UNIVERSITY OF DELHI

MASTER OF SCIENCE
(MICROBIOLOGY)

As approved in the meeting of 'Committee of Courses' held on 14-May-2018, in the meeting of 'Faculty of Interdisciplinary and Applied Sciences' held on 03-July-2018, and meeting of 'Standing Committee' held on 24-Aug-2018

PROGRAMME BROCHURE

XXXXX Revised Syllabus as approved by Academic Council on XXXX, 2018 and

Executive Council on YYYY, 2018

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I. About the Department

Historical Background of Department

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

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

Department Highlights

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

About the Programme

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

Three categories of courses are being offered in this programme: Core Courses (fourteen mandatory courses offered by the Department), Elective Courses (student must opt for two out of four Elective Courses offered by the Department), and Open Elective (student may opt for any one Open Elective offered by either the Microbiology Department or any other Department of the Faculty of Interdisciplinary and Applied Sciences). The Core Courses are of four/eight credits and include classroom as well as laboratory courses. A separate research-based course that leads to a dissertation and is worth twenty-four credits is also one of the Core Courses. The Elective Courses are four credit courses and the Open Elective is also a four credit course. The student is required to accumulate twenty-four credits each semester, a total of ninety-six credits, to fulfill the requirements for a Master of Science degree in Microbiology.

Thirty percent of the total marks for each course will be awarded through Internal Assessment. Final examinations for four credit courses will be of three hours duration while examinations for each laboratory-based course will be held over two days of eight hours each or four hours each for eight credit or four credit courses respectively.

About Post-Graduate Attributes

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

About the process of course development involving various stakeholders at different stages

The Choice-Based Credit System provides a framework within which there is flexibility in the design of courses and their content, simultaneously also providing the student a choice of the courses he/she wishes to study. The courses are assigned credits on the basis of teaching hours, which in turn is linked to course content and structure.

When revising the syllabi for the courses of the M.Sc. Microbiology programme, the courses to be implemented as well as the content of each course was extensively discussed and debated on, over several meetings between the faculty members and the students. Several alumni joined these meetings and gave useful inputs. Furthermore, the opinions of prospective employers of the corporate sector were also sought and obtained. The opinions of experts in the different areas of Microbiology were taken into consideration as well. The syllabi presented here are the culmination of the combined efforts of the faculty members of the Department, taking into account the feedback obtained from students, alumni, external experts and members of industry. The syllabi presented here have been discussed and approved by the Committee of Courses of the Department of Microbiology and by the Faculty of Interdisciplinary and Applied Sciences of University of Delhi.

II. Introduction to CBCS (Choice Based Credit System)

Choice Based Credit System:

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

Definitions:

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

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

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

(iv) 'Core Course' means a course that a student admitted to a particular programme must successfully complete to receive the degree and which cannot be substituted by any other course

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

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

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

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

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

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

III. M.Sc. Microbiology Programme Details:

Programme Objectives (POs):

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

Programme Specific Outcomes (PSOs):

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

Programme Structure:

The M.Sc. Microbiology programme is a two-year course divided into four-semesters. A student is required to complete ninety-six credits for the completion of course and the award of degree. A student has to accumulate twenty-four credits in each of the four semesters.

Part – I	First Year	Semester I	Semester II
Part – II	Second Year	Semester III	Semester IV

Course Credit Scheme

Semester	Core Courses			Elective Course			Open Elective Course			Total Credits
	No. of papers	Credits (L+T/P)	**Total Credits**	No. of papers	Credits (L+T/)	**Total Credits**	No. of papers	Credits (L+T/P)	**Total Credits**	
I	5	16+8	**24**	-	-	-	-	-	-	**24**
II	4	12+4	**16**	1	4+0	**4**	1	4+0	**4**	**24**
III	4	12+8	**20**	1	4+0	**4**	-	-	-	**24**
IV	1	0+24	**24**	-	-	-	-	-	-	**24**
Total Credits	**86**			**8**			**4**			**96**

* Duration of examination of a four credit course shall be 3 hours.

*Duration of examination of a laboratory course will be '8 hours + 8 hours' or '4 hours + 4 hours' over two consecutive days, for eight credit or four credit courses respectively.

SEMESTER-WISE DETAILS OF M.Sc. MICROBIOLOGY COURSE

	Semester I			
Number of core courses	**Credits in each core course**			
Course	Theory	Practical	Tutorial	Credits
MBCC101: Bacteriology	4	0	0	4
MBCC102: Microbial Physiology and Metabolism	4	0	0	4
MBCC103: Molecular Virology	4	0	0	4
MBCC104: Immunology	4	0	0	4
MBCC105: Practical I	0	8	0	8
Core course 'n' (total number)=5	16	8	0	24
Total credits in core course	24			
Number of elective courses	**Credits in each Elective course**			
Course	Theory	Practical	Tutorial	Credits
Elective course 1	-	-	-	-
Elective course 'n'(total no.)=0	-	-	-	-
Total credits in elective courses	0			
Number of Open Electives	**Credits in each open elective**			
	Theory	Practical	Tutorial	Credits
Open elective	-	-	-	-
Total credits in open elective	0			

Note: Each theory core paper will be of 100 marks out of which 70 marks shall be allocated for semester examination and 30 marks for internal assessment. Practical I will be of 200 marks out of which 140 marks shall be allocated for semester examination and 60 marks for internal assessment.

Semester II				
Number of Core Courses	**Credits in each Core Course**			
Course	Theory	Practical	Tutorial	Credits
MBCC201: Environmental Microbiology	4	0	0	4
MBCC202: Industrial Microbiology	4	0	0	4
MBCC203: Microbial Pathogenicity	4	0	0	4
MBCC204: Practical II	0	4	0	4
Core course 'n' (total number) = 4	12	4	0	16
Total credits in core course	16			
Number of Elective Courses	**Credits in each Elective course**			
Course	Theory	Practical	Tutorial	Credits
MBEC201: Biophysical and Biochemical Methods**	4	0	0	4
MBEC202: Plant-Pathogen Interactions**	4	0	0	4
Elective course 'n'(total no.) = 1	4	0	0	4
Total credits in Elective Courses	4			
**** Student must opt for any one of the two elective courses**				
Number of Open Electives	**Credits in each Open Elective**			
Course	Theory	Practical	Tutorial	Credits
MBOE201: Microbial Biotechnology#	4	0	0	4
Total credits in Open Elective	4			
# Open to students of other Departments of FIAS also				

Note: Each theory core and elective paper will be of 100 marks out of which 70 marks shall be allocated for semester examination and 30 marks for internal assessment. Practical II will be of 100 marks out of which 70 marks shall be allocated for semester examination and 30 marks for internal assessment. The Open Elective will be of 100 marks out of which 70 marks shall be allocated for semester examination and 30 marks for internal assessment

Semester III				
Number of core courses	**Credits in each core course**			
Course	Theory	Practical	Tutorial	Credits
MBCC301: Molecular Biology	4	0	0	4
MBCC302: Recombinant DNA Technology	4	0	0	4
MBCC303: Microbial Genetics	4	0	0	4
MBCC304: Practical III	0	8	0	8
Core course 'n' (total number) = 4	12	8	0	20
Total credits in Core Course	20			
Number of Elective Courses	**Credits in each Elective Course**			
Course	Theory	Practical	Tutorial	Credits
MBEC301: Computational Biology**	4	0	0	4
MBEC302: Food Microbiology**	4	0	0	4
Elective course 'n'(total no) = 1	4	0	0	4
Total credits in Elective Courses	4			
** **Student must opt for any one of the two Elective Courses**				
Number of Open Electives	**Credits in each Open Elective**			
Course	Theory	Practical	Tutorial	Credits
Open elective 1	-	-	-	-
Total credits in Open Elective	0			

Note: Each theory core and elective paper will be of 100 marks out of which 70 marks shall be allocated for semester examination and 30 marks for internal assessment. Practical III will be of 200 marks out of which 140 marks shall be allocated for semester examination and 60 marks for internal assessment.

Semester IV				
Number of Core Courses	**Credits in each Core Course**			
Course	Theory	Practical	Tutorial	Credits
MBCC401: Project Work	0	24	0	24
Core course 'n' (total number) = 1	0	24	0	24
Total credits in Core Course	24			
Number of Elective Courses	**Credits in each Elective Course**			
Course	Theory	Practical	Tutorial	Credits
Elective Course 1	-	-	-	-
Elective Course 'n'(total no) = 0	-	-	-	-
Total credits in Elective Courses	0			
Number of Open Electives	**Credits in each Open Elective**			
Course	Theory	Practical	Tutorial	Credits
Open Elective 1	-	-	-	-
Total credits in Open Elective	0			

Note: The paper will be of 600 marks out of which 420 marks shall be allocated for experimental work, written dissertation, presentation and *viva-voce* and 180 marks shall be for continuous evaluation (internal assessment).

List of Elective Courses

1. MBEC201: Biophysical and Biochemical Methods
2. MBEC202: Plant – Pathogen interactions
3. MBEC301: Computational Biology
4. MBEC302: Food Microbiology
5. Open Elective: MBOE201: Microbial Biotechnology

Selection of Elective Courses:

MBEC201 and MBEC202 are being offered in Semester II. The student would choose any one of these two courses that would be worth four credits. MBEC301 and MBEC302 are being offered in Semester III. The student would choose any one of these two courses that would be worth four credits. MBOE201 is an Open Elective being offered in Semester II. This course is open to students of other Departments of the Faculty of Interdisciplinary and Applied Sciences also. The students of the M.Sc. Microbiology programme can also take up an Open Elective being offered by any of the other Departments of FIAS.

Teaching:

The faculty of the Department is primarily responsible for organizing lecture work for the M.Sc. Microbiology programme. Faculty from some other Departments and Research Institutes are also associated with lecture and practical/tutorial work in the Department. There

shall be 90 instructional days excluding examination in a semester.

A separate research-based course that leads to a dissertation and is worth twenty-four credits is also one of the Core Courses. This course is taken by the student in the final semester of the programme. The student carries out a small research project under the supervision of a faculty member and is evaluated on multiple components including the ability to search, read, and assimilate literature related to the problem, to plan and execute experiments carefully and correctly, to observe and meticulously record the data obtained, to analyze the results qualitatively and quantitatively, to present the work carried out and results obtained before an audience of twenty to thirty people, and to defend the work in a *viva-voce*.

Eligibility for Admissions:

Admission criteria for M.Sc. (Microbiology)*:*

Merit and Entrance test based

Number of seats:

Twelve (6 by merit, 6 by entrance test)

Eligibility	***Course requirements***	***Marks requirement***
For Entrance Based	B.Sc. (General) or B.Sc. (Hons) or an equivalent Undergraduate Degree in any branch of Life Sciences/ Medical Sciences/ any branch of Biology	60% or above marks in qualifying exam
For Merit Based	B.Sc. (Hons.) in Microbiology from the University of Delhi (after 10+2+3)	60% or above marks in qualifying exam

Distribution of seats under different categories will vary every year alternatively by following the roster:

Year	Mode of admission	General	OBC	SC	ST	Sub-Total	Total
Even Year	Merit	3	1	1	1	6	12
	Entrance	3	2	1	0	6	
	Sub-Total	6	3	2	1	12	
Odd Year	Merit	3	2	1	0	6	12
	Entrance	3	1	1	1	6	
	Sub-Total	6	3	2	1	12	

The entrance test for admission to M.Sc. (Microbiology) programme will be based on the syllabus of the B.Sc. (Honors) Microbiology course under CBCS system, which can be downloaded from the Delhi University website. The details of the entrance test are announced every year by the University in April/May.

Assessment of Students' Performance and Scheme of Examinations:

1. English shall be the medium of instruction and examination.

2. Assessment of students' performance shall consist of:

2.1: Each four credit theory course will carry 100 marks of which 30% marks shall be reserved for Internal Assessment (IA) based on quiz/class test, seminar/presentation, mid-term exam, assignment. The IA of every course will include at least two of the above components, and the weightage given to each of the components shall be decided and announced at the beginning of the semester by the individual teacher responsible for the course. Any student who fails to participate in the Internal Assessment exercises will be debarred from appearing in the end-semester examination in the specific course and no Internal Assessment marks will be awarded. His/her Internal Assessment marks will be awarded in the next applicable semester only. No special classes will be conducted for him/her during other semesters.

2.2: Each eight credit laboratory course will be of 200 marks of which 30% marks will be reserved for Internal Assessment. Internal Assessment will be based on performance of experiments, maintenance of records of data and results obtained, and *viva voce*. A four credit laboratory course will be of 100 marks, of which 30% marks will be reserved for Internal Assessment. Internal Assessment will be based on performance of experiments, maintenance of records of data and results obtained, and *viva-voce*.

2.3: Regarding MBCC401: Project Work shall be carried out in Semester IV and will be worth twenty-four credits. The candidate will submit a dissertation in bound form at the end of the semester. Total marks for MBCC401 shall be 600 and evaluation will be as follows:

Continuous evaluation (IA)	180 marks
Experimental work	120 marks
Dissertation	100 marks
Presentation and *viva-voce*	200 marks
Total	600 marks

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

Pass Percentage & Promotion Criteria:

Pass percentage: The student is required to pass separately both in theory and laboratory-based examinations. Minimum marks for passing the examination shall be 45% in aggregate in theory courses, 45% in laboratory courses and 45% marks in dissertation. The student must score at-least 40% in each theory paper.

Promotion criteria from semester to semester: Within the same Part, the candidate will be promoted from one semester to the next (Semester I to Semester II and Semester III to Semester IV), provided the candidate has passed at least two of the papers of the current semester by securing at least 40% marks in each paper.

Note: A candidate will not be allowed to reappear (even if he/she is absent) in the practical examination except in very special cases with approval of Head of the Department.

Part I to Part II Progression:

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

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

Note: The candidate however will have to clear the remaining papers while studying in Part II of the programme in order to qualify for the receipt of a Master's degree.

Conversion of Marks into Grades:

As per the University Examination rule.

Grade Points:

Grade point table as per University Examination rule.

SGPA Calculation:

As per University Examination rule.

CGPA Calculation:

As per University Examination rule.

Grand CGPA Calculation:

As per University Examination rule.

Conversion of Grand CGPA into Marks

As notified by competent authority the formula for conversion of Grand CGPA into marks is:

Final %age of marks = CGPA based on all four semesters × 9.5

Division of Degree into Classes:

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

Attendance Requirement:

Students will be required to show a minimum of 75% attendance in every course in order to appear for the examinations at the end of each semester. In addition, five marks of the Internal Assessment component for every course will be reserved for attendance.

Span Period:

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

Guidelines for the Award of Internal Assessment Marks of M.Sc. Microbiology Programme (Semester Wise)

Theory courses: A four credit course will be evaluated for a total of 100 marks. 30% of the total marks of every theory course shall be reserved for Internal Assessment. Internal Assessment (IA) for a theory course will be based on written quiz/class test, seminar/presentation, mid-term exam, assignment. The IA of a theory course will include at least two of the above components, and the weightage given to each component shall be decided and announced at the beginning of the semester by the teacher(s) responsible for the course. Five marks will be reserved for attendance.

***Laboratory courses*:** An eight credit laboratory course will be evaluated for a total of 200 marks while a four credit laboratory course will be evaluated for a total of 100 marks. 30% of the total marks of every laboratory course shall be reserved for Internal Assessment. Internal Assessment will be based on performance of experiments, maintenance of records of data and results obtained, and *viva-voce*.

Project work/ dissertation: The twenty-four credit project-based course will be evaluated for a total of 600 marks. 30% of the total marks shall be reserved for Internal Assessment. Internal Assessment will be based on continuous evaluation of the student. The student will be evaluated on ability to search, read and assimilate literature related to the project, regularity and perseverance at experiments, ability to plan and correctly execute experiments, and maintenance of data notebooks.

IV: Course Wise Content Details for M.Sc. (Microbiology) Programme:

Semester I

MBCC101: BACTERIOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The primary objective of the course is to build a strong foundation in the area of bacterial cell structure, division, survival and propagation.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will be able to describe the morphological features, cell arrangement and structural components of bacterial cell in detail; will be able to differentiate between Gram-positive and Gram-negative bacteria.

CO2: Will have gained knowledge about cell wall structure and extracellular appendages in different bacteria and is acquainted with current methodologies available for production of protoplasts, sphaeroplasts and L-forms.

CO3: Will have gathered detailed information regarding bacterial cell division and endospore formation.

CO4: Can enlist the characteristics of archaea that differentiate it from eubacteria, and will have learnt key features of some model archaeal organisms.

CO5: Can enlist the salient features of the genome organization of *E.coli* and also the features of the unusual genome organization of selected extremophiles that allow them to survive in harsh environments.

CO6: Understands different secretion systems existing in bacteria for toxins and biomolecules secretion, and their role in bacterial survival and pathogenesis.

CO7: Will have gained in-depth knowledge about density-based signal transduction in bacteria and its significance in competence, sporulation and antibiotic resistance; would know about quorum quenching and its use in developing antimicrobial tools.

Contents:

Unit I: Bacterial cell structure and appendages: Overview of eubacterial cell organization**:** nucleoid, ribosomes, intracytoplasmic membranes and cell inclusions. Detailed account of biogenesis and function of various cell structure appendages: flagella- structure, assembly and mechanism of movement; pili and fimbriae- types, structure and their role. External cell surface structures: capsule, glycocalyx, slime layer and S-layer **10**

Unit II: Bacterial cell wall and cell membrane: Overview of gram negative and gram positive bacterial cell wall, outer membrane lipopolysaccharide (LPS). Detailed account of cell wall synthesis and its inhibitors including different antibiotics. **8**

Unit III: Bacterial cell division and reproduction: Binary fission and other forms of reproduction in bacteria, bacterial cell cycle, assembly, maintenance and disassembly of Z ring, endospore structure and stages involved in endospore development in *Bacillus subtilis.* **10**

Unit IV: Archaeal diversity, cell structure and model organisms: Phylogenetic diversity and key features of different phyla. General characteristics of archaeal cell structure and comparison with eubacteria. Detailed account of model archaeal organisms: *Methanococcus, Halobacterium, Pyrococcus* and *Sulfolobus.* **8**

Unit V: Bacterial genome: Genome organization of *E.coli* and salient features of genomes of *Deinococcus radiodurans, Azotobacter vinelandii, Buchnera sp., Agrobacterium tumefaciens* and *Epulopiscium sp.* **6**

Unit VI: Bacterial secretion system: Introduction. Sec secretion pathway, SecB secretion pathway, SRP pathway, Tat pathway. Protein secretion in Gram-negative bacteria: Type I-TypeVI. Protein secretion in Gram-positive bacteria: Type VII, Sec A2, Sortases and Injectosome. Introduction to Type VIII and Type IX secretion systems. **10**

Unit VII: Quorum sensing: Discovery, role as illustrated by bioluminescence (*Vibrio fischeri, Vibrio harveyi*), virulence (*Pseudomonas aeruginosa, Staphylococcus*), competence and sporulation (*Bacillus subtilis*) and antibiotic resistance in bacteria. Quorum quenching: impact and mechanism. **8**

Suggested Readings:

1. Prescott's Microbiology by J. Willey, L. Sherwood, C. J. Woolverton. 10th edition. McGraw Hill Education. 2017.

2. Brock Biology of Microorganisms by M. Madigan, K. Bender, D. Buckley, W. Sattley, D. Stahl. 15th Edition. Pearson Education. 2018.

3. Alcamo's Fundamentals of Microbiology by J. C. Pommerville. 10th Edition. Jones and Bartlett Learning. 2013.

4. Archaea Molecular and Cellular Biology by Ricardo Cavicchioli. American Society of Microbiology. 2007.

5. The Physiology and Biochemistry of Prokaryotes by D. White, J. Drummond, C. Fuqua. 4th Edition. Oxford University Press. 2011.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks*
I.	Will be able to describe the morphological features, cell arrangement and structural components of bacterial cell in detail. Is able to differentiate between Gram-positive and Gram-negative bacteria.	Detailed discussion on the general morphology of bacteria and the basic differences in gram-positive and gram-negative cell structure and the detailed structure of gram-negative and gram-positive bacterial cell walls and extracellular appendages through diagrammatic representations.	Visual aid quiz for identification of common bacteria with distinct morphology. Fill in the blank type test based on function and occurrence of bacterial locomotory organs and extracellular capsules.

II.	Will have gained knowledge about cell wall structure and extracellular appendages in different bacteria and will be acquainted with current methodologies available for production of protoplasts, sphaeroplasts and L-forms.	Having classroom discussions about cell wall synthesis and its inhibitors that can be useful in anti-bacterial therapy. Explaining the significance and generation of protoplasts, sphaeroplasts and L-forms.	Student presentation on generation of cell wall-less bacteria and their applicability.
III.	Will have gathered detailed information regarding bacterial cell division and endospore formation.	Make students conversant with the types of cell division in bacteria and the series of events that occur during binary fission including maintenance and disassembly of Z ring. Provide knowledge about structure and development of endospores.	Class test on diagrammatic representation of cell division. Assessment based on rearranging the order of pictures with respect to stages in endospore development in bacteria and labeling them
IV.	Can enlist the characteristics of archaea that differentiate it from eubacteria, and will have learnt key features of some model archaeal organisms.	Familiarizing students with the general characteristics of archaea and specific key features of model archaeal organisms: *Halobacterium, Pyrococcus, Sulfolobus and Methanococcus.*	Ten-minute MCQ quiz after lecture.
V.	Can enlist the salient features of the genome organization of *E.coli* and also unusual genome organization of selected extremophiles that allow them to survive in harsh environments.	Discussion about the genome organization of *E. coli.* The salient features of genomes of *Deinococcus radiodurans*, *Azotobacter vinelandii*, *Buchnera* sp., *Agrobacterium tumifaciens* and *Epulopiscium* sp.	Match the following type quiz regarding unique features of bacterial genomes
VI.	Understands different secretion systems existing in bacteria for toxins and biomolecules secretion, and their role in bacterial survival and pathogenesis.	Employing video lectures and interactive diagrams of the secretion systems that exist in bacteria for enabling students to differentiate between the Sec, SRP and Tat secretion pathway. Acquainting students with bacterial sortases.	Visual-based group quiz about identification and assembly of secretion systems in bacteria. Pop-quiz on secretion systems employed for transport of particular metabolites and proteins. Class room debate about importance of each secretion system in bacteria
VII.	Will have gained in-depth knowledge about density-based signal transduction in bacteria and its significance in competence, sporulation and antibiotic resistance. Will know about quorum quenching and its uses	Providing students with the knowledge about quorum sensing in bacteria. Making students aware of the historical developments that lead to the present day understanding of quorum sensing. Acquainting students with the involvement of quorum-mediated crosstalk in competence, sporulation, bioluminescence and antibiotic resistance in bacteria. Discussion on the topic of quorum quenching and its applicability in devising antimicrobial tools.	Ten-minute MCQ quiz after lecture. Group activity based on project designing on discovery of new quorum sensing and quenching molecules

***Assessment tasks listed here are indicative, and may vary.**

MBCC102: MICROBIAL PHYSIOLOGY AND METABOLISM

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The major objective of this paper is to develop clear understanding of various aspects of microbial physiology along with diverse metabolic pathways existing in bacteria in relation to its survival and propagation, and to enable students to better understand courses taught later such as Microbial Pathogenicity and biotechnology-based courses.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will be acquainted with methods of measuring microbial growth, calculating growth kinetic parameters with understanding of steady state and continuous growth.
CO2: Will have gained an in-depth knowledge of primary, secondary and group translocation transport systems existing in bacteria, simultaneously learning membrane transport proteins and kinetics of solute transport.
CO3: Will have learnt central metabolic pathways for carbon metabolism in bacteria enlisting differences with eukaryotic systems and their regulation in diverse physiological conditions. This allows students to apply the acquired knowledge in engineering metabolic pathways for developing industrially useful strains.
CO4: Will have gathered understanding of inorganic and organic nitrogen assimilation and its regulation. Also knows role of glutathione in cellular redox regulation and biochemistry of glutamate overproducing strains.
CO5: Will have learnt basic concepts of enzyme biochemistry, its kinetics and regulation.
CO6: Will understand details of lipid and nucleotide metabolism in *E. coli* and its regulation along with biochemical basis of lipid accumulation in yeasts.
CO7: Is conversant with intracellular signaling in bacteria in response to various nutritional and physiological stresses.

Contents:

Unit I: Growth and cell division: Measurement of growth, growth physiology, cell division, growth yields, growth kinetics, steady state growth and continuous growth. **8**

Unit II: Solute Transport: Introduction, primary and secondary transport, kinetics. Membrane transport proteins: porins and aquaporins, mechanosensitive channels, ABC transporter, group translocation PEP-PTS system. Catabolite repression, inducer exclusion and expulsion. **8**

Unit III: Central Metabolic Pathways and Regulation: Glycolysis and its regulation, Gluconeogenesis, Pentose-Phosphate Pathway, Entner-Doudoroff Pathway, Citric Acid Cycle, alternate TCA, Glyoxylate Pathway and its regulation. Examples of pathway engineering of carbon metabolic pathways to develop industrial useful strains: Co-metabolism of pentoses and hexoses, Succinic and citric acid production. **8**

Unit IV: Nitrogen metabolism: Inorganic nitrogen assimilation- nitrate and ammonia assimilation, regulation of glutamate synthetase, General reaction of amino acid and Stickland reaction. Glutathione: distribution in bacteria, biosynthesis and role in redox regulation. Outline of amino acid biosynthesis, protein utilization, detailed account of biochemistry of glutamate producing strains. **8**

Unit V: Enzymes: Introduction, activation energy, enzyme kinetics, significance of K_m, catalytic efficiency, turnover number. Methods of plotting enzyme kinetics data: Lineweaver –Burk plot, saturation kinetics. Enzyme inhibition, models and type of inhibition **8**

Unit VI: Metabolism of lipids and nucleotides: Biosynthesis and degradation of lipids and its regulation in *E. coli*, lipid accumulation in yeast. Purine and pyrimidine biosynthesis, deoxyribonucleotide synthesis, regulation of purine and pyrimidine biosynthesis, inhibitors of nucleotide biosynthesis. **12**

Unit VII: Physiological Adaptation and Intracellular signaling: Introduction to two component system. Response to physiological stress: aerobic-anaerobic shifts- Arc and Fnr system, osmotic homeostasis. Response to nutritional stress: phosphate supply- Pho regulon, and stringent response. **8**

Suggested Readings:

1. Biochemistry by Geoffrey L. Zubay. 4th Edition. Brown Co, USA. 1999.
2. Microbial Physiology by A.G. Moat, J. W. Foster, M. P. Spector. 3rd Edition. John Wiley & Sons. 2002
3. Lehninger Principles of Biochemistry by D. L. Nelson, M. M. Cox. 6th Edition. W. H. Freeman. 2012
4. The Physiology and Biochemistry of Prokaryotes by D. White, J. Drummond, C. Fuqua. 4th Edition. Oxford University Press. 2011.
5. Microbial Biochemistry by G. N. Cohen. 2nd Edition. Springer. 2014.
6. Lippincott's Illustrated Reviews: Biochemistry edited by D. R. Ferrier. 6th Edition. Lippincott Williams & Wilkins. 2013
7. Biochemical Calculations: by Irwin H. Segel. 2nd Edition. Wiley. 2004.
8. Understanding Enzymes by T. Palmer, E.Horwood. 3rd Edition. Wiley. 1991.

Facilitating the achievement of Course Learning Outcomes

Unit no.	Course Learning Outcomes	Teaching and learning Activity	Assessment Tasks
I	Student gets acquainted with methods of measuring microbial growth, calculating growth kinetic parameters with understanding of steady state and continuous growth.	Class room lecture on growth, growth physiology, cell division. Detailed talk on measurement of microbial growth, growth yields, growth kinetics, steady state growth and continuous growth.	Mathematical quiz on calculations of growth yields and kinetic constants.
II	Students gain an in-depth knowledge of primary, secondary and group translocation transport	Detailed discussion on primary and secondary transport and kinetics of solute transport. Pictorial presentations of membrane transport	Match the following type quiz of solute transport with kinetic curves and

	systems existing in bacteria simultaneously learning membrane transport proteins and kinetics of solute transport.	proteins Group translocation systems PEP-PTS system catabolite repression; inducer exclusion and inducer expulsion.	identification of solute transport with the substrates and proteins involved in transport.
III	Learn central metabolic pathways for carbon metabolism in bacteria enlisting differences with eukaryotic systems and their regulation in diverse physiological conditions. This allows students to apply learnings in engineering metabolic pathway for developing industrially useful strains.	Theory class on glycolysis and its regulation; gluconeogenesis; pentose-phosphate pathway; Entner-Doudoroff pathway; citric acid cycle; alternate TCA; glyoxylate pathway and its regulation. Interactive lectures on selected examples of pathway engineering of carbon metabolic pathways to develop industrial useful strains	'Draw the pathway' group competition. Problem solving situation-based test on pathway mutants
IV	Gather an understanding of inorganic and organic nitrogen assimilation and its regulation. Also learn the role of glutathione in cellular redox regulation and biochemistry of glutamate overproducing strains	Familiarizing students with inorganic nitrogen assimilation- nitrate and ammonia assimilation, regulation of glutamate synthetase and Stickland reaction. Discussion on glutathione distribution in Bacteria. Detailed account on biochemistry of glutamate producing strains.	MCQ on enzymes involved in various stages of nitrogen assimilation
V	Learn basic concepts of enzyme biochemistry, its kinetics and regulation.	Practical example-based teaching on calculation of activation energy, enzyme kinetics, significance of Km, catalytic efficiency, turnover number. Detailed explanation of methods for plotting enzyme kinetics data: Lineweaver – Burk plot, saturation kinetics. Class on enzyme inhibition, models and types of inhibition.	Mathematical problems of calculation of enzyme kinetic constants by plotting the data provided. Pictorial quiz for identification of type of enzyme inhibition
VI	Understand the details of lipid and nucleotide metabolism in *E. coli* and its regulation along with biochemical basis of lipid accumulation in yeasts.	Discussion on biosynthesis and degradation of lipids and its regulation in *E. coli.* Familiarizing students with lipid accumulation in yeast. Diagrammatic representations and explanation of Purine and pyrimidine biosynthesis; deoxyribonucleotide synthesis. Classes on the regulation of purine and pyrimidine biosynthesis; inhibitors of nucleotide biosynthesis.	Quiz on identifying inhibitors of nucleotide synthesis pathway
VII	Student is conversant with intracellular signaling in bacteria in response to various nutritional and physiological stresses.	Introduction to two-component system with discussion on responses to physiological stress such as aerobic-anaerobic shifts, osmotic shifts and nutritional stress	Pop quiz on identification of response molecules associated with given stress condition

***Assessment tasks listed here are indicative, and may vary.**

MBCC103: MOLECULAR VIROLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The course will facilitate in understanding of molecular virology by examining common processes and principles in viruses to illustrate viral complexity, to understand viral reproduction. The course will teach the strategies by which viruses spread within a host, and are maintained within populations. It covers the molecular biology of viral reproduction and addresses the interplay between viruses and their host organisms

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Is able to describe classification of viruses
CO2: Is able to describe tools for studying virus structure, process of virus attachment and entry, virus assembly and release
CO3: Is able to describe steps in replication of genome of RNA viruses, retroviruses, and DNA viruses
CO4: Is able to describe steps in virus infection, transmission, patterns of infection, virus virulence, and host defense against virus infection
CO5: Is able to describe methods of making virus vaccines and anti-viral drugs, drivers of virus evolution, and emerging viruses
CO6: Is able to describe unusual infectious agents, virus mediated cellular transformation and oncogenesis
CO7: Is able to describe evasion strategies used by viruses, and learn to apply their knowledge to investigate virus outbreak

Contents:

Unit I: Introduction to Virology: The big picture of all viruses using a common strategy, virus classification, the infectious cycle, studying virus infection. Koch's Postulates for viruses, virus genome types, double stranded DNA (dsDNA),gapped DNA genomes, single-stranded (ssDNA) genomes, double stranded RNA (dsRNA), single stranded RNA (ssRNA), (+) strand RNA, single stranded (+) sense RNA with DNA intermediate, single stranded RNA (-) sense, ambisense RNA genomes. **6**

Unit II: Virus Structure and Assembly: Metastability, the tools for viral structural biology. Helical symmetry, Icosahedal symmetry, Triangulation number, Quasi-equivalence. Virus attachment and entry, Initiation of infection, Affinity, Avidity, cellular receptor for viruses. Getting into the nucleus, virus disassembly, metastable structures, concentrating components for assembly, getting things to the right place. How do viruses make sub-assemblies, sequential and concerted assembly. Packaging signals, packaging of segmented genome, acquisition of an envelope, budding strategies. **6**

Unit III: RNA directed RNA synthesis, Reverse Transcription and Integration, Translation, and genome replication of DNA viruses: Identification of RNA polymerase, how RNA synthesis occurs in viruses? Reverse transcriptase, retrovirus genome organization, steps of DNA

synthesis in retroviruses. Regulation of translation in virus infected cells. Basic rules of genome replication in DNA viruses, viral origins of DNA replication. Generic steps in transcription, host polymerases, initiation, splicing, alternate splicing, promoter structure, steps in regulation of transcription, enhancers, virus coded transcriptional regulators, transcriptional cascade, export. **12**

Unit IV: Virus Infections basics, interaction with host, acute and persistent infections: Fundamental questions of viral pathogenesis. Virion defenses to hostile environment, viral spread, viremia, determinants of tissue tropism. Virus shedding, transmission of infection, host defense, innate immune response, virus virulence, identifying virulence genes. Toxic viral proteins, cellular virulence genes, immunopathology, systemic inflammatory response syndrome. Immune complexes, virus induced auto-immunity, general pattern of infection. Inapparent acute infections, defense against the acute infection. Influenza, Polio, Measles, Rotavirus, persistent infections, chronic and latent Infections. **12**

Unit V: Vaccines and anti-Viral drugs, virus evolution and emerging viruses: Herd immunity, requirement of an effective vaccine, different ways of making vaccine. Inactivated vaccine, subunit vaccines, subunit vaccines, live attenuated vaccines, polio eradication. Anti-viral drugs, search for anti-viral drugs, the path for drug discovery, mechanism based screens, cell based screen, antiviral screening. Resistance to antiviral drugs, main drivers of virus evolution, the quasi-species concept, error threshold, genetic bottlenecks, Muller ratchet, genetic shift and drift. Theories on origin of virus, evolution of new viruses, emerging viruses, Factors that drive viral emergence, evolving host-virus relationship. **10**

Unit VI: Unusual Infectious Agents, viral cancer, transformation and oncogenesis: Viroids, origin of viroids, Satellites, Prions, Transmissible spongiform encephalopathy (TSE) caused by prions, Prion hypothesis, Prion species barrier. Virus-induced cancer, Avian leucosis retroviruses, Proviral DNA sequences, Proto-oncogenes, DNA tumor Viruses, the link between DNA virus biology and transformation. **8**

Unit VII: Virus Evasion strategies and investigation of virus outbreak: Strategies for evasion, Translational regulation, Innate defense targets, Viral modulators of interferon, Autophagy, Apoptosis, Apoptotic pathway and viruses, Immune modulation, Immune modulation strategies. Case study of health risk associated with a virus epidemic, the origin of outbreak, the spread, the intervention strategies, public health response. **6**

Suggested Readings:

1. Principles of Virology: Molecular Biology, Pathogenesis and Control of Animal Viruses by S.J. Flint, L.W. Enquist, V.R. Racaniello, A.M. Skalka. 4thedition. ASM Press. 2015.
2. Introduction to Modern Virology by N. Dimmock, A. Easton, K. Leppard. 7thedition. Blackwell Publishing. 2016.
3. Basic Virology by Edward K. Wanger, M. Hewiett, D. Bloom, D. Camerini. 3rdedition. Blackwell Publishing. 2007.
4. Principles of Molecular Virology by A.J. Cann. 6thedition. Elsevier Academic Press. 2015.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Task
I	Is able to describe classification of viruses	Learn about virus classification, basis of classification, different classification systems, and virus genome types	Multiple choice questions to assess knowledge of virus classification
II	Is able to describe tools for studying virus structure, process of virus attachment and entry, virus assembly and release	Learn about concept of metastability, tools for studying virus structure, virus symmetry, virus attachment and entry, concepts of affinity and avidity, virus assembly reactions, and virus budding strategies	Fill the blanks type questions to asses understanding of concepts related to virus infection
III	Is able to describe steps in replication of genome of RNA viruses, retroviruses, and DNA viruses	Learn about RNA polymerases, RNA synthesis in RNA viruses, steps of DNA synthesis in retroviruses, viral origins of DNA replication, host polymerases, transcription regulation in viruses	True False questions to asses knowledge regarding virus replication
IV	Is able to describe steps in virus infection, transmission, patterns of infection, virus virulence, and host defense against virus infection	Learn about fundamental questions of virus pathogenesis, tissue tropism, virus virulence factors, cellular virulence genes, virus induced autoimmunity, detailed discussion about Influenza, Polio, Measles, and Rotavirus infections	Prepare and present presentation on any 1 acute virus and 1 chronic virus infection
V	Is able to describe methods of making virus vaccines and anti-viral drugs, drivers of virus evolution, and emerging viruses	Learn about concepts of herd immunity, effective vaccine, ways of making vaccines, search of anti-viral drugs, drivers of virus evolution, quasi-species concept, emerging viruses	Prepare report on steps in preparation of annual flu vaccine
VI	Is able to describe unusual infectious agents, virus mediated cellular transformation and oncogenesis	Learn about viroids, satellites, prions and various transmissible encephalopathies, prion hypothesis, virus induced cancers, RNA tumor viruses, DNA tumor viruses	Match the following type quiz regarding unusual virus infection
VII	Is able to describe evasion strategies used by viruses, and learn to apply their knowledge to investigate virus outbreak	Learn about virus evasion strategies, case study of health risks associated with a virus epidemic, origin of outbreak, spread and intervention strategies, public health response	Group discussion on any ongoing virus epidemic in world to discuss public health response and public awareness

***Assessment tasks listed here are indicative, and may vary.**

MBCC104: IMMUNOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The objective of this course is to understand the various components of the host immune system, their structure and organization, and functions to serve as the defense system of the body. It would also make the students understand the operational mechanisms which underlie the host defense system, allergy and organ transplantation.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will be able to understand the fundamental bases of immune system and immune response
CO2: Will be able to gather information about the structure and organization of various components of the immune system
CO3: Will be able to understand the genetic organization of the genes meant for expression of immune cell receptors and the bases of the generation of their diversity
CO4: Will be able to understand the operation and the mechanisms which underlie the immune response
CO5: Will be able to apply the knowledge gained to understand the phenomena like host defense, hypersensitivity (allergy), organ transplantation and certain immunological diseases

Contents:

Unit I: Three fundamental concepts in immunology: Specificity, discrimination of self from non-self and memory. **8**

Unit II: Immune cell receptors: Detailed structure and development of B cell (Ig) and T cell (TcR) receptors; Structure of CD4, CD8, MHC-I, MHC-II molecules, cellular adhesion molecules (ICAM, VCAM, selectins, integrins); Pattern Recognition Receptors (PRRs) and Toll-like receptors (TLR); Markers of suppressor / regulatory cells - $CD4^+$ $CD25^+$ $Foxp3^+T_{reg}$, iNKT. **10**

Unit III: Genetic organization: Organization of the genes for B and T cell receptors. Genetic organization of MHC-I and MHC-II complex (both HLA and H-2). Molecular mechanisms responsible for generating diversity of antibodies and T cell receptors. Peptide loading and expression of MHC-I and MHC-II molecules; Hybridoma technology and monoclonal antibodies, antibody engineering including bispecific antibodies. **10**

Unit IV: Immune response and signaling: Humoral and cell-mediated immune response; Innate immune response and pattern recognition; Recent advances in innate immune response especially NK-DC interactions; Important cytokines and their role in immune mechanisms: TNF, IFN-γ, IL-1, IL-2, IL-4, 1L-6, 1L-12, IL-17, TGFβ; Cell signaling through MAP kinases and NF-κB. **8**

Unit V: Tolerance and autoimmunity: Central and peripheral tolerance, and their mechanism; Mechanisms of autoimmunity; Immune checkpoints, Autoimmune components of diabetes mellitus (DM), multiple sclerosis (MS), pernicious anemia; Infections leading to autoimmune

diseases. **8**

Unit VI: Immunological disorders and hypersensitivity: Deficiencies / defects of T cells, B cells, and phagocytic cells; Comparative study of Type I-V hypersensitivities with examples. **8**

Unit VII: Transplantation and tumor immunology: Alloreactive response; Graft rejection and GVHD; HLA-matching; Use of CRISPR-Cas for generating transgenic animals for xenotransplantation; Tumor antigens, immune response to tumors and immunotherapy of tumors. **8**

Suggested Readings:

1. Kuby Immunology by J.A. Owen, J. Punt , S.A. Stranford. 7th edition. WH Freeman. 2013.

2. Cellular and Molecular Immunology by A.K. Abbas, A.H. Lichtman, S. Pillai. 9th edition. Saunders Elsevier. 2018.

3. Janeway's Immunobiology by K. Murphy, W. Casey. 9th edition. Garland Science Publishing. 2017.

4. Review of Medical Microbiology and Immunology by W.Levinson. 15thedition.Lange Publication. 2018.

5. Fundamental Immunology by W.E. Paul. 7th edition. Lippincott Williams and Wilkins. 2013.

6. Roitt's Essential Immunology by P.J. Delves, S.J. Martin, D.R. Burton, I.M. Roitt. 13th edition. Blackwell Publishing. 2017.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	To understand the fundamentals bases of immune system and immune response	The students will be taught fundamental bases namely specificity of the immune response, its ability to differentiate self from non-self and memory. All these topics will be well illustrated by several examples each.	The students will be asked several questions during the teaching to assess their learning. The students will also be asked to provide relevant examples to assess whether they can apply their previous knowledge to the topic being taught.
II	To gather Information about the structure and organization of various components of the immune system	Using several PowerPoint slides, the students will be given knowledge of immune organs, cells of the immune system and their receptors	The learning of the students is assessed by asking them several questions during the interactive discussions in the class while teaching this topic
III	To understand the genetic organization of the genes meant for	Students will be taught how the genes for immunoglobulins, B cell receptors, T-cell receptors,	The learning of the students is assessed by making them calculate the diversity of specificities which would be generated from:

	expression of immune cell receptors and the bases of the generation of their diversity	MHC class I and II molecules are organized, re-arranged and expressed.	a)The number of variable region genes, constant region genes, diversity region genes and the random association of light and heavy chains for immunoglobulins b)The number of monomorphic and polymorphic region genes for MHC Class I & II genes.
IV	To understand the operation and the mechanisms which underlie the immune response	The students are taught the complete orchestration of the various components of the immune system resulting into immune response to disease-causing microbes leading to protection of the host	The students will be assessed by evaluating whether they are able to apply the knowledge of immune system and immune response to day-to-day practical practices like a) Vaccination programmes b) Immunizations. This will be done by open interactive discussions during the process of teaching
V-VII	To apply the knowledge gained to understand the phenomena like host defense, hypersensitivity (allergy), organ transplantation and certain diseases	In the backdrop of the learning outcomes at I-IV, the students are made to understand how these are reflected in solving practical problems like allergic reactions, certain other diseases, tissue grafts, bone marrow grafts, vaccination *etc*.	The learning of the students will be assessed by a) Asking them to relate any actual personal experiences of having suffered any allergies and the remedies undertaken thereof b) Their experiences of acquaintances having undergone organ transplantations and the associated problems like graft rejection, getting an appropriate donor, to assess their understanding of the topics learnt in the class. c) Further assessment of the learning is made in which the students are asked to write an assignment on the given topic relevant to the area of Immunology which is assessed by the teacher.

***Assessment tasks listed here are indicative, and may vary.**

MBCC105: Practical I

Marks: 200 **Duration: 120 hours (8 credits)**

Course Objectives:

The major objective of the course is to impart hands-on training in basic microbiological, biochemical and immunological techniques. Students will be trained in basic bacterial culturing and identification methods, as well as working in biosafety cabinet. Student will become familiar with sterilization techniques when handling bacterial as well as virus-infected mammalian cells. Student will be trained in basic enzyme and immunological assays and be taught to present the results both, qualitatively and quantitatively.

Course Learning Outcomes:

The Student:

CO1. Is able to use different sterilization procedures and learn handling of micropipette.
CO2. Is able to work in Biosafety Cabinet for culturing cells, virus infection and study of viral cytopathic effects.
CO3. Can use Fluorescence Microscopy for live cell imaging and intracellular localization of viral proteins in different sub-cellular compartments.
CO4. Is versed with identification and classification of given bacterial isolate by performing variety of cultural, biochemical and molecular tests. Is able to construct phylogenetic tree using bioinformatic techniques.
CO5. Can determine pI of amino acids by titration method
CO6. Is able to determine concentration of sugar and protein in a given sample after drawing a standard curve. Is able to study glucose uptake by *E.coli.*
CO7. Is able to perform TLC for separating a mixture of amino acids, lipids, and sugars.
CO8. Is able to study ammonium uptake by *E.coli*.
CO9. Is able to determine specific growth rate of *E.coli* in different media.
CO10. Can draw a diauxic growth curve in lactose and glucose medium and learn to perform β-galactosidase assay.
CO11. Understands the techniques of enzyme assay to determine its specific activity, pH optima, pH stability, temperature optima and temperature stability and calculate inactivation constant (Kd) and $t_{1/2}$ of the enzyme reaction based on the temperature stability curve.
CO12. Can determine K_m,V_{max} and K_{cat} of a purified enzyme and determine its activation energy by plotting Arrhenius curve.
CO13. Is able to perform immune-electrophoresis, immunodiffusion assay.
CO14. Is able to perform rocket immune-electrophoresis.
CO15. Is able to stain a tissue by immune-histochemical reaction
CO16. Is able to perform quantitative precipitation assay
CO17. Is able to perform dot-ELISA.
CO18. Is able to perform latex agglutination test
CO19. Is able to perform western blotting.
CO20. Can differentiate lymphocytes, neutrophils, monocytes, eosinophils, and basophils based on morphological and staining characteristics.

Contents:

1. To train students in handling, upkeep and calibration of micropipette for measuring small volumes
2. To give hands-on training in sterilization techniques and their application in microbiology lab
3. To train student in working with a biosafety cabinet in a BSL2.5 lab
4. Culturing of eukaryotic cells of epithelial and lymphoid origins
5. Counting and passaging of eukaryotic cells of epithelial and lymphoid origins
6. Principles and techniques of freezing and thawing of eukaryotic cells for long term storage
7. Fluorescent microscopy for live/ fixed cell imaging
8. To purify and identify the given bacterial sample by determining their:- Colony morphology, staining characteristics and biochemical characteristics
9. To perform DNA extraction of the given bacterial culture and to carry out PCR amplification of the isolated DNA using universal 16S rRNA gene primers.
10. To analyze the given 16srRNA sequences by using BLAST and construct a phylogenetic tree based on the comparison results.
11. To determine the G+C content by determining the melting temperature (Tm) of the DNA of given microbial culture.
12. To draw the titration curve of amino acid and determine its pI.
13. To study glucose uptake by *E.coli*.
14. To prepare standard curve of BSA and determine the concentration of unknown protein sample using Bradford method using regression equation.
15. To separate amino acids, sugars and lipids using Thin Layer Chromatography (TLC)
16. To prepare standard curve of ammonia and determine its uptake by bacterial cells with respect to time and temperature
17. To determine the specific growth rate of E.coli in different media.
18. To study the diauxie growth curve of E.coli in media containing glucose and lactose and perform β-galactosidase assay.
19. To determine activity and specific activity of the enzyme sample provided.
20. To study the pH optima, pH stability, temperature optima and temperature stability of the given enzyme sample and to calculate inactivation constant (Kd) and $t_{1/2}$ of the enzyme reaction.
21. To determine K_m,V_{max} and $K_{cat}$of a purified enzyme.
22. To calculate activation energy (Ea) of the given enzyme sample using Arrhenius plot.
23. To perform immune-electrophoresis.
24. To perform radial immunodiffusion assay.
25. To perform rocket immune-electrophoresis.
26. To stain a tissue by immune-histochemical reaction
27. To study quantitative precipitation assay
28. To perform dot-ELISA.
29. To perform latex agglutination test
30. To perform western blotting.

31. To study morphological and staining characteristics of lymphocytes, neutrophils, monocytes, eosinophils, and basophils.

Suggested Readings:

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

2. Biochemistry Lab Manual by D.A. Thompson. 3rd edition. Create Space Independent Publishing Platform. 2013.

3. Biochemical calculations: how to solve mathematical problems in general biochemistry by Irwin H. Segel, Wiley, 2nd Edition 2004

Semester II

MBCC201: ENVIRONMENTAL MICROBIOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The major objective of this paper is to impart knowledge about structure, composition and functioning of microbial communities of diverse environment. The use of microbial population in agriculture, mineral recovery, management of various types of pollutants and conversion processes of various types of wastes into value added products will be discussed.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1. Will have an overview of the till date developments in the field of environmental microbiology with special emphasis on the role of microbes in mitigating environment pollution.
CO2. Will have become acquainted with various cultural, biochemical and molecular techniques used in understanding microbial diversity.
CO3. Will be knowledgeable about the diversity, adaptations and biotechnological applications of microbes of extreme environment.
CO4. Will be able to describe the role of soil microbes in nutrient transformation, plant-microbe interactions and biotechnology. Also knows about potability of water and its quality control.
CO5. Understands the role of microbes in management of waste plant biomass and can apply knowledge in designing microbe-based processes for pulp, textile, biofuel and animal feed production industries.
CO6. Is able to describe the role of microbes in solid and liquid waste management, gaining knowledge of various methods employed in sewage treatment and solid waste treatment.
CO7. Understands the role of microbes in bioremediation of environmental pollutants like petroleum hydrocarbons, pesticides, plastic and electronic waste; also understands utility of microbes in mineral and oil recovery.

Contents:

Unit I: Development in field of environmental microbiology: Development of microbial ecology and emergence of field of environmental microbiology, significant applications of microbes in solving environmental pollution problems **6**

Unit II: Culture-dependent and culture-independent approaches for understanding microbial diversity in the environment: Understanding microbial diversity in the environment by culture-dependent and culture-independent approaches, Analysis by FAME, measuring metabolic capabilities using BIOLOG, G+C analysis, slot-blot hybridization of community DNA, and fluorescent *in situ* hybridization of intact cells, metagenomic analysis of solid and aquatic sediments **10**

Unit III: Microbial diversity in extreme environments: Occurrence, diversity, adaptations and potential applications of oligotrophs, thermophiles, psychrophiles, organic solvent and radiation tolerants, metallophiles, acidophiles, alkaliphiles and halophiles. Biotechnological applications of

the same **6**

Unit IV: Soil and water microbiology: Importance of soil microorganisms, nutrient transformation processes, plant-microbe symbiosis, microbial antagonism, biofilms and their biotechnological applications, drinking water microbiology and quality control. **8**

Unit V: Biomass waste management of plant's residues: Lignocellulolytic microorganisms, enzymes and their biotechnological applications in: (i) biopulping, (ii) biobleaching, (iii) textiles (iv) biofuels, (v) animal feed production. **4**

Unit VI: Liquid and solid waste management: Treatment of sewage (primary, secondary and tertiary treatments), treatment of industrial effluents (distillery, textile, pulp and paper), methods to detect various pollutants (metals, sediments, toxin and organic matters). Solid waste types, composting, landfill development, incineration methods, composting and sustainable agriculture, biogas production, plastic degrading microorganisms as a tool for bioremediation, challenges in waste management. **12**

Unit VII: Bioremediation of environmental pollutants: Petroleum hydrocarbons and pesticides, use of biosensors for their detection. Microbial enhanced oil recovery, bioleaching of copper, gold and uranium, electronic waste management. **14**

Suggested Readings:

1. Microbial Ecology by R.M. Atlas, R. Bartha. 3rd edition. Benjamin Cummings Publishing Co, USA. 1993.

2. Environmental Microbiology by A.H. Varnam, M.G. Evans. Manson Publishing Ltd. 2000.

3. Manual of Environmental Microbiology edited by C.J. Hurst, R.L. Crawford, J.L. Garland, D.A. Lipson, A. L. Mills, L.D. Stetzenbach. 3rd edition. Blackwell Publishing. 2007.

4. Environmental Microbiology edited by R. Mitchell, J-D Gu. 2nd edition. Wiley-Blackwell. 2009.

5. Environmental Microbiology by R. Maier, I. Pepper, C. Gerba. 2nd edition. Academic Press. 2009.

6. Environmental Microbiology: Principles and Applications by P.K. Jjemba, Science Publishing Inc. 2004.

7. Lignocellulose Biotechnology: Future Prospects by R.C. Kuhad, A. Singh. I.K. International. 2007.

8. Environmental Microbiology of Aquatic & Waste systems by N. Okafor. 1stedition, Springer, New York. 2011.

Facilitating the achievement of Course Learning Outcomes

Unit no.	Course Learning Outcomes	Teaching and learning Activity	Assessment Tasks
I	Gets an overview of the till date developments in the field of environmental microbiology.	Discussion on applications of microbes in solving environmental pollution problems.	Quiz on naming the scientists associated with contributions in the field of environmental microbiology.
II	Gets acquainted with various cultural, biochemical and molecular techniques used in understanding microbial diversity.	Lecture on microbial diversity in the environment by discussing culture-dependent and culture-independent approaches. Familiarizing students with various techniques used in analysis of microbial diversity in environment Explaining metagenomic analysis of solid and aquatic sediments.	Student discussions on various culture-dependent and culture-independent approaches of understanding microbial diversity
III	Gets thorough with diversity, adaptations and biotechnological applications of microbes of extreme environment.	Detailed discussion on occurrence, diversity and adaptations of oligotrophs, thermophiles and psychrophiles. Presentation on acidophiles, metallophiles, organic solvent and radiation tolerant microbes, alkaliphiles and halophiles. Discussion on various potential applications of extremophilic organisms.	Quiz on identifying the microbes associated with extremophilic environment.
IV	Can describe of role of soil microbes in nutrient transformation, plant-microbe interaction and biotechnology. Also knows about potability of water and its quality control.	Explaining to students the importance of soil microorganisms, their involvement in various nutrient transformation processes and their biotechnological applications. Detailed discussion on plant-microbe symbiosis, microbial antagonism and biofilm formation by microbes. Discussing ways of determining potability of water and its quality control.	Ten-minute MCQ quiz after lecture.
V	Understands role of microbes in management of waste plant biomass and apply the knowledge in designing microbe-based processes for pulp, textile, biofuel and animal feed production industries.	Explaining importance of lignocellulolytic microorganisms in biomass waste management of plant residue. Discussing the biotechnological applications of lignin and cellulose degrading microbes and their enzymes in bio-pulping, bio-bleaching and textile industry, and in biofuels and animal feed production.	Match the following type quiz regarding microbes in lignocellulose degradation, bio-pulping and bio-bleaching.
VI	Describe the role of microbes in solid and liquid waste management gaining knowledge of various methods employed in sewage treatment and solid waste treatment.	Lecture on sewage waste management including primary, secondary and tertiary treatments methods using visual aids. Explaining ways of treating Industrial effluents generated from various industries such as distillery, textile, pulp and paper. Familiarizing students with methods of detecting various pollutants in environment such as metals, sediments, toxins and organic matter. Explaining different types of solid wastes and methods of its management such as composting, landfills and incineration methods and discussing challenges faced during waste management. Discussing the use compost for sustainable agriculture.	Visual-based identification of different ways of liquid waste management. Group activity of designing a project from selection of microbes to application in managing and recycling different solid waste.
VII	Understands role of microbes in	Lecture on Bioremediation of pollutants like petroleum hydrocarbons and pesticides.	Quiz on matching the key microbes

	bioremediation of environmental pollutants like petroleum hydrocarbons, pesticides, plastic and electronic waste; also understands utility of microbes in mineral and oil recovery.	Familiarizing students with the use of biosensors as detection tools of environmental pollutants. Discussing plastic degrading microorganism as a tool for bioremediation. Lecture on utilization of microbes in enhanced oil recovery and mineral recovery accompanied with visual aids. Discussing the use of microbes in bioleaching of copper, gold and uranium. Familiarizing students with electronic waste management.	associated with process of bioremediation.

***Assessment tasks listed here are indicative, and may vary.**

MBCC202: INDUSTRIAL MICROBIOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The course will enable students to apply the learning of microbiology concepts toward the exploitation of microbial population for industrial and human benefits. The strategies for development of microbial strains, process optimization, large scale production and product recovery will be covered for industrially relevant microbial products and therapeutic proteins.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will have gained insight on industrially important microbes, recent developments in fermentation processes and various optimization strategies at fermenter level.
CO2: Understands the concept of sterilization methods and principles of batch and continuous processes.
CO3: Attains knowledge about designing of industrial strains and various media optimization strategies
CO4: Learns about the design, types of fermenters and various critical components of bioreactors
CO5: Is able to describe control parameters, fluid rheology and process constraints in a large scale bioreactor
CO6: Gets introduced to various strategies of product recovery from a fermentation broth
CO7: Acquires knowledge about various industrially relevant microbial products and their production process

Contents:

Unit I: Introduction to industrial microbiology: Introduction to microbial products and fermentation processes, sources of industrially important microorganisms, stoichiometric analysis of biochemical reactions, carbon and nitrogen balance, oxidation-reduction principle in fermentation, recent developments in fermentation technology. Batch cultivation, continuous cultivation, multistage chemostat, feedback systems, types of fed-batch cultures, open and closed systems, Monod kinetics of microbial growth, growth and non-growth associated product formation, product formation kinetics and mathematical modeling, bioprocess optimization strategies (exponential fed-batch, DOstat, pHstat) **12**

Unit II: Sterilization methods and principles: Media sterilization, mathematical modeling of sterilization processes, Arrhenius equation, Del factor, effect of sterilization on media quality and yield coefficients, batch and continuous sterilization, filter and steam sterilization at industrial scale **6**

Unit III: Designing of industrial Strains and media optimization: Industrially important microorganisms, preservation techniques for microbial cultures, inoculum development, microbial strain improvement, high throughput screening methods, recombinant DNA technology in strain improvement, metabolic engineering and flux analysis, media optimization strategies like Plackett–Burman design, Box-Wilson central composite design, response surface methodology. **6**

Unit IV: Design and types of fermenters: Basic components of a fermenter, fermenter construction materials, designing of laboratory and industrial scale fermenters, types of impellers, mechanical seal, types of baffle and spargers, sampler design, foam controller, types of fermenter like stirred tank, bubble column, airlift, hollow fibers chambers, packed beds, fluidized beds, perfusion cultures, photo-bioreactors and animal cell culture bioreactor. **8**

Unit V: Bioprocess instrumentation and control parameters: Measurement of various control parameters in bioreactor like pH, dissolved oxygen, temperature, antifoam, principles of feed-back control, PID control, respiratory quotient, effect of dissolved oxygen on microbial production processes, effect of foam and anti-foam on oxygen transfer, oxygen mass transfer coefficient, measurement of KLa values using sulfite oxidation techniques, gassing-out techniques, fluid rheology, newtonian and non-newtonian fluids, bingham plastic, pseudo plastic, power number, Reynolds number **6**

Unit VI: Downstream processing of microbial products: Batch filtration, centrifugation, cell disruption, liquid-liquid extraction, solvent recovery**,** supercritical fluid extraction, various chromatography techniques in product recovery, diafiltration, ultra-filtration and reverse osmosis, drying (lyophilization and spray drying), whole broth processing and crystallization. **8**

Unit VII: Applications of industrial microbiology-production aspects: Development of heterologous expression platforms like bacteria, yeast, mammalian and insect cells, process optimization of recombinant biopharmaceuticals; industrial enzymes (cellulases, laccase, amylases, biosurfactants, thaumatin, food additives etc.), therapeutic proteins (haemostasis factors, thrombolytic agents, hormones and recombinant vaccines), antibodies (chimaeric and humanized antibodies, antibody fragments), microbial transformation process, cell surface display technology, development of biosimilars, good manufacturing practices, intellectual property rights and technology transfer, different phases of clinical trials of therapeutic biomolecules. Basic objective for successful economically viable fermentation process, cost breakdown for well-established fermentation processes, market potential of the products, cost aspects of various stages inthe processes development including effluent treatment **14**

Suggested Readings:

1. Principles of Fermentation Technology by P. Stanbury, A. Whitaker, S. Hall. 3rd edition. Butterworth-Heinemann. 2016.

2. Bioprocess Engineering: Basic Concepts by M. L. Shuler, F. Kargi, 2nd edition. Pearson Education India. 2015.

3. Modern Industrial Microbiology & Biotechnology by N. Okafor. 1st edition. CRC Press, USA. 2007.

4. Fermentation Microbiology and Biotechnology edited by E.M.T. El-Mansi, C.F. Bryce, A.L. Demain, A.R. Allman. 3rd edition. CRC Press. 2012.

5. Microbial Biotechnology: Fundamentals of Applied Microbiology by A.N. Glazer, H. Nikaido. 2nd edition. Cambridge University Press. 2007.

6. Pharmaceutical Biotechnology: Concepts and Applications by G. Walsh. John Wiley & Sons Ltd. 2007.

7. Pharmaceutical Biotechnology: Fundamentals and Applications by J.A.D. Crommelin, R. D. Sindelar, B. Meibohm. 4th Edition. Springer. 2013.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Task
I	Gains insight on industrially important microbes, recent development in fermentation processes and various optimization strategies at fermenter level.	Students are introduced to microbial products and industrially important microorganisms, where they learn about stoichiometric analysis, various fermentation processes such as batch, fed-batch and continuous fermentation strategies	Students are taken to fermentation facility and are asked to describe various fermenter parts, control instruments and their use in production of various microbial products
II	Understands the concept of sterilization methods and principles of batch and continuous processes.	The mathematical modelling of sterilization processes is taught with learning of different types of filters used at industrial scale.	Students are evaluated by giving them numerical problems to calculate del factor of sterilization
III	Attains knowledge about designing of industrial strains and various media optimization strategies	In class room students learn about the role of metabolic engineering recombinant DNA technology and media design strategies to produced hyper producer strains.	Students are asked to prepare report on various microbial products of commercial use.
IV	Learns about the design, types of fermenters and various critical components of bioreactors	In fermentation facility students are taught to assemble various bioreactor components and the optimization strategies are discussed	Students are assessed on the knowledge what they have obtained on fermenters through reactors assembling
V	Is able to describe control parameters, fluid rheology and process constrains in a large scale bioreactor	Learn about the role of medium in process optimization and how its fluidic impact the process design	Term paper on process design describing practical constrains in large scale processes.
VI	Gets introduced to various strategies of product recovery from a fermentation broth	Demonstration of various processes of product recovery and chromatography techniques	Multiple choice class test and hands on practical assignment on product purification
VII	Acquires knowledge about various industrial relevant microbial products and their production process	Students learn about top ten microbial products, their production strategies, FDA approval and market cost and are also taught how the process cost can be reduced further by applying the knowledge of industrial microbiology from this course	Power point presentations and group discussion on industrially relevant products

***Assessment tasks listed here are indicative, and may vary.**

MBCC203: MICROBIAL PATHOGENICITY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The objective of this course is to make the students understand various attributes which make the microbes pathogenic or disease-causing, the emergence of newer pathogens with relevance to India and the various tools for their local or global spread. The students would also learn the mechanisms of resistance of bacteria to antibiotics and role of newer vaccines in controlling infectious diseases. The course would also enable students to describe the molecular diagnostic methods and automated equipment which may be used for diagnosis of diseases caused by microorganisms.

Course Learning Outcomes:

Upon successful completion of the course, the student will be able:

CO1: To understand classical and molecular determinants of disease-causing microbes
CO2: To describe the characteristics of newer disease-causing bacteria and viruses
CO3: To study and critique the various molecular tools available to work on the molecular epidemiology of disease-causing microorganisms
CO4: To study and evaluate mechanisms underlying resistance of bacteria to antibiotics, spread of resistance and the use of newer vaccines to control infectious diseases
CO5: To gather information as to how the infectious diseases may be diagnosed using newer diagnostic tools and what automated equipment are available for use in diagnostic microbiology laboratories.

Contents:

Unit I: Classical view of microbial pathogenicity: Define pathogenicity and virulence; Quantitative measures of pathogenicity: minimal lethal dose (MLD), LD_{50}, $ID_{50,}$ $TCID_{50.}$ Virulence determinants: colonization, toxins, enzymes and invasiveness. Facultative/ obligate intracellular pathogens. **8**

Unit II: Molecular microbial pathogenicity: Molecular Koch's postulates, multiplicity of virulence determinants, coordinated regulation of virulence genes, and environmental regulation of virulence determinants by two component signal transudation systems, antigenic variation; clonal and panmictic nature of microbial pathogens, type three secretion system (TTSS, T3SS), Role of biofilms and quorum sensing in microbial pathogenicity. **10**

Unit III: Emerging and re-emerging pathogens: Illustrate emerging and re-emerging pathogens using *V. cholerae* 0139, X-MDR *M. tuberculosis, Helicobacter pylori,* Enterohaemorrhagic *E. coli* (EHEC), *Cryptosoridium parvum*, Bird/swine flu, AIDS and dengue hemorrhagic fever, opportunistic fungal pathogens. Mechanisms of emergence of new pathogens: horizontal gene transfer (HGT) and pathogenicity islands (PAI). **10**

Unit IV: Molecular microbial epidemiology: Objectives of microbial epidemiology. Biochemical and Immunological tools - biotyping, serotyping, phage typing, multilocus enzyme electrophoresis (MLEE); Molecular typing: RAPD, rep (REP, ERIC, BOX)-PCR, IS based typing,

PFGE, AFLP, MLST, VNTR and whole genome sequence, use of geographical information system (GIS) for microbial epidemiology. **8**

Unit V: Environmental change and infectious diseases: Global warming-led increase in vector-borne and water-borne infectious diseases; Impact of increasing urbanization, international travel and trade on infectious diseases. **4**

Unit VI: Antimicrobial resistance (AMR): Recent concepts – multidrug efflux pumps, extended spectrum β-lactamases (ESBL), X-MDR *M. tuberculosis*, methacillin-resistant *S. aureus* (MRSA), role of integrons. Recombinant vaccines, subunit vaccines, DNA vaccines, Vaccinia-BCG- and HIV– vector based vaccines. **10**

Unit VII: Rapid diagnostic principles: Nucleic acid probes in diagnostic microbiology, nucleic acid amplification methods, real-time PCR, lateral flow assays, diagnostic sequencing and mutation detection, automated instruments for detection / diagnosis of infectious agents (BACTAC and Vitek-2, GeneXpert). **10**

Suggested Readings:

1. Jawetz, Melnick, &Adelberg's Medical Microbiology by Carroll KC, Hobdon JA, Miller S, Morse SA, Mietzner TA. 27th edition. Lange Publication, 2016.

2. Beginner's guide to comparative genome analysis using next generation sequence data by Edward DJ and Holt KE in Microbial Informatics and Experimentation, 3:2, https://doi.org/10.1186/2042-5783-3-2, 2013.

3. Bacterial Pathogenesis: A molecular approach by Wilson BA, Salyers AA, Whitt DD, Winkler ME. 3rd edition. American Society for Microbiology Press, Washington, DC USA, 2011.

4. Bacterial Pathogenesis: Molecular and Cellular Mechanisms by Locht C, Simonet M, Caister Academic Press, 2012.

5. Molecular Microbiology: Diagnostic Principles and Practice by Persing DH, Tenover FC, Hayden R, Leven M, Miller MB, Nolte FS, Tang YW, Belkum AAV. 3rd edition. Washington, American Society for Microbiology Press, 2016

6. Infectious Disease Epidemiology: Theory and Practice by Nelson KE, Williams CM. 4th edition. Jones and Bartlett, 2019.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	To understand classical and molecular determinants of disease-causing microbes	The students are taught about toxins, colonization factors and invasiveness, and their role in imparting pathogenic potential to	The students are assessed by participatory and interactive discussions on the topics which were taught and are asked several questions to see whether they have been able to

		bacteria including the coordinated regulation of expression of virulence determinants.	assimilate the facts described to them.
2.	To describe the characteristics of newer disease-causing bacteria and viruses	Teaching the students particular characteristics which make an organism qualify as newly emerging pathogen. This is illustrated by selecting India-centric examples.	In the backdrop of the knowledge give to students on newer and emerging pathogens, they are given several questions which they are required to answer in the next class. To assess whether they have studied anything additional besides the one taught in class, the students are asked to give comments, opinions, additional information on the topics under discussion
3.	Study and critique the various molecular tools available to work on the molecular epidemiology of disease-causing microorganisms	The students study and evaluate a battery of tools namely serotyping, biotyping, phage typing, MLEE, PFGE, AFLP, MLST and whole genome sequences for the local and global spread of pathogens	The learning of the students is evaluated by asking them to identify the tool which may be specifically used to solve an outbreak of infection in a hospital, in a community, in a country or globally
4.	Study and evaluate mechanisms underlying resistance of bacteria to antibiotics, spread of resistance and the use of newer vaccines to control infectious diseases.	Students are taught to identify the reasons responsible for resistance to antibiotics namely β-lactamases, ESBL, Efflux mechanisms; role of integrons in the spread of resistance; the use of recombinant, subunit and DNA Vaccines to control the infectious diseases	The learning of the students is assessed by asking them to relate their knowledge and understanding of antibiotic resistance and spread to their experiences during visits to hospitals, crowded public places and the implications thereof. Their learning on vaccines is juxtaposed to their day-to-day exposure to vaccinations programmes being advertised in the country to assess their understanding during the study.
5.	To gather information as to how the infectious diseases may be diagnosed using newer diagnostic tools and what automated equipment are available for use in diagnostic microbiology laboratories.	The students get information about the use of nucleic acid methods for diagnosis of infectious diseases. The also gather details on instruments like BACTAC, Vitek-2 and GeneXpert for automated/semi- automated detection of infectious agents in clinical microbiology laboratories.	The learning of the students about diagnostic tests and automatic equipment for diagnosis is assessed by asking them to comment on the requirements of the rapidity for which the infectious diseases need to diagnosed *vis-à-vis* what is actually available in the market / hospitals and how this could be improved Learning assessment by assignment written by the student.

***Assessment tasks listed here are indicative, and may vary.**

MBCC204: Practical II

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The objective of the course is to familiarize students with techniques involved in studying soil and water microbiology, industrial microbiology and microbial pathogenesis. The student will receive hands-on training in various culturing and molecular techniques for studying microbial diversity and microbial activity in soil. He/she will be acquainted with a variety of water testing methods, and get practical training in yeast recombinant system, submerged and solid state batch fermentations. They will gain expertise in differentiating pathogens based on cultural methods and their MIC determination.

Course Learning Outcomes:

The student:

CO1. Is able to determine the basic properties (pH, water holding capacity, moisture content and organic matter content) of the given soil sample
CO2. Is able to measure the microbial activity in the soil by measuring the CO2 evolution, dehydrogenase activity, hydrolysis of FDA and nitrate reduction.
CO3. Can isolate metagenomic DNA from soil and perform denaturing gradient gel electrophoresis (DGGE).
CO4. Can perform total plate count with soil samples, calculate the ratio of proteolytic and amylolytic bacteria, isolate fungi present in soil samples and calculate their relative abundance and frequency of occurrence.
CO5. Can test the microbiological quality of water samples from different sources.
CO6. Knows how to enzymatically decolorize distillery or textile industrial waste.
CO7. Can perform plasmid isolation from *E. coli* cells and can perform restriction digestion and transformation of the plasmid
CO8. Is able to transform *Pichia pastoris* competent cells using electroporation technique.
CO9. Is able to overexpress green fluorescent protein (GFP) in *Pichia pastoris* host system and carry out purification of GFP protein from *P. pastoris* lysis by nickel-NTA affinity chromatography.
CO10. Is able to set up fermentation process (batch fermentation) for the production of Protein X and is able to concentrate and purify the given protein sample using column chromatography and analyse it by SDS PAGE.
CO11. Can set up SSF and SMF for the enzymes cellulase and xylanase using the fungal isolates and estimate the enzyme activities.
CO12. Knows how to produce lignocellulolytic enzymes (cellulases, hemi-cellulases and lignin degrading enzymes such as Lip, Mnp and Laccase.
CO13. Is aware of the usage of cellulases in saacharification of cellulosic material
CO14. Can grow yeast (*S. cerevisiae*) and fungus (*Rhizopus* sp.) in artificial medium and calculate the yield and productivity of the biomass produced.
CO15. Can identify pathogenic bacteria on selective/differential media:
CO16. Can carry out the coagulase test for pathogenicity of *Staphylococcus aureus*
CO17. Is able to perform the rapid (P/A format) coliform test.

CO18. Can determine the antimicrobial susceptibility testing using an octadisc and minimal inhibitory concentration (MIC) of an antibiotic using an E-test.

CO19. Is able to perform sterility testing of a sample and is acquainted with the resident microflora of skin and oral cavity.

CO20. Is able to identify selected pathogenic fungi viz. *Microsporum* sp.,*Candida albicans*, and *Aspergillus* sp. based on their cultural and microscopic characteristics.

Contents:

1. To determine the microbial activity in the soil by measuring the CO2 evolution and study the effect of moisture and organic matter on microbial activity.
2. To determine the dehydrogenase activity in soil by microorganisms.
3. To determine the nitrate reduction in soil by microorganisms.
4. To isolate metagenome from the given soil samples and to study its diversity using Denaturing gradient gel electrophoresis (DGGE).
5. To study the basic properties (pH, water holding capacity, moisture content and organic matter content) of the given soil sample.
6. To determine the microbial activity of soil by estimating the hydrolysis of FDA.
7. To perform total plate count with soil samples and calculate the ratio of proteolytic and amylolytic bacteria.
8. To study the microbiological quality of water samples from different sources.
9. To determine the BOD of sewage water
10. To study the decolorization of distillery or textile industrial waste.
11. To isolate the plasmid pGAPZA (containing GFP gene) from DH5ά E. coli cells.
12. To perform restriction digestion with AvrII of the plasmid, pGAPZA (with GFP).
13. To carry out transformation in *Pichia pastoris* competent cells using electroporation technique.
14. To perform overexpression studies of green fluorescent protein (GFP) in *Pichia pastoris* host system.
15. Purification of GFP protein from *P. pastoris* lysis by nickel- NTA affinity chromatography.
16. To set up fermentation process (batch fermentation) for the production of Protein X.
17. To concentrate and purify the given protein sample using column chromatography and analyze by SDS-PAGE
18. To set up SSF and SMF for the enzymes cellulase and xylanase using the fungal isolates and estimate the enzyme activities.
19. To study the production of lignocellulolytic enzymes (cellulases, hemicellulases and lignin degrading enzymes such as Lip, Mnp and Laccase.
20. To study the use of cellulases in saccharification of cellulosic material
21. To grow yeast (*S. cerevisiae*) and fungus (*Rhizopus* sp.) in artificial medium and to calculate the yield and productivity of the biomass produced.
22. To study cultural characteristics of pathogenic bacteria on following selective/differential media:
23. TCBS agar; Hektoen Enteric agar; XLD agar; Endo agar; Salmonella-Shigella agar; Deoxycholate citrate agar
24. To study pathogenicity of *Staphylococcus aureus* by coagulase test
25. To perform the rapid (P/A format) coliform test.
26. To study antimicrobial susceptibility testing using an octadisc.
27. To determine minimal inhibitory concentration (MIC) of an antibiotic using an E-test.

28. To perform sterility testing of a sample.
29. To study resident microflora of skin.
30. To study resident microflora of oral cavity.

Suggested Readings:

1. Microbiology: A laboratory manual by JG Cappucino, N Sherman. 10th edition. Pearson. 2014.

2. Environmental Microbiology: A lab manual by I. Pepper, C. Gerba, J. Brendecke. 46th edition. Academic Press. 2011.

MBEC201: BIOPHYSICAL AND BIOCHEMICAL METHODS

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

To introduce the student to the variety of biophysical and biochemical techniques currently available to probe the structure and function of the biological macromolecules, make them aware of the physical principles behind each technique and the instrumentation involved, make them familiar with various methods of analyzing the output data, and to build a strong foundation in the area of bacterial cell structure, division, survival and propagation.

Course Learning Outcomes:

Upon successful completion of the course, the student will:

CO1: Be able to carry out the analysis of the data from CD and Fluorescence experiments to monitor the stability of the protein under different environmental conditions
CO2: Be familiar with the output of fluorescence and confocal microscopy
CO3: Be able to evaluate the quality and highlights of the structure reported/deposited in journals/structural databases.
CO4: Be able to design a multi-step purification protocol for a target protein
CO5: Be able to understand and correctly interpret the migration of protein molecule on PAGE under native and SDS conditions
CO6: Follow the safety precautions while using radioactive methods

Contents:

Unit I: Spectroscopy: Various theories exploring the concept of light: Corpuscular theory, Wave theory, Electromagnetic theory, Planck's concept and modern theory. Basic concepts, principles and biological applications of different types of spectroscopy: absorption spectroscopy, fluorescence spectroscopy, phosphorescence, Infrared and Raman spectroscopy, Optical Rotatory Dispersion (ORD), Circular Dichroism (CD). **12**

Unit II: Microscopy: Basics of microscopy: image formation, magnification, resolution, Biological applications and instrumentation of various kinds of microscopy: Optical Microscopy, Fluorescence, Confocal and Electron Microscopy. **8**

Unit III: Macromolecular structure determination: Basics of X-ray Crystallography: symmetry, space groups, unit cells, structure factors, reciprocal lattice, Fourier transform, electron density, phase problems and it's solutions, Biological applications and interpretations. Basics of Magnetic resonance spectroscopy: chemical shifts, resonance condition, relaxation studies, coupling and decoupling, biological application and interpretations of Nuclear Magnetic Resonance (NMR) & Electron Spin Resonance (ESR). **14**

Unit IV: Separation Techniques I (Chromatography): Basics principles and applications of various chromatography methods: Partition and Absorption chromatography, gel filtration, ion-exchange and affinity chromatography. Biological applications of HPLC and FPLC. **10**

Unit V: Separation techniques II (Hydrodynamic methods): Basics of centrifugation based methods: viscosity, diffusion, sedimentation equilibrium, dialysis, solvent fractionation, centrifugation, Biological applications and interpretations of Density Gradient methods, Ultracentrifugation methods. Basics of electrophoresis: electrophoretic mobility and affecting factors, Biological applications and interpretation of different types of electrophoresis: PAGE, gradient gel, Agarose Gel Electrophoresis, 2D Electrophoresis, Dialectrophoresis, iso-electric focusing. **12**

Unit VI: Radioactive methods: Basics of radioactive isotopes and radioactive decay, sample preparation, counting, Safety precautions during handling, biological applications. **4**

Suggested Readings:

1. Fundamentals of Molecular Spectroscopy by Colin Banwell. 4th edition. McGraw Hill.1994.
2. Principles of Fluorescence Spectroscopy by J. Lakowicz, R. Joseph. 2nd edition. Springer.1999.
3. Molecular Fluorescence: principles and Applications by B. Valeur. 2nd edition. Wiley. 2013.
4. NMR – Conformation of Biological Molecules by G. Govil, R.V. Hosur. 1st edition. Springer- Verlag, 2011.
5. Biomolecular crystallography: Principles, practice and application to structural biology by B. Rupp. 1st edition. Garland Science. 2009.
6. Optical methods in Biology by E.M. Slayter. 1st edition. John Wiley. 1970.
7. NMR of proteins and nucleic Acids by K. Wuthrich. 1st edition. Wiley Interscience Publications. 1988.
8. Biophysical chemistry, Part 2: Techniques by C. R. Cantor, P. R. Schimmel. 1st edition. W.H Freeman and Co. 2008.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I.	Should be able to analyze the data from CD and Fluorescence experiments to monitor the stability of the protein under different environmental conditions	Detailed discussion on origin of CD/ Fluorescence signals in proteins. Fitting of raw data to the generate graphs using the available software.	Group discussion on interpreting data presented in selected research papers where CD /Fluorescence techniques have been used
II.	Be familiar with the output of fluorescence and confocal microscopy	Having classroom discussions about fluorescence and confocal microscopy, along with videos explaining the collection of data with examples	Group discussion on research papers using the fluorescence & confocal methods
III.	Evaluate the quality and	Make students conversant with the	Short student presentation

	highlights of the structure reported/deposited in journals/structural databases.	pitfalls in interpreting or understanding structural model generated through X-ray crystallography and NMR. Provide knowledge about criteria to judge a good structure.	discussing structural features of any macromolecule from a research paper or a PDB entry
IV.	Can design a multi-step purification protocol for a target protein	Familiarizing students with the commonly used chromatographic matrices which separate proteins based on size, affinity tag and pI.	Ten-minute MCQ quiz after lecture.
V.	Can understand and correctly interpret the migration of protein molecule on PAGE under native and SDS conditions	Discussion about the types of electrophoretic methods available for separation of biomolecules with emphasis on differences between the methods.	Match the following type quiz
VI.	Follow the safety precautions while using radioactive methods	Providing students with the knowledge about precautions to be used while using radioactivity based methods. Making students aware of use of alternate methods, other than radioactivity to gain similar insights into a system.	Ten-minute MCQ quiz after lecture about radioactive decay and safety precautions.

***Assessment tasks listed here are indicative, and may vary.**

MBEC202: PLANT-PATHOGEN INTERACTIONS

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The course will facilitate in understanding of how pathogens interact with various plants and effect plant physiology, photosynthesis, respiration, transpiration and translocation. The involvement of various enzymes and toxins and understanding the molecular interaction will help in designing biocontrol strategies and development of transgenic plants. The course covers the novel molecular diagnostic approaches and correct forecasting of plant diseases.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will have acquired knowledge about cause of plant diseases and effect of microbial infections on plant physiology, photosynthesis, respiration, transpiration, translocation

CO2: Will have learnt about various enzymes and toxins in plant diseases and also role of phytoalexins

CO3: Understands about crown gall, symptoms of viral diseases and their control, diseases of some important cereals, vegetables and crops

CO4: Will have gained insight into genetics of host-pathogen interactions, resistance genes, resistance mechanism in plants.

CO5: Will have been introduced to plant disease control, physical, chemical and biological methods of disease control

CO6: Will have attained knowledge about designing of molecular diagnosis of plant disease and development of transgenic plants with applications and constraints.

CO7: Is able to describe various important milestones in disease control and disease forecasting relevant in Indian farming.

Contents:

Unit I: Concepts and physiology of plant diseases: Causes of disease, pathogenesis, pathogenesis in relation to environment, effect of microbial infections on plant physiology, photosynthesis, respiration, transpiration, translocation. **10**

Unit II: Biochemical basis of plant diseases: Enzymes and toxins in plant diseases, phytoalexins. **8**

Unit III: Some important plant diseases and their etiological studies: Crown gall, symptoms of viral diseases and their control, diseases of some important cereals, vegetables and crops. **10**

Unit IV: Genetic basis of plant diseases: Genetics of host-pathogen interactions, resistance genes, resistance mechanisms in plants. **6**

Unit V: Disease control: Principles of plant disease control, physical and chemical methods of disease control, biocontrol, biocontrol agents - concepts and practices, fungal agents, *Trichoderma* as biocontrol agent, biocontrol agents – uses and practical constraints. **10**

Unit VI: Molecular approach: Molecular diagnosis, transgenic approach for plant protection, futuristic vision of molecular diagnosis, applications and constraints. **8**

Unit VII: Disease forecasting: History and important milestones in disease control, disease forecasting and its relevance in Indian farming. **8**

Suggested Readings:

1. Plant Pathology by G. N. Agrios. 5th edition. Academic Press. 2005

2. Plant Pathology by R.S. Mehrotra, and A. Aggarwal, 3rd edition. Tata McGraw Hill. 2017

3. Bacterial plant pathology: cell and molecular aspects by D. C. Sigee. Cambridge University Press.1993.

4. Molecular plant pathology by M. Dickinson. BIOS Scientific Publishers, London. 2003.

5. The essentials of Viruses, Vectors and Plant diseases by A.N. Basu& B.K. Giri. Wiley Eastern Limited.1993.

6. Biocontrol of Plant Diseases (Vol. I) by K.G. Mukerji and K.L.Garg. CRC Press Inc.,USA.1988.

7. Molecular Biology of Filamentous Fungi by U. Stahl and P. Tudzyski. VCH VerlagsgesellschaftmbH. 1992.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Task
I	Acquires knowledge about cause of plant diseases and effect of microbial infections on plant physiology, photosynthesis, respiration, transpiration, translocation	Learn about effects of plants pathogenesis on their physiology, photosynthesis, respiration, transpiration, and translocation.	Students are asked to collect samples from infected plants and prepare a detailed report of observations and learning
II	Learns about various enzymes and toxins in plant diseases and also role of phytoalexins	Students are introduced to the concept of enzymes and toxins involvement in establishing plant infection followed by a discussion on defense mechanism of plants	Quiz and Written test
III	Understands about crown gall, symptoms of viral diseases and their control, diseases of some important cereals, vegetables and crops	Learn about viral infection of cereals, vegetables, crops followed by concept of crown gall disease and discussion on some emerging epidemics	Seminar/presentation and students are asked to deliberate on some common plant disease in India
IV	Gains insight on genetics of host-pathogen interactions, resistance genes, resistance mechanism in plants.	Students are taught about various genes of plant and pathogen origin in establishment of plant infection followed by an elaborate discussion of use of these genes in development	Written test and student seminar

		of transgenic crops.	
V	Gets introduced to plant disease control, physical, chemical and biological methods of disease control	Students learn about various methods to control plant disease and role of various biocontrol agents in crop protection	Students are asked to give a written assignment on how to use R and avr genes in transgenic plant development
VI	Attains knowledge about designing of molecular diagnosis of plant disease and development of transgenic plants with applications and constraints.	Learn about sample preparation from infected plants and how to use conventional and molecular diagnostic technology to identify pathogen load. The concept and technologies of developing transgenic plants are also deliberated.	A group discussion on pros and cons of genetically modified crops is conduct to evaluate their understand about current status of various GMO's worldwide
VII	Is able to describe various important milestones in disease control and disease forecasting relevant in Indian farming.	Students are introduced to the concepts of developing various computer based forecasting programme to predict disease conditions and epidemics followed by a discussion on their relevance to Indian farmers	Preparation of a status report on disease forecasting programs suitable for India and possible modification under Indian weather conditions

***Assessment tasks listed here are indicative, and may vary.**

MBOE201: MICROBIAL BIOTECHNOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The course will help students to understand various applications of microbes for the development of various products of agriculture, industrial and clinical application. The knowledge of recombinant technology, bioreactors and optimization strategies will be beneficial in development of production processes.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will learn about various industrially relevant microbial products and their production process, role of biotechnology in environment management
CO2: Acquires knowledge about strains development, selection of hyper producers, microbial products, metabolic engineering and various industrial relevant microbial products and their production process
CO3: Learns about the designing of recombinant heterologous expression systems such as *E. coli*, yeast, mammalian and insect cells.
CO4: Learns about sterilization at reactor scale and different types of sterilization strategies
CO5: Attains knowledge about designing large scale industrial processes and types of cultivation strategies
CO6: Understands the concept of recombinant biomolecules, therapeutic proteins, vaccines**,** antibodies, bio-pesticides, bio-fertilizers, and probiotics
CO7: Understands different types of regulatory approvals required for drug development and difference between biologics, biosimilars and biobetters

Contents:

Unit I: Introduction to microbial biotechnology: Biotechnology and its applications in microbial processes. role of microbial biotechnology in environment management **6**

Unit II Improvement of Microbial strains: Strains development, selection of hyper producers, microbial products, metabolic engineering in development of industrial products **8**

Unit III: Recombinant gene expression platforms: Development of recombinant heterologous expression systems e.g. *E. coli*, yeast, mammalian and insect cells. Plant cells as bio-factories. Control parameters in stability of these expression platforms at industrial scale. **8**

Unit IV: Designing large scale industrial processes: Application of bioprocess engineering in microbial product development, batch fermentation, fed-batch fermentation, type of bioreactors, designs and control parameters in a fermenter, high cell density cultivation strategies, continuous cultivation processes, measurement of growth and product formation kinetics, limiting parameters in large scale process development, oxygen mass transfer coefficient. **12**

Unit V Sterilization: Different types of sterilization strategies, sterilization of large scale bioreactors, calculation of heating, holding and cooling time **8**

Unit VI: Development of microbial products: Fermented milk products, probiotics, malt beverages, wines, distilled liquors, recombinant biomolecules and therapeutic proteins, vaccines production**,** DNA based vaccines, antibody production, therapeutic enzymes, industrially important enzymes and green fuel production, Development of bio-pesticides and bio-fertilizers **10**

Unit VII Regulatory approvals and clinical trials: *Good laboratory practice (GLP),* Current Good Manufacturing Practice (CGMP), different phases of clinical trials, difference between biologics, biosimilar and bio-better, development of biosimilars and generic biomolecules, analysis of process economics **8**

Suggested Readings:

1. Principles of Fermentation Technology by P. Stanbury, A. Whitaker, S. Hall. 3rd edition. Butterworth-Heinemann. 2016.

2. Modern Industrial Microbiology & Biotechnology by N. Okafor. 1st edition. CRC Press, USA. 2007.

3. Microbial Biotechnology: Fundamentals of Applied Microbiology by A.N. Glazer and H. Nikaido. 2nd edition. Cambridge University Press. 2007.

4. Pharmaceutical Biotechnology: Concepts and Applications by G. Walsh. John Wiley & Sons Ltd. 2007.

5. Pharmaceutical Biotechnology: Fundamentals and Applications by J.A.D. Crommelin, R. D. Sindelar, and B. Meibohm. 4thEdition. Springer. 2013.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Task
I	Will learn about various industrially relevant microbial products and their production process, role of biotechnology in environment management	Students are taught about the role of microbiology and biotechnology in the development of various industrially important products	Multiple choice question test and group discussion
II	Acquires knowledge about strains development, selection of hyper producers, microbial products, metabolic engineering and various industrial relevant microbial products and their production process	Learn about strains development through recombinant DNA technology to improve the production of various microbial products	Written test and quiz on various microbial products and their production strategies
III	Learns about the designing of recombinant heterologous expression	Students are taught about the development of different	Term paper on benefits of various model expression

	systems such as *E. coli*, yeast, mammalian and insect cells.	expression platforms for recombinant therapeutic proteins and microbial enzymes	hosts and practical constrains
IV	Learns about sterilization at reactor scale and different types of sterilization strategies	The process of fermentor sterilization is demonstrated in the fermentation laboratory	Quiz about sterilization process and quantification of microbial load in the process
V	Attains knowledge about designing large scale industrial processes and types of cultivation strategies	Students gain knowledge about running large scale fermentation processes and type of cultivation strategies	Multiple choice question test and group discussion
VI	Understands the concept of recombinant biomolecules, therapeutic proteins, vaccines**,** antibodies, bio-pesticides, bio-fertilizers, and probiotics	Learn about the production of various microbial products such as therapeutic protein and other commercially important biomolecules for agriculture and human benefits	Assignment on important microbial products currently in use and market cost.
VII	Understands different types of regulatory approvals required for drug development and difference between biologics, biosimilars and biobetters	Learn about various regulatory approval procedures of FDA and EMA, development of generic biomolecules and phases of clinical trials	Written test and class discussion about different therapeutic biomolecules available in market

***Assessment tasks listed here are indicative, and may vary.**

Semester III

MBCC301: MOLECULAR BIOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The purpose of this course is to introduce the student to the advanced concepts in molecular biology. Student will gain an understanding of molecular mechanisms of DNA replication, DNA repair, transcription, translation, and gene regulation in prokaryotic and eukaryotic organisms. The student will study the techniques and experiments used to understand these mechanisms.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Is able to describe structure of DNA and RNA, organization of eukaryotic genome
CO2: Is able to compare and contrast the mechanisms of bacterial and eukaryotic DNA replication, DNA repair, transcription
CO3: Is able to explain concepts in DNA repair mechanisms, and recombination as a molecular biology tool
CO4: Is able to explain various levels of gene regulation in both prokaryotic and eukaryotic organisms
CO5: Is able to describe post-transcriptional processes, RNA editing, RNAi and miRNA
CO6: Is able to describe translation mechanism in prokaryotes and eukaryotes, regulation of translation, and post-translational processing
CO7: Is able to describe post-translational processes

Contents:

Unit I: The nature of Genetic material: The structure of DNA and RNA; melting of DNA, superhelicity, organization of microbial genomes, organization of eukaryotic genomes, chromatin arrangement, nucleosome formation. **8**

Unit II: DNA replication: Arrangement of replicons in a genome, various modes of replication, continuous, discontinuous synthesis, various replication enzymes, replication fork and priming, leading and lagging strand, elongation, termination, specific features of replication in prokaryotes and eukaryotes, action of topoisomerases, telomere maintenance and chromatin assembly, single stranded DNA replication, relationship between DNA replication and cell cycle, and DNA copy number maintenance. **8**

Unit III: Recombination and Repair of DNA: DNA repair and recombination, DNA mismatch repair, Double Strand Break repair, recombination as a molecular biology tool, CRISPR-Cas systems for editing, regulating and targeting genomes. **8**

Unit IV: Transcription: Transcription machinery of prokaryotes, various transcription enzymes and cofactors, initiation, elongation and termination, sigma factors, transcription machinery of eukaryotes, various forms of RNA polymerase and cofactors, initiation, elongation and termination, promoters, enhancers, silencers, activators, effect of chromatin structure, regulation of transcription. **10**

Unit V: Post-transcriptional processes: RNA processing, splicing, capping and polyadenylation, rRNA and tRNA processing, RNA Editing; RNAi and miRNAs, Antisense RNA, Post-transcriptional gene regulation. **10**

Unit VI: Translation: The genetic code and protein structure, Mechanisms of translation in prokaryotes, Mechanisms of translation in eukaryotes, initiation complex, ribosomes and tRNA, factors, elongation and termination, *in vitro* translation systems, polycistronic/ monocistronic synthesis, Regulation of translation, RNA instability, inhibitors of translation, stringent response in bacteria. **10**

Unit VII: Post-translational processes: Protein modification, folding, chaperones, transportation. The Signal Hypothesis. Protein degradation. **6**

Suggested Readings:

1. Gene IX by Benjamin Lewin. Jones and Bartlett Publishers. 2007.
2. Molecular Biology by R.F. Weaver, 4thedition. McGraw Hill, USA. 2007.
3. Molecular Biology of the Gene by J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick. 6thedition. Benjamin Cummings. 2007.
4. Molecular Biology of the Cell by B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P. Walter. 5thedition. Garland Science, New York and London. 2007.
5. Biochemistry by J.M. Berg, J.L. Tymoczko, L. Stryer. 5th edition. W.H. Freeman and Company, USA. 2008.
6. Current Protocols in Molecular Biology edited by: F. M. Ausubel, R. Brent, R.E. Kingston, D. D. Moore, J. A. Smith, K. Struhl. John Wiley and Sons, Inc. 2007.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Task
I	Is able to describe structure of DNA and RNA, organization of eukaryotic genome	Learn about structure of DNA and RNA, super-helicity, organization of microbial and eukaryotic genome, chromatin arrangement, nucleosome formation	Multiple choice questions to asses knowledge of structure of DNA and RNA
II	Is able to compare and contrast the mechanisms of bacterial and eukaryotic DNA replication, DNA repair, transcription	Learn about various modes of replication, various replication enzymes, replication fork, features of DNA replication in prokaryotes and eukaryotes, chromatin assembly	Fill the blanks type questions to asses understanding of concepts related to DNA replication
III	Is able to explain concepts in DNA repair mechanisms, and recombination as a molecular biology tool	Learn about DNA mismatch repair, double stranded break repair, CRISPR-Cas systems for DNA editing	True False questions to asses knowledge regarding DNA repair mechanisms
IV	Is able to explain various levels of gene regulation in both prokaryotic and eukaryotic organisms	Learn about transcription machinery of prokaryotes, various transcription enzymes, transcription machinery in eukaryotes, various RNA polymerases, regulation of	Prepare and present presentation on relation between structure and function in polymerases

		transcription	
V	Is able to describe post-transcriptional processes, RNA editing, RNAi and miRNA	Learn about RNA processing, splicing, capping, polyadenylation, RNA editing, RNAi, miRNAs, antisense RNA, post-transcriptional gene regulation	Prepare report on DNA and RNA editing tools
VI	Is able to describe translation mechanism in prokaryotes and eukaryotes, regulation of translation, and post-translational processing	Learn about genetic code and protein structure, mechanism of translation in prokaryotes and eukaryotes, in vitro translation systems, regulation of translation, RNA instability	Match the following type quiz on translation mechanisms
VII	Is able to describe post-translational processes	Learn about various types of protein modifications, folding, chaperones, transportation, and protein degradation	Group discussion on post-transnational protein modification and cell signaling

***Assessment tasks listed here are indicative, and may vary.**

MBCC302: RECOMBINANT DNA TECHNOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The objective of this course is to make the student familiar with the currently used techniques to manipulate/ analyze DNA, RNA and proteins. The student will be made familiar with the methods used to clone genes, make and screen libraries, and the various applications of the polymerase chain reaction. The student will be taught about the methods currently used to carry out genome-wide analyses and global analyses of transcription and protein expression. The student will be made familiar with how recombinant DNA technology has been exploited in the study of biology as well as in the production of pharmaceutical products.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will be familiar with the use of various cloning vectors, and methods of DNA, RNA and protein analysis.
CO2: Will be able to describe the various applications of PCR, and know how to make and screen genomic and cDNA libraries.
CO3: Will be able to understand the methods by which DNA is sequenced and will gain insights into how entire genomes of organisms are sequenced.
CO4: Will have learnt about promoter analyses, the many uses of the reporter genes, and methods to study the transcriptome.
CO5: Will be aware of the different bacterial and eukaryotic systems available for overexpression of proteins.
CO6: Will have learnt about different methods to analyze protein-DNA and protein-protein interactions, protein engineering, and methods for proteome analyses.
CO7: Will know about the creation of plant and animal transgenics, and about animal cloning methods.

Contents:

Unit I: Basics of DNA cloning, and methods of DNA and protein analysis: Simple cloning and cloning using linkers and adaptors. Cloning into various kinds of vectors – plasmids, phages lambda and M13, phagemids, cosmids, P1 phage, PACs, BACs and YACs. Selection and screening of clones. Agarose, polyacrylamide and pulsed field gel electrophoresis of DNA. Southern and Northern Blotting. Radiolabelling probes. Isolation and purification of DNA. RFLP analysis. DNA fingerprinting and its application in forensics, in disease diagnosis and in identification of strains. Native PAGE, SDS-PAGE and two-dimensional PAGE analysis of proteins. Western Blotting analysis. **10**

Unit II: Polymerase chain reaction and construction of cDNA and genomic DNA libraries: Concept of PCR and various thermophilic enzymes used in PCR. Gradient PCR versus Touchdown PCR. Designing primers. Cloning PCR products. Long PCR, Inverse PCR, Vectorette PCR, RT-PCR, 5' and 3' RACE, Real Time PCR using SYBR Green, Scorpion primers and TaqMan probes, MOPAC, Multiplex PCR, Differential Display PCR, RAPD fingerprinting of micro-organisms, Ligation Chain Reaction, Overlap PCR, Rolling Circle

Amplification Technology. Vectors used in the construction of cDNA versus genomic DNA libraries. Steps in the construction of cDNA versus genomic DNA libraries. Screening libraries by colony hybridization and colony PCR. Screening expression libraries. Enriching for clones in cDNA libraries by positive selection and subtractive hybridization. Identifying genes in complex genomes by direct selection of cDNA and exon trapping. **10**

Unit III: Genome sequencing: DNA sequencing by Sanger's method – traditional and cycle sequencing. Physical mapping by restriction fragment fingerprinting of BAC clones and STS mapping. E-PCR. Whole genome shotgun sequencing. Clone-by-clone shotgun sequencing of genome – preparation of BAC/YAC library, selection of BACs, subclone library construction, random shotgun phase and finishing phase followed by sequence authentication. Genome annotation at the nucleotide level, protein level and process level. Comparative genome sequencing of micro-organisms to identify and categorize SNPs. Array CGH. Next Generation sequencing methods: 454 FLX Roche genome analyzer platform, Illumina Solexa genome analyzer platform, Pacific Biosciences SMRT sequence analyzer platform, Ion torrent platform, Oxford Nanopore sequencing platform **8**

Unit IV: Transcriptional analysis of gene expression and transcriptomics: Gene expression analysis by Northern Blotting, RT-PCR, EST analysis and the use of reporter genes. Enzymatic and bioluminescent reporters. Reporters used in protein localization and trafficking studies. Promoter analysis – deletion analysis and linker scanning analysis coupled to reporter assays, mapping transcriptional start sites by S1 nuclease mapping, primer extension studies or 5' RACE. Transcriptome analysis by DD-PCR and EST analysis, DNA microarrays (cDNA arrays and oligo arrays), Serial Analysis of Gene Expresion (SAGE), RNA-seq. **8**

Unit V: Overexpression of recombinant proteins: Overexpression and tagging of recombinant proteins in *E.coli,* driven by lac, T7 and Tet-regulatable promoters, Expression in *B. subtilis*. Overexpression systems in *S.cerevisiae*, *P.pastoris*, *S.pombe* and *K.lactis*. Baculovirus overexpression system. Mammalian cell overexpression system. **4**

Unit VI: Analysis of protein-DNA and protein-protein interactions, protein engineering and proteome analysis: Gel retardation assay, DNA footprinting by DNase I and chemical methods, yeast one-hybrid assay, ChIP- chip, ChIP-seq. Yeast two hybrid, three-hybrid, split hybrids and reverse hybrid. Co-immunoprecipitation, pull-down, far-western. Use of GFP and its variants in FRET analysis, use of BiFC. Phage display. Insertional and deletion mutagenesis. Site directed mutagenesis by conventional and PCR-based methods. Proteome analysis by 2D gel electrophoresis coupled to mass spectrometric analysis. Principles and used of MALDI-TOF and LC-MS platforms. PMF verses MS/MS. Protein arrays and their applications. **12**

Unit VII: Pharmaceutical products of DNA technology, transgenics and animal cloning: Human protein replacements – insulin, hGH and Factor VIII. Human therapies – TPA, interferon, antisense molecules. Vaccines – Hepatitis B, AIDS, and DNA vaccines. Creating transgenic animals and plants, animal cloning. **8**

Suggested Readings:

1. Molecular Biology by D.P. Clarke, N. Pazdernik. 2nd edition. Academic Press. 2012.

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

3. DNA Technology: The Awesome Skill by I. Edward Alcamo. Harcourt Academic Press. 2001.

4. Molecular Biology of the Gene by J. Watson, T. Baker, S. Bell, A. Gann, M. Levine, R. Losick. 7th edition. Pearson. 2014.

5. Gene Cloning and DNA Analysis: An Introduction by T.A. Brown. 7th edition. Wiley-Blackwell Publishers. 2016.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Will be familiar with the use of various cloning vectors, and methods of DNA, RNA and protein analysis.	The students will be taught about the use of plasmid and phage vectors and the use of linkers and adaptors in cloning. The student will learn about various gel electrophoresis and blotting techniques as Southern, Northern, Western.	The student will be made to design a cloning strategy and detail the steps involved, given the maps of the plasmids involved.
II	Will be able to describe the various applications of PCR, and know how to make and screen genomic and cDNA libraries.	Using whiteboard and PowerPoint slides the student will be given knowledge of the various applications of polymerase chain reaction. The analysis of gene expression by real time PCR will be detailed. The step-wise construction of DNA libraries will be explained.	The student will carry out the analysis of gene expression by real time PCR and quantify in relation to an internal control. Student will be made to calculate relative gene expression.
III	Will be able to understand the methods by which DNA is sequenced and will gain insights into how entire genomes of organisms are sequenced.	Students will be taught the concepts of primer walking. Shotgun sequencing methods for whole genome sequencing will be explained. The human genome sequencing project will be discussed. Genome annotation methods will be touched upon. Next generation sequencing methods will be discussed and critiqued.	The student will derive the sequence of a template DNA given an electropherogram of the matching complementary strand. The student will give a short presentation on the sequencing of genome of any organism of their choice, highlighting the method and the main findings following annotation.
IV	Will have learnt about promoter analyses, the use of reporter genes, and methods to study the transcriptome.	The student will be made familiar with the use of luciferase, GFP, CAT as reporters. The use of GFP as a reporter in live cell imaging will be demonstrated using fluorescence microscope. The student will be taught about microarrays, RNA-seq.	The student will be evaluated by a short class test.
V	Will be aware of the different bacterial and eukaryotic systems available for	The student will be made familiar with the most commonly used prokaryotic and eukaryotic expression systems in bacteria,	The student will have to discuss and critique the different expression systems

	overexpression of proteins.	yeast, insect and mammalian cells.	currently available in an interactive classroom session.
VI	Will have learnt about different methods to analyze protein-DNA and protein-protein interactions, protein engineering, and methods for proteome analyses.	PowerPoint slides and whiteboard will be used to explain the many methods such as EMSA, foot-printing, yeast hybrids, phage display, mass spectrometry, protein arrays.	The student will be given the data from an experiment based on any one of the techniques studied that has been published in a paper. Student will be expected to identify the technique, summarize the likely experimental plan, and analyze the data obtained.
VII	Will know about the creation of plant and animal transgenics, and about animal cloning methods.	The student will be initiated into the exciting and controversial area of transgenics and animal cloning with the help of examples of transgenics created and animals cloned.	Group activity will include students presenting case studies of transgenics that have been made.

***Assessment tasks listed here are indicative, and may vary.**

MBCC303: MICROBIAL GENETICS

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The objective of this course is to understand how microorganisms can be used as tools to understand various biological phenomena. The student will become familiar with methods of transfer of genetic material in bacteria, and will understand the biology of lytic and lysogenic phages. The student will be acquainted with the different modes of gene regulation in bacteria, and the importance of bacterial transposition and its applications.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Can discuss the importance of mutation analysis, can analyze mutations by complementation and recombination tests, and can design a strategy to create gene replacement in bacteria

CO2: Is able to explain how plasmid copy number is regulated, can differentiate between Hfrstrains and strains carrying F plasmid, and can construct a genetic map of bacterial genome using conjugation-based method

CO3: Is able to compare and contrast generalized versus specialized transduction, knows how to construct genetic linkage maps using two-factor and three factor cross, is able to discuss the basis of natural competence in bacteria.

CO4: Is able to list the events in the lytic and lysogenic phases of lambda phage life cycle and the regulatory factors and events involved.

CO5: Can list the outcomes of transposition events, can design strategies to mutagenize bacteria using transposons, can explain the construction of conditional knockouts

CO6: Can differentiate between positive and negative regulation of gene expression, inducible and repressible systems. Can describe the regulation of the lac, trp, gal,ara and tol operons.

CO7: Will have learnt about the model organisms used in biological studies.

Contents:

Unit I: Genetic analysis of bacteria: Importance and uses of mutation analysis. Inheritance in bacteria, types of mutations, spontaneous and induced mutagenesis, isolating mutants, selecting mutants, mutant enrichment. Reversions versus suppression. Complementation tests, recombination tests and gene replacements. Cloning genes by complementation. Cloning genes by marker rescue. **6**

Unit II: Gene transfer and mapping by conjugation: Basis of fertility in bacteria. Self-transmissible and mobilizable plasmids. Molecular mechanism of gene transfer by conjugation – genes and proteins involved. Regulation of gene transfer by conjugation. Hfr strains. Mapping bacterial genomes using Hfr strains. Chromosomal DNA transfer by plasmids – by integrated plasmids, by chromosome mobilization and by creation of prime factors. Transfer systems in gram positive bacteria. Ti plasmid transfer system and its application in creating transgenics. **6**

Unit III: Lytic bacteriophages and gene transfer by transduction and transformation: Lytic development cycle using phages T4 and T7 as models. Regulation of expression of genes in phage T4 and phage T7. Replication of T4 versus T7 phages. Replication and packaging of filamentous phages M13 and f1. Genetic analysis of phages – complementation and recombination tests with phages. Genetic experiments with the rII genes of phage T4. Deciphering the genetic code using rII mutants. Constructing phage genetic linkage maps using two-factor and three factor crosses. Natural transformation and competence. Molecular basis of natural transformation – DNA uptake competence systems in gram positive and gram negative bacteria. Regulation of competence in *B.subtilis*. Importance of natural transformation. Artificially induced competence. Generalized versus specialized transduction: T4, lambda phage. Mapping bacterial genes by transduction. **12**

Unit IV: Lysogenic phages: Lambda phage – gene and promoter organization. Lambda lytic cyle – regulation of gene expression – very early, early and late gene expression. Establishment and maintenance of lysogeny. Regulation of gene expression in lysogenic phase - role of cI, cII and cIII proteins. Lambda immunity region and immunity to superinfection. Events leading to induction – role of cI and cro repressors in regulating the events. Other lysogenic phages – P2 and P4. Lysogenic phages and bacterial pathogenesis. **6**

Unit V: Transposons: Discovery of transposition. Classes of bacterial transposons. Regulation of transposition activity. Effects of transposition in bacteria. Assays to analyze transposition events – suicide vectors and mating out assays. Molecular mechanisms of transposition – genetic evidence supporting the mechanisms. Conjugative transposons. Transposon mutagenesis. Cloning out genes by transposon mutagenesis. Mu transposon, Mu*d* transposons and gene fusions, mini-Mu elements and their use in *in vivo* cloning. Yeast Ty-1 transposon. Site-specific recombination: *loxP*-Cre, phase variation system in *Salmonella*. **10**

Unit VI: Gene regulation: Control of gene expression. Positive gene regulation, negative gene regulation and attenuation, using the *lac*, *gal*, *trp*, *ara*, *tol* operons. **12**

Unit VII:Model organisms used in genetic studies: Yeast (*Saccharomyces cerevisiae*), fruitfly (*Drosophila melanogaster*), nematode worm (*Caenorhabditis elegans*), mouse (*Mus musculus*), Arabidopsis (*Arabidopsis thaliana*). **8**

Suggested Readings:

1. Molecular Genetics of Bacteria by L. Snyder, J. Peters, T. Henkin, W. Champness. 4th edition. ASM Press. 2013.
2. Fundamental Bacterial Genetics by N. Trun, J. Trempy. 1st edition. Wiley-Blackwell Publishing. 2004.
3. Modern Microbial Genetics edited by U.N. Streips, R.E. Yasbin. 2nd edition. Wiley-Liss Publishers. 2002.
4. Microbial Genetics by S.R. Maloy, J.E. Cronan, Jr., D. Freifelder. 2nd edition. Jones and Bartlett Publishers. 1994.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Can discuss the importance of mutation analysis, can analyze mutations by complementation and recombination tests, and can design a strategy to create gene replacement in bacteria	The student will be explained the importance of genetic analysis using bacterial mutants with the help of specific examples. The student will learn how to use complementation and recombination to map genes as well as to clone out genes. Through group discussion the student will be made to come up with a strategy for bacterial gene knockout	The student will be asked to solve problems based on complementation test and recombination tests. The student will have to solve problems on deletion-based mapping of point mutations.
II	Is able to explain how plasmid copy number is regulated, can differentiate between Hfr strains and strains carrying F plasmid, and can construct a genetic map of bacterial genome using conjugation-based method	Using slideshow as well as a whiteboard, the students will be taught the bases of copy number control of three different classes of plasmids. The student will be taught the importance of conjugation, and the role of Hfr strains in creating genetic diversity among bacteria.	The student will have to solve problems involving the mapping of the bacterial genome based on Hfr transfers. A quiz based on different mutants will be given to assess their understanding of the different copy number control mechanisms.
III	Is able to compare and contrast generalized versus specialized transduction, knows how to construct genetic linkage maps using two factor and three factor cross, is able to discuss the basis of natural competence in bacteria.	Student will learn to distinguish between transformation mechanisms in gram positive and gram negative bacteria. Student will be taught the importance of transduction in the transfer of genetic material between bacteria. Through class discussion the student will learn to distinguish between generalized and specialized transduction. Two-factor and three-factor crosses will be worked out collectively on the whiteboard.	The student will be made to create genetic maps based on co-transduction frequencies in two-factor and three-factor crosses.
IV	Is able to list the events in the lytic and lysogenic phases of lambda phage life cycle and the regulatory factors and events involved.	The entire regulatory circuits of phage lambda will be explained with the help of whiteboard as well as slide show.	Student will have to figure out the plaque phenotypes obtained with different lambda mutants in a class test.
V	Can list the outcomes of transposition events, can design strategies to mutagenize bacteria using transposons, can explain the construction of conditional knockouts	The importance of bacterial transposition, the mechanisms by which they occur, bacterial mutagenesis using transposons, strategies to clone out specific genes using transposons, the role of *loxP*-cre and *FRT*-Flp in creating conditional knockouts will be taught through whiteboard as well as slide show.	The students will be assessed in their abilities to apply transposition to various problems by a short written assignment.

VI	Can differentiate between positive and negative regulation of gene expression, inducible and repressible systems. Can describe the regulation of the lac, trp, gal, ara and tol operons.	The regulation of the different operons as deciphered by different mutants and the phenotypes obtained will be explained in detail with the help of whiteboard as well as power point presentation.	The student will be expected to give genotypes of mutants based on the phenotypes obtained, and phenotypes obtained based on mutant genotypes, in a short group activity.
VII	Will have learnt about the model organisms used in genetic studies.	The characteristics of the different organisms that have resulted in their establishment as model systems for specific areas will be discussed.	The students will be divided into groups for short presentations that touch upon one landmark finding from each model organism.

***Assessment tasks listed here are indicative, and may vary.**

MBCC304: PRACTICAL III

Marks: 200 **Duration: 120 hours (8 credits)**

Course Objectives:

The objective of this course is to train the student in basic molecular biology and microbial genetics techniques. The student will learn how to isolate, analyze, and manipulate DNA, amplify DNA, fingerprint microbes, overexpress and purify recombinant proteins. The student will become familiar with transferring genetic material into bacteria by transformation and conjugation methods.

Course Learning Outcomes:

The student:

CO1. Is able to perform restriction digestion and carry out its analysis by agarose gel electrophoresis.
CO2. Is able to perform restriction digestion and carry out its analysis by agarose gel electrophoresis.
CO3. Learns how to prepare competent cells and determine transformation efficiency
CO4. Becomes familiar with alpha-complementation
CO5. Is able to isolation plasmid DNA from minicultures and large culture volumes.
CO6. Is able to isolate genomic DNA.
CO7. Learns how to do basic cloning
CO8. Learns how to amplify DNA by PCR
CO9. Is able to fingerprint microorganisms by RAPD analysis
CO10. Is able to overexpress recombinant proteins and analysis by SDS-PAGE
CO11. Is able to purify recombinant His-tagged protein
CO12. Is able to analyze expression by western blotting
CO13. Can carry out phage titration
CO14. Can perform bacterial transduction
CO15. Can set up bacterial conjugation
CO16. Learns how to set up bacterial transposition
CO17. Can find ORFs in given nucleotide sequence using ORF Finder.
CO18. Can create phylogenetic tree from the given nucleotide and protein sequence.
CO19. Can perform protein modeling using SWISS-MODEL.
CO20. Can create multiple sequence alignments

Contents:

1. To analyze plasmid DNA by restriction digestion followed by agarose gel electrophoresis.
2. To analyze plasmid DNA by restriction digestion followed by polyacrylamide gel electrophoresis.
3. To prepare competent cells by chemical method and determine their transformation efficiency
4. To study insertional inactivation using alpha-complementation
5. To isolate plasmid DNA from minicultures.
6. To isolate plasmid from maxicultures.
7. To isolate genomic DNA.

8. To clone the GFP gene into a bacterial expression vector and analyze expression by fluorescence microscopy
9. To amplify a gene off genomic DNA using PCR
10. To perform RAPD analysis for microbial identification
11. To analyze gene expression using real time PCR
12. To overexpress heterologous proteins in *E.coli* and analyze expression by SDS-PAGE
13. To purify a recombinant protein isolated from *E.coli*
14. To analyze protein expression by western blotting
15. To determine the titre of the given phage lysate
16. To transfer genes between bacteria via transduction
17. To transfer genes between bacteria via bacterial conjugation
18. To carry out transposition in bacteria
19. To find ORFs in given nucleotide sequence using ORF Finder.
20. To create phylogenetic tree from the given nucleotide and protein sequence.
21. To Study Protein Parameters using Protparam.
22. To study domain architecture using ExPASy PROSITE.
23. To perform protein modeling using SWISS-MODEL.
24. To create multiple sequence alignments
25. To visualize and understand structures from PDB using PyMol/DeepView.

Suggested Readings:

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

2. Sequence - Evolution - Function: Computational Approaches in Comparative Genomics by E.V. Koonin , M.Y. Galperin. Kluwer Academic, USA. 2003.

3. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins edited by A. D. Baxevanis, B.F. Francis Ouellette . 3rd edition. Wiley and Sons. 2004.

MBEC301: COMPUTATIONAL BIOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The course will introduce the student to the variety of computational methods currently available for predicting functional behavior of biological systems. The algorithms behind each method and the shortcomings in present methods will be discussed. Students should be able to analyze the output data to predict a biologically relevant function.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will be able to access and derive information from various primary and secondary databases
CO2: Will be able to create and usefully interpret the results of a multiple sequence alignment.
CO3: Can create and correctly interpret phylogenetic trees to gain insight into evolutionary path of the target molecule
CO4: Is able to use various algorithms for predicting genes in genomes
CO5: Knows about a variety of databases available that contain knowledge of various aspects of protein structure, function, evolution relationship.
CO6: Will be familiar with different algorithms available for structure comparison in proteins.
CO7: Will be able to create a model of the given target protein

Contents:

Section A: Sequence analysis:

Unit I: Biological Databases: Introduction. Types of databases in terms of biological information content. Protein and gene information resources. Different formats of molecular biology data. Specialized resources for genomics, proteomics and metabolomics. **8**

Unit II: Sequence Alignment: Methods and algorithms of pairwise and multiple sequence alignment. Global and local alignment. Alignment scoring matrices. Database similarity searching. Different approaches of motif detection. Concept and use of protein families. Concept of orthology, paralogy and homology in gene and protein sequences. **8**

Unit III: Molecular Phylogenetics: Methods and tools for phylogenetic analysis. Creation evaluation and interpretation of evolutionary trees. Advantages and disadvantages of phenetic and cladistic approaches. **8**

Unit IV: Genomics and Gene Annotation: Organization and structure of prokaryotic and eukaryotic genomes. Genome annotation and databases. Automated *in-silico* methods of finding gene and relevant features. Genome Sequencing using first and seconding generation sequencing methods. Advantages of genome sequencing projects in modern biological research. **8**

Section B: Structural Bioinformatics:

Unit V: Protein Structure Databases: Different databases of macro-molecular biomolecules; Accessing and mining protein structure classification databases such as SCOP, CATH; Tools for

viewing and interpreting macromolecular structures. **10**

Unit VI: Protein Structure Comparison: Various algorithms and programs for superimposition of structures. RMSD calculations, multiple structure alignment methods: DALI and VAST. **6**

Unit VII: Protein Structure Prediction and Molecular Modeling and structure-function analysis: Principles of secondary and tertiary structure predictions. *Ab-initio* and homology based methods of secondary and tertiary structure predictions. Homology modeling. Threading and *ab-initio* protein structure prediction. Using evolutionary information. Gene neighborhood. Phylogenetic profiles. Gene fusion. Catalytic templates. Prediction and analysis of binding cavities for function prediction. **12**

Suggested Readings:

1. Introduction to Computational Biology: An Evolutionary Approach by Haubold, Wiele. 1st edition. Springer International. 2006.
2. Introduction to Bioinformatics by A. Lesk. 3rd edition. OUP India. 2009.
3. Statistical methods in Bioinformatics: An introduction by W. Ewens, G.R. Grant. 2nd Edition. Springer-Verlag. 2006.
4. Bioinformatics: Sequence and genome analysis by D. Mount. 2nd edition. Cold Spring Harbor Lab Press. 2004.
5. Bioinformatics: A practical guide to the analysis of genes & proteins. Edited by Baxevanis, Outlette. 2nd edition. John Wiley and Sons. 2001.
6. An Introduction to Protein Informatics by K-H Zimmermann. 1st edition, Springer International. 2007.
7. Fundamental Concepts of Bioinformatics by Krane. 1st edition. Pearson Education. 2003.
8. Discovering Genomics, Proteomics and Bioinformatics by Campbell. 2nd edition. Campbell Pearson Education. 2007.
9. Structural bioinformatics: an algorithmic approach by F. J. Burkowski. 1st edition, Chapman & Hall/CRC. 2009.
10. Structural Bioinformatics edited by J. Gu, P.E. Bourne. 2nd Edition. Wiley-Blackwell. 2009.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I.	Should be able to access and derive information from various primary and secondary databases	Discussion on the publically available databases and the information stored in various formats.	MCQ type test based on the utility of various databases and differences between the information stored in each.
II.	Will be able to create and usefully interpret the results of a multiple sequence alignment.	Classroom discussions about various algorithms and programmes available for two sequences and multiple sequence alignment.	Hands on assessment for a given set of sequences (individual activity)
III.	Will be able to create and	Make students conversant with the	Hands on practical assessment for a

	correctly interpret phylogenetic trees to gain insight into evolutionary path of the target molecule	types of phylogentic tree making methods and algorithms	given set of sequences (individual activity)
IV.	Use of various algorithms for predicting genes in genomes.	Familiarizing students with the general characteristics genomes and gene prediction algorithms with emphasis on differences between methods.	Hands on practical assessment for a given genome (Group activity)
V.	Know about variety of databases available that contain knowledge of various aspects of protein structure, function, evolution relationship.	Detailed discussion about classification of proteins on the basis of structure and sequence and their clustering on the basis of evolutionary information.	Short Presentation discussing the highlights of a structural bioinformatics database (individual activity)
VI.	Should be familiar with different algorithms available for structure comparison in proteins.	Acquainting students of the need of comparing protein structures. Detailed discussion on the differences and similarities between various servers (using specific algorithms) for structure comparison.	MCQ type QUIZ to highlight differences between the algorithms/servers/software available.
VII.	Should be able to create a model of the given target protein	Detailed classroom discussion on various methods available for generating a structure of protein given its sequence. Discussion on current limitations of each method and criteria to choose the most useful method given the target protein.	Hands on individual activity of generating the protein model for a given target

***Assessment tasks listed here are indicative, and may vary.**

MBEC302: FOOD MICROBIOLOGY

Marks: 100 **Duration: 60 hours (4 credits)**

Course Objectives:

The course will enable students to understand the taxonomical classification, phenotypic and biochemical identification of food associated molds, yeasts, yeast-like fungi and bacteria. The course will teach the strategies to develop fermented and non-fermented milk products, plant-based products, fish products, meat products bioactive compounds and malt beverages, wines, distilled liquors and vinegar. The role of microbes in food spoilage, preservation and various food borne diseases will be discussed.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will know about production and evaluation of the quality of starter cultures and fermented milk products and understands the use and production of probiotics, prebiotics and nutraceuticals.
CO2: Is aware of fermentation protocols for production of microbial biomass such as edible yeasts, mushrooms, single cell proteins and single cell oils. The student also learns about production of microbial carotenoid pigments such as lycopene and β-carotene.
CO3: Gathers information regarding microbes causing food intoxications and food-borne infections.
CO4: Knows traditional food preservation techniques including drying, salting, pickling, refrigeration, freezing, oxidation, vacuum packaging, canning/bottling, smoking, sugaring, chemical preservation and irradiation.
CO5: Is able to utilize modern techniques viz. high-pressure processing (HHP), bacteriocins, manosonication (MS) and pulsed electric field (PEF) for effective food preservation. The student can also calculate kinetics of inactivation, process and product parameters.
CO6: Gains knowledge about conventional methods for food quality analysis and is able to use the most recent and non-invasive techniques of quantification and detection of food borne microbes and pathogens such asESS and various new imaging techniques.
CO7: Understands the relevance of microbial standards for food safety, quality assurance programs that revolutionize food safety.

Contents:

Unit I: Microorganisms important in food microbiology: Taxonomical classification of microbes associated with food products, their phenotypic and biochemical identification. Food associated molds, yeasts, yeast-like fungi and bacteria. Microbiome of food material **8**

Unit II: Microbiology of foods: Microbial habitat of specific food materials, adaptations and changes in microbiome of vegetables, fruits, milk, fermented and non-fermented milk products, fresh meats, poultry and non-dairy fermented foods. **8**

Unit III: Microbial spoilage of foods: Types and causes of spoilage of cereals and cereals products, spoilage of vegetables and fruits, spoilage of meat and meat products, spoilage of fish and other sea foods, spoilage of eggs and other poultry products, spoilage of milk and milk

products. Study of microorganisms responsible for spoilage and microbial succession during spoilage. Brief insights into chemical and physical spoilage of foods. **10**

Unit IV: Food preservation: General principles of food preservation, various classical, physical, chemical, and biological methods of preservation. New developments in food preservation techniques. Analysis of practical implementation of such techniques. **8**

Unit V: Fermentation processes: Production of fermented milk and milk products, plant-based products, fish products, meat products and nutraceuticals. Manufacture of starter cultures from lab to pilot scale. Batch submerged and solid-state fermentation of foods. **8**

Unit VI: Food beverages and enzymes: Concept of human microbiome, probiotics and prebiotics. Insight into health benefits of fermented milk products. Understanding benefits of tradition and non-traditional fermented foods. Introduction to the concept of bioactive compounds and brief study of such compounds from fermented foods including malt beverages, wines, distilled liquors and vinegar. **8**

Unit VII: Food-borne diseases: Food borne infections including bacterial, viral and fungal infections. Study of infections due to food borne parasites. In depth study of various types and causes of food intoxication. Summary of prevention of microbial food infections. Identification and first aid for specific types of food infections. **10**

Suggested Readings:

1. Food Microbiology by W.C. Frazier, D.C. Westhoff , K.N. Vanitha. 5th edition. McGraw Hill Education. 2013.

2. Modern Food Microbiology by J.M. Jay, M.J. Loessner, D.A. Golden. 7th edition. Springer. 2006.

3. Fundamental Food Microbiology by B. Rayand A. Bhunia. 5th edition. CRC press. 2013.

4. Food Microbiology by M. R. Adams, M. O. Moss, P. McClure. 4th edition. Royal Society of Chemistry. 2015.

5. Food Microbiology: Fundamentals and Frontiers by M. P. Doyle, L. R. Beuchat. 3rd edition. ASM press. 2007.

6. Food Microbiology: An Introduction by T. Montville, K. Matthews, K.Kniel. 4th edition. ASM press. 2017.

Facilitating the achievement of Course Learning Outcomes

Unit no.	Course Learning Outcomes	Teaching and learning Activity	Assessment Tasks
I	The student knows about production and evaluation of the quality of starter cultures and fermented milk products and understands the use and	Use of videos and pictorial aids for familiarization of students with the production of starter cultures and fermented milk products Discussion on probiotics, prebiotics and	Match the following type 5-minute test

	production of probiotics, prebiotics and nutraceuticals.	nutraceuticals.	
II	Student becomes aware of fermentation protocols for production of microbial biomass such as edible yeasts, mushrooms, single cell proteins and single cell oils. The student also learns about production of microbial carotenoid pigments such as lycopene and β-carotene.	Theory lecture on the production of yeasts- baker's yeast, single cell protein and single cell oils, cultivation of edible mushrooms algal biomass. Use of videos to enable students to visualize the industrial production of the same.	Written assignment in which students design a process for production of a microbial biomass
III	Gathers information regarding microbes causing food intoxications and food-borne infections.	Provide knowledge about the microbes involved in food intoxications including *Staphylococcus aureus*, *Clostridium botulinum* and fungi producing mycotoxins. Familiarization of students with common food infections	Short answer type test based on symptomatic identification of food intoxication/ food borne infection.
IV	Knows traditional food preservation techniques including drying, salting, pickling, refrigeration, freezing, oxidation, vacuum packaging, canning/bottling, smoking, sugaring, chemical preservation and irradiation.	Detailed discussion on the use of classical methods of food preservation including drying, salting, pickling, refrigeration, freezing, oxidation, vacuum packaging, canning, bottling, smoking, sugaring, chemical preservation and irradiation.	Quiz on conventional food preservation method to be employed for specific food groups.
V	Is able to utilise modern techniques viz. high-pressure processing (HHP), bacteriocins, manosonication (MS) and pulsed electric field (PEF) for effective food preservation. The student can also calculate kinetics of inactivation, process and product parameters.	Classroom debate on the short comings of classical preservation techniques and the need to shift to modern food preservation techniques. Theory class on modern food preservation techniques Teaching students the calculation of inactivation kinetics, process and product parameters.	Mathematical problem based on calculation of inactivation kinetics, process and product parameters.
VI	Gains knowledge about conventional methods for food quality analysis and is able to use the most recent and non-invasive techniques of quantification and detection of food borne microbes and pathogens such as ESS and various new imaging techniques.	Discussion about conventional methods for food quality analysis- culture dependent methods, colony count, immunological assays and PCR-based methods. Interactive lecture on recent advances in quantification and detection of food borne microbes.	Short student presentation on a new detection or quantification technique of food borne microbes and pathogens.
VII	Understands the relevance of microbial standards for food safety, quality assurance programs that revolutionize food safety.	Making students aware of the relevance of microbial standards for food safety Acquainting students with quality assurance programs that revolutionize food safety.	Group discussion on need and relevance of microbial standards of food safety and existing QC norms in India

***Assessment tasks listed here are indicative, and may vary.**

Semester IV

MBCC401: Project Work

Max marks: 600 **Duration: 360 hours (24 credits)**

Continuous evaluation (IA)	180 marks
Experimental work	120 marks
Dissertation	100 marks
Presentation and *viva-voce*	200 marks
Total	600 marks

Course Objectives:

The primary object of this course is to expose the student to research culture and technology. The student learns how to choose a research problem, plan and perform experiments, collect data, and analyze the data qualitatively and quantitatively. The student gets trained in presenting the results in the form of an oral presentation as well as a thesis. The student presents his/ her research orally at the end of the semester, and this is coupled to a *viva-voce*. This not only equips the student for a career in research/ industry, but also fosters self-confidence and self-reliance in the student as he/she learns to work and think independently.

Course Learning Outcomes:

CO1. Student is able to conceive a problem based on current published research
CO2. Student is able to carry out comprehensive survey of literature on the topic of research
CO3. Student is able to make culture media for various microbes
CO4. Student is able to isolate microorganism from different environmental/ food sources
CO5. Student is able to identify the isolated microorganism using biochemical and molecular methods
CO6. Student is able to assess the microorganism's ability to produce various enzymes
CO6. Student becomes well-versed in different enzymatic assay systems
CO7. Student learns correct handling and use of instruments
CO8. Student learns correct handling of reagents and chemicals
CO9. Student learns how to execute experiments correctly.
CO10. Student learns the importance of including controls in all experiments
CO11. Student learns how to plot the results.
CO12. Student learns how to analyze data, using statistical tools where necessary
CO13. Student learns how to interpret the results from all possible angles.
CO14. Student learns how to present the project in the form of a slide show before and audience of 20-30 people.
CO15. Student is exposed to the science of thesis writing.