M. Tech (Biotechnology)

2021 Regulations, Curriculum & Syllabi

Stay Ahead

BANNARI AMMAN INSTITUTE OF TECHNOLOGY

An Autonomous Institution Affiliated to Anna University – Chennai • Approved by AICTE • Accredited by NAAC with "A+" Grade

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BANNARI AMMAN INSTITUTE OF TECHNOLOGY
REGULATIONS 2021
(CHOICE BASED CREDIT SYSTEM)

Common to all M.E. / M.Tech. Degree Programmes

NOTE: *The regulations given hereunder are subject to amendments as may be decided by the Academic Council of the Institute from time to time. Any or all such amendments will be effective from such date and to such batches of students, including those already in the middle of the programme as may be decided by the Academic Council.*

1. ELIGIBILITY FOR ADMISSION

(i) Candidates seeking admission to the First Semester of M.E./M.Tech. degree programmes will be required to satisfy the eligibility criteria for admission thereto prescribed by the Directorate of Technical Education, Chennai and Anna University, Chennai.

(ii) Students admitted under 'Full-Time' should be available in the departments during the entire duration of working hours (from morning to evening on a full-time basis) for the curricular, co-curricular and extra-curricular activities.

The full-time students should not attend any other full-time programme(s) / course(s) or take up any full-time job / part-time job during working hours in any institution or company during the period of the full-time programme. Violation of the above rules will result in the cancellation of admission to the PG programme.

2. DURATION OF THE PROGRAMME

(i) **Minimum Duration:** Master of Engineering (M.E.) / Master of Technology (M.Tech.) extends over a period of two years. The two academic years will be divided into four semesters, with two semesters per year.

(ii) **Maximum Duration**: A candidate shall complete all the passing requirements of M.E./M.Tech. programmes within a maximum period of 4 years / 8 semesters, these periods being reckoned from the commencement of the first semester to which the candidate was first admitted, regardless of the break-of-study availed.

3. BRANCHES OF STUDY

Following M.E./M.Tech. programmes are offered by the institute

M.E. Programmes

1. Communication Systems
2. Computer Science and Engineering

3. Embedded Systems
4. Industrial Automation and Robotics
5. Industrial Safety Engineering
6. Power Electronics and Drives
7. Software Engineering
8. Structural Engineering

M. Tech. Programme

9. Biotechnology

4. STRUCTURE OF PROGRAMMES

(i) **Curriculum:** Every post-graduate programme will have a curriculum with syllabi consisting of theory and practical courses that include

Program Core Courses (PCC) include the core courses relevant to the chosen specialisation.

Program Elective Courses (PEC) include the elective courses relevant to the chosen specialisation.

Research Methodology and IPR Course to understand the importance and the process of creation of patents through research.

Employability Enhancement Courses (EEC) include project work, practical courses, internship, mini project and industrial/practical training.

Audit Courses (AC) expose the students to Disaster Management, Yoga, English for Research Paper Writing, Value education, Pedagogy Studies, Stress Management, and Personality Development through Life Enlightenment Skills. Registration for any of these courses is optional to students.

(ii) **Project Work:** Every student, individually, shall undertake Dissertation Phase I during the third semester and Dissertation Phase II during the fourth semester under the supervision of a qualified faculty. The project work can be undertaken in an industrial / research organisation or institute in consultation with the faculty guide and the Head of the Department. In the case of project work at an industrial / research organisation, the same shall be jointly supervised by a faculty guide and an expert from the organisation. The student shall be instructed to meet the supervisor periodically and attend the review committee meetings to evaluate the progress.

(iii) **Elective Courses: Five Elective** courses are offered to the students admitted in various disciplines as prescribed in the curriculum to widen their knowledge in their specialisation area.

(iv) **Online Courses:** A Student may be permitted to credit online courses with the approval of a Departmental Consultative Committee constituted by the Head of the Department, subject to a maximum of six credits. Such students may be exempted

from attending the classes if such course(s) are offered in the semester. Summary of such online courses, taken by the students, along with the offering agency shall be presented to the Academic Council for information and further suggestions. However, the student needs to obtain certification from the agency offering the course to become eligible for writing or seeking exemption from the End Semester Examinations. In case of credits earned through online mode from the Institute / University, the credits may also be transferred directly after due approval from the Departmental Consultative Committee and the Controller of Examinations.

(v) **Industrial Training:** Every full-time student shall take up training in industry/research laboratories, under the supervision of a faculty guide during summer/winter vacation till the pre-final semester of the programme subject to the evaluation prescribed in Clause 15.

If industrial training/internship is not prescribed in the curriculum, the student may undergo industrial training/internship optionally, and the credits earned will be indicated in the Mark Sheet. If the student earns three credits in industrial training/internship, the student may drop one Program Elective in the III semester. In such cases, industrial training/internships need to be undergone continuously from one organisation only. However, if the number of credits earned is 1 or 2, these credits shall not be considered for the classification of the degree. The student is only allowed to undergo a maximum of 6 weeks of industrial training/internship during the entire duration of the study.

Duration of Training / Internship	**Credits**
2 Weeks	1
4 Weeks	2
6 Weeks	3

(vi) **Mini Project**: The students shall undertake a mini project individually in consultation with the respective faculty and Head of the Department, as specified in the curriculum. A student is expected to make a presentation about the mini-project during the final evaluation as given in Clause 15.

(vii) **Value Added / Certificate Courses:** Students can opt for any one of the value-added courses in II and III semesters, approved by the Academic Council. A separate certificate will be issued on successful completion of the course by the Controller of Examinations.

(viii) **Credit Assignment:** Each course is normally assigned a certain number of credits with 1 credit per lecture hour per week, 1 credit for 2 hours of practical per week, 1 credit for 1 hour of tutorial per week. The exact numbers of credits assigned to the different courses of various programmes are decided by the respective Board of Studies.

(ix) **Minimum Credits:** For the award of the degree, the student shall earn a minimum number of total credits as prescribed by the respective Board of Studies as given below:

S.No.	M.E./M. Tech. Programmes	Total Credits
1.	M.E. Communication Systems	68
2.	M.E. Computer Science and Engineering	68
3.	M.E. Embedded Systems	68
4.	M.E. Industrial Automation and Robotics	68
5.	M.E. Industrial Safety Engineering	68
6.	M.E. Power Electronics and Drives	68
7.	M.E. Software Engineering	68
8.	M.E. Structural Engineering	68
9.	M.Tech. Biotechnology	68

5. COURSE ENROLLMENT AND REGISTRATION

5.1 Each student, on admission, shall be assigned to a Faculty Advisor (vide Clause 7) who shall advise/counsel the student about the details of the academic programme and the choice of courses considering the student's academic background and career objectives.

5.2 Every student shall enrol for the courses of the succeeding semester in the current semester. However, the student shall confirm the enrolment by registering for the courses within the first five working days after the commencement of the semester concerned.

5.3 After registering for a course, a student shall attend the classes, satisfy the attendance requirements, earn Continuous Assessment marks and appear for the End Semester Examinations.

5.3.1 Each student on admission to the programme shall register for all the **courses prescribed in the curriculum** in the **first semester of study**.

5.3.2 The enrolment for all the courses of semester II will commence 10 working days prior to the last working day of the semester I. The student shall confirm the enrolment by registering for the courses within the first five working days after the commencement of semester II.

5.3.3 If a student wishes, the student may drop or add courses (vide Clause 5.5)

within **five** working days after the commencement of the semester concerned and complete the registration process duly authorised by the PG coordinator of the programme. In this case, if a student fails in a course, he/she may be permitted to register for the course in the subsequent semester or when it is offered.

5.3.4 A student who has passed all the courses prescribed in the curriculum for the award of the degree shall not be permitted to re-enrol to improve the student's marks in a course or the aggregate marks / CGPA.

5.4 Minimum Credits to Register for Project work

The Project work for M.E./M.Tech. consists of dissertation phase I and dissertation phase II. Dissertation phase I is to be undertaken during the III semester, and dissertation phase II, which is a continuation of phase I, is to be undertaken during the IV semester. Minimum 24 credits are required to be earned to enrol on dissertation phase I.

If a student fails to earn the requisite minimum credits, the student cannot enrol for dissertation phase I. In such a case, the student can enrol for the project work in a subsequent semester after earning the minimum credits specified.

5.5 Flexibility to Add or Drop courses

5.5.1 A student has to earn the total number of credits specified in the curriculum of the respective programme of study in order to be eligible to obtain the degree. However, if a student wishes, the student is permitted to earn more than the total number of credits prescribed in the curriculum of the student's programme by opting for additional courses.

5.5.2 From the II to final semesters, the student has the option to register for additional courses or drop existing courses. The total number of credits that a student can add or drop is limited to 6, subject to a maximum of 2 courses. In such cases, the attendance requirement as stated in Clause 6 is mandatory.

The courses that a student registers in a particular semester may include:

i. Courses of the current semester and

ii. Courses dropped in the lower semesters.

The maximum number of credits that can be registered in a semester is 36. However, this does not include the number of Re-appearance (RA) and Withdrawal (W) courses registered by the student for the appearance of Examination.

5.6 Reappearance Registration

5.6.1 If a student fails in a theory course, the student shall do reappearance registration for that course in the subsequent semester or when it is offered next.

5.6.2 On registration, a student may attend the classes for the reappearance registration courses if the student wishes. However, the attendance requirement (vide Clause 6) is not compulsory for such courses.

5.6.3 The student who fails in any practical/mini project or any other EEC courses shall register for the same in the subsequent semester or when offered next and **repeat** the course. In this case, the student shall attend the classes, satisfy the attendance requirements (vide Clause 6) and earn continuous assessment marks.

5.6.4 The student who fails in dissertation phase I / II shall register for the same in the subsequent semester or when offered next and **repeat** the course. In this case, the student shall attend the classes, satisfy the attendance requirements (vide Clause 6), earn continuous assessment marks and appear for the end semester examinations. Reappearance registration is not available for such courses.

5.6.5 If a student is prevented from writing the end semester examination of a course due to lack of attendance, the student has to register for that course again, when offered next, attend the classes and fulfil the attendance requirements as per Clause 6.

6. REQUIREMENTS FOR APPEARING FOR THE END SEMESTER EXAMINATION OF A COURSE

A student who has fulfilled the following conditions (vide clause 6.1 and 6.2) shall be deemed to have satisfied the attendance requirements for appearing for the End Semester Examination of a particular course.

Each semester shall normally consist of 75 working days or 540 periods of each 50 minutes duration for the full-time mode of study.

6.1 Ideally, every student is expected to attend all the periods and earn 100% attendance. However, a student shall secure not less than 80% attendance course wise taking into account the number of periods required for that course as specified in the curriculum.

6.2 If a student secures attendance between 70% and 79% in any course in the current semester due to medical reasons (prolonged hospitalisation/accident / specific illness) or participation in Institution/University/State/National/International level extra and co-curricular activities, with prior permission from the Head of the Department, shall be permitted to appear for the current semester examinations subject to the condition that the student shall submit the medical certificate/participation certificate attested by the Head of the Department. Such certificates shall be forwarded to the Controller of Examinations for verification and permission to attend the examinations.

6.3 A student shall normally be permitted to appear for the end semester examination of a course if the student has satisfied the attendance requirements (vide Clause 6.1-6.2) and has registered for the examination in those courses of that semester by paying the prescribed fee.

6.4 A student who does not satisfy clauses 6.1 and 6.2 and secures less than 70% attendance in a course will not be permitted to write the end semester examination. The student has to register and repeat this course in the subsequent semester or when it is offered next (vide clause 5.6.4).

6.5 A student who has already appeared for a course in a semester and passed the examination is not entitled to reappear in the same course to improve grades/marks.

7. FACULTY ADVISOR

To help students plan their courses of study and for general advice on the academic programme, the Head of the Department of the students will attach a certain number of students to a teacher of the department, who shall function as a faculty advisor for those students throughout their period of study. The faculty advisor shall advise the students in registration and reappearance (Arrear) registration of courses, authorise the process, monitor their attendance and progress and counsel them periodically. If necessary, the faculty advisor may also discuss with or inform the parents about the progress/performance of the students concerned.

The responsibilities of the faculty advisor shall be:

i. To inform the students about the various facilities and activities available to enhance the student's curricular and co-curricular activities.

ii. To guide student enrolment and registration of the courses

iii. To authorise the final registration of the courses at the beginning of each semester.

iv. To monitor the academic and general performance of the students, including attendance, and to counsel them accordingly.

v. To collect and maintain the academic and co-curricular records of the students

8. COMMITTEES

8.1 Class Committee Meeting

i. For all the courses taught, prescribed in the curriculum, a class committee meeting shall be convened twice a semester, comprising faculty members handling all the courses and two student representatives from the class.

ii. One of the faculty members (not handling any courses to that class), nominated by the Head of the Department, shall coordinate the activities of

this Committee. During these meetings, the student members shall meaningfully interact and express their opinions and suggestions of all students to improve the effectiveness of the teaching-learning process. It is the responsibility of the student representatives to convey the proceedings of these meetings to all other students.

9. ASSESSMENT AND PASSING REQUIREMENTS

9.1 Assessment

The assessment will comprise continuous assessment and end semester examination, carrying marks as specified in the scheme (Clause 15). All assessments will be done on absolute marks basis. However, to report the performance of a student, letter grades and grade points will be awarded as per Clause 9.4.

9.2 End Semester Examinations

End semester examinations will normally be conducted as per the timetable circulated by the CoE's Office. A student will be permitted to appear for the end semester examination of a semester only if he/she completes the study of that semester satisfying the requirements given in Clause 5 and 6, and registers simultaneously for the examinations of the highest semester eligible and the courses, pertaining to that semester, that needs reappearance.

9.3 Employability Enhancement Courses

Every candidate shall submit reports on industrial training / mini-project, dissertation phase I and dissertation phase II on dates announced by the institute/department through the faculty guide to the head of the department. If a candidate fails to submit the reports of any of these courses not later than the specified date, he/she is deemed to have failed in it. The reports /papers shall be orally presented by the student before a team of experts consisting of an internal examiner, usually the supervisor, and an external examiner, appointed by the Controller of the Examination.

A candidate is permitted to register for dissertation phase II only after passing dissertation phase I. A candidate who fails in industrial training / mini-project, dissertation phase I or dissertation phase II shall register for redoing the same at the beginning of a subsequent semester.

9.4 Letter Grade and Grade Point

The letter grade and the grade point are awarded based on the percentage of total marks secured by a candidate in an individual course as detailed below:

Letter Grade	**Grade Points**
O (Outstanding)	10
A + (Excellent)	9
A (Very Good)	8
B + (Good)	7
B (Above average)	6
C (Satisfactory)	5
RA (Reappearance Registration)	0
I (Incomplete)	0
W (Withdrawal)	0
AB (Absent)	0
SA(Shortage of Attendance)	0

'RA' - Reappearance registration is required for that particular course

'I' - Continuous evaluation is required for that particular course in the subsequent examinations.

After completion of the evaluation process, Semester Grade Point Average (SGPA) and Cumulative Grade Point Average is calculated using the formula:

$$SGPA/CGPA = \frac{\sum_1^n C_i * g_i}{\sum_1^n C_i}$$

where

C_i Credit allotted to the course.

g_i Grade Point secured corresponding to the course.

n number of courses successfully cleared during the particular semester in the case of SGPA and all the semesters, under consideration, in the case CGPA.

9.5 A student can apply for revaluation of his/her semester examination answer paper in a theory course, within 3 working days from the declaration of results, along with prescribed application to the Controller of Examinations through the Head of Department. Revaluation is not permitted for laboratory courses, industrial training, and project works.

9.6 Passing a Course

A candidate who secures Grade Point 6 or more in any course of study will be declared to have passed that course, provided he/she secures a minimum of 50% of the total mark in the end semester examination of that course.

If a student fails to secure a pass in theory courses and laboratory courses in the current semester examination, he/she is allowed to write arrear examinations for the next three consecutive semesters, and their internal marks shall be carried over for the above mentioned period of three consecutive semesters.

In case if he/she has not completed all the courses of the semester I at the end of semester IV, he/she shall redo the semester I courses along with regular students. The same procedure shall be followed for the subsequent semesters of II, III and IV, subject to the maximum permissible period for this programme.

9.7 If a candidate fails in the end semester examinations of Phase I, he/she has to resubmit the project report within 30 days from the date of declaration of the results. If he/she fails in the end semester examination of Phase II of M.E. / M.Tech., he/she shall resubmit the project report within 60 days from the date of declaration of the results. The resubmission of the project report and the subsequent viva voce examination will be considered as reappearance with payment of the exam fee. If a student fails to resubmit the project report within the stipulated period and fails in the subsequent viva-voce examination, the student shall register for the course again in the subsequent semester.

10. REJOINING THE PROGRAMME

A candidate who has not completed the study of any of the semesters as per Clause 6 or who is allowed to rejoin the programme after the period of discontinuance or who on his/her own request is permitted to repeat the study of any semester (break of study), may join the semester which he/she is eligible or permitted to join, only at the time of its normal commencement for a regular batch of candidates and after obtaining the approval from the Director of Technical Education and Anna University, Chennai. In such a case, earlier continuous assessment in the repeated courses will be disregarded. However, no candidate will be allowed to enrol in more than one semester at any point of time.

11. QUALIFYING FOR THE AWARD OF THE DEGREE

A candidate will be declared to have qualified for the award of the M.E. / M.Tech. Degree provided:

i. He/she has completed the course requirements and has passed all the prescribed courses of study of the respective programme listed in Clause 3 within the duration specified in Clause 2.

ii. No disciplinary action is pending against the candidate.

12. CLASSIFICATION OF THE DEGREE AWARDED

12.1 First Class with Distinction:

A student who satisfies the following conditions shall be declared to have passed the examination in First class with Distinction:

- Should have passed the examination in all the courses of all the four semesters in the student's First Appearance within two years (Three years in case of authorised break of study of one year (if availed)). Withdrawal from examination (vide Clause 13) will not be considered as an appearance.
- Should have secured a CGPA of not less than 8.50.
- Should NOT have been prevented from writing end Semester examination due to lack of attendance in any of the courses.

12.2 First Class:

A student who satisfies the following conditions shall be declared to have passed the examination in first-class:

- Should have passed the examination in all the courses of all four semesters within three years, including one year of authorised break of study (if availed) or prevention from writing the End Semester Examination due to lack of attendance (if applicable).
- Should have secured a CGPA of not less than 6.50

12.3 Second Class:

All other students (not covered in clauses 12.1 and 12.2) who qualify for the award of the degree shall be declared to have passed the examination in the second class.

12.4 A student who is absent in the End Semester Examination in a course/project work after having registered for the same shall be considered to have appeared in that examination (except approved withdrawal from end semester examinations as per clause 13) for the purpose of classification.

13. WITHDRAWAL FROM EXAMINATION

13.1 A student may, for valid reasons, be granted permission by the Head of the Department to withdraw from appearing in the examination in any course(s) only once during the entire duration of the degree programme.

13.2 Withdrawal application shall be valid only if the student is eligible to write the examination as per Clause 6 and if such withdrawal request is made prior to the submission of marks of the continuous assessment of the course(s) with the recommendations from the Head of the Department.

13.3 If a student withdraws a course or courses from writing end semester examinations, he/she shall register the same in the subsequent semester and write the end semester examination(s)

13.4 Withdrawal shall not be considered as an appearance for deciding the eligibility of a candidate for first class with distinction or first class.

13.5 Withdrawal is permitted for the end semester examinations in the final semester only if the period of study the student concerned does not exceed 3 years for M.E. / M.Tech. as per clauses 12.1 and 12.2.

14. AUTHORISED BREAK OF STUDY FROM A PROGRAMME

14.1 A student is permitted to go on a break of study for a fixed period of one year as a single break in the entire course of study.

14.2 A student who would like to avail the break of study, on account of short term employment / medical treatment / personal reasons) shall apply to the Head of the Institution through the concerned Head of the Department (application available with the Controller of Examinations), in any case, not later than the last date for registering for the semester.

14.3 The students permitted to re-join the programme after a break of study/prevention

due to lack of attendance shall be governed by the curriculum and regulations in force at the time of re-joining. A committee constituted by the Head of the Institution shall prescribe additional/equivalent courses, if any, from the regulation in force to bridge the requirement between the curriculum in force and the old curriculum.

14.4 The total period for completion of the programme reckoned from the commencement of the first semester to which the student is admitted shall not exceed the maximum period specified in Clause 2, irrespective of the period of break of study in order that he/she may be eligible, for the award of the degree (vide Clause 11 and 12).

14.5 In case of any valid reasons for the extension of break-of-study, such extended break-of-study may be granted by the Head of the Institution for a period not more than one year in addition to the earlier authorised break of study. Such extended break-of-study shall be counted for the purpose of classification of degree (vide clause 12).

14.6 If a student does not report back to the institute, even after the extended break of study, the name of the student shall be deleted permanently from the college enrolment. Such candidates are not entitled to seek readmission under any circumstances.

15. SCHEME OF ASSESSMENT

I	**THEORY COURSES**	**Marks**
	Continuous Assessment	**50**
	Distribution of marks for Continuous Assessment: Periodical Test I (15) Periodical Test II (15) Term Paper Report (10) & Presentation (10)	
	End Semester Examination	**50**
	Total Marks	**100**
II	**THEORY COURSES WITH LAB COMPONENT**	**Marks**
	Continuous Assessment	**50**
	Distribution of marks for Continuous Assessment: Periodical Test I (15) Periodical Test II (15) Lab Examination (10) Viva-voce (10)	
	End Semester Examination (QP pattern as per (I))	**50**
	Total Marks	**100**
III	**PRACTICAL COURSES**	**Marks**
	Continuous Assessment	**100**
	Distribution of marks for Continuous Assessment: Conduct of Experiment i. Preparation (10) ii. Experiment and Analysis of Results (20) iii. Record (5) Self-Learning Experiment (15) Test - Cycle I (15) Test - Cycle II (15) Final Viva-voce (20)	
	Total Marks	**100**
IV	**DISSERTATION PHASE I**	**Marks**
	Continuous Assessment	**50**
	Distribution of marks for Continuous Assessment: Review I *Identification of topic and Justification (5)* *Literature Survey (5)* Review II *Work plan & Approach (10)* *Progress, Results and Discussion (10)* Review III *Conclusion (10)* *Implementation & Applications (10)*	

	End Semester Examination	
	Presentation (20) Report (10) Viva Voce (20)	**50**
	Total Marks	**100**

V	**DISSERTATION PHASE II**	**Marks**
	Continuous Assessment	**50**
	Distribution of marks for Continuous Assessment:	
	Review I *Work plan & Approach (10)* Review II *Progress (10)* *Results and Discussion (10)* Review II *Conclusion (10)* Implementation & Applications *(10)*	
	End Semester Examination	
	Presentation (20) Report (10) Viva Voce (20)	**50**
	Total Marks	**100**

VI	**MINI PROJECT**	**Marks**
	Continuous Assessment	**100**
	Distribution of marks for Continuous Assessment:	
	Review I	**25**
	Review II	**25**
	Presentation & Viva voce	**50**
	Total Marks	**100**

VII	**INDUSTRIAL TRAINING / INTERNSHIP**	**Marks**
	Continuous Assessment	**100**
	Presentation	**30**
	Viva-voce	**30**
	Case study / Report	**40**
	Total Marks	**100**

VIII	**VALUE ADDED COURSES / CERTIFICATE COURSES (Continuous Assessment Only)**	**Marks**
	Test I	50
	Test II	50
	Grades: Excellent (>80) / Good (61≤Marks ≤ 80) / Satisfactory (50≤Marks ≤ 60))	

Optional Test: *A student becomes eligible to appear for the one optional test conducted after the Periodical Test II, only under the following circumstances, if absent for Test I or Test II or both, on account of (i) medical reasons (hospitalisation / accident / specific illness) (ii) participation in the college/university/state / national/international level Sports events with prior permission from the Head of the Institution and (iii) on satisfying the conditions (i) or (ii), the student should have registered for the Optional Test, through the concerned faculty member who handles the course or through the respective Head of the Department, submitted to the Controller of Examinations. Such Optional Tests are not conducted for the courses under the categories III, IV, V, VI, VII and VIII listed above.*

16. DISCIPLINE

A student is expected to follow the rules and regulations laid down by the Institute and the affiliating University, as published from time to time. Any violations, if any, shall be treated as per the procedures stated thereof.

If a student indulges in malpractice in any of the end semester / continuous assessments, he/she shall be liable for punitive action as prescribed by the institution / university from time to time.

VISION OF THE DEPARTMENT

To excel in academics and become a pioneer in research by nurturing the students with technical and innovative expertise to connect better with industry and society.

MISSION OF THE DEPARTMENT

I. To equip students with the knowledge and practical skills relevant to the real-life applications.

II. To establish a Centre of Excellence in the frontier areas of research.

III. To develop manpower with a high level of professionalism.

M. TECH - BIOTECHNOLOGY

PROGRAM EDUCATIONAL OBJECTIVE

I. The graduates of Biotechnology will acquire the skills in approaching and solving challenges related to healthcare, agriculture and environmental sectors through Biotechnological approaches.

II. The graduates of Biotechnology shall be equipped to develop and deliver novel designs/processes/products that could cater to the industrial demands to improve the social ecosystems.

III. The graduates of Biotechnology will have multidisciplinary skills to become entrepreneurs/ teachers and contribute for sustained economic growth through life science research

PROGRAM OUTCOME

PO1. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector

PO2. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations

PO3. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

PO4. Carry out research /investigations independently and develop explicit solutions for solving real-world problems

PO5. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities.

PO6. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

MAPPING OF PEOs & POs

PEO	PROGRAM OUTCOME					
	1	**2**	**3**	**4**	**5**	**6**
PEO I	**X**		**X**	**X**		**X**
PEO II	**X**	**X**	**X**			**X**
PEO III		**X**		**X**	**X**	

M. Tech. BIOTECHNOLOGY

Minimum Credits to be Earned 68.0

FIRST SEMESTER

Code No.	Course	Objectives & Outcomes		L	T	P	C
		PEOs	POs				
21BT11	Research Methodology and IPR	I,II,III	a,b,c,d,e,f	2	0	0	2
21BT12	Cellular Energetics and Metabolism	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT13	Recombinant DNA Technology	I,II,III	a,b,e,f	3	0	0	3
21BT14	Integrated Bioprocess Technology	I,II,III	a,b,c,d,e,f	3	0	0	3
	Program Elective I	-	-	-	-	-	3
21BT16	Recombinant DNA Technology Laboratory	I,II,III	a,b,c,d,e,f	0	0	4	2
21BT17	Integrated Bioprocess Technology Laboratory	I,II,III	a,b,c,d,e,f	0	0	4	2
	Audit Course I	-	-	-	-	-	0
			Total	11	0	8	18

SECOND SEMESTER

Code No.	Course	Objectives & Outcomes		L	T	P	C
		PEOs	POs				
21BT21	Bio-Analytical Techniques	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT22	Immunotechnology	I,II,III	a,c,d,e,f	3	0	0	3
21BT23	Computational Modelling And Big Data Analysis	I,II,III	a,b,c,d,e,f	3	0	2	4
	Program Elective II	-	-	-	-	-	3
	Program Elective III	-	-	-	-	-	3
21BT26	Immunotechnology Laboratory	I,II,III	a,b,c,d,e,f	0	0	4	2
21BT27	Mini Project	I,II,III	a,b,c,d,e,f	0	0	4	2
	Audit Course II*	-	-	-	-	-	0
			Total	9	0	10	20

THIRD SEMESTER

Code No.	Course	Objectives & Outcomes		L	T	P	C
		PEOs	POs				
	Program Elective IV	-	-	-	-	-	3
	Program Elective V	-	-	-	-	-	3
21BT33	Dissertation Phase I	I,II,III	a,b,c,d,e,f	0	0	20	10
			Total	0	0	20	16

FOURTH SEMESTER

Code No.	Course	Objectives & Outcomes		L	T	P	C
		PEOs	POs				
21BT41	Dissertation Phase II	I,II,III	a,b,c,d,e,f	0	0	28	14
			Total	0	0	28	14

ELECTIVES							
Code No.	**Course**	**Objectives & Outcomes**		**L**	**T**	**P**	**C**
		PEOs	**POs**				
DISCIPLINE ELECTIVES							
21BT51	Industrial Microbiology	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT52	Omics Technology	I,II,III	a,b,d	3	0	0	3
21BT53	Thermo Analytical Techniques	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT54	Tissue Engineering And Regenerative Medicine	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT55	Forensic Biotechnology	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT56	Clinical Trials And Bioethics	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT57	Agricultural Biotechnology	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT58	Nanomedicine	I,II,III	a,b,c,d,e	3	0	0	3
21BT59	Developmental Biology	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT60	Bioreactor Design And Process Economics	I,II,III	a,c,d,e,f	3	0	0	3
21BT61	Human Heredity And Genetics	I,II,III	a,c,d,e,f	3	0	0	3
21BT62	Fermentation And Food Process Engineering	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT63	Modern Food Biotechnology	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT64	Pharmacogenomics	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT65	Biomass Valorization And Applications	I,II,III	a,c,d,e,f	3	0	0	3
21BT66	Environmental Biotechnology	I,II,III	a,c,d,e,f	3	0	0	3
21BT67	Entrepreneurship Essentials And Legal Startups	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT68	Biostatistics	I,II,III	a,b,c	3	0	0	3
21BT69	Pharmaceutical Biotechnology	I,II,III	a,b,c,d,e,f	3	0	0	3
21BT70	Natural Products And Drug Discovery	I,II,III	a,b,c,d,e,f	3	0	0	3
SPECIAL COURSES							
21XE01	English For Research Paper Writing	-	-	2	0	0	0
21XE02	Cost Management Of Engineering Projects	-	-	2	0	0	0
21XE03	Stress Management	-	-	2	0	0	0
21XE04	Disaster Management	-	-	2	0	0	0
21XE05	Value Education	-	-	2	0	0	0
21XE06	Pedagogy Studies	-	-	2	0	0	0
21XE07	Business Analytics	-	-	2	0	0	0

21BT11 RESEARCH METHODOLOGY AND IPR 2 0 0 2

Course Objectives

- To understand some basic concepts of engineering research and its methodologies
- To identify various sources of information for literature review and data collection
- To classify the various procedures to formulate appropriate research problem and design of experiments

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Identify the scope and objective of the research problems
2. Analyze the research information and check for the data integrity
3. Apply the scientific and technical knowledge in preparing the research documents
4. Analyze the impact of IPR in technological development of a nation
5. Evaluate the usefulness of IPR protection for research work and investment in R&D

UNIT I **6 Hours**

RESEARCH PROBLEM IDENTIFICATION

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Basis of statistical parameters - Designing of experiments

UNIT II **6 Hours**

INVESTIGATIONS AND DATA ANALYSIS

Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations, Effective literature studies approaches, analysis Plagiarism, Research ethics. Ensuring data integrity through ALCOA

UNIT III **6 Hours**

TECHNICAL DOCUMENT PREPARATON

Effective technical writing, how to write report, Paper - Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

UNIT IV **6 Hours**

NATURE OF INTELLECTUAL PROPERTY

Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT

UNIT V **6 Hours**

PATENT RIGHTS AND NEW DEVELOPMENTS IN IPR

Scope of Patent Rights, Licensing and transfer of technology, Patent information and databases, Geographical Indications - Administration of Patent System

FOR FURTHER READING

New developments and guidelines in IPR and patent drafting

Total: 30 Hours

Reference(s)

1. Stuart Melville and Wayne Goddard, Research methodology: an introduction for science & engineering students
2. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International Publishers
3. Wayne Goddard and Stuart Melville, Research Methodology: An Introduction
4. Ranjit Kumar, 2nd Edition, Research Methodology: A Step by Step Guide for beginners
5. Halbert, Resisting Intellectual Property, Taylor & Francis Ltd ,2007
6. T. Ramappa, Intellectual Property Rights Under WTO, S. Chand, 2008

21BT12 CELLULAR ENERGETICS AND METABOLISM

3 0 0 3

Course Objectives

- To apply the principles of chemical thermodynamics for biochemical processes
- To analyse mathematical simulation of metabolic pathways and energy production
- To evaluate models to regulate and manipulate metabolic pathways

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Apply state functions in thermodynamics for biochemical reactions
2. Analyse the significance of organisation and dynamics of cellular energetics
3. Analyse the integration of phosphor transfer pathways
4. Evaluate the regulation scheme of metabolic pathways
5. Evaluate the flux analysis of metabolic networks

UNIT I **9 Hours**

FUNDAMENTALS OF CELLULAR THERMODYNAMICS

Energy of the system; Reversible and irreversible process; Entropy of the system; Chemical potentials; Thermodynamics of coupled reactions; Coupled transport processes at membranes; Bioenergetics and Biological oxidation-reduction reactions

UNIT II **9 Hours**

INTEGRATED OXIDATIVE PHOSPHORYLATION

Membrane transport and initial activation; Cytosolic pathway; Mitochondrial transport and metabolism; Substrate level phosphorylation; Reducing power shuttling across mitochondrial membrane; Electron transfer in the respiratory chain; Modulation of oxidative phosphorylation

UNIT III **9 Hours**

CIRCUITS IN CELLULAR ENERGETICS

Adenylate kinase phosphotransfer system in cell energetics and AMP signalling; Biological role of Adenylate kinase; Adenylate kinase isoform -based metabolic network; Adenylate kinase catalysed -phosphoryl transfer and energy economy; Glycolytic phosphotransfer circuits; Glycogen energy transfer network

UNIT IV **9 Hours**

REGULATION OF METABOLIC PATHWAYS

Regulation of Enzymatic Activity; Regulation of Enzyme concentration; Operon regulation; Regulation at whole cell level; Regulation of Metabolic networks; Transport mechanisms and their models; Mechanisms and their dynamic representation

UNIT V **9 Hours**

TOOLS IN METABOLIC ENGINEERING

Metabolic flux analysis (MFA); Methods for MFA; Metabolic control analysis (MCA); Determination of Flux control coefficients; MCA of Linear and Branched pathways; Enhancement of product yield and productivity, Legal aspects in metabolic pathway manipulations; Application of Metabolic engineering in industrial processes

UNIT VI

FOR FURTHER READING

Case studies on mathematical simulation of metabolic pathways and muscle contraction; Phosphotransfer networks and cellular energetics; Case studies on metabolic engineering of Saccharomyces cerevisiae for the synthesis of alkaloids; Case studies on key differences in cellular pathways of unicellular and multicellular organisms

Total: 45 Hours

Reference(s)

1. Molecular System Bioenergetics: Energy for Life. (2008). Germany: Wiley. Pauline D., Bioprocess Engineering Principles, Elsevier, 2nd Edition, 2012
2. Diederichs, F. (2019). Cellular Energetics: Thermodynamics of Cycling Between Coupled Reactions. Germany: De Gruyter
3. G.N. Stephanopoulos, A.A. Aristidou, J. Nielsen: Metabolic Engineering. Principles and Methodologies. Academic Press, 1998
4. Singh, S. P., Du, G. (2018). Current Developments in Biotechnology and Bioengineering: Synthetic Biology, Cell Engineering and Bioprocessing Technologies. Netherlands: Elsevier Science

21BT13 RECOMBINANT DNA TECHNOLOGY 3 0 0 3

Course Objectives

- To develop the skill of the student in the area of recombinant DNA technology and its application
- To familiarize student about the various component and techniques used in DNA manipulation
- To motivate and facilitate student to undertake the project and research work in rDNA technology

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Analyze the strategies of gene cloning and expression.
2. Apply molecular techniques in rDNA technology
3. Attribute of library construction and screening in rDNA
4. Analyze the methods for gene transfer techniques and selection of recombinant clones
5. Apply rDNA techniques in biotechnology

UNIT I **9 Hours**

CLONING AND EXPRESSION STRATEGIES

Enzyme used in rDNA technology, PCR- basic process, types and applications, Cloning and expression vectors - plasmid, bacteriophage, binary, Ti plasmid, viral, yeast, mammalian and plant based expression vectors, Expression of recombinant proteins

UNIT II **9 Hours**

MOLECULAR TECHNIQUES

DNA sequencing- Principle of chemical and enzymatic methods. Automated DNA sequencing, high throughput Pyrosequencing, next generation sequencing - Lynx Therapeutics, Massively Parallel Signature Sequencing (MPSS); In-situ hybridization; Site-directed mutagenesis.

UNIT III **9 Hours**

CONSTRUCTION OF LIBRARY AND SCREENING

cDNA and genomic DNA library; Screening of recombinants - Antibiotic resistance, lacZ complementation (Blue-white selection), fluorescent markers (GFP); Screening of genomic libraries with oligo-probe; Immunological screening for expressed genes; Preparation of radiolabelled/non-radiolabelled DNA & RNA probes; Blotting techniques.

UNIT IV **9 Hours**

GENE TRANSFER AND SELECTION OF RECOMBINANT CLONES

Gene transfer methods - biological, chemical, physical or mechanical; Agrobacterium- mediated gene transfer in plants, chloroplast transformation; Synthesis and purification of proteins from cloned genes-Native and fusion proteins.

UNIT V **9 Hours**

RECOMBINANT DNA APPLICATIONS

DNA fingerprinting, DNA Profiling, Multiplex PCR, Diagnosis of inherited disorders and infectious, diseases, diagnosis and management of cancer; Gene targeting and silencing; Gene therapy in ADA and cystic fibrosis; CRISPR/Cas9 gene therapy; Challenges and future of gene therapy

FURTHER READING

Isolation and purification of nucleic acid (genomic/plasmid DNA and RNA), Quantification and storage of nucleic acids; Insertional inactivation; Safety guidelines for recombinant DNA research; Control of spills and mechanism of implementation of biosafety guidelines

Total: 45 Hours

Reference(s)

1. T. A. Brown, Gene cloning and DNA analysis: An Introduction, Cheltenham, UK:WileyBlackwell Publishers, 2010
2. S. B. Primrose and R. M. Twyman, Principles of gene manipulation and genomics, Oxford, UK: Wiley-Blackwell Publishers, 2014
3. Jeremy W. Dale, Malcolm von Schantz, Nicholas Plant, From genes to genomes: Concepts and applications of DNA technology, Oxford, UK: Wiley-Blackwell Publishers, 2011.
4. Terry Brown, Gene cloning and DNA analysis, Oxford, UK: Wiley-Blackwell Publishers, 2015.
5. P. J. Smith and C. J. Jones, DNA recombination and repair. USA: Oxford University Press, 2000.
6. J. Sambrook, D. Russell,andD. W. Russell, Molecular cloning-A laboratory Manual (A set of Volume 1, 2 and 3), USA: Cold Spring Harbor Laboratory Press, 2000

21BT14 INTEGRATED BIOPROCESS TECHNOLOGY

3 0 0 3

Course Objectives

- To acquire the knowledge about media design and statistical media optimization for maximum production of metabolites through integrated biochemical approach
- To analyze the various growth kinetics, production kinetics, various reactors involved, scale up and scale down process in bioreactors
- To apply the separation and purification techniques

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector

b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations

c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems

e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities

f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. 1.Formulate medium using statistical tool for the maximum production of metabolites and biocatalyst for various commercial use
2. 2.Evaluate own model required for the microbial growth and model the kinetics of living cells and to develop a strategy to solve the issues emerging during fermentation processes
3. 3.Develop a research career or to get job in biotechnology industry with strong foundation in bioreactor design and scale-up or to become entrepreneur
4. 4.Design suitable process for the separation of bioproducts
5. 5.Design suitable process for final polishing of bioproducts

UNIT I **9 Hours**

PRODUCTION STRAIN FOR INDUSTRIAL FERMENTATIONS

Techniques for isolation and screening of modeling, microorganisms for industrial scale production; strain improvement and selection . Design of media for commercial and industrial applications, Statistical medium optimization -Plackett Burman design, Response surface methodology Central composite design, ANN, edge computing utilization, and concept drifting

UNIT II **9 Hours**

KINETICS OF MICROBIAL GROWTH AND PRODUCT FORMATION

Introduction to Structured Models for growth and product formation using Penicillin V as a case study. Kinetics of cell growth and product formation; Simple unstructured kinetic models for microbial Introduction to Structured Models for growth and product formation using Penicillin V as a case study. Morphological and Rheological behavior of fermentation broth, Image processing. Structured models of DNA replication and case studies based on recombinant protein isolation

UNIT III **9 Hours**

REACTORS, SCALE UP OF REACTORS

Design for homogeneous systems, Batch, Continuous and Fed-batch systems. Reactors in series, Non Ideality in reactors. Scale up criteria -procedure and scale-down. Pinch analysis for energy integration, Case studies for integrated bioprocess in pilot plant. Technoeconomic feasibility analysis. Design and cultivation of Batch, Fed-batch and continuous process in both microbial and mammalian cells

UNIT IV **9 Hours**

SEPARATION OF BIOACTIVE COMPOUNDS:

Downstream Processing in Biotechnology; Selection of unit operation with due consideration of physical, chemical and biochemical aspect of biomolecules; Cell disruption methods: Mechanical & enzymatic methods; Insoluble removal: Filtration, centrifugation; Extraction: Solvent, aqueous two-phase, Supercritical, Microwave-Assisted, Ultrasound-Assisted and centrifugal Extraction, Commercial industrial applications.

UNIT V **9 Hours**

PURIFICATION OF BIOACTIVE COMPOUNDS AND PRODUCT POLISHING

Precipitation; Membrane separations: Ultrafiltration, microfiltration, electro dialysis, Reverse osmosis, pervaporation; Chromatographic separations processes- Scale-up of chromatography, Process considerations in Preparative liquid chromatography, HPLC and FPLC, Tray, spray, and Freeze drying, Commercial industrial applications.

FOR FURTHER READING

Case studies for integrated bioprocess in pilot plant. Technoeconomic feasibility analysis

Total: 45 Hours

Reference(s)

1. 1.Michael L. Shuler, Fikret Kargi, Matthew De Lisa 2017. Bioprocess Engineering, 3rd Edition, Prentice Hall International Series.
2. 2.Peter Stanbury, Principles of Fermentation technology 2015, third edition, ButterworthHeinemann
3. 3.Shigeo Katoh and Fumitake Yoshida, 2010, Biochemical Engineering - A Textbook for Engineers, Chemists and Biologists, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.
4. 4.Bailey, J.E. and Ollis, D.F. Biochemical Engineering Fundamentals", McGraw Hill, 2nd Edition, 1986.

21BT16 RECOMBINANT DNA TECHNOLOGY LABORATORY

0 0 4 2

Course Objectives

- To widen the practical skills in the area of recombinant DNA technology
- To acquire practical skills in gene cloning, expression, restriction enzyme digestion and SDS PAGE
- To examine the different expression pattern of rDNA products

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Demonstrate the PCR and affinity chromatography techniques
2. Analyze the gene cloning, expression, restriction enzyme digestion and SDS PAGE techniques
3. Apply the genetic engineering techniques to express gene of interest

1 **10 Hours**

EXPERIMENT 1

In Vitro amplification of gene of interest by PCR

2 **10 Hours**

EXPERIMENT 2

Purification and ligation of amplified gene

3 **10 Hours**

EXPERIMENT 3

Transformation and screening of recombinant

4 **10 Hours**

EXPERIMENT 4

Isolation of recombinant plasmid and its restriction digestion

5 **10 Hours**

EXPERIMENT 5

Optimization of protein expression over time at different IPTG concentrations

6 **10 Hours**

EXPERIMENT 6

Confirmation of recombinant protein expression on SDS-PAGE

Total: 60 Hours

Reference(s)

1. J. Sambrook, D. Russell, and D. W. Russell, Molecular cloning-A laboratory Manual (A set of Volume 1, 2 and 3), USA: Cold Spring Harbor Laboratory Press, 2000

21BT17 INTEGRATED BIOPROCESS TECHNOLOGY LABORATORY

0 0 4 2

Course Objectives

- At the end of the course, students will learn key methods for bioprocess optimization in bioreactors
- At the end of the course, students will equip themselves with industry oriented experiments involving biochemical operations
- At the end of the course, students will familiarize in the mass transfer aspects for the production of metabolites

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Analyze the physico chemical and biological parameters involved in process and reactor optimization problems
2. Evaluate the strategies in the production of bioproducts
3. To investigate, design and conduct experiments, analyze and interpret data, and apply the laboratory skills to solve complex bioprocess engineering problems.

1 **6 Hours**

EXPERIMENT 1

Growth kinetics in Batch and Fed batch culture

2 **6 Hours**

EXPERIMENT 2

Fermentation kinetics in Batch culture

3 **6 Hours**

EXPERIMENT 3

Classical method of media optimization and Statistical method of media optimization (Plackett Burman)

4 **6 Hours**

EXPERIMENT 4

Statistical method of media optimization using Response Surface Methodology and ANN

5 **6 Hours**

EXPERIMENT 5
Design of sterilization process

6 **6 Hours**

EXPERIMENT 6
Isolation and purification of recombinant products

7 **6 Hours**

EXPERIMENT 7
Fermenter preparation and operation

8 **4 Hours**

EXPERIMENT 8
OTR and OUR by sodium sulphite method/ dynamic degassing method

9 **6 Hours**

EXPERIMENT 9
Morphological and rheological properties broth in bioreactor

10 **6 Hours**

EXPERIMENT 10
Rate of drying determination using Spray dryer and Tray dryer

Total: 60 Hours

Reference(s)

1. Michael L. Shuler, Fikret Kargi, Matthew De Lisa 2017. Bioprocess Engineering, 3rd Edition, Prentice Hall International Series
2. Pauline Doran, Bioprocess Engineering Calculation, Blackwell Scientific Publications
3. Peter Stanbury, Principles of Fermentation technology 2015, third edition, ButterworthHeinemann

21BT21 BIO-ANALYTICAL TECHNIQUES 3 0 0 3

Course Objectives

- Familiarize with the working principles, tools and techniques of analytical methods
- Design experiment and understand instrumentation
- Understand the strengths, limitations and creative use of bioanalytical techniques for problem solving

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Identify and use appropriate spectroscopic technique to analyse biomolecules and monitor biochemical reactions
2. Apply the right chromatographic/hybrid methods for purification and analysis of biomolecules
3. Apply microscopic techniques and tools for probing the morphology of biological samples and other materials via imaging
4. Analyze the characteristics of cells and other biomolecules
5. Apply the principles of XRD and EDAX to elucidate the 3D crystalline structure of proteins and elemental composition of materials

UNIT I **9 Hours**

SPECTROSCOPY

Electromagnetic spectrum, quantization of energy, Jablonski diagram, electronic, vibrational and rotational spectroscopy. Principles, instrumentation, sampling and applications of UV-VIS, FT-IR, Fluorescence, Raman, CD and NMR spectroscopic techniques-case studies with simple biomolecules, drugs and proteins .Mass spectrometry-Ionization methods, sample introduction-mass analyzers and ion detectors-Tandem mass spectrometry-peptide and protein analysis-carbohydrates and small molecules-specific applications

UNIT II **9 Hours**

CHROMATOGRAPHY

Brief introduction on the principles of Gas, liquid, Column, reverse phase, normal phase, ion exchange, size exclusion, hydrophobic interaction, bioaffinity, pseudo affinity, thin layer and paper chromatographic techniques. HPLC: Instrumentation, detectors, columns, pumps, solvent programming and applications with examples. Gas Chromatography- Instrumentation, temperature programming and uses with specific examples. Hyphenated techniques in chromatography, GC-MS and LC-MS. Inductively coupled plasma with mass spectrometry(ICP-MS) and Metal analysis by ICP-MS

UNIT III **9 Hours**

MICROSCOPY

Principles, instrumentation, applications of imaging techniques: Dark field, phase contrast, fluorescence, confocal microscopy, atomic force microscopy, and transmission and scanning electron microscopy. Morphology and identification of cells and material characterization

UNIT IV **9 Hours**

FLOW CYTOMETRY AND ELECTROPHORESIS

Pre-treatment, Stabilization and preparation methods of bioproducts for analysis. Analyte extraction from biological samples. Cell fractionation and flow cytometry, Comparing Univariate Cell Distributions-Fluorochromes-Probability Binning-Readings on flow cytometry data analysis. Electrophoresis-Principle, equipment and electrophoresis techniques-SDS PAGE and Agarose gel electrophoresis, 2D gel electrophoresis, isoelectric focusing, capillary electrophoresis and applications in analyzing macromolecules

UNIT V **9 Hours**

X-RAY DIFFRACTION AND EDAX

Crystal geometry and structure-Introduction to lattice and lattice systems, Braggs plan, miller indices, point groups and space groups, X-ray production and x-ray spectra. Braggs law and intensity of X-rays, single and polycrystalline XRD, protein crystallization and elucidation of its crystalline structure by XRD, phase problem, electron density mapping, percent crystallinity, EDAX-operational principle and application in elemental mapping of materials

FOR FURTHER READING

Probability Binning-Braggs plan, miller indices

Total: 45 Hours

Reference(s)

1. Skoog, D.A., Crouch, S.R., and Holler, F.J. Principles of Instrumental Analysis, 6th edition, Brooks/Cole, USA, 2006.
2. Williams, D. and Fleming, I. Spectroscopic Methods in Organic Chemistry, 6th edition, McGraw-Hill Higher Education, Maidenhead, UK, 2008.
3. Marko Haramija, Introduction to Mass Spectrometry of Biomolecules: Theory and Principle, Nova Science Publishing, 2016
4. James M. Miller, Chromatography : Concepts and contrasts , Wiley, 2019
5. A. Manz, N. Pamme and D. Iossifidis, Bioanalytical Chemistry, World Scientific Publishing Company, 2004
6. Basic Methods in Microscopy, Protocols, Concepts from cells: A Laboratory Manual, D.L.Spector and R.D. Goldman (Editors), Cold Spring Harbor Laboratory Press, New York 2006

21BT22 IMMUNOTECHNOLOGY 3 0 0 3

Course Objectives

- Acquire knowledge about the structure, functions and integration of immune system.
- Analyze the antigen-antibody interactions that offers defence
- Analyze the immunotechniques and their applications in biotechnological industry

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector

c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems

e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities

f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Apply the structural knowledge of immune cells at the molecular and cellular level for immune defence.
2. Apply the molecular and cellular mechanisms involved in the development and regulation of the immune response
3. Apply the major immunological laboratory techniques and their application to both clinical analysis and experimental research
4. Analyze the design of vaccines, strategies for immune intervention
5. Evaluate the immunological techniques and their applications in biotechnical industry

UNIT I **9 Hours**

IMMUNE SYSTEM AND ITS RESPONSE

Cells of the immune system and their development,Primary and secondary lymphoid organs, Humoral immune response, Cell mediated immune responses,T lymphocyte and B lymphocyte Tolerance,Homeostasis in immune system, Complement

UNIT II **9 Hours**

ANTIGEN AND ANTIBODY

Production of antibodies:Polyclonal, monoclonal:Hybridoma technology, Antibody:Isolation and identification,Validation and their use,Agglutination and precipitation tests:Coombs test,ELISA types,ELISPOT,Plaque forming cell assay,Epitope mapping, Antigen detection assay, SDS PAGE, immunoblotting and immunoprecipitation, Immunofluorescence and immunohistochemistry, Measurement of Ag Ab interaction.

UNIT III **9 Hours**

CELLULAR IMMUNOLOGICAL TECHNIQUES

PBMC separation from the blood,Ficoll-hypaque method, Identification of lymphocytes based on CD markers,FACS, Lymphoproliferation assay,Cr5I release assay,Macrophage cultures detection assays,Rosette assay,Cytokine bioassays: IL2, IFN gamma, TNF alpha,Mixed lymphocyte reaction,HLA typing.

UNIT IV **9 Hours**

VACCINE TECHNOLOGY

Principles in vaccine development:Adjuvant, Immunization (Active and Passive immunization),Vaccine validation,Protein based vaccines,DNA vaccines,RNA vaccines,Plant based vaccines,Edible vaccine,Recombinant antigens as vaccines,Multivalent subunit vaccine,Reverse vaccinology,New Types of Replicating vaccines.

UNIT V **9 Hours**

IMMUNOTHERAPEUTICS

Engineered antibodies:Catalytic antibodies, idiotypic antibodies, plantibodies:Combinatorial libraries for antibody isolation. Cancer immunotheraphy and Immunosuprressive therapy,Cytokine therapy,Immunoglobulin therapy,Replacement and immunomodulators, Gene transfer techniques for immunological diseases.

FOR FURTHER READING

Case studies on Production of green chemicals, algal biofuels, recombinant Insulin. Case studies should deal with medium design, reactor design & process optimization

Total: 45 Hours

Reference(s)

1. Emily P. Wen, Ronald Ellis and Narahari S. Pujar, Vaccine Development and Manufacturing, Wiley, 1st Edition, 2014.
2. Gerd-Rudiger Burmester, Antonio Pezzutto and Jurgen Wirth,Color Atlas of Immunology, Thieme Medical Publishers, 1st Edition, 2003.
3. Judith A. Owen, Jenni Punt and Sharon Stranford,Kuby Immunology, W.H. Freeman and Company, 7th Edition, 2013.
4. Peter J. Delves, Seamus J. Martin, Dennis R. Burton and Ivan M. Roitt,Roitts Essential Immunology,Wiley Blackwell Publication, 12th Edition, 2011.
5. Robert R. Rich, Thomas A Fleisher, William T. Shearer, Harry Schroeder, Anthony J. Frew and Cornelia M. Weyand,Clinical Immunology-Principles and Practice,Elsevier, 4th Edition, 2013.
6. Ashim K. Chakravarty, Immunology and Immunotechnology, Oxford University Press India Publication, 2006.

21BT23 COMPUTATIONAL MODELLING AND BIG DATA ANALYSIS

3 0 2 4

Course Objectives

- Understand the significance of computational platforms for biological data analysis
- Analyze the factors involved in in-silico structural modelling of Bio-molecules
- Analyze the significance of machine learning and artificial intelligence approaches in Bio data analysis

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Assess the factors involved in structural modelling of Bio-molecules.
2. Attribute the bio-molecular interactions using computational approaches
3. Outline the role of mining biological data for accurate inferences
4. Design various in-silico approaches using big data analytics.
5. Integrate interdisciplinary domains like ML & AI for biological big data analysis

UNIT I **9 Hours**

STRUCTURAL MODELLING OF BIOMOLECULES

Introduction to Bio-molecules and its structure Macromolecular structure databases-RCSB-PDB CATH SCOP NDB RNAStructuromeDB Structure formats Structural Bioinformatics in Drug discovery Structure prediction algorithms: Homology modelling Threading approaches and ab-initio approach

UNIT II **9 Hours**

STRUCTURE BASED INTERACTION PROFILING

Structure function relationship Molecular recognition Molecular docking Docking models: lock and key; induced-fit; conformation ensemble Molecular complementarity and flexibility Docking steps: Molecular representation; Scoring methods Algorithm search (Monte Carlo GA Exhaustive search and Simulated Annealing) Virtual Screening Molecular Dynamics Force field System equilibration Dynamic simulation algorithm Trajectory analysis.

UNIT III **9 Hours**

BIOLOGICAL BIG DATA AND DATA MINING

Nature of Biological data Data sources in life science Challenges faced in Data integration Data management in Bioinformatics Database design Database models: E-R Model; Relational model; Data structures: Linear and Non-linear data structures

UNIT IV **9 Hours**

APPLIED BIOLOGICAL DATA ANALYITICS

Next Generation sequencing approaches and data interpretation; Differential Gene Expression Analysis, Metagenomic data analysis framework, Immuno-informatics: Sequence analysis and prediction methods, Chemo-informatics, Computational Neuroscience: Domains and Fundamentals

UNIT V **9 Hours**

MACHINE LEARNING AND A I FOR BIOLOGISTS

Introduction to Machine learning, Supervised and unsupervised learning, Linear and Logistic regression models, Machine learning for Protein Engineering, Fundamentals of Artificial Intelligence, Intelligent agents, Structure of Intelligent agents, Artificial Intelligence for Biological data analysis.

1 **3 Hours**

EXPERIMENT 1

Exploring and data retrieval from various sequence and structure databases and NGS raw reads processing via computational platforms.

2 **5 Hours**

EXPERIMENT 2

Homology protein modelling (Offline and online tools)

3 **6 Hours**

EXPERIMENT 3

Molecular Docking using Autodock Vina

4 **6 Hours**

EXPERIMENT 4

MD Simulation of Solvated peptides (using GROMACS)

5 **5 Hours**

EXPERIMENT 5

Differential Gene Expression Data analysis using R language

6 **5 Hours**

EXPERIMENT 6

Metagenomic data analysis in Galaxy pipeline

Total: 75 Hours

Reference(s)

1. Andrew R Leach, Molecular Modelling-Principles and applications, Prentice Hall, II edition, 1996.
2. Eliel .E.L. and Wilen .S.H, Stereo Chemistry, John Wiley and Sons, 1994
3. Zoe Lacroix, Terence Critchlow, Bioinformatics:Managing Scientific Data , Morgan Kaufmann Publishers (Elsevier Science), 2003
4. Daan Frenkel, Berend Smit,Understanding Molecular Simulation: Algorithms to applications, Academic Press, 2001
5. George F Luger, Artificial Intelligence, Pearson Education, 4 th Edition, 2001
6. Mitchell, Thom M, Machine Learning, Mcgraw-Hill International Edit, 1997.

21BT26 IMMUNOTECHNOLOGY LABORATORY 0 0 4 2

Course Objectives

- At the end of the course, students will learn key methods on immunological techniques
- At the end of the course, students will equip themselves with practical exposure in the clinical diagnosis
- At the end of the course, students will familiarize in different immunological techniques

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Analyze the importance of diagnostics assays that involve antigen-antibody reaction
2. Evaluate the strategies in the different immunological techniques
3. Apply the immunotechnology in clinical diagnosis

1 **8 Hours**

EXPERIMENT 1

Collection of serum, storage and purification of total IgG (salt precipitation).

2 **8 Hours**

EXPERIMENT 2

Separation of spleenocytes and proliferation against mitogens

3 **8 Hours**

EXPERIMENT 3

Evaluation of Antigen by Sandwich ELISA

4 **8 Hours**

EXPERIMENT 4

Characterization of antigens by native and SDS PAGE

5 **8 Hours**

EXPERIMENT 5

Characterizations of antigens by Western blot analysis: Wet and semidry transfer

6 **10 Hours**

EXPERIMENT 6

Conjugation of Immunoglobins (Streptavidin, colloidal gold)

7 **10 Hours**

EXPERIMENT 7

Design Experiments

Total: 60 Hours

Reference(s)

1. Antibodies: A Laboratory Manual, Edward A. Greenfield, Cold Spring Harbor Laboratory Press, 2nd Edition, 2014
2. Current protocols in immunology / editorial board John E. Coligan.et al,. 2003, New York : Wiley Interscience, 2003.
3. Practical Immunology Frank C. Hay and Olwyn M.R. Westwood, Blackwell Science Ltd., 4 th edition, 2002

21BT27 MINI PROJECT **0 0 4 2**

Course Objectives

- To extend knowledge to devise a real time problem and project goals
- To identify the various tasks of the project to determine standard procedures
- To recognize the various procedures for validation of the product and cost effectiveness

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector

b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations

c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems

e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities

f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand a real world problem, identify the requirement and develop the design solutions
2. Analyze the technical ideas, strategies and methodologies related to the identified problem
3. Apply the new tools, algorithms, techniques that contribute to obtain the solution of the project
4. Evaluate and validate through conformance of the developed prototype and analysis the cost effectiveness
5. Create a technical report and present the oral demonstrations

21BT33 DISSERTATION PHASE I 0 0 20 10

Course Objectives

- Prepare report and present the oral demonstrations
- To identify the various tasks of the project to determine standard procedures
- To recognize the various procedures for validation of the product and cost effectiveness

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. To recognize the various procedures for validation of the product and cost effectiveness
2. To recognize the various procedures for validation of the product and cost effectiveness
3. Apply the new tools, algorithms, techniques that contribute to obtain the solution of the project
4. Evaluate and validate through conformance of the developed prototype and analysis the cost effectiveness
5. Create a technical report and present the oral demonstrations

21BT41 DISSERTATION PHASE II 0 0 28 14

Course Objectives

- To extend knowledge to devise a real time problem and project goals
- To identify the various tasks of the project to determine standard procedures
- To recognize the various procedures for validation of the product and cost effectiveness

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector

b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations

c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems

e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities

f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand a real world problem, identify the requirement and develop the design solutions
2. Analyze the technical ideas, strategies and methodologies related to the identified problem
3. Apply the new tools, algorithms, techniques that contribute to obtain the solution of the project
4. Evaluate and validate through conformance of the developed prototype and analysis the cost effectiveness
5. Create a technical report and present the oral demonstrations

ELECTIVES

21BT51 INDUSTRIAL MICROBIOLOGY 3 0 0 3

Course Objectives

- To understand the techniques involved in fermentation process and reactor systems.
- To analyze the significance of bio-resources and its role in microbial biotechnology.
- To analyze the microbial techniques pertaining to Pharmaceutical Microbiology

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the microbial isolation and Quantification techniques
2. Analyze the various bioreactors and fermentation techniques
3. Apply the Biomass, Bioenergy and Biomining techniques and their applications in the product recovery
4. Apply the microbial production techniques and explore their applications
5. Evaluate the microbial techniques in pharmaceutical industry

UNIT I **9 Hours**

MICROBIAL TECHNIQUES

Isolation, Methods of Isolation, Identification of Microbial stains, identification and methods of purification of microbial strains; Quantification of microorganisms - direct and indirect methods; maintenance and preservation of microbial cultures, principles of microbial growth, genetic improvement of microbial strains

UNIT II **9 Hours**

FERMENTATION TECHNOLOGY

Principles and types of bioreactors- operation of bioreactors- media for industrial fermentation, solid substrate fermentation, primary and secondary metabolites; culture systems.

UNIT III **9 Hours**

BIOMASS, BIOENERGY AND BIOMINING

Sources and utilization of biomass, production of alcohol, acetone, glycerol, biogas, biohydrogen; commercial biobleaching process, biobleaching of copper, uranium; biosorption of metals.

UNIT IV **9 Hours**

MICROBIAL PRODUCTION

Alcohols - Ethanol,& Butanol, Acetone; Organic acids - Citric acid, Acetic acid, Succinic acid, Vinegar, Lactic acid; IIndustrial production of Vitamins -B2 ,B12 , Ascorbic acid

UNIT V **9 Hours**

PHARMACEUTICAL MICROBIOLOGY

Industrial production of Insulin, human growth hormone, monoclonal antibodies, Interferons & antibiotics (Penicillin, Streptomycin)

FOR FURTHER READING

Enzymes in commercially important fermentation processes.

Total: 45 Hours

Reference(s)

1. U. Sathyanarayana, Biotechnology,Kolkata: Books and Allied (P) Ltd., 2005
2. W. Crueger and A. Crueger, Biotechnology: A Textbook: of Industrial Microbiology, Panima Publishing Corporation, 2003
3. P. F. Stanbury, A. Whitaker and S. J. Hall, Principles of Fermentation Technology, Butterworth-Heinemann (Elsevier Science), 2005
4. C. Ratledge and B. Kristiansen, Basic Biotechnology, Cambridge University Press, 2001
5. R. M. Atlas and Renk, Principles of Microbiology, McGraw-Hill Higher Education, 1995.
6. L. M. Prescott, J. P. Harley and D. A. Klein, Microbiology, Wm. C. Brown Publishers, 2004

21BT52 OMICS TECHNOLOGY 3 0 0 3

Course Objectives

- To make students identify about the major techniques involved in sequence analysis and assembly
- To summarize the basic principles of instrumentation and techniques in proteomics and genomics
- To develop and organize application-based knowledge on various omics tools

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector

b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations

d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems

Course Outcomes (COs)

1. Explain variegated fields in omics and gain deep Knowledge in that field
2. Apply different techniques involved in biomolecules analysis
3. Analyze data and profiles of biomolecules obtained using this technology
4. Evaluate its importance in the field of biotechnology and bioinformatics
5. Create new tools and techniques as a up gradation from the presently available technology

UNIT I **9 Hours**

TECHNOLOGIES IN GENOMICS

DNA Library Preparation, Next Generation sequencing Technologies-PacBio Single molecule real time sequencing (SMRT) and Oxford Nanopore sequencing, Genome Assembly- Reference assembly Denovo Assembly, Hybrid Assembly, Genome mapping, Yeast Two-Hybrid System, DNA Chips, Chromatin immunoprecipitation (ChIP/ ChIP-Seq), Bioinformatics tools for Genome analysis

UNIT II **9 Hours**

TRANSCRIPTOMICS

Data gathering-RNA isolation, Expressed sequence tags, Serial and cap analysis of gene expression (SAGE/CAGE), Microarrays, NGS based RNA sequencing (RNA-Seq), Molecular inversion probes and sRNA, Massively Parallel Signature Sequencing (MPSS), Data analysis-Image processing, RNA-Seq data analysis, Quality control, Alignment, Quantification, Differential expression, Validation; Databases and software for Transcriptomics

UNIT III **9 Hours**

TECHNOLOGIES IN PROTEOMICS

2D-Polyacrylamide gel electrophoresis,Two-Dimensional Difference Gel Electrophoresis (2D-DIGE), Isoelectric focusing, Mass spectrometry-Ion source, Analyzer, Detectors,Protein or Peptide sequencing by tandem mass spectrometry,Quantitative techniques-ICAT, SILAC, iTRAQ,Structural analysis-X-ray crystallography, NMR, Cryo Electron microscopy,Bioinformatics tools for Proteome analysis

UNIT IV **9 Hours**

TECHNOLOGIES IN METABOLOMICS

Sampling in metabolomics,Sample preparation-Solid-phase microextraction, Liquid-liquid micro extraction, Three-phase droplet electroextractions, Parallel-electromembrane extraction,Data handling in metabolomics,Metabolite Identification and Annotation,Uncertainty of measurements, Tools in Metabolomics CE-MS, LC-MS,GC-MS, NMR, Ion-mobility separations, Data Integration; Applications and the Future of Metabolomics, Current and future challenges for metabolomics

UNIT V **9 Hours**

INTEGRATED OMICS TECHNOLOGY

Integrated omics technology-Workflow, Omics data types and Repositories, Multiomics data integration tools and visualization portals, Approaches for Integrated omics, Data driven approach-Statistical, Supervised Machine learning, Unsupervised approach, Knowledge based approach-Interactive approach, Dynamic mechanistic approach, Data integration and Interpretation, Challenges and Future perspectives in integrated omics technology

FURTHER READING

Omics-Based Clinical Discovery Science, Technology and Applications, Multi OMICS Approaches to diseases, the challenge of the application of omics technologies in chemicals risk assessment: Background and outlook

Total: 45 Hours

Reference(s)

1. Heyer L, Campbell A, Discovering Genomics, Proteomics and Bioinformatics, Cold Spring Harbor Lab Press, 2006
2. S.B Primrose and R.M Twyman, Principles of Gene Manipulation and Genomics, Blackwell Publishing, 2006
3. Daniel C. Liebler, Introduction to Proteomics: Tools for the New Biology, Humana Press, 2002
4. Michael Lammerhofer, Wolfram Weckwerth, Metabolomics in Practice: Successful Strategies to Generate and Analyze Matabolic data, 2010
5. Pevsner J, Bioinformatics and Functional Genomics, Wiley-Blackwell, ISBN: 978-81-265-3834-8
6. Kihara, D, Protein function prediction for omics era, Springer Science & Business Media

21BT53 THERMO ANALYTICAL TECHNIQUES 3 0 0 3

Course Objectives

- To enable the students for understanding the principles of different thermo analytical techniques and coupled thermal methods, their instrumentation and operation
- To expose the students on the use of these thermal methods in material science for evaluating thermal and thermomechanical properties, phase transitions, life time prediction, degradation kinetics etc
- To learn how these thermal methods are used in process monitoring such as resin curing, interaction between biomolecules , protein folding, evaluation of thermodynamic parameters of thermo reversible processes and quantitative analysis

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the theory and operation of TGA and its use in analyzing the thermal degradation kinetics of materials
2. Analyse the principle , types and working of DSC and demonstrate its qualitative and quantitative applications in chemical, material and life sciene areas
3. Analyse the theory and instrumentation of DTA and thermometry and their uses
4. Evaluate the working principle and instrumentation of TMA and thermoilatometry and their applications
5. Analyse the working principle and operation of DMA and its use in evaluating the viscoelastic properties

UNIT I **9 Hours**

THERMOGRAVIMETRY

Introduction- Theory, types of TGA, Instrumentation- shapes of TG curves, TG trace- derivative TG trace and their interpretation , applications(polymer, textiles, biomass, etc), moisture content, -Kinetics of degradation and kinetic models, thermal stability of materials, curie temperature, mechanism of thermal degradation, aging studies, TG analysis of polymers, vegetable fibers, textile fibers and vegetable oils, biomass, bacterial biomass, biomaterials

UNIT II **9 Hours**

DIFFERENTIAL SCANNING CALORIMETRY

Theory and instrumentation- types of DSC- temperature programming, Phase transition studies(Glass transition, Melting, polymorphism etc) -first order and second order transitions, crystallization temp, endo and exothermic degradation, Kissinger plot, kinetics of degradation, coupled thermal analysis - TG-DSC. Specific heat, crystallinity, monitoring chemical reactions and curing reactions in polymers. Evaluation of thermodynamic parameters for thermo reversible processes- protein folding/unfolding studies

UNIT III **9 Hours**

DIFFERENTIAL THERMAL ANALYSIS (DTA) AND THERMOMETRY

DTA, theory, instrumentation and applications- phase transitions- factors that affect DTA traces-simultaneous TGA-DTA analysis and applications. Thermometric titrations and Isothermal titration calorimetry (ITC)- theory ,instrumentation and applications-protein-ligand interaction-protein-protein interaction

UNIT IV **9 Hours**

THERMO MECHANICAL ANALYSIS (TMA) AND THERMODILATOMETRY

Theory, instrumentation, difference between TMA and dilatometry, linear and sinusoidal heating rates, modulated temperature programming-applications-thermal expansion coefficient-glass transition temperature-softening temperature-solid-solid transitions-melting behavior, TMA and dilatometry curves for different transitions

UNIT V **9 Hours**

DYNAMIC MECHANICAL THERMAL ANALYSIS (DMTA OR DMA)

Principle, instrumentation- measurement modes- sample preparation-stress(compressive, shear and tensile), strain, , viscoelasticity, loss tangent, storage modulus, shear modulus, Newtonian and non-Newtonian flow, viscosity, elasticity, stress-strain curves, Hookes and Newtons law, Hookian solid, Newtonian fluid, purely elastic and purely viscous responses, viscoelastic response, presentation and interpretation of DMA curves, Viscoelstic spectrum of amorphous polymer- applications-material characterization-(polymers, elastomers, biomaterials, composites, ceramics, glass, adhesives, oils, paints and varnishes, cosmetics, metals and alloys, leather, skin, hair etc)

FOR FURTHER READING

Newtonian fluid, purely elastic and purely viscous responses, viscoelastic response

Total: 45 Hours

Reference(s)

1. K. Menard, Dynamic Mechanical Analysis: A Practical Introduction, CRC Press, Boca Raton,
2. R. Bird, C. Curtis, R. Armstrong, O. Hassenger, Dynamics of Polymer Fluids, 2nd ed., Wiley,
3. P. J. Haines; Thermal methods of analysis: Principles, Applications and Problems Blackie,
4. A T. Riga and C. M. Neag (Editors); Materials Characterization by Thermomechanical Analysis, ASTM STP 997, STP 1136, American Society for Testing and Materials
5. Kevin Menard, Dynamic Mechanic Analysis-A practical introduction, 2 nd edition, CRC Press,
6. Edith Turi, Thermal Characterization of polymeric materials, 2nd Edition Academic press 1997

21BT54 TISSUE ENGINEERING AND REGENERATIVE MEDICINE

3 0 0 3

Course Objectives

- To develop the skill of the student in the emerging field of Regenerative medicine
- To familiarize students with the various techniques used in Tissue engineering
- To make the students think about higher studies and careers in the field of Tissue engineering

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Compare different biomaterials and generate ideas for their use in tissue engineering
2. Apply the concepts of biomechanical connections underlying cell and tissue biology at the molecular level
3. Apply the knowledge of mechanobiology in designing bioreactors
4. Analyze the existing ethical concerns in regard to tissue regeneration
5. Evaluate the efficacy, limitations and applications of stem cells technology

UNIT I **9 Hours**

INTRODUCTION AND SCOPE OF TISSUE ENGINEERING AND REGENERATIVE MEDICINE

The History of Tissue Engineering and current perspectives of Regenerative Medicine, Cell culture; primary cultures & cell lines; cell quantification; cells as therapeutic agents with examples; Growth factors and signals for tissue engineering; extracellular matrix (ECM) (structure, function and applications); typical tissue-engineered device Ethical Issues in Tissue Engineering.

UNIT II **9 Hours**

BIOMATERIALS IN TISSUE ENGINEERING

Biomaterials: Definition, Classification: Polymers, ceramics (biosorbable and bioactive), hydrogels and metallic implants. Surface, Scaffold fabrication and tailoring Biomaterials; physical and chemical properties of materials - mechanical properties of implants. Bulk analysis- FTIR, SEM; Surface analysis - AES. Sterilization techniques: ETO, gamma radiation, autoclaving. Effects of sterilization on material properties.

UNIT III **9 Hours**

BIOREACTORS IN TISSUE ENGINEERING

Establishment of spatially uniform cell distributions on 3D scaffolds; Maintenance of desired nutrient and gas concentrations in the medium; Expose the developing tissue to physical stimuli; Types of bioreactors for tissue engineering applications (Spinner flask bioreactor, Rotating wall bioreactor, Direct perfusion bioreactors, Hollow fiber bioreactor, Hydrostatic pressure bioreactors, Biomimetic bioreactors); bioreactors for various tissues, e.g. cartilage, muscle, tendon, bone and blood vessels.

UNIT IV **9 Hours**

GROWTH FACTOR DELIVERY, STEM CELLS AND GENE TRANSFER IN REGENERATIVE MEDICINE

Growth factor delivery systems; Introduction to stem cells- different types of stem cells, the plasticity of stem cells; cell separation methods and treating cells individually; mesenchymal stem cells, hematopoietic stem cells & tissue-derived stem cells in tissue engineering applications. Gene transfer and its applications in tissue engineering

UNIT V **9 Hours**

TISSUE ENGINEERING APPLICATIONS IN CLINICS

Current clinical applications & research in (with its limitations) - Artificial blood vessels, artificial pancreas, liver, skin, corneal and bone tissue engineering.

FOR FURTHER READING

Translational Applications in Neurodegenerative Diseases and Tissue-Engineering Approaches to Restore Kidney Function

Total: 45 Hours

Reference(s)

1. Atala & R. P. Lanza, Methods of Tissue Engineering, Academic Press, 2002
2. J. P. Fisher, A.G. Mikos and J.D. Bronzino, Tissue Engineering, CRC Press, 2007
3. Ratner, Hoffman, Schoen and Lemons, Biomaterials Science - An Introduction to Materials in Medicine, Academic Press, 1996.
4. V. Yannas, Tissue and Organ Regeneration in Adult, Springer, 2001
5. R. P. Lanza, R. Langer, and W. L. Chick, Principles of Tissue engineering, Academic Press, 1997.
6. W. M. Saltzman, Drug Delivery: Engineering Principles for Drug Therapy, Oxford University Press, 2001

21BT55 FORENSIC BIOTECHNOLOGY 3 0 0 3

Course Objectives

- Acquire knowledge about the forensic programs in the Biotechnology field
- To render a knowledge of biotechnology applications in forensic sector
- To create a platform to perform research in interdisciplinary fields

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the basic concept of forensic science in crime investigation
2. Demonstration of various physical/technical samples for forensic studies
3. Organization and evaluation of documents and analysis of forensic results
4. Outline the crime data with advanced genetic tools
5. Organization and management of Good laboratory practices

UNIT I **9 Hours**

INTRODUCTION TO FORENSIC SCIENCE

Forensic science: Definition, History and development of forensic science, Areas in forensic science, Crime scene investigation: plan of action, preliminary survey, collection, preservation and analysis of physical evidence, Legal aspects: court procedure, production and authentication of scientific and technical evidence, expert testimony

UNIT II **9 Hours**

ANALYSIS OF BIOLOGICAL AND NON-BIOLOGICAL EVIDENCE

Biological samples, Autopsy: Postmortem examination, DNA analysis: A molecular marker, DNA typing, mitochondrial DNA, Blood grouping and identification blood typing, Biological evidences for examination: Body fluids, semen, blood and blood stains, saliva, hair, urine and faecal, Non-biological samples: papers, ink, foot prints, soil, vehicle tyre marks, body features, skeleton remains from the deceased

UNIT III **9 Hours**

FORENSIC EXAMINATION AND DOCUMENTATION

Forensic reports, Components of the forensic reports, Classification and Preliminary examination of documents: handwriting characteristics, forgery and their types: age of document, invisible writing and alterations in the document, Preservation of documents, Photography of documents, Bioterrorism, Doping, Poaching, Biometrics, Forensic entomology

UNIT IV **9 Hours**

FORENSIC GENETICS

Human genetics, DNA mutation, heredity, Hardy-Weinberg law, DNA profiling/DNA fingerprinting, PCR amplification, DNA sequencing, forensic DNA database, forensic significance of DNA profiling, procedures and ethical concern with DNA databanking, DNA chips and SNPs

UNIT V **9 Hours**

MANAGEMENT SYSTEMS

Basic standards for forensic study, Quality management: Quality analysis, Quality plan, Quality records, Quality control vs Quality assurance, Accreditation for Labs: ISO series; Routine lab work, research & development, Laboratory Information Management System (LIMS), Laboratory safety and security

FOR FURTHER READING

Case studies on crime scene investigation, identification of document age, changes in the documents/scripts, examination of fingerprints, development of various fingerprinting methods, analysis of crime records and documentation

Total: 45 Hours

Reference(s)

1. Sharma, B.R., Forensic Science in Criminal Investigation and Trials, Central Law Agency, Allahabad, 1974
2. S.H.James, and J.J. Nordby, Forensic Science an Introduction to Scientific and Investigative Techniques. London: CRC Press, 2003
3. Settle,F.A., Handbook of Instrumental Techniques for Analytical Chemistry, Prentice Hall, 1997
4. Willdard, H. H., Instrumental Methods of Analysis, 1974
5. Henry C. Lee and R.E. Gaensslen., DNA and other Polymorphism in Forensic Science Year book Medical Publishers, Inc., 1990
6. Simon, Ball. Environment Law: The Law and Policy Relating to Protection of Environment. Delhi: Universal Law Publishing, 1991

21BT56 CLINICAL TRIALS AND BIOETHICS 3 0 0 3

Course Objectives

- To Acquire knowledge on drug discovery and development
- To understand the process of clinical trial, its ethics and follow the regulatory framework important for benefit for the society
- To prepare the necessary documents required for conducting clinical trials & project management strategies for efficient trials

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the development process & clinical trials
2. Understand the ethical considerations in clinical trials
3. Apply the guidelines in clinical research
4. Analyze the necessary documents required for clinical research
5. Evaluate the clinical trial management process

UNIT I **9 Hours**

FUNDAMENTALS OF DRUG DEVELOPMENT AND CLINICAL TRIALS

Origin and History of Clinical Research, Introduction to Drug Discovery and drug Development, Clinical Trials in India-The National Perspective, Clinical Trial Phase I, Clinical Trial Phase II, Clinical Trial Phase III, Clinical Trial Phase IV-methods, Principles of sampling-Inclusion and exclusion criteria, Methods of allocation and randomization, Termination of trial.

UNIT II **9 Hours**

ETHICAL TRIALS CONSIDERATIONS IN CLINICAL TRIALS

Historical guidelines in Clinical Research-Nuremberg code, Declaration of Helsinki, Belmont report, Research ethics and Bioethics-Principles of research ethics-Ethical issues in clinical trials-Use of humans in Scientific Experiments-the informed consent-Introduction to ethical codes and conduct-Introduction to animal ethics-Animal rights and use of animals in the advancement of medical technology

UNIT III **9 Hours**

GUIDELINES IN CLINICAL RESEARCH

International Conference on Harmonization (ICH)-Structure of ICH, Principles of ICH GCP, ICH Harmonization Process, Responsibilities of Stakeholders: Sponsors, Investigators, CROs, Monitors, Institutional ethics committee(IRB), ICMR guidelines for clinical research in India, Regulatory authority: India & abroad- CDSCO (India), FDA (U.S), Medicines and Healthcare Products Regulatory Agency (U.K)

UNIT IV **9 Hours**

ESSENTIAL DOCUMENTS

Essential Documents in Clinical Trials: SOP, Clinical Trial Protocol and Protocol Amendment(S), Investigator Brochure, Master Files, Informed Consent Forms, Consort statement, Case Record Form

UNIT V **9 Hours**

TRIAL MANAGEMENT

Project management in clinical trials-principles of project management-Application in clinical trial management-Risk assessment Pharmacovigilance, Project Auditing, Inspection.

FOR FURTHER READING

Use of humans and animal in Scientific Experiments - ethical issues

Total: 45 Hours

Reference(s)

1. Lee, Chi-Jen et al., Clinical Trials or Drugs and Biopharmaceuticals. CRC / Taylor & Francis, 2011
2. Emanuel, Ezekiel J et al., The Oxford Textbook of Clinical Research Ethics. Oxford University Press, 2008
3. Abdel-aleem, Salah M., The Design and Management of Medical Device Clinical Trials:Strategies and Challenges. Wiley, 2011
4. Lopes, Renato D et al., Understanding Clinical Research. McGraw-Hill Education, 2013.
5. Matoren, Gary M. The Clinical Research Process in the Pharmaceutical Industry, Marcel Dekker, 1984.
6. Friedman, L.M., Furberg, C.D., DeMets, D., Reboussin, D.M., Granger, C.B. Fundamentals of Clinical Trials, springer, 2015

21BT57 AGRICULTURAL BIOTECHNOLOGY 3 0 0 3

Course Objectives

- Understand the basic molecular biology with extensive applications in agriculture, health, industry and environment
- Analyze the advancements in field of genetic engineering and their application in plant improvement.
- Analyze the biotechnological techniques that can be utilized for development of GMO and Transgenic crops

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the tools and techniques involved in genetic engineering of plants
2. Apply various techniques of plant tissue culture for the large scale production of commercially important crops
3. Apply genetic engineering techniques for quality improvement in plants.
4. Analyze recent advances in the field of plant biotechnology for development of plant based therapeutically important products
5. Evaluate the recent developments in Plant transformation strategies

UNIT I **9 Hours**

BASICS OF BIOTECHNOLOGY

Components of plant genetic engineering; Methods for analysis of differential gene expression in plants; Enhancer trap, Promoter tagging, gene tapping gene tagging, Insertional mutagenesis, Activation tagging; Tissue-specific promoters, characterization of plant promoters; Agrobacterium and Ti Plasmid based and physical DNA delivery methods.

UNIT II **9 Hours**

TISSUE CULTURE

Micro propagation of commercially important plant species; Genetic fidelity; Production of useful compounds via biotransformation and secondary metabolite production: suspension cultures, immobilization, examples of chemicals being produced for use in pharmacy, medicine and industry. Bioreactors- scaling up and cost reduction; synthetic seeds. Plant Hormones- biosynthesis and mode of action.

UNIT III **9 Hours**

GENETIC MANIPULATION IN PLANTS

Genetic engineering for resistance against abiotic and biotic stresses; Genetic Engineering for increasing crop productivity by manipulation of photosynthesis, nitrogen fixation and nutrient uptake efficiency; Genetic engineering for quality improvement (protein, essential amino acids, vitamins, mineral nutrients); Edible vaccines. Value-addition by transformation; development, production and release of transgenic plants;

UNIT IV **9 Hours**

MOLECULAR PHARMING

Molecular farming of plants for applications in veterinary and human medicine systems: Boosting heterologous protein production in transgenics, Rapid production of specific vaccines, High-yield production of therapeutic proteins in chloroplasts. Bio fertilizers and Biopesticies

UNIT V **9 Hours**

STRATEGIES IN PLANT TRANSFORMATION

Recent developments in plant transformation strategies; Role of antisense and RNAi-based gene silencing in crop improvement; Regulated and tissue-specific expression of transgenes for crop improvement; Gene stacking; Pathway engineering: Principles and case studies; Marker-free transgenic development strategies; High throughput phenotyping of transgenic plants.

FOR FURTHER READING

Bio-safety and bioethics issues; Intellectual property rights in biotechnology. Ecological aspects of GMOs and impact on biodiversity;

Total: 45 Hours

Reference(s)

1. Methods in Plant Molecular Biology and Biotechnology by B.R.Glick, 2014
2. Plant Biotechnology-The genetic manipulation of plants, Second Edition by Adrian Slater, Nigel Scott, and Mark Fowler, 2008
3. International Society for Acquisition of Agribiotech Applications- www.isaaa.org, an open resource for Agricultural Biotechnology related applications, world status of Agricultural Biotechnology
4. Gene Cloning and DNA Analysis. 5th Ed. Blackwell Publishing, Brown TA
5. Biotechnology Expanding Horiozon. KalyaniPublishers, Singh BD. 2007
6. Plant tissue culture, Third Edition: Techniques and experiments, Roberta H.Smith, 2012

21BT58 NANOMEDICINE 3 0 0 3

Course Objectives

- Acquire knowledge on the development of nanocarriers
- Apply concepts of nanomedicine to a focused clinical area of their choice
- Acquire knowledge to apply these nanosystems for the diagnosis and therapy

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities

Course Outcomes (COs)

1. Comprehend the principles behind nanomaterials.
2. Acquire knowledge on the characterization of nanomaterials
3. Gain a broad understanding of concepts and applications of nanomedicine.
4. Acquire knowledge to apply these nanosystems for the diagnosis and therapy.
5. Risk associated with nanomaterials and nanomedicines.

UNIT I **9 Hours**

INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY

Defination of Nano, Synthesis of nanomaterials-Physical, chemical and biological. One dimensional, two dimensional and three dimensional nanostructured materials, Quantum Dots, metal oxides, semiconductors, composites, mechanical-physical-chemical properties. Nanoemulsion, Micelle. Carbon nanotubes. Gold nanorods in sensing, Assembling by polycations, Polymer-based capsules. Particle size-antimicrobial activity.

UNIT II **9 Hours**

CHARACTERIZATION OF NANOMATERIALS

Scanning Electron Microscope (SEM), Atomic Force Microscopy (AFM), Transmission Electron Microscopy (TEM), EDAX, SAED, X-ray diffraction, X-ray photoelectron spectroscopy, UV-visible-DRS, Raman Spectroscopy, Photoluminescence (PL), Electrochemical impedance spectroscopy, BET, VSM, Laser confocal microscopy, Particle size analyzer, Zeta sizer, FT-IR, TGA.

UNIT III **9 Hours**

DESIGNING OF NANOMEDICINE

Basic concepts in the design of nanomedicine, specification and desired features of nanomedicine, nanomaterials and general process steps involved in the preparation of nanomedicines. Nanomedicines for various disease conditions: infectious diseases, neurological diseases: (challenges of blood brain barrier), pulmonary disorders, cardiovascular diseases, Lipid based nanomedicines. Nanomedicne for tissue engineering, regenerative medicine, cancer treatment. cancer: nano-chemotherapy, -radiation therapy, -immunotherapy, -nuclear medicine therapy, -photodynamic therapy, -photothermal and RF hyperthermia therapy, -scintillation therapy, gene-therapy: DNA, RNA delivery. Theranosticnanomedicines: Basic concept, multifunctional nanomedicines for theranosis. Surface mediated drug delivery, receptor mediated drug delivery.

UNIT IV **9 Hours**

REGENERATIVE NANOMEDICINE

Biocompatibility of traditional medical implants, Adhesive interactions with implant surfaces, Nanorobot immunoreactivity- nanopyrexia, Nanorobot, mutagenicity and carcinogenicity, Thermocompatibility, mechanocompatibility, Cell membrane disruption, Systemic nanoparticle distribution and phagocytosis, Nanomaterial volumetric intrusiveness- nanobiotechnology in tissue engineering, Nanobiotechnology for organ replacement and assisted function.

UNIT V **9 Hours**

NANOTOXICOLOGY

Basics of cellular and organ level toxicity, effect of nanosize, shape, surface properties and composition on toxicity of nanomedicines, Assessment of nanomaterial toxicity: In vitro toxicity assessment-cell viability, lactate dehydrogenase release, reactive oxygen species generation, change in mitochondrial membrane potential and nuclear fragmentation. In vivo toxicity assessment: inflammatory response, acute toxicity studies, LD50 determination, histopathological studies. Comet assay. Case studies: Ag, Quantumdots, carbon-basednanomaterials, polymeric, protein and lipid nanoparticles. Transport of nanomaterials in soil/sediments. Study of physical and chemical properties of nanomaterials influencing their behavior in the environment and in biological systems.

FOR FURTHER EADING

Nanobiotechnology for organ replacement and assisted function

Total: 45 Hours

Reference(s)

1. C. N. R. Rao, A. Muller, A. K. Cheetham (Eds), The chemistry of nanomaterials: Synthesis, properties and applications, Wiley VCH Verlag Gmbh & Co, Weinheim, 2004.
2. Nanomedicine for Cancer Therapy: From Chemotherapeutic to Hyperthermia-Based Therapy , Springer, Piyush Kumar, RohitSrivastava, 2017
3. Michael Giersig, Gennady B. Khomutov, Nanomaterials for Application in Medicine and Biology, Springer, 2008
4. Robert A. Freitas, Nanomedicine, Volume IIA: Biocompatibility, Landes Bioscience, 2011
5. Jain K. K., Handbook of Nanomedicine, Springer, 2012
6. Stergios Logothetidis, Nanomedicine and Nanobiotechnology, Springer, 2012

21BT59 DEVELOPMENTAL BIOLOGY 3 0 0 3

Course Objectives

- To analyze and interpret the developmental schema in living systems
- To analyze the role of genetic implications in developmental biology
- To evaluate the developmental schema implicated in animal and plant systems

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the basic concepts and principles in developmental biology
2. Apply the significant genetic principles in developmental biology
3. Analyze the implications of developmental biology concepts in animal systems
4. Apply the implications of developmental biology concepts in plant systems
5. Analyze the relationship between evolutionary and developmental biology

UNIT I **9 Hours**

INTRODUCTION TO DEVELOPMENTAL BIOLOGY

History, The cycle of life: Fertilization; Cleavage; Gastrulation; Organogenesis; Metamorphosis; Gametogenesis, Comparative embryology, Epigenesis and preformation, Four principles of Karl Ernst, Fate maps and Cell lineages, Teratology.

UNIT II **9 Hours**

DEVELOPMENTAL GENETICS

Genomic equivalence, Gene Anatomy: Exons; Introns; Promoters; Enhancers, Differential Gene Expression, Transcription factors, Epigenetics, Transcription regulation: Methylation mediated, Control of Gene Expression at the level of Translation, miRNA mediated transcriptional and translational regulation, Post-translational gene regulation.

UNIT III **9 Hours**

ANIMAL DEVELOPMENTAL BIOLOGY

Gametes, Structure of Gametes, External Fertilization: Sea Urchin case study, Internal Fertilization: Mammals case study, Early Development in Snails, Patterning the Body plan: Drosophila case study.

UNIT IV **9 Hours**

PLANT DEVELOPMENTAL BIOLOGY

Life cycle of Angiosperm, Characteristics of plant growth and Development, Molecular genetics of plant development, Establishment of Symmetry in plants, Shoot and root development, Leaf development and Phyllotaxy, Floral Development: Arabidopsis & Antirrhinum case studies.

UNIT V **9 Hours**

EVO-DEVO

Introduction to Evolutionary Developmental Biology (Evo-Devo), Functional links in Development and Evolution, Neural Mechanism underlying the evolvability of behavior, Conservation of Gene Functions, Evolution of time-keeping mechanisms, Trends in Evo-Devo.

FOR FURTHER READING

Medical Implications of Developmental Biology, Teratogens on embryo development

Total: 45 Hours

Reference(s)

1. Gilbert, S.F & Barresi, M.J.F, Developmental biology, 11th Ed, Sinauer Associates Inc.Massachusetts, USA, 2017
2. Wolpert, Beddington, Brockes, Jessell, Lawrence, Meyerowitz, Principles of Development, 3rd Ed, Oxford University Press, New Delhi, India, 2006.
3. Kalthoff, Analysis of Biological Development, 2nd Ed, McGraw-Hill Science, New Delhi, India, 2000.
4. Rajni Arora & Anita Grover, Developmental Biology: Principles and concepts, R. Chand & Co, New Delhi, India, 2019.
5. Dr. K.V.Sastry & Dr. Vineeta Shukla, Developmental Biology, Rastogi Publications, Uttar Pradesh, India, 2018.

21BT60 BIOREACTOR DESIGN AND PROCESS ECONOMICS

3 0 0 3

Course Objectives

- Acquire knowledge about the designing of different bioreactors and process economics
- Analyze the design and construction of bioreactors for different bioprocess applications
- Analyze the factors involved in the process and their economics for development

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector

c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems

e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities

f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Specify required technologies for the cultivation of different living cells.
2. Design reactors for the production of various metabolites
3. Apply Biochemical concepts for a good process design
4. Simulate and model the novel bioreactor system for advanced bioprocess design
5. Relate process and economics for successful process

UNIT I **9 Hours**

FUNDAMENTALS OF REACTOR DESIGN

Overview of SLF and SSF; elements in bioreactor design- overview of bioreactor, its developments using microbial processes, mammalian cell culture, plant cell culture & environmental applications; Microbial growth and product formation kinetics, Thermal death kinetics of microorganisms; Multiple reactions-series, parallel and mixed. Basic Design Equations/ Mole Balances: Batch, Fed Batch and Repetitive Batch Reactors, Continuous: Stirred tank and tubular flow reactors.

UNIT II **9 Hours**

BIOREACTOR REQUIREMENTS

Fermentation Process-General requirements; Basic design and construction of fermenters and its ancillaries; Material of construction, Vessel geometry, Bearing assemblies, Motor drives, Aseptic seals; Flow measuring devices, Valves, Agitator and Sparger Design, Sensors. Bioprocess and bioreactor design considerations for plant and animal cell cultures. Effect of media on reactor design. Non-isothermal homogeneous reactor systems. Adiabatic reactors, batch and continuous reactors, optimum temperature progression

UNIT III **9 Hours**

BIOCHEMICAL ASPECTS AND DESIGN OF BIOREACTOR

Biochemical aspects of bioreactor analysis for cells and enzymatic reactions: Batch reactor- calculation of batch time, quantitative evaluation of batch processes, sources of non-ideality; continuous flow bioreactors- CFSTBR including chemostat and turbidostat and PFTBR, mean residence time, washout condition; recycle bioreactors; combination of bioreactors- SISO, MISO, MIMO etc.; Semi-continuous bioreactors including batch-fed and fed-batch. Process and mechanical design of bioreactor, volume, sparger, agitator type, calculations for coil and jacket, sterilization system.

UNIT IV **9 Hours**

NOVEL BIOREACTORS DESIGN

Design of Immobilized enzyme packed bed Reactor. Fluidized bed reactors, Slurry Reactors, Air lift & Loop reactors, Packed bed and Hollow fiber membrane bioreactors, Bioreactors for waste treatment processes; Scale-up of bioreactors, SSF bioreactors. Conceptual numericals.

UNIT V **9 Hours**

ECONOMIC CONSIDERATION IN MODERN BIOTECHNOLOGICAL PROCESSES

Design Consideration for building, expanding or retrofitting a process; process synthesis and process analysis; Economic evaluation of a project for manufacturing a biological product; Profitability Analysis - Estimates of capital investment, operating cost, and revenues of a project. Problem analysis in process and plant development

Total: 45 Hours

Reference(s)

1. Shuler, M.L., Kargi F., Bioprocess Engineering , Prentice Hall, 2nd Edition, 2002
2. Pauline D., Bioprocess Engineering Principles, Elsevier, 2nd Edition, 2012.
3. Nielsen, J. and Villadsen, J. Bioreaction Engineering Principles. Springer, 2nd Edition, 2007
4. S.Liu, Bioprocess Engineering: Kinetics, Biosystems, Sustainability, and Reactor Design, Elsevier, 2016
5. T Panda, Bioreactors analysis and design, Tata McGraw Hill, New Delhi, New York, 2011
6. Bioprocess Design and Economics, Demetri Petrides, Ph.D, 2003

21BT61 HUMAN HEREDITY AND GENETICS 3 0 0 3

Course Objectives

- Impart knowledge on inheritance patterns
- Analyze the disease genes using gene mapping and linkage analysis
- Analyze simple and complex genetic disorders

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Apply the inheritance pattern of monogenic and polygenic traits
2. Analyse the pedigree symbols and patterns.
3. Analyse the mutation types and their consequences in the human system
4. Analyse the molecular cytogenetic methods
5. Evaluate the impact of genetic analysis through gene manipulation techniques

UNIT I **9 Hours**

GENETIC TRAITS AND INHERITANCE

Mendelian inheritance; monogenic traits: autosomal inheritance- dominance, recessive; sex-linked inheritance; sex-limited and sex-influenced traits; Polygenic trait: continuous- normal growth charts, dysmorphology, discontinuous-threshold model, liability and recurrence risk; multifactorial disorders-alcoholism, diabetes mellitus and obesity

UNIT II **9 Hours**

PEDIGREE ANALYSIS

Family history, pedigree symbols, construction of pedigree, presentation of molecular genetic data in pedigree. Complications to pedigree patterns- nonpenetrance, Pedigrees of Sex-linked & Autosomal (dominant & recessive), Mitochondrial, Incomplete dominance & Penetrance

UNIT III **9 Hours**

MUTATION

Spontaneous, induced, lethal, conditional, reversion, mutagenic suppression, germinal and somatic mutation, insertion, deletion, duplication, translocation, transposition, ploidy. Oncogenes, Proto-oncogenes, Tumor suppressor genes, Loss of function mutations (p53), Gain of function mutations (AAT). Rare genetic disorders: Ectrodactyly, Feet facing backwards

UNIT IV **9 Hours**

CYTOGENETICS

Human chromosomal analysis, Karyotyping- banding, aberrant karyotypes, Syndromes due to numerical chromosome changes & structural alterations, common chromosomal abnormalities in cancer; Molecular cytogenetic methods: fluorescence in situ hybridization (FISH), comparative genomic hybridization (CGH), spectral karyotyping (SKY), combined binary ratio labeling (COBRA)

UNIT V **9 Hours**

GENETIC ANALYSIS

Allele, multiple alleles, pseudo alleles, Linkage maps, mapping with molecular markers, tetrad analysis, fine structure analysis of gene. DNA finger printing and its applications, DNA bar coding, marker assisted selection and QTL mapping

FOR FURTHER READING

Chromosome Breakage and Instability Syndromes, Chromosomal abnormalities in spontaneous abortions

Total: 45 Hours

Reference(s)

1. Tom Strachan and Andrew P. Read, Human Molecular Genetics, Garland publishing, Incorporated, 2004
2. Mange and Mange (2005). Basic Human Genetics. Sinauer Assoc
3. P. K. Gupta, Cytogenetics, Rastogi Publications, 2007
4. Shekokar Archana, Ghubde Ramakrishna, Pedigree Analysis and Cytogenetic Study in Vitiligo, 2012
5. Michael Cummings, Human Heredity, CENGAGE Learning Custom, 2005
6. Daniel J. Kevles, In the Name of Eugenics- Genetics and the Uses of Human Heredity, Harvard University Press, 1995

21BT62 FERMENTATION AND FOOD PROCESS ENGINEERING

3 0 0 3

Course Objectives

- Understand the fermentation process and industrial cultures.
- To understand the concept of basic fermentation processes and its control systems etc.
- To get a practical knowledge about running the fermenter and its scale up and modes of operation etc.

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand flow of the Fermentation pathways for industrial products
2. Apply the Media preparation and optimization techniques for the fermentation process.
3. Analyze the process efficiency of different types of fermenters
4. Apply the downstream processing techniques used to separate fermentation end products
5. Create appropriate fermentation methods for different types of products.

UNIT I **9 Hours**

FERMENTATION PATHWAYS FOR INDUSTRIAL PRODUCTS

Biochemical pathways of metabolic reactions for utilization of carbon sources and formation of different metabolites by microorganisms; possibility of control of the reactions for the increased formation of useful metabolites. Strain Development - Various techniques of modifying the strains for increased production of industrial products. Use of chemicals, UV rays, genetic engineering to produce newer strains

UNIT II **9 Hours**

MEDIA FOR FERMENTATION

Importance of media components for production of industrial products by fermentation; use of different sources of carbon, nitrogen, minerals and activators for commercial fermentation; importance of pH, temperature and aeration in fermentation; optimization of fermentation media.

UNIT III **9 Hours**

DIFFERENT TYPES OF FERMENTERS

Laboratory and plant fermenters; shake flasks and advantages; laboratory fermentation systems with various controls and sampling and data collection provisions; aeration and agitation; production fermenters; sterilization of media; cooling systems; inoculation, temperature and pH control systems; scale-up of fermentation process

UNIT IV **9 Hours**

DOWNSTREAM PROCESSING

Various equipments for product recovery; micro-filters and Ultra-filtration systems for separation of cells and fermentation medium and for concentration of medium containing product; chromatographic systems of separation; extraction of product with solvent; evaporation and crystallization; centrifugation

UNIT V **9 Hours**

FERMENTATIVE PRODUCTION OF FOOD AND BEVERAGES

Processes for preparing fermented products including Yogurt (curd) and other Traditional Indian Products like idli, dosa, dhokla, shrikhand, etc., Soya based products like soya sauce, natto, etc., Cocoa, Cheese etc.; control of quality in such products. Alcoholic beverages based on fruit juices (wines), cereals (whisky, beer, vodka etc,), sugar cane (rum) etc. Process description, quality of raw materials, fermentation process controls etc

FOR FURHER READING

Strain Development - Various techniques of modifying the strains for increased production of industrial products

Total: 45 Hours

Reference(s)

1. Stanbury, P.F., A. Whitaker and S.J. Hall, Principles of Fermentation Technology, 2nd Edition, Butterworth Heinemann (an imprint of Elsevier), 1995
2. Shuler, M.L., Kargi F., Bioprocess Engineering , Prentice Hall, 2nd Edition, 2002
3. Bailey, J.E. and Ollis, D.F. Biochemical Engineering Fundamentals", McGraw Hill, 2nd Edition, 1986.
4. Pauline D., Bioprocess Engineering Principles, Elsevier, 2nd Edition, 2012.
5. Hartmeier, Winfried, Immobilized Biocatalysts: An Introduction, Springer Verlag, 1986
6. Rosenberg, E & Cohen I.R. (1983). Microbial Biology. H.S. International Editions

21BT63 MODERN FOOD BIOTECHNOLOGY 3 0 0 3

Course Objectives

- Understand and evaluate the nutritional value of foods to formulate the balanced diet.
- Develop skills to assess and apply nutrition standards and guidelines for achieving optimum human nutrition and health
- Create the knowledge to design functional and special foods for the nutritional and health benefits

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the heat and mass transfer principles in food processing
2. Apply the modern equipments and techniques in food processing
3. Analyze the efficiency of thermal processing in baking sector
4. Apply the modern thermal processing in food preservation
5. Apply the Non-thermal methods in food processing

UNIT I **9 Hours**

HEAT AND MASS TRANSFER OPERATIONS

Material and energy balance, Transport Phenomena for food systems, Flow behaviour of non-Newtonian fluids, Rheology of dough, Unsteady state Heat Transfer with phase change, Heat transfer during drying and freezing

UNIT II **9 Hours**

FOOD EQUIPMENT DESIGN

Equipment design aspect of evaporators, dryers, freezers. Form Fill Seal, Vacuum and other packaging machines. Materials used for food processing equipment and corrosion control

UNIT III **9 Hours**

THERMAL PROCESSING

Newer techniques in thermal food processing - Retort processing, UHT, Extrusion - hot and cold

UNIT IV **9 Hours**

NOVEL FOOD PROCESSING TECHNIQUES

Radio-frequency heating Microwave for food cooking and dehydration, Ohmic heating. Advances in Freezing and refrigeration techniques

UNIT V **9 Hours**

: NON THERMAL PROCESSING

Pulsed electric field, high-intensity light pulses, irradiation technique, thermo-sonication, High hydrostatic processing of foods, super critical CO2 technique

FOR FURTHER READING

Modified atmosphere, enzymatic processing and hurdle technology. Advanced Membrane Technology for water and liquid foods and effluent treatment

Total: 45 Hours

Reference(s)

1. Handbook of food and bioprocess modeling by Sablani S., Rahman M, 2007
2. Advances in food processing and technology by Peter Fellows.
3. Food processing and technology: Principle and practice by P Fellows 2009.

3 0 0 3

21BT64 PHARMACOGENOMICS

Course Objectives

- To impart knowledge on Pharmacogenomics
- To analyze the methods and tools involved in Pharmacogenomics
- To explore the ethics, regulations and applications in Pharmacogenomics

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the fundamental concepts in Pharmacogenomics and drug design
2. Apply the pharmacogenomics to design and develop drugs
3. Analyze the various tools in pharmacogenomics research
4. Analyze the ethical issues and regulatory affairs in pharmacogenomics
5. Evaluate the potential applications of pharmacogenomics in clinical research

UNIT I **9 Hours**

INTRODUCTION TO PHARMACOGENOMICS

Definition- Pharmacogenomics, Pharmacogenetics, Pharmacoepigenetics; Introduction to Human genome, Human Genome Project (HGP), Mutations; Single Nucleotide Polymorphisms (SNPs), Expressed Sequence Tags (ESTs); Pharmacogenomics in personalized medicine; Drug discovery and development; Barriers in drug discovery; Interethnic response to drugs; Polypharmacy

UNIT II **9 Hours**

PHARMACOGENOMICS AND DRUG DESIGN

Protein structure and Variation in Drug targets-Pharmacokinetics and Pharmacodynamics-Mutation in drug targets-Insilico design of small molecules-Automated drug design methods-Structure based drug design-Ligand based drug design-Machine learning based drug design-Artificial Intelligence(AI) based drug design

UNIT III **9 Hours**

TOOLS IN PHARMACOGENOMICS

Next Generation Sequencing approaches-Microarrays-Marker based disease analysis-Online tools for PGx Research-PharmGKB, SIDER2, DG1db, STRING, STITCH, CTD, COSMIC, PROMISCUOUS, PharmVar, SuperCYP, dbSNP, FINDbase, SNPedia, PGRN

UNIT IV **9 Hours**

REGULATORY PERSPECTIVES

Introduction to Drug regulation-Variability in Drug response- Role of FDA- Revising Physician labelling of previously approved drugs- Ethics in Pharmacogenomics- Phases and Challenges in Pharmacogenomics-Technology selection, Reduction to practices and future perspectives- Differential diagnosis

UNIT V **9 Hours**

APPLICATIONS OF PHARMACOGENOMICS

Application of Pharmacogenomics for the design and development of drugs targeting- Drug transporters- Cardiovascular diseases-Cancer treatment-Neurodegenerative diseases-Anti-depressant-Alcoholism-Tobacco addiction-Opioids- P-glycoproteins

FOR FURTHER READING

pressant-Alcoholism-Tobacco addiction-Opioids- P-glycoproteins

Total: 45 Hours

Reference(s)

1. Licinio J and Wong M., Pharmacogenomics: The Search for Individualized Therapies., Wiley-VCH Verlag GmbH & Co. KGaA, 2002
2. Yan Q., Pharmacogenomics in Drug Discovery and Development, Humana Press, 2008.
3. Kalow W., Meyer UA., Tyndale RF., Pharmacogenomics., Taylor and Francis, 2nd Edition, 2005
4. Chakraborty Chiranjib, Pharmacogenomics: an approach to new drug development, Astral International Pvt Ltd
5. Russ B. Altman, David Flockhart, David B. Goldstein, Principles of Pharmacogenetics and Pharmacogenomics, Cambridge University Press 2012
6. Y. W. Francis Lam and Stuart A. Scott, Pharmacogenomics Challenges and opportunities in Therapeutic Implementation, Second Edition, 2019

21BT65 BIOMASS VALORIZATION AND APPLICATIONS

3 0 0 3

Course Objectives

- Acquire knowledge about the biomass and its composition.
- Analyze the pretreatment and characterization strategies in biomass conversion.
- Analyze the biotechnological route for conversion of biomass to biochemicals.

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. An ability to independently carry out research /investigation and development work to solve practical problems
2. Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
3. Graduates will demonstrate knowledge of professional and ethical responsibilities
4. Graduate will show the understanding of impact of engineering solutions on the society and also will be aware of contemporary issues
5. Graduates will excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

UNIT I **9 Hours**

BIOREFINERY AND BIOMASS VOLARIZATION

Chemical composition of biomass; Polysaccharides; Structure and chemistry of lignin; Principles and evolution of the biorefinery concept; Different types of biorefineries; Main sources of sugars, Chemicals from monosaccharides; Main sources of vegetable oils Chemicals from vegetable oils, fatty acids and glycerol.

UNIT II **9 Hours**

PRETREATMENT AND FRACTIONATION PROCESSES OF BIOMASS

Treatment and fractionation techniques according to the type of biomass, conversion platform (sugar and thermochemical); Physical processes: mechanical disintegration, ultrasound, extrusion, irradiation; Physico-chemical processes: hydrothermal, simple steam explosion or in the presence of acid, SO_2 , ammonia or CO_2

UNIT III **9 Hours**

PRETREATMENT AND DETOXIFICATION PROCESSES OF BIOMASS

Chemical processes: alkaline extraction, with solvents, hot water and alternative or pressurized solvents; acid hydrolysis; kraft, sulfite and organosolv processes; alkaline and wet oxidation; ozonolysis - Biological processes: with enzymes, fungi, microorganisms; Detoxification of hydrolysates obtained by chemical or enzymatic hydrolysis, for subsequent use in fermentation media.

UNIT IV **9 Hours**

BIOTECHNOLOGICAL PROCESSES FOR BIOMASS CONVERSION

Bioprocesses for biopolymer production - possible examples pullulan, xanthan, polyhydroxy alkanoates; Bioproduction of surfactants and microbial protein examples; Enzymes, production and industrial applications. Biodiesel production from the transesterification and catalytic hydrogenation. Production of bio-alcohols by ABE fermentation.

UNIT V **9 Hours**

BIOREFINERY PROCESSES ASSESSMENT

Strategies for process integration and analysis of biorefineries; Biorefinery processes optimization problems and strategies; Carbon balance assessment; Analysis of case studies.

FOR FURTHER EADING

Nanobiotechnology for organ replacement and assisted function

Total: 45 Hours

Reference(s)

1. Shijie Liu, Bioprocess Engineering: Kinetics, Biosystems, Sustainability, and Reactor Design, Elsevier, 2013.
2. Debalina Sengupta, Ralph W. Pike Chemicals from Biomass: Integrating Bioprocesses into Chemical Production Sustainable Development, CRC Press, 2013.
3. Pauline M. Doran, Bioprocess Engineering Principles, 2nd edition, Academic Press, 2013.
4. S.Yang, H.El-Ensashy, N.Thongchul (Eds.). Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals, and Polymers. 2013, Wiley Press. ISBN 978-0-470-54195-1
5. D.A. Skoog, F.J. Holler, S.R. Crouch. Principles of Instrumental Analysis. 6th Edition. 2007, Thomson Brooks/Cole. ISBN-13: 978-0495012016
6. P.R. Stuart, Mahmoud M. El-Halwagi, Integrated Biorefineries: Design, Analysis, and Optimization, CRC Press, 2012

21BT66 ENVIRONMENTAL BIOTECHNOLOGY 3 0 0 3

Course Objectives

- Develop a basic knowledge on the global issues pertaining to environment
- Understand the process of biodegradation and bioremediation
- Analyze the various techniques involved in treating the wastes

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector

c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems

e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities

f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Analyze the challenges and problems associated with the climatic issues with the current environmental scenario.
2. Analyze the various biological treatment methods to treat the wastewater.
3. Analyze the various waste minimization techniques and control measures that help to reduce wastes.
4. Analyze the various hazardous waste minimization techniques and control measures that help to reduce hazardous wastes.
5. Evaluate various biodegradation and bioremediation methods and their performance in eliminating wastes.

UNIT I **9 Hours**

BIOREMEDIATION

Introduction of Bioremediation-advantages and applications-Types of bioremediation-Natural (attenuation)-Ex-situ and In-situ. Bioremediation technologies-Bio stimulation, Bio augmentation, Bioventing, bio-sparging. Phytoremediation-Rhizofiltration, Phytostabilisation, Phytovolatilisation, Phytodegradation, Phytoextraction. Mycoremediation.

UNIT II **9 Hours**

BIOLOGICAL TREATMENT OF WASTEWATER

Physico-chemical characteristics of wastewater-Overview of aerobic and anaerobic treatment processes-Process design of aerobic and anaerobic system-Activated sludge process-Trickling filter-Rotating biological contactors-Fluidized bed reactor-Up flow anaerobic sludge blanket reactor (UASB).

UNIT III **9 Hours**

WASTE MANAGEMENT

Solid wastes-types of solid wastes,characteristics of solid wastes,segregation, collection, transportation. Hospital Waste Management-Disaster Management-Radioactive and nuclear power waste-e-waste Management.Management Disposal methods -sanitary land filling,recycling,composting,incineration.

UNIT IV **9 Hours**

MICROBIAL SYSTEMS FOR DETOXIFICATION OF ENVIRONMENTAL POLLUTANTS

Degradation of high concentrated toxic pollutants-non-halogenated-halogenated-petroleum hydrocarbons.Mechanisms of detoxification-oxidation reactions,dehalogenation-biotransformation of metals.Algal biotechnology-biological removal of nutrients

UNIT V **9 Hours**

ALTERNATE ENERGY SOURCES

Overview of renewable sources-Biomass as a source of energy-Production of biocompost and vermicompost-Alternate Source of Energy-Biodiesel, Bioethanol,Biobutanol, Biohydrogen, Bio-electricity through CHP-Value added products from renewable sources.

FOR FURTHER READING

Case studies on Production of green chemicals,algal biofuels,bioplastics and biopolymer.Case studies should deal with medium design,reactor design and process optimization

Total: 45 Hours

Reference(s)

1. Chakrabarty K.D.,Omen G.S.,Biotechnology and Biodegradation.Advances in Applied Biotechnology Series,Vol.1,Gulf Publications Co.,London,1st edition,1989
2. Metcalf,Eddy.Waste Water Engineering Treatment,Disposal and Reuse.McGraw Hill,4th edition.2003.
3. Scragg A.,Environmental Biotechnology., Longman,1st edition,1999
4. Martin A.M. Biological Degradation of Wastes.Elsevier, 1st edition,1991.
5. Sayler,Gray S.,Robert F.,James W. B.,Environmental Biotechnology for Waste Treatment.Plenum Press,1st edition,1991.

21BT67 ENTREPRENEURSHIP ESSENTIALS AND LEGAL STARTUPS

3 0 0 3

Course Objectives

- Inspire students and create an entrepreneurial spark to convert their innovative ideas into viable startups
- Acquire foundational knowledge on various aspects of entrepreneurial venture creation and management during its life-cycle
- Develop the platform for startups with disruptive technologies, policies, and legal procedures

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Develop knowledge on entrepreneurial competencies and design thinking
2. Analyze viable business ideas for new venture creation and acquire skills for creating a Business model and building a prototype
3. Analyze the various form of business structure and IPR
4. Analyze the financial management steps and legal procedures in startups
5. Create the suitable policy and legal procedures for promoting technology-based startups

UNIT I **9 Hours**

ENTREPRENEURIAL COMPETENCE

Characteristics of a Successful Entrepreneur, difference between traditional business and Technopreneurship, self-discovery, role of entrepreneurs in boosting world economy, Environmental scanning, Market research, SWOT Analysis, Design Thinking for Customer Delight. Case studies-Dilip Shanghvi-Sun Pharmaceuticals, Kiran Mazumdar Shaw-Biocon, Kallam Anji Reddy-Dr. Reddys Laboratories, Cyrus S. Poonawalla-Serum Institute of India, Mr. C. K. Ranganathan-CavinKare, Divya Gokulnath - cofounder of BYJUs

UNIT II **9 Hours**

ENTREPRENEURIAL ROADMAP

Idea generation-DISRUPT model, effective Brainstorming Idea Evaluation-decision matrix analysis, paired comparison analysis, B Plan, Supply chain analytics, Business Model Canvas, Customer discovery, Value proposition design, prototyping, One minute Elevator Pitch

UNIT III **9 Hours**

ENTREPRENEURIAL OUTLOOK

Various forms of ownership-sole proprietorship, partnership, company: private limited & public limited company and cooperative, foreign ownership, Growth Strategies in small industry-Expansion, Diversification, Joint Venture, Merger and Sub Contracting, IPR-trademark, patent and Copyright, IT and BT startups-Artificial intelligence, big data and Machine learning, Minimum Viable Product, E Commerce, lean startups

UNIT IV **9 Hours**

FINANCIAL MANAGEMENT AND LEGAL STARTUPS

Source of finance, Finance and Human Resource Mobilization, Raising funds, term loans, capital structure, management of working capital, costing, break even analysis, Taxation-income Tax, Excise duty-sales Tax, venture capital, angel investors. Small scale industry enterprise setup, Licenses and Registration-Digital signal certificate, MSME/SSI registration, ISO certification, FSSAI, Import/Export code, Provident fund registration, ESI registration, Employment stock option plan (ESOP), Legal documentation-non disclosure agreement, founders agreement, term sheet, shareholders agreement, share purchase agreement

UNIT V **9 Hours**

STARTUP SUPPORTS AND SCHEMES

Central and State Government Industrial Policies and Regulations, Business Network International (BNI), E Cell, TBI and EDIIMSME Recent policies and schemes, Funding agencies-AICTE, CSIR, DBT, DST, ICMR, VILLGRO, INSA, SERB, TNSCST, Startup India seed fund, ASPIRE, MUDRA, ATAL innovation mission, e-BIZ, DIDF, MGS, CGTMSE, VCA, NewGen IEDC, SPRS, BIRAC, NEED, schemes for women entrepreneurs

FOR FURTHER READING

Self-discovery and Customer discovery exercises, pioneer biotech companies, Managing Risks and Learning from Failures-case study

Total: 45 Hours

Reference(s)

1. Donald F Kuratko, Entrepreneurship-Theory, Process and Practice, 9th Edition, Cengage Learning, 2014
2. Khanka. S.S., Entrepreneurial Development S.Chand and Co. Ltd., Ram Nagar, New Delhi, 2013.
3. Entrepreneurship and Business of Biotechnology, S N Jogdand Himalaya Publishing House, 2007
4. EDII Faulty and External Experts-A Hand Book for New Entrepreneurs Publishers: Entrepreneurship Development, Institute of India, Ahmadabad, 1986
5. Hisrich R D, Peters M P, Entrepreneurship 8th Edition, Tata McGraw-Hill, 2013.
6. A Legal Guide for Entrepreneurs Working on a Startup Venture, Ekaterina Mouratova, PLLC,2017

21BT68 BIOSTATISTICS 3 0 0 3

Course Objectives

- Exemplify the different approaches of Probability theory, which will enable them in the decision making in the face of uncertainty
- Summarize and apply the concepts of Statistics in solving biological problems
- Develop a framework for solving the biological problems through MATLAB

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector

Course Outcomes (COs)

1. Apply the concept of probability and probability distributions in bio-science field
2. Implement the equations of curve fit and compute various statistical measures
3. Analyze sample data and interpret the same for population which will be useful in solving engineering problems
4. Analyze the statistical experiments for calculating the experimental variance
5. Analyze the biological data using MATLAB.

UNIT I **9 Hours**

PROBABILITY

Axioms of probability - Addition and multiplication theorems on probability - Conditional probability - Bayes theorem (problems only) - Random variable: Continuous and discrete random variables - Discrete distributions: Binomial and Poisson - Continuous distributions: Normal, Exponential and Weibull - Simple problems and properties

UNIT II **9 Hours**

CORRELATION AND CURVE FITTING

Correlation and Regression properties and problems - Rank correlation - Multiple and Partial Correlations Principle of least squares: Fitting of straight line, exponential curve and power curve

UNIT III **9 Hours**

TESTING OF HYPOTHESIS

Concepts of sampling - Methods of sampling - Sampling distributions and classifications - Standard Error - Tests of hypothesis: Tests of hypothesis about proportion, mean and their differences - Chi-square distributions: Test of goodness of fit and test of independence of attributes

UNIT IV **9 Hours**

DESIGN OF EXPERIMENTS

Basic principles of experimental designs - Analysis of variance: one-way, Two-way classifications - Latin square design - 2 Factorial Design

UNIT V **9 Hours**

COMPUTATIONAL STATISTICS

A Brief Tutorial-M-Files-Basics-Distinctive Features of Matlab-Arithmetic operators-Plotting 2-dimensional graph-Expectation: Mean and variance-parameter estimation: Mean square error and standard error-Exploring Bivariate data: Scatter plots and surface plots.

UNIT VI

FOR FURTHER READING

Data collection with two samples for a particular variable in an industry- Setting of hypothesis - Verification of hypothesis - Presentation of the data with results

Total: 45 Hours

Reference(s)

1. Johnson R.A., Miller & Freunds: Probability and Statistics for Engineers , Pearson Education, 8th Edition, 2013
2. Walpole R.E , Myers R.H, Myers R.S.L and Ye K, Probability and Statistics for Engineers and Scientists , Pearsons Education, Delhi , 2002
3. Lipschutz S and Schiller J, Schaums outline Series: Introduction to Probability and Statistics, McGraw Hill Publications, New Delhi, 1998
4. Ross. S , A first Course in Probability , 8th Edition, Pearson Education , New Jersey, 2010
5. Rudra Pratap, Getting Started with MATLAB, Oxford University Press, 2002
6. Kanti B Datta, Mathematics Methods of Science and Engineering Aided with MATLAB, Cengage Learning, 2012

21BT69 PHARMACEUTICAL BIOTECHNOLOGY 3 0 0 3

Course Objectives

- Introduce diverse sources and classes of biopharmaceuticals
- Expose students to various modes of drug delivery
- Build deeper understanding of application of biotechnology tools in the world of medicine

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the difference between chemical and bio-based pharmaceuticals
2. Apply the knowledge of biological effects of bioactive substances for their use as therapeutics
3. Analyze the need for formulation of biopharmaceuticals
4. Analyze various criteria for selection of drug carriers that result in effective drug delivery
5. Evaluate drug action based on the difference in physiological functions of a host

UNIT I **9 Hours**

DRUG DEVELOPMENT PROCESS

Drug discovery approaches, modulatory effects, binding strength, effective and inhibitory concentration, side effects, ADME, Lipinski rule, action of drugs on humans, pharmacokinetics, pharmacodynamics, routes of drug administrations, patenting, phases of clinical studies, design and conduct of clinical trials, case studies of drug discovery

UNIT II **9 Hours**

PRODUCTION FACILITIES

Basic principles, GMP compliant design, zoning concept, upstream, downstream, role of chromatography in biopharma industries, single and multiple product plants, clean rooms, clean and plant utilities, water for injection, waste management, fundamental of quality assurance, structure of quality management, documentation, audits, quality assurance and quality control in manufacturing, equipment qualification, process validation

UNIT III **9 Hours**

ENGINEERING OF BIOREACTORS

Reaction kinetics of biological systems, yields in cell culture, cell growth kinetics, heterogenous reaction systems in bioprocess, purpose and importance of bioreactors in bioprocess industries, rheological properties of fermentation broths, factors affecting broth viscosity, flow patterns in stirred tank, heat transfer in agitated tank and columns, classification of bioreactors, single use bioreactors, major components of bioreactor and their purpose, bioreactor configurations

UNIT IV **9 Hours**

UNIT OPERATIONS

Drying, solid-liquid extraction, crystallization, evaporation, distillation, ultra-filtration and diafiltration, size reduction, solid dosage forms, air conditioning and humidification, culture clarification process, clean-in-place of bioreactors

UNIT V **9 Hours**

PROCESS CONTROL AND OPTIMISATION

Fundamentals of process control, control strategies, multivariable and supervisory control, scale up and optimisation, modelling and assessment in process development, sustainability assessment of bioprocess, Process economics of bioproducts, measures to cross contamination and product confusion, product releas, pharmacovigilance, product recall

Total: 45 Hours

Reference(s)

1. Anthony J. Hickey, David Ganderton (2009) Pharmaceutical Process Engineering, 2nd Edition, CRC Press
2. David J. am Ende (2010) Chemical Engineering in the Pharmaceutical Industry: R&D to Manufacturing. John Wiley & Sons, Inc
3. Michael L. Shuler, Fikret Kargi (2017) Bioprocess Engineering: Basic Concepts, 3rd Edition, Pearson publishers
4. Gary Walsh, Biopharmaceuticals: Biochemistry and Biotechnology, John Wiley & Sons, Inc., 2nd Edition, 2003
5. Manufacturing of Pharmaceutical Proteins (from technology to Economy) by Dr.-Ing. Stefan Behme, Wiley-VCH Verlag GmbH & Co. ISBN 978-3-527-32444-6
6. Biochemistry by Lubert Stryer, W.H.Freemanand Company. ISBN 13:978-1-4292-7635-1

21BT70 NATURAL PRODUCTS AND DRUG DISCOVERY

3 0 0 3

Course Objectives

- To explain the knowledge about the use of natural products in modern pharmaceutical research
- To learn the modern methods for discovering new biologically active substances in nature
- To demonstrate the models used to develop new drugs or pharmacological tools

Programme Outcomes (POs)

a. Demonstrate problem analysing ability to develop solutions for the shortcomings encountered in biological science sector
b. Design and perform precise investigations on complex problems and contemporary issues of life science domain using modern technological innovations
c. Excel in research blended academic learning and exhibit a higher degree of attributes which is necessary for both industrial and research sector
d. Carry out research /investigations independently and develop explicit solutions for solving real-world problems
e. Apply the acquired technical knowledge and ethical principles to realize the professional and ethical responsibilities
f. Write and present an extensive technical report/document that disseminate the knowledge to the academic and research community

Course Outcomes (COs)

1. Understand the role of natural products in drug discovery, integrating traditional knowledge with modern molecular technologies
2. Apply the importance of bioactivity-guided phytofractions as potential therapeutic tools over crude extracts
3. Analyse the ecology and ethnopharmacology as sampling instruments in the search for new drugs
4. Analyse the toxic plants for its forensic significance
5. Evaluate the principles and methods of testing of herbal drug

UNIT I **9 Hours**

TRADITIONAL MEDICINE AND DRUG DISCOVERY

Plant Metabolites as Potent Leads for Pharmacologically Active Compounds; Ayurvedic medicine; Maibaron medicine; Traditional Chinese medicine; Ongoing trials with Plant Derived extracts; Challenges and Opportunities - Biological, Economic, Ecological, and Legal Aspects of Harvesting Traditional Medicine

UNIT II **9 Hours**

BIOACTIVITY GUIDED PHYTOFRACTIONS

Bioactivity guided phytofractions - Separation, characterization and standardization techniques of Phytofractions; Bioassay guided phytofraction as a therapeutic tool

UNIT III **9 Hours**

ETHANOPHARMACOLOGY AND BIOPROSPECTING

Recognition of indigenous/traditional medical knowledge; Selected Guidelines for Ethnobotanical Research- Biodiversity conservation and contemporary models; Tools used for Bioprospecting and Drug Discovery

UNIT IV **9 Hours**

THERAPEUTICS

Historical aspect of poisonous plants; Common toxic plants and plant toxins; Toxins of forensic significance; Detoxification of plant poison; Therapeutic use of poisonous plants

UNIT V **9 Hours**

QUALITY CONTROL AND REGULATION

Adulteration in Herbal Drugs; Screening of Herbal Drugs; Toxicity studies of Herbal Drugs; Labelling of Herbal Products; Quality assurance Policies and Regulations

UNIT VI

FOR FURTHER READING

Chemotaxonomy of medicinal plants; immunomodulators for plants; Natural products in lifestyle diseases; Molecular farming; Therapeutic Potential of Metalloherbal Nanoceuticals

Total: 45 Hours

Reference(s)

1. Das, A. K., Mandal, V., Mandal, S. C. (2015). Essentials of Botanical Extraction: Principles and Applications. Netherlands: Elsevier Science
2. Demain, A. L. (2007). Natural Products: Drug Discovery and Therapeutic Medicine. Netherlands: Humana Press
3. Dubey, Nawal & Dwivedy, Abhishek & Chaudhari, Anand & Das, Somenath. (2018). Common Toxic Plants and Their Forensic Significance, Natural Products and Drug Discovery, Elsevier
4. Bandaranayake, W.M. (2006). Quality Control, Screening, Toxicity, and Regulation of Herbal Drugs. In Modern Phytomedicine (eds I. Ahmad, F. Aqil and M. Owais).