics of bacteria.
13. To isolate plasmid from *E. coli* culture (miniprep) and estimate the DNA by fluorometry.
14. To clone a DNA fragment in plasmid vector by ligation, transformation of ligation mix in *E. coli* cells and selection of transformants.

15. To perform 'Colony PCR' to screen for the positive *E. coli* transformants containing the ligated product and perform restriction digestion of the positive clone.
16. Text-based search of the NCBI database.
17. Sequence (DNA/Protein) alignment based database search, multiple sequence alignment and phylogenetic analysis.

Masters of Plant Molecular Biology and Biotechnology

Semester 2

PBCC 201: Molecular Basis of Plant Growth and Development

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This course is designed to provide an in-depth knowledge about the various molecular and biochemical processes that regulate different aspects of plant development.

Course outcome

The candidate would have developed a very good understanding of the various developmental schemas operative in plant systems as well as molecular processes that control them.

Contents

- **Unit 1: Light Control of Plant Development** -- Skotomorphogenesis and photomorphogenesis; Discovery of phytochromes and cryptochromes, their structure, biochemical properties and cellular distribution; Molecular mechanisms of light perception, signal transduction and gene regulation; Biological clocks and their genetic and molecular determinants.
- **Unit 2: Floral Induction and Development** -- Photoperiodism and its significance; Vernalization and hormonal control; Inflorescence and floral determination; Molecular genetics of floral development and floral organ differentiation.
- **Unit 3: Biosynthesis of Plant Hormones and Elicitors** -- Structure and metabolism of auxins, gibberellins, cytokinins, abscisic acid, ethylene, brassinosteroids, salicylic acid, strigolactones, nitric oxide, jasmonates and related compounds.
- **Unit 4: Molecular Mechanism of Hormone Action** -- Hormone signal perception, transduction and regulation of gene expression during plant development; Role of mutants in understanding hormone action; Phospholipids and Ca^{2+}-calmodulin cascade; MAP kinase cascade; Two-component sensor-regulator system.
- **Unit 5: Seed Development, Dormancy and Seed Germination** -- Hormonal control of seed development; Seed maturation and dormancy; Hormonal control of seed germination and seedling growth; Mobilization of food reserves during seed germination.
- **Unit 6: Senescence and Programmed Cell Death (PCD)** – Molecular mechanism of PCD in animals, Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants; Differences and similarities in PCD and senescence.

Suggested Readings

1. Alberts B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P. (2015) Molecular Biology of the Cell. Garland Publishing, Taylor & Francis Group, USA.

2. Buchanan, B. B., Gruissem, W. and Jones, R. L. (2015) Biochemistry and Molecular Biology of Plants. John Wiley & Sons and American Society of Plant Biologists, USA.

3. Hopkins, W. G. and Huner, N. P. A. (2008) Introduction to Plant Physiology. John Wiley, UK.

4. Jones, R. L, Ougham, H., Thomas, H. and Waaland, S. (2012) The Molecular Life of Plants. Wiley-Blackwell and American Society of Plant Biologists, USA.

5. Srivastava, L. M. (2002) Plant Growth and Development: Hormones and Environment. Academic Press, USA.

6. Taiz, L. and Zeiger, E., Moller, I. M. and Murphy, A.(2015) Plant Physiology and Development. Sinauer Associates Inc. Publishers, USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 2

PBCC 202: Plant Biochemistry and Metabolism

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This paper is designed to provide a very detailed understanding of various biochemical processes in plants.

Course outcome

This paper would lead to a detailed understanding of the different metabolic processes operating in a plant system. The paper would provide a view into structural diversity of various biomolecules, their movement, synthesis and turn over. It would help in understanding the key points in pathways of metabolism where the efforts can be focused for the genetic improvement of quality traits.

Contents

- **Unit 1: Carbon Assimilation** -- Light absorption and energy conversion; Calvin Cycle; Hatch-Slack pathway; Reductive pentose phosphate pathway; Carbon dioxide uptake and assimilation; Photorespiration; Glycolate metabolism.
- **Unit 2: Biological Oxidation and Release of Energy** -- Glycolytic pathway; Kreb's cycle; High energy compounds; Oxidative phosphorylation; Chemiosmotic hypothesis; Pentose phosphate shunt pathway.
- **Unit 3: Metabolism of Macromolecules** -- Biosynthesis and inter-conversion of carbohydrates; Biosynthesis, inter-conversion and degradation of lipids; Metabolism of nucleotides and amino acids.
- **Unit 4: Nitrogen, Sulphur and Phosphorus Metabolism** -- General aspects of nitrogen economy; Nitrate reduction; Pathways of ammonia assimilation; Reductive amination; Trans-amination; Regulation of nitrogen assimilation; Uptake, transport and assimilation of sulphate and phosphate.
- **Unit 5: Nitrogen Fixation** -- Symbiotic and non-symbiotic nitrogen fixation; Role of lectins; nod genes; nif genes; Structure, function and regulation of nitrogenase; Leghaemoglobin; Nodulins; Regulation and enhancement of nitrogen fixation.
- **Unit 6: Long-distance Transport Mechanisms** -- Turgor and stomatal movements; Solute movement; Source-sink relationship; Water relations.

  Unit 7: Secondary Metabolism -- Importance of secondary metabolites; Biosynthesis of phenolic compounds, isoprenoids, alkaloids and flavonoids.

Suggested readings

1. Buchanan, B., Gruissem, W. and Jones, R. (2000) Biochemistry & Molecular Biology of Plants. American Society of Plant Physiologists, USA.
2. Dey, P. M. and Harborne, J. B. (1997) Plant Biochemistry. Academic Press, USA.
3. Metzler, D. E. (2007) Biochemistry. Academic Press, USA.
4. Nelson D. L. and Cox, M. M. (2008) Principles of Biochemistry. W H Freeman & Co., USA.
5. Stryer L., Berg, J. M. and Tymoczko, J. L. (2006) Biochemistry. W.H. Freeman & Co., USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 2

PBCC 203: Proteomics And Metabolomics

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

Protein and metabolite profile in living systems are important in order to understand the regulatory and metabolic capacity of the system. Thus, this paper provides basic concepts in the study of the proteome and metabolome of an organism.

Course outcome

The candidate would develop a very detailed understanding about the various techniques and analysis methods for the study of the plant proteome and metabolome.

Contents

- **Unit 1: Introduction to Proteomics --** Protein structure and folding, basic concepts and techniques, proteome, basics and workflow design of proteomics technology, comparative proteomics, importance of proteomics.
- **Unit 2: Tools and Techniques in Proteomics --** Principles and applications of the separation technology, I-D and 2-D Polyacrylamide Gel Electrophoresis (PAGE), workflow, high-throughput methods, importance and applications in proteomics.
- **Unit 3: Proteomic Profiling --** Protein sequencing, MS analysis and related techniques (LC-MS/MS), advanced methods in proteomics (microfluidic chips, ICAT, iTRAQ, AQUA, ESI-Q-IT-MS, SELDI-TOF-MS) database search, relative quantification, analysis and interpretation, quantitative proteomics, post-translational modifications and their profiling, high-throughput methods for interaction of proteins with and other biomolecules.
- **Unit 4: Immunology and Immuno-techniques --** Overview of immune systems, antigens, epitopes, haptens, immunogens and immunoglobulins, antigen-antibody interaction, utility of antibodies in routine laboratory experiments, proteomics and diagnostics.
- **Unit 5: Basics of Metabolomics** -- Definition and scope, metabonomics, small metabolites, separation methods, Gas chromatography (GC), High Performance Liquid Chromatography (HPLC), detection methods such as Mass Spectrometry (MS), Secondary ion MS (SIMS), Desorbtion Electron Spray Ionization (DESI), Laser Ablation ESI (LAESI), NMR, statistical analysis of the data, XCMS, MetAlign LCMStats.
- **Unit 6: Applications and Future Challenges in Proteomics and Metabolomics** -- Impact in agriculture and health.

Suggested readings

1. Antonio, C. (2018) Plant Metabolomics: Methods and Protocols (Methods in Molecular Biology). Humana Press, USA.
2. Branden, C. I. and Tooze, T. (1999) Introduction to Protein Structure. Garland Publishing, USA.
3. Saito, K., Dixon, R. A. and Willmitzer, L. (2006) Plant Metabolomics (Biotechnology in Agriculture and Forestry). Springer, USA.
4. Lesk, A. M. (2010) Introduction to Protein Science: Architecture, Function and Genomics. Oxford University Press, UK.
5. Lammerhofer, M. and Weckwerth, W. (2013). Metabolomics in Practice: Successful Strategies to Generate and Analyze Metabolic Data. Oxford University Press, UK.
6. Weckwerth, W. (2006) Metabolomics: Methods and Protocols (Methods in Molecular Biology). Humana Press, USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 2

PBOE 204: Data Analytics and Biocuration

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This paper is designed to provide basic requisite skills for core computer programming, in-depth data analysis, database development and management.

Course outcome

The candidate would develop skills in basic statistical analysis of biological data as well as the usage of programming languages. The candidate would be able to handle and analyze 'Big Data' analysis. They would develop skills for the management and development of highly curated biological databases.

Contents

- **Unit 1: Data Analytics using 'R' Statistical Package** – Basic statistics for biologists; Introduction to the 'R' data analysis package, basic work environment, syntax, introduction to the 'Bioconductor' packages for data analysis.
- **Unit 2: Application of the Bioconductor Packages** -- Application of bioconductor packages in the analysis of RNA-seq, chromatin immune-precipitation, bisulphite sequencing data, data analysis and visualization.
- **Unit 3: Basics of Programming and Database Management** -- Perl, Bioperl and MySQL.
- **Unit 4: Data standards, Integration and Visualization** -- BioDbCore guide lines, FAIRsharing. Ethics in data sharing, Introduction to machine-learning and artificial intelligence approaches in data integration and interpretation and predictive modeling. Visualization tools such as Gbrowse.
- **Unit 5: Introduction to Biocuration** -- Basics, International society of Biocuration, various methods of biocuration,
- **Unit 6: Ontologies** -- Basics and importance of ontology development, OBO (Open Biological and Biomedical Ontology) format, OBO foundary, biomedical and plant based ontologies.
- **Unit 7: Literature-Based Curation** -- Text/Literature-based curation, text mining approaches, introduction to tools such as Textpresso.
- **Unit 8: Data Digitization Aspects** -- Importance of digitization of experimental data, experimental data submission repositories and formats.

Suggested readings

1. Bessant, C., Shadforth, I. and Oakley, D. (2009) Building Bioinformatics Solutions: with Perl, R and MySQL. Oxford University Press, UK.
2. Tisdall, J. (2001). Beginning Perl for Bioinformatics. O'Reilley Media, USA.
3. Tisdall, J. (2010). Mastering Perl for Bioinformatics: Perl programming for Bioinformatics. O'Reilley Media, USA.
4. Buffalo, V., (2015) Bioinformatics Data Skills: Reproducible and robust research with open source tools. O'Reilley Media, USA.
5. Web link: www.bioconductor.org.
6. Web link: www.obofoundary.org; www.oboedit.org
7. Web link: www.biocuration.org

Masters of Plant Molecular Biology and Biotechnology

Semester 2

PBCC 205:Practicals

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

The paper is designed to provide hands-on practical training on various molecular and biochemical techniques.

Course outcome

The candidate would learn how to carry some basic techniques to study various molecular and metabolic plant processes such as gene expression, hormone signaling and enzyme activity.

List of Practicals

1. To prepare yeast competent cells and transform yeast cells with plasmid DNA.
2. To learn basics of microscopy and differentiate dicot and monocot morpho- histological characteristics by using respective model systems, viz. Arabidopsis and rice. Visualization of GFP expression in transgenic Arabidopsis by using fluorescence microscope.
3. Induction of a protein in *E. coli* by IPTG and checking its expression by SDS-PAGE.
4. To perform amplification of cDNA by PCR and to perform 3'-RACE (Rapid amplification of cDNA ends).
5. To isolate plant DNA from different sources and perform restriction digestion and Southern blotting.
6. To perform Southern hybridization of plant genomic DNA.
7. Demonstrate red/far-red reversibility of seed germination in Arabidopsis using wild- type and mutant strains.
8. Demonstrate rapid induction of gene expression by auxin in coleoptile segments of dark-grown rice seedlings.
9. Effect of different abiotic stresses on seed germination of wild type and mutant *Arabidopsis thaliana*.
10. To study the effect of calcium on pollen viability and germination assay.
11. To study substrate inducibility of nitrate reductase (NR) enzyme.
12. Determination of optimal pH for nitrate reductase activity.
13. Spectrophotometric assay of acid phosphatase.
14. Protein-protein interaction analysis by filter-lift assay and color development in yeast two-hybrid methodologies.

Masters of Plant Molecular Biology and Biotechnology

Semester 2

PBEC 206: Biotechnological Approaches in Control of Plant Form and Function

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This course is designed to develop skills and understanding with relevance to frontier areas of plant biotechnology and control of form and function in plants.

Course outcome

The candidate would develop an advanced understanding on several frontier aspects that are important for the development and release of genetically engineered plant varieties.

Contents

- **Unit 1: Regulation of Plant Architecture** -- Leaf, root, and shoot meristem, floral transition, inflorescence.
- **Unit 2: Male Sterility and Heterosis** -- Formation of male gametes, male sterility, hybrid vigour.
- **Unit 3: Seed Development and Yield** -- Formation of female gametes, pollination and fertilization, fruit and seed development, genetic improvement of yield.
- **Unit 4: Phenomic Analysis** -- Plant phenotype reflects genotype and environment interaction, phenomic platforms, Role of phenomics in crop improvement.
- **Unit 5: Post-harvest Waste Management** -- Types of agriwastes, Biological treatments for waste management, Alternate treatment technologies for product development.
- **Unit 6: Biosafety Risk Assessment & Regulatory Aspects** -- Biodiversity conservation and protection; Environment Protection; Comparative account of national and international rules for GMOs and their release.
- **Unit 7: Hands-on Training** -- Molecular analysis of transgenics, Expression analysis of organ-specific marker genes

Suggested readings

1. Buchanan, B. B., Gruissem, W., Jones, R. L. (2015) Biochemistry & Molecular Biology of Plants. John Wiley & Sons, Ltd, UK.
2. Fritsche-Neto, R., Borem, A. (2015) Phenomics. Springer International Publishers, Switzerland.
3. Stewart Jr. C. N. (2016). Plant Biotechnology and Genetics: Principles, Techniques and Applications. John Wiley & Sons, Inc., USA.

4. Thomas, J. A., Fuchs, R. L. (2002) Biotechnology & Safety Assessment. Academic Press, USA.
5. Traynor, P. L. (2002) Biosafety & Risk Assessment in Agricultural Biotechnology. Agricultural Biotechnology Support Project, Mich. State Univ, USA.
6. Wolpert, L., Tickle, C., Martinez, A. (2015) Principles of Development. Oxford Publishers, UK.

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Semester 2

PBEC 207: Advanced Plant Imaging Techniques

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

The objective of this paper is to provide exposure to various approaches and methodologies involved in imaging to study plant systems at cellular level.

Course outcome

Students would acquire specific practical skills regarding various sample preparations and imaging techniques which are essential for conducting advanced plant science research.

Contents

- **Unit 1: Fundamental Principles of Microscope design** -- Image formation, resolution and contrast. Transmitted light and fluorescence microscopy techniques. Cameras, signal to noise ratio, digital image recording, processing and analysis, multispectral imaging. Advanced fluorescence – fluorescent probes, fluorescent biosensors, confocal laser scanning microscopy.
- **Unit 2: Tissue Fixation, Embedding and Sectioning** --Theoretical aspects, discussions and practical training sessions focused on the underlying principles related to tissue fixation, dehydration, paraffin embedding & microtomy, de-paraffinization, slide preparation.
- **Unit 3: Imaging Applications in Plants** -- Organelle-specific stains, intracellular localization of fluorescently-labeled chimeric proteins, protein-protein interaction analysis by BiFC, Ca^{++} dynamics in a cell.
- **Unit 4: Lab Biosafety Aspects** -- Chemical safety including handling of acids/bases, volatiles and organic compound related to microscopy techniques. Bio-hazard safety, proper handling and disposal of biological material used in microscopy techniques. High-energy radiation safety, appropriate handling of high-energy radiation such as UV-light and Laser etc.
- **Unit 5: Hands-on Training** -- Tissue preparation (Tissue fixation, Embedding and sectioning), staining and visualization; Localization of Fluorescent-tagged protein in the plant cell by transient expression analysis; Protein-interaction analysis by co-localization of fluorescent tagged proteins by FRET and or BiFC methods.

Suggested Readings

1. Imaging/Microscopy, general. Cold Spring Harbour Protocols: Web link: http://cshprotocols.cshlp.org/site/ Taxonomy/imaging_microscopy_l1.xhtml.
2. Imaging of Protein: Protein Interactions. Cold Spring Harbour Protocols; Web link: http://cshprotocols.cshlp.org/cgi/collection/imaging_of_protein:protein_interactions.
3. Imaging Protein Interactions by FRET Microscopy: FRET Measurements by Acceptor Photobleaching. Cold Spring Harbour Protocols: Web Links: http://cshprotocols.cshlp.org /content/2006 /6/pdb.prot4598.abstract.
4. Paddock, S. W. (2014) Confocal Microscopy: Methods and Protocols. Humana Press, USA.
5. Ruzin, S.E. (1999) Plant Microtechnique and Microscopy. Oxford University Press, USA.
6. Schwartzbach, S. D., Skalli, O. and Schikorski, T. (2016) High-Resolution Imaging of Cellular Proteins. Humana Press, USA.
7. Yolanda, M. and Hartmann, H. (2017) Light Microscopy, Methods and Protocols. Humana Press, USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 3

PBCC 301: Structure and Function of Eukaryotic Genome

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This paper is designed to provide a detailed account of the structure of the eukaryotic genomes as well as to understand the molecular processes that control the functioning of the genome.

Course outcome

The candidates would develop in-depth understanding of the eukaryotic genome organization and function in terms of mechanism of regulation of genes expression and its impact on organism. It would also appraise the students on the utility of such information in control of useful traits and diagnostics.

Contents

- **Unit 1: Genomes and Comparative Genomics** -- High throughput genome sequencing; *Arabidopsis*, rice and human genomes; Centromeres and telomeres; Distribution of repeat and transposable elements and their function; Gene order (Colinearity, Identification of orthologs, Functional predictions); Whole genome alignments, phylogenetic footprinting of coding sequences and regulatory regions for annotation; Evolution of genomes.
- **Unit 2: Epigenetic Control of Gene Expression** -- DNA methylation and its role in regulation of gene expression and in maintaining genome stability; chromatin modifications implicated in gene silencing and activation, the role of non-coding RNA, and higher order chromatin structures; Epi-transcriptome; Dosage Compensation: X-chromosome inactivation; Epigenetic control of flowering; Resetting the epigenome.
- **Unit 3: Transcriptional Control of Gene Expression** -- Gene architecture; Promoter architecture; Regulatory sequences, enhancers and mechanism of their action; RNA polymerases, Mediator complex and general transcription factors; DNA-protein interactions; Heterogeneous nuclear RNA; Cap structure and function; Polyadenylation; Britten-Davidson model; Transcription factors, DNA-binding and activation domains, activation of latent activators, co-activators; Transcription factories.
- **Unit 4: Post-transcriptional Control of Gene Expression** -- Introns and exons - size, distribution and evolution; Mechanism of RNA splicing; Catalytic RNA; Alternative splicing; RNA stability; Small RNAs and RNA interference; Small RNAs in control of gene expression.
- **Unit 5: Protein Level Controls** -- Study of global protein levels (proteomics); Dynamic modulation of protein structure and function; Translational control; Protein modification and degradation.

- **Unit 6: Functional genomics** -- Approaches for differential RNA measurements; Gene tagging; Gene trapping; Gene silencing; Knockout mutants; TILLING; Genome editing.
- **Unit 7: Applications in Agriculture and Human Health**-- Transcriptional control of selected disease and their diagnosis; Promoters and transcription factors for genetic modification of crops.

Suggested Readings

1. Berg, J. M, Tymoczko, J. L., Stryer, L. (2012) Biochemistry. WH Freeman and Company, New York.
2. Buchanan, B. B., Gruissem, W. and Jones, R. (2015) Biochemistry & Molecular Biology of Plants. John Wiley & Sons, Ltd., West Sussex.
3. Kahl, G. and Meksem, K. (2008) The Handbook of Plant Functional Genomics. Wiley-VCH Verlag GmbH & Co., Germany.
4. Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. (2014) Lewin's Genes XI. Jones and Bartlett Publishers, LLC, Burlington.
5. Latchman, D. S. (2015) Gene Control. Garland Science, New York.
6. Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin, K. C. (2016) Molecular Cell Biology. WH Freeman and Company, New York.
7. Stewart Jr., C. N, (2016) Plant Biotechnology and Genetics: Principles, Techniques and Applications. John Wiley & Sons, Inc., New Jersey.

Masters of Plant Molecular Biology and Biotechnology

Semester 3

PBCC 302: Concepts of Pattern Formation and Differentiation

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This course is devised to provide an in-depth understanding of the concepts of plant development taking leads from other model systems as well.

Course outcome

The candidate would develop an understanding of the various schema of organ and tissue development in plants.

Contents

- **Unit 1: Developmental Differences between Animal and Plants** -- Germ line development; Regeneration and totipotency; Post embryonic development.
- **Unit 2: Differentiation in Plants** -- Totipotency, Meristems, Organogenesis, adventive somatic embryogenesis, Apomixis.
- **Unit 3: Cellular Architecture** -- Cell division cycle; Cell movements and planes of cell division; Regulation of cell size, cell shape and organ initiation.
- **Unit 4: Embryonic Pattern Formation** -- Drosophila, Arabidopsis and maize.
- **Unit 5: Cell Lineages and Developmental Control Genes** -- *Caenorhabditis,* Arabidopsis and Maize.
- **Unit 6: Special Aspects of Plant Differentiation** -- Trichome differentiation; phloem and xylem differentiation; Phyllotaxy; Fertilization and incompatibility.
- **Unit 7: Molecular Mechanisms for Specialized Cell Types** --
    - **Transcriptional controls**: DNA Rearrangements - Phase changes in Salmonella, mating cell types in yeast, Surface antigens in Trypanosomes, Immunoglobulin diversity production; DNA methylation and developmental decisions - X-chromosome inactivation and Barr body formation; genomic imprinting of Igf2, etc.
    - **Post transcriptional controls** - Alternative RNA splicing (sex determination in Drosophila; muscle protein diversity), RNA transport, mRNA stability and gene expression (With reference to HIV infection and ferretin synthesis).

Suggested Readings

1. Gilbert, S. F. (2000) Developmental Biology. INC Publishers, USA.
2. Westhoff, P. (1998) Molecular Plant Development: from gene to plant. The Bath Press, UK.
3. Wolpert, L., Tickle, C., Martinez, A. (2015) Principles of Development. Oxford Publishers, UK.

4. Turnbill, G.N. (2005) Plant Architecture and its Manipulation: Annual Review of Plant Physiology Vol.17, Blackwell Publ. CRC Press, USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 3

PBCC 303: Agricultural Biotechnology

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

This course is designed to develop understanding of various techniques, methodologies and concerns about research on agricultural biotechnology.

Course outcome

The candidate would develop in-depth understanding of various aspects of agricultural biotechnology which is important to develop skills to meet the demands of the biotech industries.

Contents

- **Unit 1: Food and Agriculture** -- Food and agriculture; Scenarios of rise in population and food production at National and International levels; Indian farming; Major crop plants; Achievements and limitations of conventional plant breeding science.
- **Unit 2: Molecular Mapping and Marker-assisted Breeding** -- Marker-assisted plant breeding; Relative advantages/ disadvantages in conventional plant breeding and molecular breeding; Molecular polymorphism, Construction of genetic and physical map; Marker Assisted Selection (MAS) for genes of agronomic importance.
- **Unit 3: Plant Biotechnology** -- Historical perspectives of the birth of transgenic science; comparison of transgenic methods over conventional plant breeding methods; Major inputs in production of transgenic plants. Gene discovery.
- **Unit 4: Genetic Transformation**--Various transformation methods; Agrobacterium-mediated gene delivery; Disarming the Ti plasmid; Principles of vector designing; Screenable and selectable markers, Generation of marker-free transgenic methods, chloroplast transformation.
- **Unit 5: Transgenic Crops for Resistance to Biotic/abiotic Stresses and Quality Improvement** -- Viral resistance, fungal resistance, insects and pathogens resistance, drought, salinity, heat stress, low temperature stress, flooding and submergence stress, post-harvest bioengineering, concept of biofactories, herbicide resistance, engineering other traits.
- **Unit 6: Biosafety and IPR-related issues** -- Production and acceptance of transgenic crops; Public and private sectors in plant biotechnology Intellectual property rights (IPR), Plant breeders rights (PBRs) and farmers rights.

Suggested Readings

1. Altman, A. Hasegawa, P. M. (2011) Plant Biotechnology and Agriculture: Prospects for the 21st Century. Academic Press, USA.
2. Gurib-Fakim, A. (2014) Novel Plant Bioresources: Applications in Food, Medicine and Cosmetics. Wiley Blackwell, USA.
3. Kirakosyan, A. (2016) Recent Advances in Plant Biotechnology. Springer, USA.
4. Stewart, C. N. (Jr.) (2016) Plant Biotechnology and Genetics: Principles, Techniques, and Applications. Wiley, USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 3

PBEC 304: Plant Stress Biology

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objectives

Biotic and abiotic stress conditions are major deterrents of plant productivity. This paper aims to develop a deep understanding of plant responses to various stress conditions at both molecular and biochemical levels. It also provides understanding to various approaches that can be taken to engineer/breed biotic and abiotic resistance in crop plants.

Course outcome

The candidate would develop detailed understanding of various molecular and biochemical processes that are involved in regulating plant stress response. They will also develop understanding about the intricacies involved in engineering various molecular components for enhancing plant stress tolerance.

Contents

- **Unit 1: Introduction to Stress Biology --** Present-day agriculture and stress conditions, important stresses affecting crop plants in Indian ecosystems; changing stress scenario in view of climate change.
- **Unit 2: Introduction to Abiotic Stresses --** Effects of salt, drought, flooding and heat stresses on crops.
- **Unit 3: Biochemical and Physiological Impacts of Stresses --** Comprehensive molecular changes caused by abiotic stresses in plants; Current knowledge on proteins, genes, promoters, transcription factors and molecular signaling related to stress; Unfolded protein response.
- **Unit 4: Prospects of Managing Damage Due to Abiotic Stress --** Breeding crops resistant to abiotic stresses; Application of genomic tools in plant breeding against abiotic stresses; Transgenic approach in engineering resistance against abiotic stresses.
- **Unit 5: Bacterial and Fungal Pathogenicity --** Biotrophs, necrotrophs and hemibiotrophs; protein secretion systems of plant pathogenic bacteria.
- **Unit 6: Viral Pathogenicity --** Viral gene functions, virus-host and virus-vector interactions; RNA interference and viruses; viral satellites.
- **Unit 7: Plant Disease Resistance Genes --** Gene-for-gene hypothesis; virulence and avirulence; Features of resistance genes.
- **Unit 8: Resistance, Tolerance and Susceptibility --** Acquired and innate immunity in plants; Hypersensitive response; Systemic acquired resistance; Pathogenesis related proteins; Phytoalexins.

- **Unit 9: Signaling in Plant Disease** -- Genetic dissection of resistance pathways; resistance proteins as signaling molecules; Role of hormones in resistance.
- **Unit 10: Hands-on Training --** Assessment of stresses at cell and plant level**,** comparison of structural features of selected biotic and abiotic resistance genes downloaded from databases, simulation of different abiotic stresses, inoculation of pathogen and study of symptoms, real time PCR-based analysis of selected transcripts of resistant and susceptible lines of plants exposed to biotic/abiotic stresses.

Suggested Reading

1. Tuteja, N. and Gill, S. S. (2013) Climate Change and Plant Abiotic Stress Tolerance. Wiley, USA.
2. Buchanan, B. B., Gruissem, W. and Jones, R. L. (2015) Biochemistry and Molecular Biology of Plants. Wiley, USA.
3. Dickinson, M. (2003) Molecular Plant Pathology. Bios Scientific Publishers, Taylor and Francis Group, USA.
4. Hull, R. (2014) Plant Virology. Academic Press, USA.
5. Jenks, M. A. and Hasegawa, P.M. (2014) Plant Abiotic Stress. Wiley, USA.

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Semester 3

PBCC 305: Practicals

Marks = 200 *Teaching Hrs. = 120 (Credits= 8)*

Course objectives

The paper is designed to provide hands-on practical training on various molecular and biochemical techniques.

Course outcome

This course will impart competence in various advanced molecular and data analytics techniques related to plant development, gene expression at both transcript and protein level, molecular marker analysis, as well as transgenic plant analysis.

List of Practicals

1. Analysis and interpretation of RNA-seq data.
2. *In silico* identification of SNP and SSR markers in rice.
3. To detect polymorphism between two varieties of *Oryza sativa* using SSR markers.
4. To isolate RNA from a given plant material and to perform the qualitative analysis by formaldehyde agarose gel electrophoresis.
5. Perform real-time PCR analysis for quantification of gene expression.
6. Analysis of sRNAs from NGS (Next Generation Sequencing) data.
7. To confirm T-DNA insertion in an Arabidopsis mutant and identify heterozygous and homozygous plants for insertion using PCR method.
8. To resolve and visualize low molecular weight RNAs by denaturing urea-PAGE.
9. To study organogenesis and differentiation of shoots and roots from various explants.
10. To study somatic embryogenesis in higher plants.
11. To study androgenesis in higher plants.
12. To study cytosine methylation and restriction protection of DNA.
13. To study differences in cytosine methylation at genomic level by methylation dependent PCR.
14. To demonstrate Agrobacterium-mediated gene delivery and study the expression of gus gene by histochemical and fluorimetric methods.
15. To analyze the transgenic plant for the expression of foreign protein by Western blotting method.
16. Detection of viral DNA accumulation in plants using Southern analysis and DIG-labeled probes.
17. Intracellular protein localization by transient expression of protein: GUS/GFP Fusion constructs in onion peel cells assays by particle gun bombardment.

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Semester 3

PBEC 306: Small RNA Biology and Epigenetics

Marks = 100 *Teaching Hrs. = 60 (Credits= 4)*

Course objective

Epigenetic landscape (including both DNA methylation and histone modifications) of an organism has a significant bearing in regulating various developmental and metabolic processes at global level. Similarly sRNAs have emerged as a major modulators of global gene expression patterns. Thus, this course is designed to develop an in-depth understanding of the interplay of sRNAs and epigenetic modifications in regulating various molecular processes in plants.

Course outcome

The candidate would understand how various molecular processes maintain the epigenetic status of the plant genome. They will also understand how the epigenetic status is interpreted by the molecular machinery to modulate various biochemical and developmental processes in plants. Further, they will also learn how sRNA mediated regulatory processes are implicated in maintaining plant epigenetic status.

Contents

- **Unit 1: Chromatin Modeling and Remodeling** -- Polycomb complexes, SWI/SNF1 complexes and other chromatin modifiers.
- **Unit 2: Interpretation of DNA Methylation Marks by Cellular Machinery** -- Study of methylated DNA binding proteins, their structure and function, methods of altering DNA methylation.
- **Unit 3: Study of Histone Modifications** -- Histone modifications, modifying enzymes, histone deacetylase inhibitors.
- **Unit 4: Chromatin Modification and Development** -- Effect on somatic embryogenesis, leaf development, photosynthesis, flowering and ageing.
- **Unit 5: Epigenetics and Environment** -- Role in plant stresses, epigenetic memory.
- **Unit 6: Epigenetics in Human Systems** -- Role in immune response, cancer and cardiovascular diseases.
- **Unit 7: Non-coding RNAs** -- Types and occurrence of non-coding RNAs, small RNAs in different biological systems, diversity and evolution of small RNAs.
- **Unit 8: Identification and Characterization of Small RNAs** -- Discovery, detection and validation of small RNAs, target prediction and validation, databases on small RNAs, an overview of bioinformatics tools in small RNA biology.
- **Unit 9: Small RNA Pathways** - Biogenesis of different classes of small RNAs, components and their characteristic features.

- **Unit 10: Regulation of Gene Expression by Small RNAs** -- Transcriptional gene silencing (TGS), Post-transcriptional Gene Silencing (PTGS), gene activation, evolutionary transition of small RNA-target gene pair.
- **Unit 11: Biological Processes Regulated by Small RNAs** -- Diverse roles of small RNAs in regulating biological processes in different organisms: bacteria, plants & animals, trans-kingdom cross-talk mediated by small RNAs.
- **Unit 12: Small Non-coding RNAs as Effective Tools in Biotechnology** -- amiR technology, siRNA technology, Virus-induced gene silencing (VIGS), RNA Interference (RNAi) and RNA activation (RNAa), target mimicry, Short tandem target mimic technology (STTM) & miR sponges, CRISPR-Cas mediated genome editing technology, crop improvement, diagnostics and therapeutic applications in human diseases.
- **Unit 13: Hands-on Training --** Techniques for studying differential methylation of DNA, gene expression in response to altered DNA methylation, expression profiling of small RNAs, survey of small RNA databases, case studies of plant miRNA families.

Suggested Readings

1. Esteller, M. (2008) Epigenetics in Medicine and Biology. CRC Press, USA
2. Rajewsky, N., Jurga, S. and Barsizewsky, J. (2018) Plant Epigenetics. Springer International Publishing AG, USA
3. Mallick, B. and Ghosh, Z. (2014) Regulatory RNAs: Basics, Methods and Applications. Springer, Germany.
4. Nellan, W. and Hammann, C. (2007) Small RNAs: Analysis and Regulatory Functions. Springer Science and Business Media, USA.
5. Gaur, R. K. and Rossi, J. J. (2009) Regulation of Gene Expression by Small RNAs. CRC Press, USA.

Masters of Plant Molecular Biology and Biotechnology

Semester 4

PBCC 401: Dissertation

Marks = 600 *Teaching Hrs. = 480 (Credits= 24)*

Dissertation work shall comprise an in-depth study pertaining to a specific research topic under the direct supervision of a faculty member. The student shall spend the entire Semester-4 in experimentation and study on the topic and shall submit the Dissertation in bound form at the end of the semester.

Course objectives

This course is designed to provide extensive practical training to the students so as to enable them to conceive a research problem, design experimental strategy, conduct experiments as well as compile and discuss the results. The students are required to work in the research labs of the Department and thus are exposed to the actual research and development environment in the filed of plant sciences.

Course outcome

The candidates would learn how to independently pursue a research problems. They would understand how a research problem is formulated based on available research data and socio-economic impact. Candidates will also develop practical skills for accurately conducting various molecular and biochemical techniques. They will also develop understanding about how the experimental data is compiled, analyzed and discussed in light of previously available literature data. Thus, this paper would provide a glimpse of how actual research in plant biological is conducted.