Savitribai Phule Pune University

(*Formerly University of Pune*)

Faculty of Science and Technology

Revised Syllabi for

M.Sc. (Microbiology) Part-I

NEP 2020

For Colleges

Affiliated to Savitribai Phule Pune University

To be implemented from Academic Year 2023-2024

Title of the Program

M.Sc. (Microbiology) As per NEP 2020

1. Preamble:

The main theme of teaching microbiology course is the application of basic principles of life sciences to develop into technology. Modern biology combines the principles of chemistry and biological sciences (molecular and cellular biology, genetics, and immunology) with technological disciplines (engineering, computer science) to produce goods and services and for environmental management. Tools of molecular biology play an important role in preparation of an engineered clone, a recombinant or a genetically manipulated organism (GMO). The objective of the Master's Programme in Microbiology is to equip the students with updated knowledge of prokaryotic and eukaryotic cellular processes, microbial taxonomy, biostatistics, molecular biophysics, molecular biology and biochemistry.

The Board of Studies in Microbiology has identified the following thrust areas and prospective plans for syllabi reforms at postgraduate level:

- **Microbial diversity**: Facets of microbial diversity which includes morphological, structural, metabolic, ecological, behavioral and evolutionary aspects
- **Microbial diversity in extreme environments**: Properties and application of extremophiles and also includes collecting information of diversity, exploration and utilization of diversity to identify and harvest biomolecules for human health improvisation, microorganisms from extreme environments, Archaebacteria, etc.
- **Mathematical approach for Biologists**: Numerical Microbiology Problem solving, Concept of mathematical models, Application of Mathematical models to microbiological processes
- **Advanced Biochemistry and Molecular Biology Techniques**: Chromatography techniques, next generation sequencing methods (Pyrosequencing, Ion torrent, Nanopore sequencing)
- **Cell and developmental Biology**
- **Research Methodology**: Use of search engines for scientific data mining, use of reference management tools, statistical data analysis using software

To enrich students' knowledge and train them in the above-mentioned areas; we feel certain topics in the present syllabus need to be supplemented and strengthened by inclusion of a few additional topics. Areas that need to be introduced in syllabi have been identified as:

- Extremophiles
- Bioinformatics
- Mathematical approach for Biologists
- Molecular tools for characterization and identification of bacteria
- Advanced Biochemistry techniques
- Advanced Molecular Biology Techniques
- Morphogenesis and organogenesis in plants
- Signal transduction
- Radioisotopes in Biology and Confocal Microscopy

In addition, we feel that the students should be well acquainted with research methodology which includes different skill developments in scientific writing, data handling and processing, development of research ideas and planning / designing of research projects. The skill sets thus evolved will help the students in academic and applied research. This syllabus aims to give the student a significant level of theoretical and practical understanding of the subject.

2. Introduction:

With the changing scenario at local and global level, we feel that the syllabus orientation should be altered to keep pace with developments in the education sector. The need of the hour is proper syllabi that emphasize on teaching of technology as well as the administrative aspects of modern biology. Theory supplemented with extensive laboratory expertise will help these students to avail these opportunities. Both these aspects i.e. theory and more of practical needs to be stressed, such that a postgraduate student can start work directly in applied fields (industry or institutions), without any additional training.

Thus, the university / college itself will be developing trained and skilled manpower. We are restructuring the syllabus in this viewpoint. The restructured syllabus will combine the principles of chemistry and biological sciences (molecular and cell biology, genetics, immunology and analytical tools, biochemistry, biostatistics and bioinformatics) with technological disciplines to produce goods and services and for environmental management.

Microbiology curricula are operated at two levels viz. undergraduate and postgraduate. The undergraduate curricula are prepared to impart basic knowledge of the respective subject from all possible angles. In addition, students are to be trained to apply this knowledge particularly in day-to-day applications of Microbiology and to get a glimpse of research.

3. Objectives to be achieved:

- To enrich students' knowledge and train them in the pure microbial sciences

- To introduce the concepts of mathematics in biology
- To inculcate research aptitude
- To inculcate sense of scientific responsibilities and social and environment awareness
- To help students build-up a progressive and successful career in Microbiology

4. Course Structure and assessment of credits:

I. Total credits:

A full master's degree course in Science would be of 88 credits. One credit course of theory will be of one clock hour per week, running for 15 weeks and one credit for practical course will consist of 30 clock hours of laboratory exercises. There shall be four semesters and credits are distributed over 4 semesters. There will be 2 core compulsory theory courses (4 credits each), one core compulsory theory course (2 credits) and one core compulsory Practical course (4 credits). In addition to this, choice based optional paper means elective courses are offered consisting of 2 theory credits courses and allied 2 practical credit courses. There are also Research Methodology (RM), Internship/ On the Job training (O/T) and Research Project credits assigned to a particular semester.

Savitribai Phule Pune University, Pune

Credit Framework for Post Graduate (PG):

Level	**Semester**	**Credits Related to Major**		**Research Methodology (RM)**	**Internship/ On Job Training (O/T)**	**Research Project (R**	**Total**
		Major Core	**Major Elective**				
6.0	I	10 (T) + 4 (P)	2 (T) + 2 (T/P)	4	0	0	**22**
	II	10 (T) + 4 (P)	2 (T) + 2 (T/P)	0	4 (O/T)	0	**22**
Exit option: Award PG Diploma on completion of 44 credits after three years UG Degree **OR** continue with PG second year							
6.5	III	10 (T) + 4 (P)	2 (T) + 2 (T/P)	0	0	4	**22**
	IV	8 (T) + 4 (P)	2 (T) + 2 (T/P)	0	0	6	**22**
Total 4 Years		**54**	**16**	**4**	**4**	**10**	**88**
2 years-4 Semesters. Award PG Degree on completion of 88 credits. After Three Years UG Degree or 1 Year- 2 Semesters PG Diploma (44 credits) after Four Year UG degree							

II. M. Sc. First year Microbiology Semester I assessment of Credits:

MB: Microbiology; CT: Core Compulsory Theory; CP: Compulsory Practical; ET: Elective Theory EP: Elective Practical; RM-T: Research Methodology Theory; RM-P- Research Methodology Practical

Components Study	Course Code		Course Name	Credit	Assessment		
					IA	UE	Total
Core Compulsory Theory Papers	MB 501 MJ		Microbial Systematics	4	30	70	100
	MB 502 MJ		Biochemistry, Cell, and Developmental Biology	4	30	70	100
	MB 503 MJ		Basic Quantitative Biology	2	15	35	50
Core Compulsory Practical paper	MB 504 MJP		Practicals based on MB 511 MJ MicrobialSystematics, MB 512 MJ Biochemistry,Cell and Developmental Biology, and MB 513 MJ Basic Quantitative Biology	4	30	70	100
Research Methodology Theory	MB 510 RM		Research Methodology	2	15	35	50
Research Methodology Practical	MB 510 RMP		Research Methodology	2	15	35	50
Choice Based Optional Papers Elective/ Departmental Course **Any one group**	Group I	MB 505 MJ	Microbial Extremophiles	2	15	35	50
		MB 505 MJP	Practicals Based on Microbial Extremophiles	2	15	35	50
	O R						
	Group II	MB 506 MJ	Microbial communication, Membrane transport and signal transduction approaches for Biologist	2	15	35	50
		MB 506 MJ	Practicals Based on Microbial communication, Membrane transport and signal transduction	2	15	35	50
	O R						
	Group III	MB 507 MJ	Advanced Quantitative Biology	2	15	35	50
		MB 507 MJP	Practicals based on Advanced Quantitative Biology	2	15	35	50
	OR						
	Group IV	MB 508 MJ	Experimental Design and Quantitative approaches for Biologist	2	15	35	50
		MB 508 MJP	Practicals based on Experimental Design and Quantitative approaches for Biologist	2	15	35	50

III. M. Sc. First year Microbiology Semester II assessment of credits:-

MB: Microbiology; CT: Core Compulsory Theory; CP: Compulsory Practical; ET: Elective Theory EP: Elective Practical; OJT- Internship/ On job training

Course Type	Course Code		Course Name	Credit	Assessment		
					IA	UE	Total
Core Compulsory Theory Papers	MB 551 MJ		Molecular Biology-I	4	30	70	100
	MB 552 MJ		Enzymology, Bioenergetics and Metabolism	4	30	70	100
	MB 553 MJ		Laboratory Techniques and Instrumentation	2	15	35	50
Core Compulsory Practical paper	MB 554 MJP		Practicals based on MB 521 MJ Molecular Biology I, MB 522 MJ Enzymology, Bioenergetics and Metabolism and MB 523 MJ Laboratory Techniques and Instrumentation	4	30	70	100
Internship/ On jobtraining	MB 581 OJT		Internship / On job training	4	30	70	100
Choice Based OptionaPapers Elective/ Departmental Course **Any one group**	Group I	MB 560 MJ	Molecular Biology tools an applications	2	15	35	50
		MB 560 MJP	Practical based on MB 560 MJ Molecular Biology tools and application	2	15	35	50
	OR						
	Group II	MB 561 MJ	Nitrogen Metabolism, Respiration and Photosynthesis	2	15	35	50
		MB 561 MJP	Practicals based on MB 561 MJ Nitrogen Metabolism, Respiration and Photosynthesis	2	15	35	50
	OR						
	Group III	MB 562 MJ	Molecular Biophysics	2	15	35	50
		MB 562 MJP	Practicals based on MB 562 MJ Molecular Biophysics	2	15	35	50
	OR						
	Group IV	MB 563 MJ	Bioinformatics	2	15	35	50
		MB 563 MJP	Practicals based on MB 563 MJ Bioinformatics	2	15	35	50

IV. Course Evaluation:

Each course will be evaluated for 70% marks by UE and 30 % will be based on In-semester continuous assessment.

V. Examination Results:

Results at the end of the semester will be declared using a grade point system as per the University rules.

VI. The GPA:

The formula for GPA will be based on weighted average. The final GPA will not be printed unless a student passes courses equivalent to minimum 88 credits. Total credit hour means a sum of credit hours of the courses which a student has passed.

VII. Rules and University Guidelines:

All other rules will be as per the university guidelines for postgraduate courses under credit-based system.

VIII. Important Note:

The above circular supersedes all previous circulars on the credit system being operated at SPPU.

5. General Instructions:

The post-graduate degree will be awarded to students who obtain a total 88 credits (22 average credits per semester). One credit will be equivalent to 15 clock hours of teacher-student contact per semester.

Assessment shall consist of

a) In-semester continuous assessment and

b) End-semester assessment.

The teacher concerned shall announce the units for which each in-semester assessment will take place. However, the end-semester assessment shall cover the entire syllabus prescribed for the course. An in-semester assessment of 30% marks should be continuous and at least two tests should be conducted for courses of 4 credits and a teacher must select a variety of procedures for examinations such as:

1. Written test and/or midterm test (not more than one or two for each course)
2. Term paper
3. Journal/Lecture/Library notes
4. Seminar presentation and Short Quizzes
5. Assignments
6. Extension work
7. An open book test (with the respective subject teacher deciding what books are to be allowed for this purpose)
8. Mini research project by individual student or group of students

The concerned teacher in consultation with the Head of the PG Department shall decide the nature of questions for the unit test.

Semester end examination for remaining 70% marks will be conducted by Savitribai Phule Pune University. The student has to obtain 40% marks in the combined examination of In-semester assessment and Semester-End assessment with a minimum passing of 30% in both these separately.

To pass the degree course, a student shall have to get a minimum aggregate 40% marks (E and above grade point scale) in each course. If a student misses an internal assessment examination, he/she will have a second chance with the permission of the Principal in consultation with the concerned teacher. Such a second chance shall not be the right of the student.

Internal marks will not change. A student cannot repeat internal assessment. Students who have failed the semester-end exam may reappear for semester-end examination only twice in subsequent periods. The students will be finally declared as failed if he/she does not pass in all credits within a total period of four years. After that, such students will have to seek fresh admission rules prevailing at that time.

A student cannot register for the third semester, if she/he fails to complete 50% credits of the total credits expected to be ordinarily completed within two semesters.

There shall be Revaluation of answer scripts of semester examination but not of internal assessment papers as per the Ordinance no. 134 A and B. While marks will be given for all examinations, they will be converted into grades. The semester end grade sheets will have only grades and final grade sheets and transcripts shall have grade points average and total percentage of marks (up to two decimal points). The final grade sheet will also indicate the PG center to which the candidate belongs.

Each assessment/test will be evaluated in terms of grades. The grades for separate assignments and the final (semester-end) examination will be added together and then converted into a grade and later a grade point average. Results will be declared for each semester and the final examination will give total grades and grade point average.

Reference: Savitribai Phule University's circular on "Rules and Regulation for PG Choice Based credit system for Science Programme of Affiliated Colleges", effective from June 2019 and further amendments.

Program Specific Outcomes (PSOs) for M. Sc. Microbiology NEP	
PSO No.	**Program Specific Outcomes (PSOs)** **Upon completion of this programme the student will be able to**
PSO1	**Academic competence:** **i)** Describe microbial processes that can be used for the development of biochemical and immunological tools to improve the quality of human life. **ii)** Study the cytology, biochemistry, growth as well as application of environmentally and industrially important microbes with a specific emphasis on improving environmental sustainability and human health. **iii)** Describe and understand the concepts of role of microorganisms in geochemical processes like leaching of metals and bioremediation methods
PSO2	**Personal and Professional competence:** **i)** Apply tools of molecular taxonomy and bioinformatics to the study of diverse microbial groups. **ii)** Evaluate industrially important microbial products in terms of their purity, safety and ethically acceptable application for the benefit of mankind. **iii)** Combine public presentation skills of effective articulation and nonverbal communication with a sound understanding of microbial science to effectively communicate ideas
PSO3	**Research competence:** **i)** Validate scientific hypothesis and editorialize experimental scientific data by using statistical tools applicable to biological sciences. **ii)** Integrate principles of biology and physical sciences to standardize detection and quantification methods using sophisticated techniques.
PSO4	**Entrepreneurial and Social Competence:** **i)** Employ skill sets related to Quality assurance and testing of pharmaceutically important products in accordance with internationally accepted standards. **ii)** Evaluate the importance of new groups of consumer goods such as prebiotics, probiotics and nutraceuticals. **iii)** Apply the concepts of microbial interactions in basic and advanced treatment of waste water treatment processes.

M. Sc. Microbiology Part I Semester I

MB 501 MJ- Microbial Systematics
Compulsory Theory Paper
Total: 4 Credits Workload:-15 hours /credit
(Total Workload:-4 credits x 15 hours =60 hours in semester)

Course Outcomes (COs)	
After studying this course learners will be able to	
CO1	• define species concept in prokaryotes and eukaryotes • list measures and indices of diversity • define –unculturable' bacteria and list culture independent molecular methods for identifying unculturable bacteria • list different molecular methods used in microbial taxonomy • know difference between 6 Classes of Fungi
CO 2	• explain 5-Kingdom and 3 domain classification system and facets of microbial diversity • understand molecular evolution • explain Socio-biology and Lamarckism, Darwinism, Neo Darwinism and understand Game theory , r and k selection
CO 3	• apply the use molecular clocks in taxonomy • summarize various theories of evolution

MB 501 MJ - Microbial Systematics
Compulsory Theory Paper
Total: 4 Credits Workload :-15hours/credit
(Total Workload:-4 credits x 15 hours =60 hours in semester)

Credit	Credit Title and Contents	Number of Lectures
I	**Microbial Systematics:** 1. Species concept in prokaryotes and eukaryotes 2. Five-Kingdom classification system and Three-Domain classification system 3. Overview of fungal systematics and Differentiating characters among different Classes of fungi 4. Determinative Bacteriology (Phenetic Approach) and Systematic Bacteriology (Phylogenetic Approach) 5. Polyphasic Approach 6. Molecular clocks, phylogeny and molecular distances	15
II	**Microbial Diversity:** 1. Facets of microbial diversity: morphological, structural, metabolic, ecological, behavioral and evolutionary	15

	2. Species divergence and measurement of microbial diversity 3. Measures and indices of diversity; alpha, beta and gamma diversity	
III	**Exploration of Uncultured Microbial Diversity** 1. Concept of 'unculturable' bacterial diversity 2. Strategies for culture of 'unculturable' bacteria 3. Culture independent molecular methods for identifying unculturable bacteria (PCR, RFLP, ARDRA, DGGE, TGGE, RAPD, Microarray, FISH, RISA) 4. Methods of extracting total bacterial DNA from a habitat and metagenome analysis	15
IV	**Evolution:** 1. History and development of evolutionary theory (Lamarckism, Darwinism), Neo Darwinism: Spontaneous mutation controversy, evolution of rates of mutation, types of selection, levels of selection, group selection and selfish genes. 2. Socio-biology, kin selection, evolutionary stability of cooperation, sociality and multi- cellularity in microorganisms, Game theory. Co-evolutionary strategies, host parasite co- evolution 3. Molecular evolution: origin of life, the origin of new genes and proteins aging, evolutionary trade-offs, r and k selection	15

Suggested References: MB 501 MJ - Microbial Systematics Compulsory Theory Paper

1. Barnett H. L. and Hunter B. B. (1960). Illustrated Genera of Imperfect Fungi. Burgess Publishing Co., Minnesota.
2. Black J. G. (2013). Microbiology: Principles and Explorations. 6th Edition. John Wiley & Sons, IncBromham L. and Penny D. (2003). The Modern Molecular Clock. Nat Rev Genet. 4(3):216-224. Nature Publishing Group.
3. Brown J. (2014). Principles of Microbial Diversity. ASM Press.
4. Buchanan, R. E. and Gibbons, N. E. (editors). 1974. Bergey's Manual of Determinative Bacteriology. 8th ed. Williams & Wilkins Co., Baltimore
5. Garrity G., Boone D. R. and Castenholz R. W. (2001). Bergey's Manual of Systematic Bacteriology. Volume One: The Archaea and the Deeply Branching and Phototrophic Bacteria. 2nd Edition. Springer-Verlag New York
6. Garrity G., Brenner D. J., Krieg N. R. and Staley J. R. (2005). Bergey's Manual of Systematic Bacteriology. Volume Two: The Proteobacteria, Part A: The Gamma proteobacteria. 2nd Edition. Springer-Verlag US
7. Garrity G., Brenner D. J., Krieg N. R. and Staley J. R. (2005). Bergey's Manual of Systematic Bacteriology. Volume Two: The Proteobacteria. Part B: Alphaproteobacteria.2nd Edition. Springer-Verlag US
8. Garrity G., Brenner D. J., Krieg N. R. and Staley J. R. (2005). Bergey's Manual of Systematic Bacteriology. Volume Two: Part C. the combination of the Beta-, Delta- and Epsilon proteobacteria. 2nd Edition. Springer-Verlag US

9. Keller M. and Zengler K. (2004) Tapping in to Microbial Diversity. Nature Reviews. 2(2): 141-150
10. Kirk J. L., Beaudette L. A., Hart M., Moutoglis P., Klironomos J. N., Lee H. and Trevors J (2004). Methods of studying soil microbial diversity. J Microbiol Methods. 58(2):169-18 doi: 10.1016/j.mimet.2004.04.006. PMID: 15234515.
11. Krieg N. R., Ludwig W., Whitman W., Hedlund B. P., Paster B. J., Staley J. T., Ward Brown, D. and Parte A. (Editors). (2010). Bergey's Manual of Systematic Bacteriolog Volume 4. 2nd Edition. Springer-Verlag New York
12. Lively C. M. (1996). Host-Parasite Coevolution and Sex: Do interactions between biologic enemies maintain genetic variation and cross-fertilization? BioScience. 46 (2):107–11 https://doi.org/10.2307/1312813
13. Lodder J. (1974). The Yeasts: A Taxonomic Study. North Holland Publishing Co. Amsterda

MB 502 MJ: Biochemistry, Cell and Developmental Biology
Compulsory Theory Paper
Total: 4 Credits Workload: -15 hours/ credit
(Total Workload:-4 credits x 15 hours= 60 hours in semester)

Course Outcomes (COs)	
After studying this course learners will be able to	
CO 1	Students learn about structural features of amino acids and proteins and their functions.
CO 2	Students get introduced with biochemistry and molecular biology technique.
CO 3	Students get introduced to developmental biology in that hox code, mechanism of gastrulation, pattern formation in body axis
CO 4	Students get introduced with ultrastructure and organization of eukaryotic cell, protein transport and cell cycle.

MB 502 MJ: Biochemistry, Cell and Developmental Biology.
Compulsory Theory Paper
Total: 4 Credits Workload: -15 hours/ credit
(Total Workload:-4 credits x 15 hours= 60 hours in semester)

Credit	**Credit Title and Contents**	**Number of Lectures**
I	**Protein Chemistry:** 1. Structural features of amino acids, classification of amino acids, Amino acids as buffers 2. Henderson Hasselbalch equation and its role in buffer formulation. Peptide linkage, partial double bond nature of peptide bond 3. Determination of primary structure of polypeptide (N-terminal, C-	15

	terminal determination, method of sequencing of peptides). 4. Structural classification of proteins: primary, secondary, tertiary, quaternary structures of proteins, 5. Non-covalent interactions, Conformational properties of proteins, Polypeptide chain geometry, Resonance forms of the peptide group, cis/trans isomers of peptide group, Ramachandran plot. 6. Secondary, Super-secondary, Motif & Domain. 7. Tertiary and Quaternary structures of proteins, (Myoglobin and hemoglobin)	
II	**1. Nucleic acid chemistry:** Structure of bases, nucleosides, nucleotides, phosphodiester linkages, 5' phosphate, 3' hydroxyl polarity of nucleic acids, tautomeric forms of bases and their implication in the pairing of bases, structure of DNA (A, B and Z forms), Tm value, Cot curves, structure of t-RNA, rRNA, m-RNA and other RNAs **2. Carbohydrate Chemistry:** Mono, di, oligosaccharides, and polysaccharides, with examples, asymmetric center in sugars, D-series, L-series, dextro, laevo-rotatory, reducing and non-reducing sugars, sugar anomers, sugar epimers, sugar derivatives such as sugar alcohols, amino sugars, sugar acids, deoxy sugars. 3. **Lipid Chemistry**: Classification of lipids according to chemical structure, fatty acids, saturated, unsaturated, branched, nomenclature system, structure and function of triglycerides, phospholipids, sphingolipids, terpenes, prostaglandins, waxes, and steroids.	15
III	**Developmental Biology:** 1. Introduction to developmental biology. Different model systems used to study developmental biology 2. Conserved nature of development, Concepts of commitment, determination and differentiation, 3. Morphogen gradients in developmental regulation, Hox code, MPF 4. Gastrulation and cellular movements involved in it, Organizer and its importance giving examples of invertebrates (*Drosophilla*) and vertebrate (*Xenopus*) model systems, pattern formation in body axis, antero-posterior and dorso-ventral polarity. 5. Morphogenesis and organogenesis in plants: Organization of shoot and root apical meristem; shoot and root development; transition to flowering, floral meristems and floral development in *Arabidopsis*.	15
IV	**Cell Biology:** 1. Structural organization and function of Endoplasmic Reticulum, Golgi apparatus, Nucleus, Mitochondrion, chloroplast, Lysosomes, peroxisomes; Cytoskeleton and function of Molecular motors.	15

	2. Protein trafficking among various cellular compartments (by secretory and cytosolic pathway: targeting to secretory vesicles, cell membrane, lysosomes, nucleus, mitochondria and peroxisomes) 3. Events in cell cycle, Regulation of cell cycle. Apoptosis	

Suggested References: **MB 502 MJ: Biochemistry, Cell and Developmental Biology Compulsory Theory Paper**

Credit I and II:

1. Branden C. I. and Tooze J. (2012). Introduction to Protein Structure. United States: CRC Press. ISBN:9781136969898,
2. Garrett, R. H. and Grisham, C. M. (2004) Biochemistry. 3rd Ed. Brooks/Cole, Publishing Company, California.
3. Moat A. G., Foster J. W. and Spector M. P. (2003) Microbial Physiology. Germany: Wiley. ISBN: 9780471461197
4. Nelson D. L. and Cox M. M. (2021). Lehninger's Principles of Biochemistry.8thEdition. Mac Millan Worth Pub. Co. New Delhi. ISBN:9781319228002
5. Segel I. H. (2010). Biochemical Calculations. 2nd Ed. Wiley India Pvt. Limited. ISBN: 9788126526437
6. Tymoczko J. L., Gatto G. J., Stryer L. and Berg J. M. (2018). Biochemistry: A Short Course. United States: W. H. Freeman. ISBN: 9781319114633
7. Voet D. and Voet J. G. (2011). Biochemistry. United Kingdom: Wiley. ISBN: 9780470570951

Credit III: Development and Differentiation

1. Gilbert S. F. and Barresi M. J. F. (2020). Developmental Biology. United States: Oxford University Press. ISBN:9781605358222,
2. Müller W. A. (2012). Developmental Biology. United States: Springer New York. ISBN: 9781461222484.
3. Wolpert L., Tickle C. and Martinez Arias A. (2015). Principles of Development. United Kingdo Oxford University Press. ISBN: 9780199678143

Credit IV: Cell Biology

1. Alberts B., Johnson A., Lewis J., Morgan D., Raff M., Roberts, K. and Walter P. (2015). Molecular Biology of the Cell. 6th edition. Garland Science; Taylor and Francis Group. New York. ISBN: 9781317563754
2. Lodish H., Berk A., Kaiser C. A., Krieger M., Bretscher A., Ploegh H., Martin K. C., Yaffe M. and Amon A. (2021). Molecular Cell Biology. 9th Edition. Macmillan Learning.ISBN: 9781319208523
3. Metzler D. E. and Metzler C. M. (2001). Biochemistry: The Chemical Reactions of Living Cells. Netherlands: Elsevier Science. ISBN: 9780124925410

……

MB 503 MJ -Basic Quantitative Biology
Compulsory Theory Paper
Total: 2 Credits Workload:-15 hours/credit
(Total Workload:-2 credits x15 hours = 30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	Understand importance of statistics in biology
CO 2	Understand basic terms used in statistics Formulate a hypothesis for the experiment as well as test it using appropriate methods.
CO 3	Methods for Systematically collection and arranging different type of data
CO 4	Calculate basic statistical parameters, plot graphs by using data
CO 5	Calculate and interpret the observations by using tests used inferential statistics
CO 6	Describe the method to collect samples in the most appropriate way to carry out desired experiments. Record the data obtained in the experiment in a suitable way.
CO 7	Design the experiments based on the different principles.
CO 8	Apply the measures of central tendency, dispersion to the data and calculate the probability of obtaining the expected results in the experiments.
CO 9	Analyze large data to get a meaningful inference from it.
CO10	Compare the different methods of measuring central tendency and evaluate the best suitable one for a particular data
CO11	Formulate a hypothesis for the experiment as well as test it using appropriate methods.

MB 503 MJ -Basic Quantitative Biology.
Compulsory Theory Paper
Total: 2 Credits Workload:-15 hours/credit
(Total Workload:-2 credits x15 hours = 30 hours in semester)

Credit	**Credit Title and Contents**	**Number of Lectures**
I	**Descriptive Statistics** 1.Fundamental concepts – Basic terminologies, sample statisticsand population parameter, variable and its types (qualitative and quantitative, discrete and continuous) measurement scales (nominal, ordinal, interval and ratio), data (types and sources) 2.Collection and organization of data, tabulation (frequency distribution table and its components), diagrammatic and graphical representation (Bar diagram and its types, pie chart, histogram, frequency polygon and ogive curves, survival curves). 3. Measures of central tendency –arithmetic mean, median , mode, geometric mean	15

	4.Measures of dispersion and their coefficients –Standard deviation and variance 5.Correlation, scatter plots, Pearson's correlation coefficient, simple linear regression (no significance testing) (*only problems be asked from 2, 3, 4 and 5 in the examination*)	
II	**1. Probability** Probability, basic concept (sample space, experiment, event, outcome) i. Permutation and combination, addition and multiplication rule ii. Probability distribution and its types iii. Binomial, normal and poisson distribution. (*Only problem be asked on 1 in examination*) **2. Inferential Statistics:** i. Central Limit Theorem, Distribution of sample mean, standard error and confidence interval ii. Test of significance: a. Overview, Inference, concepts of null hypothesis, alternate hypothesis, test statistic, significance level, p-value, type I and type II errors, one tailed and two tailed tests, degrees of freedom b. Types: Parametric and non-parametric (comparative account) c. Parametric tests (Mean and proportion)): t-test and z-test (*Biological examples/data should be used to solve the problem; only problems be asked on 2.c in the examination*)	15

Suggested References: MB 503 MJ -Basic Quantitative Biology
Compulsory Theory Paper

1. Bailey N. T. J. (1995). Statistical methods in Biology. 3rd Edition. Cambridge University Press
2. Brown D. and Rothery P. (1993). Models in Biology: Mathematics, Statistics and Computing. John Wiley &Sons, USA. ISBN: 9780471933229
3. Daniel W. W. and Cross C. L. (2007), Biostatistics A foundation for Analysis in the Health Sciences. Wiley. ISBN: 978-1-119-49657-1
4. Gupta S. P. (2021). Statistical Methods. 46th Edition. Sultan Chand & Sons Publisher, New Delhi. ISBN: 978-93-5161-176-9
5. Khan I. A. and Khanum A. (2004). Fundamentals of Biostatistics. 3rd Edition. Ukaaz Publications, Hyderabad. ISBN: 8190044109, 9788190044103
6. Lindgren B. W. (1976). Statistical Theory. 3rd Edition Macmillan Publishing Co. Inc. ISBN 13: 9780023708305
7. McNeil B. and Harvey L. (2008). Practical Fermentation Technology. Wiley InterScience. ISBN 978-0-470-01434-9
8. Montgomery D. C. (2019). Design and Analysis of Experiments. 10th Edition. Wiley.

ISBN: 978-1-119-49244-3
9. Newman S. C. (1952). Biostatistical Methods in Epidemiology. John Wiley & Sons.
10. Petrie A. and Sabin C. (2019). Medical Statistics at a Glance. 5nd Edition. Wiley.
11. Rosner B. (2015). Fundamentals of Biostatistics. 8th Edition. Publisher: Cengage Learning. ISBN: 1305465512, 9781305465510
12. Sundar Rao P. S. S. and Richard J. (2012). Introduction to Biostatistics and Research Methods. 5th Edition. PHI Learning Private Limited, New Delhi.

MB 504 MJP: Biochemical Techniques Compulsory Practical Paper

Total: 4 Credits Workload:-30 hours /credit

(Total Workload:-4 credits x 30 hours=120 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	To follow and appreciate protocols and practices in the laboratory as per the standards for successful practical completion
CO 2	Methods to prepare biological buffers
CO 3	Effective ways of presentation of biological data and its statistical using software
CO 4	Microbiological procedures required for isolation, characterization and identification of microbes.
CO 5	Methods for visualization of cell division
CO 6	Basic aspects of developmental biology
CO 7	Methods for extraction of microbial biomolecules and their estimation Computational aspect of protein structures

MB 504 MJP: Biochemical Techniques Compulsory Practical Paper Total: 4 Credits Workload:-30hrs /credit **(Total Workload:-4 credits x 30 hrs=120 hrs in semester)**	
Credit Title and Contents	Number of Hours
1. Safety rules in Laboratory: Laboratory safety, hazard from chemicals, handling of chemicals, disposal of chemicals and cultures, recording of scientific experiments. 2. Standardization of laboratory procedures, calibration and validation instruments, preparing /designing SOP for the same, maintenance of instruments. 3. Buffer: Determination of pKa of a monoprotic weak organic acid by titration and graph method. 4. Preparation of buffer using KH2PO4 and K2HPO4. 5. Preparation of buffer using acetic acid and sodium acetate.	120

6. Preparation of buffer using K2HPO4 and H3PO4. 7. Computer applications: Using datasheets, and sorting data with different parameters, plotting graphs – bar charts, line graphs, pie charts, adding error bars.(Using Microsoft Excel) 8. Statistical analysis of data – Students t test. 9. Enrichment, Isolation and identification of the following from natural samples: Gram Negative. 10. Enrichment, Isolation and identification of the following from natural samples: Gram Positive. For Practical 9 and 10 identifications of the bacteria to at least the Genus level using the Bergey's Manuals is expected. The identification key must be designed for each isolated and identified bacterium. Students are expected to isolate at least one Genus from each group. *(At least 5 different types of samples should be processed to obtain isolates*) 11. Studying the stages of mitosis in the growing tip of onion root cells. 12. Studying and observing polyploidy induced by colchicin treatment on Onion root tip. 13. Demonstration of mounting embryo fruit fly at various developmental stages on permanent slides. 14. Extraction of Protein using TCA from bacterial culture. 15. Extraction of Exo-polysaccharide from Microbial culture using organic solvent. (may use ethanol method) 16. Spectrophotometry: estimation of above extracted protein sample: Bradford and UV-Spectrophotometry. 17. Spectrophotometry: estimation of above extracted EPS sample: Phenol Sulphuric Acid method. 18. Interpretation of Ramchandran Plot and study of conformations of protein molecule using Molecular Graphics Visualization Tool (e.g. Swiss PDB)	

Suggested References: MB 504 MJP- Biochemical Techniques. Compulsory Practical Paper

Safety rules in Laboratory

- Fuscaldo A. (2012). Laboratory Safety Theory and Practice. United Kingdom: Elsevier Science.
- Leboffe M. J. and Pierce B. E. (2010). Microbiology Laboratory theory and Application. Chapter 1. Introduction: Safety and laboratory guidelines. 3rd edition. Morton Publishing Company. 1-8.
- Plummer M. and Plummer D.T. (2001). Introduction to practical biochemistry. 3rd Edition, Tata McGraw- Hill Edition.
- United States Environmental protection agency (EPA), EPA QA/G-6. 2007. Guidance for preparing SOP. 1-6.

- World Health Organization Staff, World Health Organization. Laboratory Biosafety Manual, 3/Ed. (2006). India: AITBS Publishers.
- https://www.labmanager.com/lab-health-and-safety/science-laboratory-safety-rules-guidelines-5727

Buffer:

- Jayaraman J. (2004). Laboratory Manual in Biochemistry. India: New Age International (P) Limited Publishers.
- Plummer M. and Plummer D.T. (2001). Introduction to practical biochemistry. 3rd Edition, Tata McGraw- Hill Edition.
- Sadasivam S. and Manickam A. (2008). Biochemical methods. 3rd Edition, New Age International Publishers, India.
- Segel I. H. (2010). Biochemical Calculations, 2nd Edn. India: Wiley India Pvt. Ltd.

Computer applications:

- Conner N. and MacDonald M. (2013). Office 2013: The Missing Manual. United States: O'Reilly Media.
- McFedries P. (2019). Microsoft Excel 2019 Formulas and Functions. PearsonEducation.
- https://www.britannica.com/technology/spreadsheet

Statistical analysis of data:

- Boslaugh S. (2012). Statistics in a Nutshell. Germany: O'Reilly Media Incorporated.
- McFedries P. (2019). Microsoft Excel 2019 Formulas and Functions. Pearson Education
- Salkind N. J. (2016). Statistics for People Who (Think They) Hate Statistics: Using Microsoft Excel 2016. United States: SAGE Publications.

Enrichment, Isolation and identification of the following extremophiles from natural samples: Gram positive and Gram Negative:

- Mohammad B. T., Al Daghistani H. I., Jaouani A., Abdel-Latif S. and Kennes C. (2017). "Isolation and characterization of thermophilic bacteria from Jordanian hot springs: *Bacillus licheniformis* and *Thermomonas hydrothermalis* isolates aspotential producers of thermostable enzymes". International Journal of Microbiology. 2017: Article ID: 6943952. 1-12. https://doi.org/10.1155/2017/6943952
- Nakatsu C. H., Miller R. V., Yates M. V. and Pillai S. D. (2020). Manual of Environmental Microbiology. United States: Wiley. ISBN:9781555818821

Studying the stages of mitosis in growing tip of onion root cells and to observe polyploidy induced by colchicine treatment on root tip:

- Manzoor A., Ahmad T., Bashir M. A., Hafiz A. and Silvestri C. (2019). Studies on

colchicine induced chromosome doubling for enhancement of quality traits in ornamental plants. Plants.8:194. Doi: 10.3390/plants8070194.

Demonstration of mounting of embryos (fruit fly) at various developmental stages on permanent slides

- Gilbert S. F. and Barresi M. J. F. (2020). Developmental Biology. United States: Oxford University Press.
- http://egyankosh.ac.in/bitstream/123456789/16459/1/Unit-25.pdf

Extraction of Protein and Exo-polysaccharide

- Bajpai V. K., Majumder R., Rather I. A. and Kim K. (2016). "Extraction, isolation and purification of exopolysaccharide from lactic acid bacteria using ethanol precipitation method". Bangladesh journal of pharmacology. 11(3): 573-576. doi: 10.3329/ bjp.v11i3.27170

Colorimetry and spectrophotometry:

- Jayaraman J. (2004). Laboratory Manual in Biochemistry. India: New Age International (P) Limited Publishers.
- Plummer M. and Plummer D.T. (2001). Introduction to practical biochemistry. 3rd Edition, Tata McGraw- Hill Edition.
- Prasad S., Mandal I., Singh S., Paul A., Mandal B., Venkatramani R. and Swaminathan R. (2017). Near UV-Visible electronic absorption originating from charged amino acids in a monomeric protein. Chem. Sci. 8: 5416 —5433. Royal Society for Chemistry.
- Sadasivam S. and Manickam A. (2008). Biochemical methods. 3rd Edition, New Age International Publishers, India.
- https://www.ruf.rice.edu/~bioslabs/methods/protein/abs280.html

Interpretation of Ramachandran

- Bansal M. and Srinivasan N. (2013). Biomolecular Forms and Functions: A Celebration of 50 Years of the Ramachandran Map. Singapore: World Scientific.
- Bourne P. E. (2011). Structural Bioinformatics. Germany: Wiley.
- Ramachandran G.N., Ramakrishnan C. and Sasisekharan V. (1963). Stereochemistry of Polypeptide Chain Configurations. J. Mol. Biol. 7: 95-99
- Pazos F. and Chagoyen M. (2014). Practical Protein Bioinformatics. Germany: Springer International Publishing

MB 510 RM- Research Methodology
Compulsory Theory Paper
Total: 2 Credits Workload :-15hrs/credit

(Total Workload:-2 credits x 15 hrs =30 hrs in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	Understand research terminology
CO 2	Describe quantitative, qualitative and mixed methods approaches to research
CO 3	Identify the components of a literature review process
CO 4	Analyze and interpret the research
CO 5	Apply ethical principles of research in preparation of scientific documents

MB 510 RM- Research Methodology Compulsory Theory Paper Total: 2 Credits Workload :-15hrs/credit (Total Workload:-2 credits x 15 hrs =30 hrs in semester)		
Credit	**Credit Title and Contents**	**Number of Lectures**
I	1. History of research. 2. Research concept: Definition, Characteristics, Objectives, Utility 3. Types of Research: Descriptive vs. Analytical Research; Applied vs. Fundamental Research; Quantitative vs. Qualitative Research; Conceptual vs. Empirical Research 4. Problem Identification & Formulation: Formulating the research problem, Defining the research problem, Origin of the research problem 5. Literature Review: Purpose of the literature review, Types of information and sources, Primary and secondary sources 6. Research Objectives 7. Research design: Types of research design (descriptive research design, correlational research design, experimental research design, explanatory research design) 8. Research methods: Quantitative research, Qualitative research, Experimental research, and mixed methods approaches, Data Analysis and Interpretation, Sample collection and processing techniques (Water, soil, air and medical) 9. Citation: Methods, Bibliography, citation rules 10. Current trends in Research: Mono-disciplinary Research, Trans-disciplinary Research, Inter-disciplinary Research, Threats and Challenges to Good Research	15

II	1. Data Presentation: Presentation skills, formal scientific presentation skills; Preparing power point presentation, Presenting the work, Scientific poster preparation 2. Research report writing: Purpose of the writing, Types and Formats of scientific reports, scientific writing skills, Significance of communicating science, ethical issues, Copy rights and plagiarism, Components of a research paper 3. Preparation of Project Proposal – Time frame and work plan – Budget and Justification	15

Suggested References : MB 510 RM- Research Methodology

Suggested References:

1. Research in Medical and Biological Sciences: From Planning and Preparation to Grant Application and Publication. (2015). Netherlands: Elsevier Science.
2. Arora, R. (2004). Encyclopedia of Research Methodology in Biological Sciences. India: Anmol Publications Pvt. Limited.
3. Handbook of Research Methodology: A Compendium for Scholars & Researchers. (2017). Educreation Publishing.
4. Kumar, R. (2010). Research Methodology: A Step-by-Step Guide for Beginners. United Kingdom: SAGE Publications.

MB 510 RMP: Research Methodology
Compulsory Practical Paper
Total: 2 Credits Workload :-30hrs/credit
(Total Workload:-2 credits x 30 hrs =60 hrs in semester)

Credit	Title and Contents	Number of hours
	Seminar presentations, group activities, and scientific writing sessions based on above theory course. These will include but not limited to- 1. Use of search engines for scientific data mining 2. Use of reference management tools 3. Preparing power point presentation 4. Statistical data analysis using software 5. Presenting a research article 6. Writing an abstract for a research paper 7. Preparing a graphical abstract using software 8. Writing a concept note for research project 9. Scientific poster preparation & presentation 10. Writing a scientific news article or a science blog 11. Preparing and scientoon **12.** Participating in group discussions, conferences, symposia etc.	**60**

MB 505 MJ: Microbial Extremophiles
Group I Major Elective Theory
Total: 2 Credits Workload:-15hrs. /credit
(Total Workload:-2 credits x 15 hrs. = 30 hrs in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	study of extremophiles - microorganisms surviving under harsh conditions
CO 2	applications at industrial level of extremophiles
CO 3	mechanisms of surviving of extremophiles under harsh conditions
CO 4	classes of extremophiles

MB 505 MJ: Microbial Extremophiles
Group I Major Elective Theory
Total: 2 Credits Workload:-15hrs. /credit
(Total Workload:-2 credits x 15 hrs. = 30 hrs in semester)

Credits	**Credit Title and Contents**	**Number of Lectures**
I	**Microbial Extremophiles I** 1. Diversity of Extremophiles 2. Microbial forms of extremophiles in various habitats. 3. Sample Collection, Enrichment, isolation, classification, 4. Properties, and application of extremophiles: Thermophiles, Psychrophiles, Acidophiles and Alkaliphiles 5. Adaptation mechanisms of extremophiles	15
II	**Microbial Extremophiles II** 1. Sample Collection, Enrichment, isolation, classification, properties, and application of extremophiles: Halophiles, Piezophiles (Barophiles), Xerophiles and Oligophiles 2. Adaptation mechanisms of extremophiles 3. Biotechnological Applications of extremophilic Bacteria 4. Recent developments in extremophilic Bacteria	15

Suggested References: MB 505 MJ-Microbial Extremophiles. Group I Major Elective Theory

Credit I: Microbial Extremophiles I

1. Gerday C. and Glansdorff N. (2009). Extremophiles. United Kingdom: Eolss Publishers. ISB 9781905839933
2. Horikoshi K., Stetter K. O., Antranikian G., Robb F. and Bull A. (2010). Extremophil Handbook. Germany: Springer.
3. Satyanarayana, T. & Raghukumar, C & Shivaji, Sisinthy. (2005). Extremophilic microb Diversity and perspectives. Current science. 89. 78-90.
4. Sharma V. and Salwan R. (2020). Physiological and Biotechnological Aspects of Extremophil Netherlands: Elsevier Science. ISBN: 9780128183236

Credit II: Microbial Extremophiles II

1. Subba Rao D. V. and Durvasula R. V. (2018). Extremophiles: From Biology to Biotechnology. United States: CRC Press. ISBN: 9781351650731
2. Stan-Lotter H., Oren A. and Seckbach J. (2013). Polyextremophiles: Life Under Multiple Forms of Stress. Netherlands: Springer Netherlands.
3. Coker JA. (2016) Extremophiles and biotechnology: current uses and prospect. F1000 Research. 5:396 (https://doi.org/10.12688/f1000research.7432.1)
4. Zhu Daochen, Adebisi Wasiu Adewale, Ahmad Fiaz, Sethupathy Sivasamy, Danso Blessing, Sun Jianzhong, Recent Development of Extremophilic Bacteria and Their Application in Biorefinery , Frontiers in Bioengineering and Biotechnology, 8 (2020) 1-18, ISSN=2296-4185
5. Merino Nancy, Aronson Heidi S., Bojanova Diana P., Feyhl-Buska Jayme, Wong Michael L., Zhang Shu, Giovannelli Donato, Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context, Frontiers in Microbiology, 10 (2019) 1-25, ISSN=1664-302X

MB 505 MJP -Practicals based on Microbial ExtremophilesGroup I Major Elective Practical

Total: 2 Credits Workload:-15hours/credit

(Total Workload:-2 credits x 30 hours = 60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	Technical details pertaining to samples required for isolation of extremophilic microbes
CO 2	Methods to isolate and identify extremophilic microbes from different sources such as thermophiles / psychrophiles / acidophiles
CO 3	To build identification key for extremophilic microbes
CO 4	Identify extremophilic microbes using such keys

CO5	Technical details pertaining to samples required for isolation of extremophilic microbes
CO6	Methods to isolate and identify extremophilic microbes from different sources such as halophiles / alkaliphiles / oligophiles
CO7	To build identification key for extremophilic microbes
CO8	Identify extremophilic microbes using such keys

MB 505 MJP -Practicals based on Microbial Extremophiles
Group I Major Elective Practical
Total: 2 Credits Workload:-15hours/credit
(Total Workload:-2 credits x 30 hours= 60 hours in semester)

Credit	Credit Title and Contents	Number of Hours
I	**Microbial Extremophiles I: (Thermophiles/Psychrophiles/Acidophiles** 1. Sample Collection, Processing and Isolation 2. Morphological characterization of indigenous isolates based on staining techniques *3.* Identification using Biochemical Tests *(Using Bergey's Manual)* 4. (At least 4 different types of samples should be processed to obtain representative isolate of the groups)	30
II	**Microbial Extremophiles II:** **(Halophiles/Alkaliphiles/Oligophiles)** 1. Sample Collection, Processing & Isolation 2. Morphological characterization of indigenous isolates based on staining, techniques *3.* Identification using Biochemical Tests *(Using Bergey's Manual)* (At least 4 different types of samples should be processed to obtain representative isolate of the groups)	30

Suggested References MB 505 MJP -Practicals based on Microbial Extremophiles
Group I Major Elective Practical

Isolation and identification of the following extremophiles from natural samples:
Acidophiles: -

1. Joe S. J., Suto K., Inoie C. and Chida T. (2007). Isolation and characterization of acidophil heterotrophic iron-oxidizing bacterium from enrichment culture obtained from acid mine drainage treatment plant. J BiosciBioeng. 104(2):117-123. doi: 10.1263/jbb.104.117.
2. Ňancucheo I., Rowe O. F., Hedrich S. and Johnson D. B. (2016). Solid and liquid media fo isolating and cultivating acidophilic and acid-tolerant sulfate-reducing bacteria, FEMS Microbiology Letters, 363: 10, fnw083. https://doi.org/10.1093/femsle/fnw083

3. Sánchez-Andrea I., Stams A. J., Amils R. and Sanz J. L. (2013). Enrichment and isolation acidophilic sulfate-reducing bacteria from Tinto River sediments. Environ Microbiol Rep. 5(5): 672-678. doi: 10.1111/1758-2229.12066

Halophiles: -

4. Gupta S., Sharma P., Dev K., Srivastava M. and Sourirajan A. (2015). A diverse group of halophilic bacteria exist in Lunsu, a natural salt water body of Himachal Pradesh, India. Springer Plus 4: 274. https://doi.org/10.1186/s40064-015-1028-1
5. Kumar S., Karan R., Kapoor S., Singh S. P. and Khare S. K. (2012). Screening and isolatic of halophilic bacteria producing industrially important enzymes. Braz J Microbiol. 43(4): 1595–1603. doi: 10.1590/S1517-838220120004000044
6. Yeannes M. I., Ameztoy I. M., Ramirez E. E. and Felix M. M. (2011). Culture alternative medium for the growth of extreme halophilic bacteria in fish products. Food Science and Technology. 31(3): 561-566. https://doi.org/10.1590/S0101- 20612011000300002

MB 506 MJ -Microbial communication, Membrane transport and signal transduction
Group I Major Elective Theory

Total: 2 Credits Workload:-15hours /credit
(Total Workload:-2 credits x 15 hours = 30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	Students will be aware of quorum sensing phenomenon with molecular mechanisms in Myxobacteria and molecular mechanisms
CO 2	Developing insights of quorum sensing in gram negative and gram positive bacteria
CO 3	Will become acquainted with formation and dispersal of biofilm and extrapolate applications of biofilm in pathogenic and nonpathogenic bacteria
CO 4	Will have gained in depth knowledge of membrane dynamics, architecture and composition and solute and ion mediated transport mechanisms.
CO5	Students will get knowledge about the signal transduction mechanism and chemotaxis in microorganisms

MB 506 MJ -Microbial communication, Membrane transport and signal transduction
Group I Major Elective Theory

Total: 2 Credits Workload:-15hours /credit
(Total Workload:-2 credits x 15 hours = 30 hours in semester)

Credit	**Credit Title. and Contents**	**Number of Lectures**
I	**Communication and Coordination among microorganisms** 1. Life cycle of *Dictyostelium discoideum*, Molecular mechanism of quorum sensing in slime molds,	15

	2. Life cycle of myxobacteria, Molecular mechanism of quorum sensing in myxobacteria. 3. Quorum sensing in Gram positive and Gram-negative bacteria 4. Biofilms, their organization, signals involved in their formation and dispersal 5. Applications of study on biofilms in pathogenic and non-pathogenic environments	
II	**Membrane transport and signal transduction** 1. The composition and architecture of membranes, Membrane dynamics 2. Solute transport across membranes: Passive diffusion, facilitate transport, primary and secondary active transport using P, V and type ATPases 3. Ionophores, Ion mediated transport, transport of ions across membranes (ion pumps), ligand and voltage gated ion channels 4. Liposomes and model membrane Signal transduction pathways i bacteria, second messengers, regulation of signaling pathways, bacterial two-component systems, chemotaxis.	15

Suggested References: MB 506 MJ -Microbial communication, Membrane transport and signal transduction

Group I Major Elective Theory

Credit I: Communication and Coordination among microorganisms

1. Gilbert S. F. (2010). Developmental Biology. 9th Ed. Sinauer Associates Inc. Mass. USA.
2. Dworkin M. (1996) Recent advances in the social and developmental biology of the myxobacteria, Microbiological Reviews: 70–102
3. Dale K., Mark R. and Lee K. (2010) Myxobacteria, Polarity, and MulticellularMorphogenesi Cold Spring Harb Perspect Biol 2010; 2: a000380
4. Toole ‘O’ G., Kaplan H. B. and Kolter R. (2000) Biofilm formation as microbial developme Annual Review of Microbiology: 54: 49-79.
5. Miller M. B. and Bassler B. L. (2001) Quorum sensing in bacteria. Annu. Rev.Microbiol. 55: 165–99.
6. Waters C. M. and Bassler B. L. (2005) Quorum sensing: cell-to-cell communication in bacteria. Annu. Rev. Cell Dev. Biol. 21: 319–346.

Credit II: Membrane transport and signal transduction

1. Alberts B., Johnson A., Lewis J., Morgan D., Raff M., Roberts, K. and Walter P. (201 Molecular Biology of the Cell. 6th edition. Garland Science; Taylor and Francis Group.Ne York. ISBN: 9781317563754
2. Cantley L. C., Sever R. and Hunter T. (2014). Signal Transduction: Principles, Pathways, a Processes. United States: Cold Spring Harbor Laboratory Press.
3. Changeux J., Comoglio, P., Sandhoff, K., Schatz G., Pinna L., Tager J., Orrenius S., Jaenic R. (2012). Biochemistry of Cell Membranes: A Compendium of Selected Topics. Switzerlar

Springer Basel AG.
4. Evangelopoulos A.E., Changeux J.P., Wirtz K.W.A., Packer L. and Sotiroudis T.G. (201 Receptors, Membrane Transport and Signal Transduction. Germany: Springer Berl Heidelberg.
5. Fairweather I. Cell Signaling in Prokaryotes and Lower Metazoa. (2004). Germany: Springer Netherlands.
6. Pabst G. (2014). Liposomes, Lipid Bilayers and Model Membranes: From Basic Research to Application. United Kingdom: Taylor & Francis.
7. Sperelakis N. (2012). Cell Physiology Source Book: Essentials of Membrane Biophysics. Netherlands: Elsevier Science.
8. Stein W. D. and Litman T. (2014). Channels, Carriers, and Pumps: An Introduction to Membrane Transport. Netherlands: Elsevier Science.
9. Wardhan R. and Mudgal P. (2018).Textbook of Membrane Biology.Singapore: Springer Singapore

MB 506 MJP - Practicals Based on Microbial communication, Membrane transport and signal transduction

Group I Major Elective Practicals

Total: 2 Credits Workload:-15hours/credit

(Total Workload:-2 credits x 30 hours = 60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	Gaining insights into the biofilm formation and determination of quorum sensing signals in bacteria.
CO 2	Will have learnt the chemotaxis response by various methods
CO 3	Will be able to study mechanism of osmosis and diffusion with effect of various physical and chemical factors.
CO 4	Will comprehend the details of cell disruption methods and effect of transport by swab testing.

MB 506 MJP- Practicals Based on Microbial communication, Membrane transportand signal transduction **Group I Major Elective Practicals** Total: 2 Credits Workload:-15hours/credit **(Total Workload:-2 credits x 30 hours = 60 hours in semester)**		
Credit	**Credit Title and Contents**	**Number of Hours**
I	**Practicals Based on Credit I: Microbial Communication and Coordination among microorganisms** 1. Crystal violet assay for estimation of biofilm formation	30

	2. Bioassay for determination of quorum sensing signals produced by bacteria 3. Determination of chemo-taxis responses shown by bacteria using agar plate or capillary tube method	
II	**Practicals Based on Credit II: Membrane transport and signal transduction** 1. Study principles of osmosis and diffusion using artificial membranes (dialysis membrane) (explain how various physical and chemical factors affect the diffusion) 2. Different methods of cell disruption 3. Swab evaluation with respect to transport of bacterial sample	30

Suggested References: MB 506 MJP- Group I Major Elective Practicals
Practicals Based on Microbial communication, Membrane transport and signal transduction

Practical based on Credit I: Microbial Communication and Coordination among microorganisms

1. Crystal violet assay for estimation of biofilm formation:

- O'Toole G. A. (2011) Microtiter dish biofilm formation assay. Journal of Visualized Experiments. 47:3–5. doi: 10.3791/2437.
- Merritt J. H., Kadouri D. E. and O'Toole G. A. Growing and analyzing static biofilms. Curr. Protoc. Microbiol. 2006 doi: 10.1002/9780471729259.mc01b01s00.

2. Bioassay for determination of quorum sensing signals produced by bacteria:

- Martín-Rodríguez A. J. and Fernández J. J. (2016). A bioassay protocol for quorum sensing studies using *Vibrio campbellii*. Bio Protoc. 6: e1866
- Papenfort K. and Bassler B. (2016). Quorum sensing signal-response systems in Gram-negative bacteria. Nat. Rev. Microbiol. 14:576–588. 10.1038/nrmicro.2016.89.

3. Determination of chemo-taxis responses shown by bacteria.using agar plate or capillary tube method:

- Law A. M. J., Aitken M. D. (2005). Continuous-flow capillary assay for measuring bacterial chemotaxis. Appl. Environ. Microbiol.71: 3137–3143. 10.1128/AEM.71.6.3137- 3143.2005,

Practical based on Credit II: Membrane transport and signal transduction

4. Study principles of osmosis and diffusion using artificial membranes (dialysis membrane) (explain how various physical and chemical factors affect the diffusion):

- Ravindra Babu B., Rastogi N.K. and Raghavarao K.S.M.S. (2006). Effect of process parameters on transmembrane flux during direct osmosis. Journal of Membrane Science. 280(1–2): 185-194
- Stillwell W. (2016). Membrane Transport. An Introduction to Biological Membranes. 23– 451. doi: 10.1016/B978-0-444-63772-7.00019-1. PMCID: PMC7182109

5. Different methods of cell disruption:

- https://microbenotes.com/cell-disruption-methods/
- Islam M. S., Aryasomayajula A. and Selvaganapathy P. R. (2017). A Review on Macroscale and Microscale Cell Lysis Methods. Micromachines (Basel). 8(3): 83. doi: 10.3390/mi8030083 Swab evaluation with respect to transport of bacterial sample:
- Human R. P. and Jones G. A. (2004). Evaluation of swab transport systems against a published standard. J Clin Pathol. 57:762–763. doi: 10.1136/jcp.2004.016725.

……

MB 507 MJ - Advanced Quantitative Biology
Group II Major Elective Theory

Total: 2 Credits Workload:-15 hours /credit
(Total Workload:-2 credits x 15 hours = 30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	To appreciate the variation among the independent and dependent variables
CO 2	The method of treatment of numerical biological data from different populations to evaluate the variation among them
CO 3	The method of understanding and analysis of relationship between outcome and several predictor variables in biology
CO 4	To appreciate the difference among analysis qualitative and quantitative data.
CO 5	The techniques to analyze the data based upon categorical variables in biology
CO 6	Methodology to determine the relation among qualitative variables in biology

B 507 MJ - Advanced Quantitative Biology
Group II Major Elective Theory

Total: 2 Credits Workload:-15 hours /credit
(Total Workload:-2 credits x 15 hours = 30 hours in semester)

Credit	**Credit Title and Contents**	**Number of Lectures**
I	**Inferential Statistics-2** 1. F-test: Introduction and hypothesis testing using F- test 2. Analysis of variance – Introduction, assumptions and types of ANOVA, hypothesis testing using one way ANOVA, two way ANOVA, 3. Post Hoc analysis: Fischer's least significant difference test, Tukey's test 4. Multiple linear regression: Definition, overview, assumptions and applications in analysis of biological data with examples	15
II	**Non-parametric tests:** 1. Introduction, Comparison to parametric tests, assumptions.	15

	2. Chi square test – Overview, assumptions, Hypothesis testing using Chi square test for Goodness of fit and Independence 3. Run test for randomness of observations 4. Hypothesis testing using: a) Sign test, b) Wilcoxon's signed rank test c) Mann-Whitney test d) Kruskal- Wallis test e) Friedman test 5. Correlation coefficient – Spearman's rank correlation coefficient *(Biological examples/data should be used)*	

Suggested References MB 507 MJ - Advanced Quantitative BiologyGroup II Major Elective Theory

1. Bailey N. T. J. (1995). Statistical methods in Biology. 3rd Edition. Cambridge University Press
2. Brown D. and Rothery P. (1993). Models in Biology: Mathematics, Statistics and Computing. John Wiley &Sons, USA. ISBN: 9780471933229
3. Daniel W. W. and Cross C. L. (2007), Biostatistics A foundation for Analysis in the Health Sciences. Wiley. ISBN: 978-1-119-49657-1
4. Feller W. (1967). Introduction to probability theory and its applications. Volume I. John Wiley and Sons.
5. Feller W. (1991). Introduction to probability theory and its applications. Volume II. 2nd Edition. Wiley. ISBN: 978-0-471-25709-7
6. Gupta S. P. (2021). Statistical Methods. 46th Edition. Sultan Chand & Sons Publisher, New Delhi. ISBN: 978-93-5161-176-9
7. Haefner J. W. (1996). Modeling Biological Systems: Principles and Applications. 2nd Edition. Springer. ISBN-13: 978-0387-2501 1-3
8. Khan I. A. and Khanum A. (2004). Fundamentals of Biostatistics. 3rd Edition. Ukaaz Publications, Hyderabad. ISBN: 8190044109, 9788190044103
9. Lindgren B. W. (1976). Statistical Theory. 3rd Edition Macmillan Publishing Co. Inc. ISBN 13: 9780023708305
10. McNeil B. and Harvey L. (2008). Practical Fermentation Technology. Wiley InterScience. ISBN 978-0-470-01434-9
11. Montgomery D. C. (2019). Design and Analysis of Experiments. 10th Edition. Wiley. ISBN: 978-1-119-49244-3
12. Newman S. C. (1952). Biostatistical Methods in Epidemiology. John Wiley & Sons.
13. Petrie A. and Sabin C. (2019). Medical Statistics at a Glance. 5nd Edition. Wiley
14. Rosner B. (2015). Fundamentals of Biostatistics. 8th Edition. Publisher: Cengage Learning. ISBN: 1305465512, 9781305465510

15. Sundar Rao P. S. S. and Richard J. (2012). Introduction to Biostatistics and Research Methods. 5th Edition. PHI Learning Private Limited, New Delhi

……

MB 507 MJP -Practicals Based on Advanced Quantitative Biology
Group II Major Elective Practical
Total: 2 Credits Workload:-30hours/credit
(Total Workload:-2 credits x 30 hrs =60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	To appreciate the way the biological variables are distributed in nature
CO 2	Methodology of experimentation in biology and generation of the data
CO 3	The methods of processing the biological data and make inferences.
CO 4	Use of different software to process the numerical data and its interpretation

MB 507 MJP -Practicals Based on Advanced Quantitative Biology **Group II Major Elective Practical** Total: 2 Credits Workload:-30hours/credit **(Total Workload:-2 credits x 30 hrs =60 hours in semester)**	
Credit Title and Contents	**Number of Hours**
1. Analysis of data using parametric and non-parametric tests, comparison of results and interpretation (*using hypothetical data*). *2.* Study the effect of environmental factors pH, temperature, salt, sugar (any two factors) on growth of bacteria using statistical tests (*Experimentation, data collection, analysis of data using suitable statistical technique and interpretation should be carried out).* 3. Applications of probability distribution (Normal, Binomial and Poisson distributions) to analyze the data 4. Computer applications: Statistical analysis of data – t-Test, ANOVA, Chi square test, F test using computer softwares (*Using Microsoft Excel or other software*)	60

Suggested References: MB 507 MJP -Practicals Based on Advanced Quantitative Biology Group II Major Elective Practical

1. Bailey N. T. J. (1995). Statistical methods in Biology. 3rd Edition. Cambridge University Press
2. Brown D. and Rothery P. (1993). Models in Biology: Mathematics, Statistics and Computing. John Wiley &Sons, USA. ISBN: 9780471933229
3. Daniel W. W. and Cross C. L. (2007), Biostatistics A foundation for Analysis in the Health Sciences. Wiley. ISBN: 978-1-119-49657-1
4. Feller W. (1967). Introduction to probability theory and its applications. Volume I. John Wiley and Sons.
5. Feller W. (1991). Introduction to probability theory and its applications. Volume II. 2nd Edition. Wiley. ISBN: 978-0-471-25709-7
6. Gupta S. P. (2021). Statistical Methods. 46th Edition. Sultan Chand & Sons Publisher, New Delhi. ISBN: 978-93-5161-176-9
7. Haefner J. W. (1996). Modeling Biological Systems: Principles and Applications. 2nd Edition. Springer. ISBN-13: 978-0387-2501 1-3
8. Khan I. A. and Khanum A. (2004). Fundamentals of Biostatistics. 3rd Edition. Ukaaz Publications, Hyderabad. ISBN: 8190044109, 9788190044103
9. Lindgren B. W. (1976). Statistical Theory. 3rd Edition Macmillan Publishing Co. Inc. ISBN 13: 9780023708305
10. McNeil B. and Harvey L. (2008). Practical Fermentation Technology. Wiley InterScience. ISBN 978-0-470-01434-9
11. Montgomery D. C. (2019). Design and Analysis of Experiments. 10th Edition. Wiley. ISBN: 978-1-119-49244-3
12. Newman S. C. (1952). Biostatistical Methods in Epidemiology. John Wiley & Sons.
13. Petrie A. and Sabin C. (2019). Medical Statistics at a Glance. 5nd Edition. Wiley.
14. Rosner B. (2015). Fundamentals of Biostatistics. 8th Edition. Publisher: Cengage Learning. ISBN: 1305465512, 9781305465510
15. Sundar Rao P. S. S. and Richard J. (2012). Introduction to Biostatistics and Research Methods. 5th Edition. PHI Learning Private Limited, New Delhi.

MB 508 MJ -Experimental Design and Quantitative approach for Biologists

Group III Major Elective Theory

Total: 2 Credits Workload:-15hours/credit

(Total Workload:-2 credits x 15 hours=30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
Credit I:	
CO 1	Students will be able to gain knowledge about research methodology in detail.
CO 2	Students will be able to hypothesize the probabilistic statements and make predictions about the data under study.
CO 3	Students will be able to identify, select, and tabulate data under study.
CO 4	Students will be able to learn experimental designs and understand improved process and able to build confidence making informed decisions about the data
CO 5	Students will be able to learn the relationships between multiple input and output variables.
CO 6	Students will be able to learn epidemiology, able to use, comment and criticize various epidemiological methods.
Credit II	
CO 1	Students will be able to learn basics about numbers. .
CO 2	Students will be able to perform comparative study about different types of mathematical functions.
CO 3	Students will be able to correlate exponential function, bacterial growth and bacterial death
CO 4	Students will be able to learn mathematical basis of 12-D concept in autoclaving
CO 5	Students will be able to apply differentiation and integration in biology.
CO 6	Students will be able to apply mathematical and computational skills in real life.
CO 7	This course will enhance quality of student's mathematical, analytical and creative skills
CO 8	This course will enable the students and the faculty to become lifelong learners and practitioners of mathematics

MB 508 MJ -Experimental Design and Quantitative approach for Biologists Group III Major Elective Theory		
Credits	**Credit Title and Contents**	**Number of Lectures**
I	**Design of Experiments:** 1. Sampling methods (Random and non-random), sampling errors 2. Survey design, DOE in Agriculture, principles (randomization, replication and local control), types of experimental designs (CRD, RCBD and LSD) 3. Factorial design (Full, Fractional and Plackett Burman) 4. Epidemiological Study designs: Case control, cohort, concurrent,	15

	cross-sectional, retrospective/prospective 5. Clinical/field trials-Randomization, Bias removal (Blinding single and double), controlled and uncontrolled trials	
II	**Quantitative approach for Biologists** 1. Concept of Real numbers and Imaginary numbers (1 lecture) 2. Dependent and Independent variables and concept of Mathematical Function, symbolic representation of function as f(x) etc 3. Different types of Functions: a. Linear Function: properties of linear functions, graphical representations. Examples in Biology (e.g. all estimations using extrapolation of measurements on graphs, linear growth of microbes logN=logN0+ Kt and many more) b. Exponential Function: properties of exponential functions, graphical representations. Examples in Biology (bacterial growth, thermal inactivation of microbes mathematical basis of 12 D concept in autoclaving, radioactive decay) c. Power Function: Exponential Function: properties of power functions, graphical representations. Examples in Biology rate kinetics where more than one substrate molecules bind to multimeric enzymes, kinetics of binding of bivalent or multivalent antibodies to antigen) 4. Introduction to Differentiation and Integration. Applications in Biology. Note: No descriptive questions on this syllabus. Only solving the problems.	15

Suggested References: MB 508 MJ -Experimental Design and Quantitative approach for Biologists Group III Major Elective Theory

1. Arya J. C and Lardner R. W. (1983). Mathematics for the Biological Sciences. Published online by Cambridge University Press: 22 September 2016. ISBN 0-13-362611-0 (Prentice-Hall).
2. Brown D. and Rothery P. (1993). Models in Biology: Mathematics, Statistics and Computing. John Wiley &Sons, USA. ISBN: 9780471933229
3. Daniel W. W. and Cross C. L. (2007), Biostatistics A foundation for Analysis in the Health Sciences. Wiley. ISBN: 978-1-119-49657-1
4. Doran P. M. (2012). Bioprocess Engineering Principles. 2nd Edition Elsevier Science & Technology Books. ISBN: 9780122208515
5. Haefner J. W. (1996). Modeling Biological Systems: Principles and Applications. 2nd Edition. Springer. ISBN-13: 978-0387-2501 1-3
6. Khan I. A. and Khanum A. (2004). Fundamentals of Biostatistics. 3rd Edition. Ukaaz Publications, Hyderabad. ISBN: 8190044109, 9788190044103

7. Montgomery D. C. (2019). Design and Analysis of Experiments. 10th Edition. Wiley. ISBN: 978-1-119-49244-3
8. Park K. (2020), Park's Textbook of Preventive and social Medicines. 25th Edition. Banarsidas Bhanot Publishers. ISBN: 9780195647068

MB 508 MJP -Practicals Based on Experimental Design and Quantitative approach for Biologists
Group III Major Elective Practical (Elective)

Total: 2 Credits Workload:-30 hours /credit
(Total Workload:-2 credits x 30 hours=60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	To prepare the research proposal as per the standards
CO 2	To prepare the epidemiological study proposal, and carry out investigation as per the standards and analysis of the data
CO 3	Selection of appropriate design for an experiment and statistical analysis of the responses using software
CO 4	To use the mathematical calculations for preparation of solutions.
CO 5	To solve, interpret and give proper treatment to the mathematical problems based on biological applications
CO 6	Treatment of biological data and its statistical analysis with the aid of software.

MB 508 MJP: Practicals Based on Experimental Design and Quantitative approach for Biologists
Group III Major Elective Practical (Elective)

Total: 2 Credits Workload:-30 hours /credit
(Total Workload:-2 credits x 30 hours=60 hours in semester)

Credits	Credit Title & Contents	Number of Hours
I	**Design of experiments;** 1. Designing Mock Research Proposal which includes: a) Title b) Hypothesis c) Review of Literature *d)* Methodology *(Specify Statistical Methods)* *e)* Possible outcomes *(Statistical Interpretations)* f) References (*Scientific writing should be followed for Research proposal*) **2. Epidemiological study Proposal *(Mini Project)*:** a) Identification of Problem and Establishing Hypothesis b) Selection of Design c) Data Collection d) Data Analysis e) Data Presentation	30

	f) Conclusion (*Scientific writing should be followed for proposal*) **3. Statistical Survey:** a) Identification of Problem and Establishing Hypothesis b) Survey Design (Questionnaire based) c) Preparation of Questionnaire d) Data Collection e) Data Analysis f) Data Presentation g) Conclusion of Survey (*Actual statistical survey need to be carried out to demonstrate its mechanism*) **4. Factorial Study Design (Placket barmen, Fractional Factorial and full factorial) for Optimization of Media conditions:** a. Data collection from Research Papers/Dissertations/Journals b. Data Treatment using Statistical Software's (Microsoft Excel, Minita SPSS and Design Expert) (*Sr.no.1 is compulsory, select any one from sr.no.2 to 4*)	
II	**Quantitative approach for Biologists:** 1. Numerical Microbiology: Problem solving: Unit conversion, preparation of standard solutions (Wt/V, V/V, %, Normal solution, Molar solutions etc.), Numerical Problems on size, volume, number (CFU and PFU), dilutions, Neubauer chamber, direct Microscopic count, Numerical Problems on Bacterial Growth. Numerical problems on diversity indices. 2. Computer applications: Using data sheets, and sorting data with different parameters, plotting graphs–bar charts, line graphs, pie charts, adding error bars. Statistical analysis of data – Students t test, ANOVA, Chi square test, F test using computer software *(Using Statistical Packages*)	30

Suggested References: MB 508 MJP: Practicals Based on Experimental Design andQuantitative approach for Biologists
Group III Major Elective Practical (Elective)

1. Arya J. C and Lardner R. W. (1983). Mathematics for the Biological Sciences. Published online by Cambridge University Press: 22 September 2016. ISBN 0-13-362611-0 (Prentice-Hall).
2. Brown D. and Rothery P. (1993). Models in Biology: Mathematics, Statistics and Computing. John Wiley &Sons, USA. ISBN: 9780471933229
3. Daniel W. W. and Cross C. L. (2007), Biostatistics A foundation for Analysis in the Health Sciences. Wiley. ISBN: 978-1-119-49657-1
4. Doran P. M. (2012). Bioprocess Engineering Principles. 2nd Edition Elsevier Science & Technology Books. ISBN: 9780122208515
5. Haefner J. W. (1996). Modeling Biological Systems: Principles and Applications. 2nd

Edition. Springer. ISBN-13: 978-0387-2501 1-3

6. Khan I. A. and Khanum A. (2004). Fundamentals of Biostatistics. 3rd Edition. Ukaaz Publications, Hyderabad. ISBN: 8190044109, 9788190044103
7. Montgomery D. C. (2019). Design and Analysis of Experiments. 10th Edition. Wiley. ISBN: 978-1-119-49244-3
8. Park K. (2020), Park's Textbook of Preventive and social Medicines. 25th Edition. Banarsidas Bhanot Publishers. ISBN: 9780195647068

……...

M. Sc. Microbiology Part I Semester II

MB 551 MJ - Molecular Biology I
Compulsory Theory Paper
Total: 4 Credits Workload:-15 hours /credit
(Total Workload:-4 credits x15 hours=60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	To remember the basic differences between the Eukaryotic and the Prokaryotic Genome organization-working
CO 2	To understand the regulation of Eukaryotic and Prokaryotic Gene expression with examples
CO 3	To apply recombinant DNA technology and genetic engineering in the field of molecular Biology
CO 4	To analyze and evaluate the molecular diagnostic techniques and itsapplications

MB 551 MJ - Molecular Biology I
Compulsory Theory Paper
Total: 4 Credits Workload:-15 hours /credit
(Total Workload:-4 credits x15 hours=60 hours in semester)

Credit	**Credit Title and Contents**	**Number of Lectures**
I	1. Prokaryotic Genome organization, DNA replication, Mutagenesis and DNA repair. 2. Eukaryotic Genome organization, DNA replication and recombination, Chromatin remodeling, Histone modification and its effect on the function of chromatin, C value paradox, Rot and Cot concept, pseudogenes, 3. Transcription and Regulation in Prokaryotes and Eukaryotes: RNA polymerases, transcription unit, positive and negative regulation, role of attenuators, anti-termination	15
II	1. Prokaryotic and Eukaryotic translation: role of initiation factors, Shine-Dalgarno sequences, Kozak sequence, translocation of ribosomes, Role of elongation factors, termination codons and	15

	role of release factors, fidelity of translation, Puromycin translation assay. 2. Eukaryotic RNA Processing: i. mRNA splicing (Spliceosome and auto splicing by Intron I and Intron II); rRNA processing; tRNA processing; RNA Editing, ii. Nuclear export of mRNA iii. Regulatory RNAs and noncoding RNAs: Si RNA, Micro RNA, RNA interference (RNAi) iv. CRISPER-cas system. 3. Molecular Techniques: yeast two and three hybrid assay, Activity gel assay, DNA helicase assay, Chromatin Immuno-precipitation (ChIP), Designing probe, Epitope tagging	
III	1. Enzymes used in Recombinant DNA technology; Restriction endonuclease, DNA ligase, T4 DNA polymerase, Terminal transcriptase, Alkaline phosphatase, polynucleotide kinase 2. Cohesive and blunt end ligation, linkers; adaptors; homopolymeric tailing labeling of DNA: 3. Nick translation, random priming, radioactive and nonradioactive probes 4. Hybridization techniques: Northern, Southern, south-western and far-western and colony hybridization, fluorescence in situ hybridization. 5. Vectors for cloning and gene expression: i. Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Blue script vectors, Baculovirus and Pichia vectors, plant-based vectors (Ti and Ri as vectors). Vectors for gene expression: types (pMal, GST, pET-based vectors), 6. Construction of genomic DNA and cDNA libraries; Human and *E. coli* genome project: introduction and applications. Concept of comparative genomics	15
IV	**Molecular diagnostics and applications:** 1. Introduction to Microarray and array techniques, the lab-on-a-chip concept 2. Use of array techniques detection of polygenic diseases and diseases-associated changes in gene expression 3. Detection of RNA signatures of 'Antibiotic Resistance' in bacteria 4. Detection of microRNA (mi RNA): A signature of cancer diagnostics	15

Suggested References: MB 551 MJ - Molecular Biology I Compulsory Theory Paper

1. Ko T., Oliveira M. M., Alapin J. M., Morstein J., Klann E. and Trauner D. (2022). Optical Control of Translation with a Puromycin-Photoswitch. . Am. Chem. Soc. 144(47): 21494–21501.
2. Aviner R. (2020). The science of puromycin: From studies of ribosome function to applications in biotechnology. Comput Struct Biotechnol J. 18: 1074-1083. doi: 10.1016 /j.csbj.2020.04.014. PMID: 32435426; PMCID: PMC7229235.

3. Xu Y. and Li Z. (2020). CRISPR-Cas systems: Overview, innovations and applications in human disease research and gene therapy. Comput Struct Biotechnol J. 18: 2401-2415. doi: 10.1016/j.csbj.2020.08.031. PMID: 33005303; PMCID: PMC7508700.
4. Gupta S., Ramesh K., Ahmed S. and Kakkar V. (2016). Lab-on-Chip Technology: A Review on Design Trends and Future Scope in Biomedical Applications. International Journal of Bio-Science and Bio-Technology. 8: 311-322. 10.14257/ijbsbt.2016.8.5.28.
5. Goldstein E. S., Krebs J. E. and Kilpatrick S. T. (2017). Lewin's GENES XII. United States: Jones & Bartlett Learning.
6. Twyman R. and Primrose S. B. (2009). Principles of Genome Analysis and Genomics. Germany: Wiley James D. Watson, Tania Baker, Stephen P. Bell, Alexander Gann,
7. Levine M., Baker T. A., Losick R., Bell S. P., Watson J. D. and Gann A. (2014). Molecular Biology of the Gene. United Kingdom: Pearson..
8. Alberts B., Johnson A., Lewis J., Morgan D., Raff M., Roberts, K. and Walter P. (2015) Molecular Biology of the Cell. 6th edition. Garland Science; Taylor and Francis Group. New York. ISBN: 9781317563754.
9. Lodish H., Berk A., Kaiser C. A., Krieger M., Bretscher A., Ploegh H., Martin K. C., Yaffe M. and Amon A. (2021). Molecular Cell Biology. 9th Edition. Macmillan Learning.ISBN: 9781319208523
10. Weaver R. (2008) Molecular Biology, 4th Edition, McGrew Hill Science.
11. Glick B. R. and Patten C. L. (2017). Molecular Biotechnology: Principles and Applications of Recombinant DNA. United Kingdom: Wiley.

……

MB 552 MJ - Enzymology, Bioenergetics and Metabolism

Compulsory Theory Paper

Total: 4 Credits Workload:-15 hours /credit

(Total Workload: - 4 credits x15 hours = 60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO 1	understand about enzyme kinetics, the mechanisms of enzyme catalysis, and the mechanisms of enzyme regulation in the cell.
CO 2	gain knowledge of purification methods of enzymes. They will define terms related to thermodynamics. They will draw structure of hormones.
CO 3	conceive the concept of energy, cite examples and assess its importance to living organisms.
CO 4	understand the Kinetics of enzyme reactions and gain knowledge of role of enzyme inhibitors
CO 5	write metabolic pathways with respect to carbohydrate and lipid metabolism. They will solve problems based on enzyme kinetics, purification and thermodynamics.

CO 6	study metabolic pathways for various nitrogenous compounds.
CO 7	collect information about types and functions of micronutrients
CO 8	Students will summarize types of cooperativity and models of allosteric enzymes.

MB 552 MJ - Enzymology, Bioenergetics and Metabolism
Compulsory Theory Paper
Total: 4 Credits Workload:-15 hours /credit
(Total Workload:- 4 credits x15 hours = 60 hours in semester)

Credit	Credit Title and Contents	Number of Lectures
I	**Enzymology** 1. Overview: Purification of enzyme, purification chart 2. Overview: MM Equation and Kinetic Plots. 3. Kinetics of reversible inhibitions: Competitive, uncompetitive, non-competitive, mixed, substrate. Primary and secondary plots, Determination of Ki using secondary plots. Significance of inhibitors 4. King Altman approach to derive – two substrate enzyme catalyzed reactions 5. Concept of allosterism, positive and negative cooperativity, models of allosteric enzymes (Monad, Wyamann and Changeux and Koshland Nemethy and Filmer model), kinetics of allosteric enzymes, Hill plot, examples of allosteric enzymes and their significance in regulation.	15
II	**Bioenergetics and Biosynthesis of Nitrogenous Compounds** 1. Overview: Laws of thermodynamics, entropy, enthalpy, free energy, an equilibrium constant with reference to biological significance. 2. Gibbs free energy equation. 3. Determination of free energy of hydrolytic and biological oxidation reduction reactions under standard and non-standard conditions 4. Overview of High Energy Compounds 5. Coupled reactions 6. Determination of feasibility of reactions 7. Problems based on 2, 3 and 6. 8. Atkinson's energy charge. 9. Biosynthesis of five families of amino acids and histidine, 10. Biosynthesis of purine and pyrimidine bases	15
III	**Lipid and Carbohydrate Metabolism** 1. Synthesis of lipids: Phospholipids and triacylglycerols, 2. Synthesis of membrane lipids: Glycerophospholipids, sphingolipids,	15

	sterols 3. Degradation of fatty acids (alpha, beta and Omega oxidation and unsaturated fatty acids) *4.* Lipids as signal molecules (eg. phosphatidylinositol, eicosanoids). 5. Overview of Glycolysis and gluconeogenesis 6. Regulation of glycolysis and gluconeogenesis 7. Synthesis of microbial exopolysaccharides (alginate) 8. Cellulose synthesis and breakdown 9. Regulation of Glycogen synthesis & breakdown, 10. Metabolic flux and its regulation by various metabolic intermediates, 11. TCA cycle- regulation, role in energy generation, Role in generati biosynthetic intermediates and glyoxylate cycle	
IV	**Micronutrients and Hormones** **A. Structure, function of following micronutrients in metabolism:** 1. Water soluble vitamins and their coenzyme forms (Niacin, Riboflavin, Pantothenic acid, Thiamine, Pyridoxal, Vitamin B_{12}, Folic acid, Glutathione) 2. Fat soluble vitamins (A, D, E, and K) 3. Minerals as vitamins (Iron, Manganese, Magnesium, Cobalt, Molybdenum, Copper, Zinc, Nickel **B. The chemical structure and functions of each hormone in connection with the gland responsible for its production:** 1. The parathyroid 2. The pancreas 3. The adrenals 4. The pituitary glands 5. Sex hormones	15

Suggested References: MB 552 MJ -Enzymology, Bioenergetics and Metabolism Compulsory Theory Paper

1. Gacesa P. (1998). Bacterial alginate biosynthesis--recent progress and future prospects. Microbiology (Reading). 144 (Pt 5):1133-1143. doi: 10.1099/00221287-144-5-1133. PMID: 9611788.
2. Garrett R. H. and Grisham C. M. (2004) Biochemistry. 3rd Ed. Brooks/Cole, Publishing Company, California
3. Madigan M. T., Sattley W. M., Bender, K. S., Stahl D. A., Buckley, D. H.(2018). Brock Biology of Microorganisms. United Kingdom: Pearson.
4. McQuillen K., Dawes I. W. and Mandelstam J. (1982; Digitized 2010). Biochemistryof bacterial growth. United Kingdom: Wiley
5. Moat A. G., Foster J. W. and Spector M. P. (2003) Microbial Physiology. Germany: Wiley. ISBN: 9780471461197
6. Nelson D. L. and Cox M. M. (2005). Lehninger's Principles of Biochemistry, Fourth edition, W.H. Freeman & Co. New York.

7. Pacheco-Leyva I., Guevara Pezoa F. and Díaz-Barrera A. (2016). "Alginate Biosynthesis in *Azotobacter vinelandii*: Overview of Molecular Mechanisms in Connection with the Oxygen Availability", International Journal of Polymer Science. 2016: Article ID 2062360. https://doi.org/10.1155/2016/2062360
8. Palmer T. and Bonner P. L. (2007). Enzymes: Biochemistry, Biotechnology, Clinical Chemistry. United Kingdom: Elsevier Science.
9. Segel I. H. (2010). Biochemical Calculations. 2nd Ed. Wiley India Pvt. Limited. ISBN: 9788126526437
10. Tymoczko J. L., Berg J. M., Stryer L., Gatto G. J. (2015). Biochemistry. United States: W. H. Freeman
11. Urtuvia V., Maturana N., Acevedo F., Peña C. and Díaz-Barrera A. (2017) Bacterial alginate production: an overview of its biosynthesis and potential industrial production. World Journal of Microbiology & Biotechnology. 33(11):198. DOI: 10.1007/s11274-017-2363-x. PMID: 28988302
12. Vassoler Serrato Rodrigo. (2022). 'Bacterial Alginate Biosynthesis and Metabolism'. Alginate - Applications and Future Perspectives [Working Title], IntechOpen. Crossref, doi: 10.5772/ intechopen.109295.
13. White D., Fuqua C., Drummond J. and Drummond J. T. (2012). The physiology and biochemistry of prokaryotes. United Kingdom: Oxford University Press

……..

MB 553 MJ -Laboratory Techniques and Instrumentation

Compulsory Theory Paper

Total: 2 Credits Workload: -15 hours /credit

(Total Workload: -2 credits x 15 hours = 30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	Study of techniques will help in understanding basics
CO2	Study of techniques will help in application of electromagnetic spectrum.
CO3	Studies of structure will lead to in depth knowledge of Biomolecules
CO 4	Techniques of Spectroscopy will improve technical knowledge which will help in Skill development.

MB 553 MJ -Laboratory Techniques and Instrumentation **Compulsory Theory Paper** Total: 2 Credits Workload: -15 hours /credit (Total Workload: -2 credits x 15 hours = 30 hours in semester)		
Credits	**Credit Title and Contents**	**Number of Lectures**

I	**Separation and analysis of biomolecules** 1. Techniques for sample preparation: Dialysis, ultra-filtration, centrifugal vacuum concentration 2. Chromatography Partition Coefficient, Selectivity, Resolution, Column Efficiency, Van Deemter equation, Interpretation of chromatograms, Principle, instrumentation and application gel filtration, Ion exchange, affinity chromatography, High-Performance Liquid Chromatography (HPLC), Fast Protein Liquid Chromatography (FPLC), Supercritical Fluid Chromatography, Reversed Phase Chromatography and Gas chromatography. 3. Electrophoresis Methods: Agarose, Native PAGE, SDS PAGE, Pulse field gel electrophoresis, capillary electrophoresis, isoelectric focusing, 2-dimensional electrophoresis, immune-electrophoresis	15
II	**Spectroscopy** Introduction: Electromagnetic spectrum, Atomic orbitals, Molecular orbitals, Electronic, Rotational, and Vibrational transitions in spectroscopy, Interpretation of spectra. 1. UV/Visible spectroscopy Instrumentation, Molar Absorptivity, Beer and Lambert's Law, Bathochromic and hypochromic shifts. 2. Fluorescence spectroscopy-Instrumentation, Quantum Yield, Quenching, FRET, Binding and Folding studies, Flow cytometry and FACS 3. Infrared spectroscopy Principle, Instrumentation, Absorption bands, FTIR and its applications 4. Mass spectroscopy- Principles of operation, Ionization, Ion fragmentation, Mass Analysers,	15

Suggested References: MB 553 MJ -Laboratory Techniques and Instrumentation Compulsory Theory Paper

1. Boyer R. F. (2000). Modern experimental biochemistry. India: Pearson Education
2. Chakravarty R., Goel S., and Cai W. (2014). Nanobody: The “Magic Bullet” for Molecular Imaging? Theranostics, 4(4), 386-398. doi:10.7150/thno.8006
3. Dennison C. (2013). A guide to protein isolation. Netherlands: Springer Netherlands
4. Ekman R., Silberring J., Westman-Brinkmalm A., Kraj A., Desiderio D. M. and Nibbering N. M. (2009) Mass spectrometry: instrumentation, interpretation, and applications, John Wiley & Sons, Inc., Canada.
5. Feldheim D. L. and Foss C. A. Jr. (2002). Metal nanoparticles synthesis and characterization and applications Marcel Dekker, Inc

6. Hofmann A., Walker J. M., Wilson K. and Clokie S. (2018). Wilson and Walker's Principles and techniques of biochemistry and molecular biology. United Kingdom: Cambridge University Press.
7. Holme D. J. and Peck H. (1998) Analytical Biochemistry. 3rd Edition. Prentice Hall, Pearson Education Limited, Harlow England. ISBN 0 582 29438 -X
8. Narayanan P. (2000) Essentials of Biophysics. New Age International Publication, New Delhi.
9. Niemeyer C. M. and Mirkin C. A. (2006). Nanobiotechnology. John Wiley & Sons
10. Nölting B. (2013). Methods in modern biophysics. Germany: Springer Berlin Heidelberg.
11. Pattabhi V. and Gautham N. (2002) Biophysics. Kluwer Academic Publishers, New York and Narosa Publishing House, Delhi.
12. Rai M. and Duran N. (2011). Metal nanoparticles in Microbiology. Springer Verlag Berlin Heidelberg.
13. Segel I. H. (1991) Biochemical Calculations: How to Solve Mathematical Problems in General Biochemistry. 2nd Edition. JohnWiley & Sons.
14. Sohier J. Laurent C., Chevigné A., Pardon E., Srinivasan V., Wernery U. and Galleni M. (2013) Allosteric Inhibition of VIM Metallo-β-Lactamases by Camelid Nanobody. Biochemical Journal. 450(3): 477-486. Doi:10.1042/bj20121305.
15. Webster D. M. (2000). Protein Structure Prediction-Methods and Protocols, Methods in Molecular Biology. Vol 143 Humana Press.

……

MB 554 MJP- Practicals based on MB 551 MJ Molecular Biology I, MB 552 MJ Enzymology, Bioenergetics and Metabolism, and MB 553 MJ Laboratory Techniques and Instrumentation

Compulsory Practical Paper

Total: 4 Credits Workload:-30 hours/credit

(Total Workload:-4 credits x 30 hours= 120 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	To familiarize students with the molecular Biology techniques which includes study of DNA, RNA, proteins etc
CO2	To gain an understanding of the solution, the calculations and preparation for cellular extraction of biomolecules and Purification.
CO3	To experience a hands-on approach and the troubleshooting during processing of the biomolecules
CO 4	To have an insight in the usage of bioinformatics and data bases in gene annotation procedure

MB 554 MJP - Compulsory Practical Paper Practicals based on MB 551 MJ Molecular Biology I, MB 552 MJ Enzymology, Bioenergetics and Metabolism, and MB 553 MJ Laboratory Techniques and Instrumentation Total: 4 Credits Workload:-30 hours/credit **(Total Workload:-4 credits x 30 hours= 120 hours in semester)**	
Credit Title and Contents	**Number of Hours**
1. Plasmid DNA isolation, DNA quantitation and characterization by gel electrophoresis. 2. Construction of restriction digestion map of plasmid DNA 3. Curing of bacterial Plasmid 4. Gene annotation 5. Isolation and characterization of lipase/cellulase/chitinase producing microbe 6. Purification of enzymes using ammonium sulphate precipitation/ Gel Filtration, Establishment of enzyme purification chart 7. Purification of enzymes using organic solvent precipitation, Establishment of enzyme purification chart 8. Determination of Km, Vmax and Kcat values of enzyme 9. Determination of molar extinction coefficient of biomolecule 10. Isolation of Aflatoxin producing organism. Extraction and detection of Aflatoxin in food. 11. Demonstration of SDS-PAGE for purification of proteins 12. Paper and thin layer chromatography technique for the separation of the amino acids from biological sample. 13. Paper and Thin layer chromatography technique for separation of the Sugars from biological sample (two dimensional). 14. Virtual lab exercise to understand the instrumentation, experimentation and interpretation of data obtained using MALDI TOF 15. Virtual lab exercise/ Visit to understand the instrumentation, experimentation and interpretation of microscopy data (SEM, TEM, AFM).	120

Suggested References: MB 554 MJP- Practicals based on MB 551 MJ Molecular Biology I, MB 552 MJ Enzymology, Bioenergetics and Metabolism, and MB 553 MJ Laboratory Techniques and Instrumentation

Compulsory Practical Paper

1. Adetunji M. C., Alika O. P., Awa N. P., Atanda O. O and Mwanza M. (2018).

Microbiological quality and risk assessment for aflatoxins in groundnuts and roasted cashew nuts meant for human consumption. Journal of Toxicology.2018: Article ID 1308748. https://doi.org/10.1155/2018/1308748

2. Akardere E., Özer B., Çelem E. B. and Önal S. (2010). Three-phase partitioning of invertase from Baker's yeast. Separation and Purification Technology. 72(3): 335-339. https://doi.org/10.1016/j.seppur.2010.02.025
3. Archer C. T., Kim J .F., Jeong H., Park J. H., Vickers C. E., Lee S. Y. and Nielsen L. K.(2011). The genome sequence of *E. coli* W (ATCC 9637): comparative genome analysis and an improved genome-scale reconstruction of *E. coli*. BMC Genomics. 12: 9. https://doi.org/10.1186/1471-2164-12-9
4. Baltas N., Barbaros D., Pinar E. A., Sevgi K. and Ahmet A. (2016). Purification and characterization of extracellular α-amylase from a thermophilic *Anoxybacillus thermarum* A4 strain. Brazilian Archives of Biology and Technology. 59: e16160346. https://doi.org/10.1590/1678-4324-2016160346.
5. Braicu C., Puia C., Bodoki E. and Socaciu C. (2008). Screening and quantification of aflatoxins and ochratoxins in different cereals cultivated in Romania using thin-layer chromatography- densitometry. Journal of Food Quality.3: 108-120. https://doi.org/10.1111/j.1745- 4557.2007.00187.
6. Carr P. W. and Stoll D. R. (2015). Two-dimensional liquid chromatography: Principles, practical implementation and applications. Primer. Agilent Technologies. Germany. https://www.agilent.com/cs/library/primers/public/5991-2359EN.pdf
7. Delaney S., Murphy R. and Walsh F. (2018). A comparison of methods for the extraction of plasmids capable of conferring antibiotic resistance in a human pathogen from complex broiler cecal samples. Frontiers in microbiology. 9: 1731. https://doi.org/10.3389/fmicb.2018.01731
8. Fakruddin M., Chowdhury A., Hossain M. N. and Ahmed, M. M. (2015). Characterization of aflatoxin producing *Aspergillus* flavus from food and feed samples. SpringerPlus. 4:159. https://doi.org/10.1186/s40064-015-0947-1
9. Feng W., Wang X. Q., Zhou W., Liu G. Y. and Wan Y. J. (2011). Isolation and characterization of lipase-producing bacteria in the intestine of the silkworm, *Bombyx mori*, reared on different forage. J Insect Sci.11: 135. doi: 10.1673/031.011.13501.
10. Ilesanmi O. I., Adekunle A. E., Omolaiye J. A, Olorode E. M. and Ogunkanmi A. L. (2020). Isolation, optimization and molecular characterization of lipase producing bacteria from contaminated soil. Scientific African. 8; e00279. https://doi.org/10.1016/j.sciaf.2020.e00279.
11. Islam F. and Roy N. (2018). Screening, purification and characterization of cellulase from cellulase producing bacteria in molasses. BMC Res Notes. 11(1):445. doi: 10.1186/s13104-018- 3558-4.
12. Jayaraman J. (2004). Laboratory Manual in Biochemistry. India: New Age International (P) Limited Publishers.
13. Miquet J. G., González L., Sotelo A. I. and González Lebrero R. M. (2019). A laboratory work to introduce biochemistry undergraduate students to basic enzyme kinetics-alkaline

phosphatase as a model. Biochem Mol Biol Educ. 47(1):93-99. doi: 10.1002/bmb.21195.

14. Miranda-Hernández M. P., Valle-González E. R., Ferreira-Gómez D., Pérez N. O., Flores-Ortiz K. F. and Medina-Rivero E. (2016). Theoretical approximations and experimental extinction coefficients of biopharmaceuticals. Anal Bioanal Chem. 408:1523–1530 https://doi.org/10.1007/s00216-015-9261-6
15. Nagpure A., Choudhary B. and Kumar S. (2014). Isolation and characterization of chitinolytic *Streptomyces* sp. MT7 and its antagonism towards wood-rotting fungi. Ann. Microbiol. 64, 531–541. https://doi.org/10.1007/s13213-013-0686-x
16. Palmer T. and Bonner P. L. (2007). Enzymes: Biochemistry, Biotechnology, Clinical Chemistry. United Kingdom: Elsevier Science.
17. Paul D., Dhar (Chanda) D., Chakravarty A. and Bhattacharjee A. (2020). An insight into analysis and elimination of plasmids encoding metallo-β-lactamases in *Pseudomonas aeruginosa*. Journal of Global Antimicrobial Resistance. 21: 3-7. https://doi.org/10.1016/j.jgar.2019.09.002
18. Plummer M. and Plummer D.T. (2001). Introduction to practical biochemistry. 3rd Edition,Tata McGraw- Hill Edition.
19. Russell P. J. (2010). iGenetics: A Molecular Approach. 3rd edition. Pearson Education, Inc., publishing as Pearson Benjamin Cummings, San Francisco
20. Sadasivam S. and Manickam A. (2008). Biochemical methods. 3rd Edition, New Age International Publishers, India.
21. Sambrook J. and Russell D. (2001) Molecular Cloning: A Laboratory Manual, 3rd edition. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press
22. Scopes R. K. (1994) Protein Purification Principles and Practice. Third Edition, Springer
23. Shahbaz U. and Yu X. (2020). Cloning, isolation, and characterization of novel chitinase-producing bacterial strain UM01 (*Myxococcus fulvus*). J Genet Eng Biotechnol. 18, 45. https://doi.org/10.1186/s43141-020-00059-1
24. Sulyman A. O., Igunnu A. and Malomo S. O. (2020). Isolation, purification and characterization of cellulase produced by *Aspergillus niger* cultured on *Arachis hypogaea* shells. Heliyon. 6: 12: e05668.https://doi.org/10.1016/j.heliyon.2020.e05668
25. Syed D. G., Agasar D. and Pandey A. (2009). Production and partial purification of α-amylase from a novel isolate *Streptomyces gulbargensis*. Journal of Industrial Microbiology and Biotechnology. 36(2): 189–194. https://doi.org/10.1007/s10295-008-0484-9
26. Trevors J. T. (1986). Plasmid curing in bacteria**.** FEMS Microbiology Reviews 32:149-157
27. Wacoo A. P., Wendiro D., Vuzi P. C. and Hawumba J. F. (2014). Methods for detection of aflatoxins in agricultural food crops. Journal of Applied Chemistry. 2014: Article ID 706291. https://doi.org/10.1155/2014/706291
28. Watson J. D., Gann A., Baker T. A., Levine M., Bell S. P., Losick R. and Harrison S.C. (2014). Molecular Biology of the genes. 7th edition. Cold Spring Harbor Laboratory Press. Cold Spring Harbor, New York

29. Webster D. M. (Editor). Protein Structure Prediction: Methods and Protocols. In: Methods in Molecular Biology; Volume 143. Humana Press.
30. Wilson K. and Walker J. (2005). Principles and Techniques of Biochemistry and Molecular Biolog. 6th edition. Cambridge University Press, New York.

MB 581 OJT- Internship / On job training

Course under NEPAs per SPPU Guidelines:

Component of Study	Code	Course Name	Credits
Internship/ On job training	MB 581 OJT	Internship / On job training	4

MB 555 MJ-Molecular biology tools and applications

Group I Major Elective Theory

Total: 2 Credits Workload:-15 hours /credit

(Total Workload:-2 credits x 15 hours= 30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	Explain principle and procedures of various molecular techniques
CO2	Explain the concept of microarray
CO3	Describe various hybridization techniques
CO 4	Explain the concept of recombinant DNA technology
CO 5	Describe the use of Biopolymerases

MB 560 MJ -Molecular biology tools and applications
Group I Major Elective Theory

Total: 2 Credits Workload:-15 hours /credit

(Total Workload:-2 credits x 15 hours= 30 hours in semester)

Credits	Credit Title and Contents	Number of Lectures
I	**Tools in Molecular Biology:** 1. Study of protein-DNA interactions: electrophoretic mobility shift assay; DMS foot printing, DNase foot printing; methyl interference assay, protein-protein interactions using yeast two hybrid systems; phage display. 2. DNA microarray, Construction of microarrays – genomic arrays, cDNA arrays and oligo arrays 3. Super shift assay and EMSA, Sequence tagged sites, Filter binding	15

	assay, Protein foot printing, finding the replicon, DNA fingerprinting, Measuring transcription rates 4. Hybridization techniques: Free solution, membrane based (DOT blot, SLOT blot), Fluorescence in situ hybridization (FISH) and Microarray technology	
II	**Applications of recombinant DNA technology in production of:** 1. Synthesis of commercial products: Amino acids (L-Valine and L-cysteine), ascorbic acid, Peptide antibiotics, 2. Hybrid Human-Mouse monoclonal antibodies, Human monoclonal antibodies, anti-cancer antibodies 3. Biopolymers: gum, rubber, polyhydroxy alkanoates. 4. Un-conventional microbial systems for production of high quality protein drug	15

Suggested References: MB 560 MJ -Molecular biology tools and applications

Group I Major Elective Theory

1. Alberts B. (2017). Molecular Biology of the Cell. Publisher: W.W. Norton. United States.
2. Blalock E. M. (2011). A beginner's guide to microarrays. United States. Springer US.
3. Burton D. R., Silverman G. J. and Barbas C. F. (2004). Phage Display: A Laboratory Manual. United States: Cold Spring Harbor Laboratory Press.
4. Cooper G. M. and Hausman R. E. (2016). The Cell: A Molecular Approach. United Kingdom: Oxford University Press, Incorporated.
5. Dale J. W., von Schantz M., Plant N. and Plant N. (2012). From genes to genomes: concepts and applications of DNA technology. United Kingdom: Wiley.
6. Friedberg E., Lindahl T., Muzi-Falconi M., Elledge S. J. and Lehmann A. (2014). DNA Repair, Mutagenesis, and Other Responses to DNA Damage: A Subject Collection from Cold Spring Harbor Perspectives in Biology. United States: Cold Spring Harbor Laboratory Press.
7. Fu H. (2004). Protein-protein Interactions: Methods and Applications. Ukraine: Humana Press.
8. García-Cañas V., Simó C. and Cifuentes A. (2014). Fundamentals of advanced omics technologies: from genes to metabolites. Netherlands: Elsevier Science.
9. Glick B. R. and Patten C. L. (2017). Molecular Biotechnology: Principles and Applications of Recombinant DNA. India: Wiley.
10. Goldstein E. S., Krebs J. E. and Kilpatrick S. T. (2017). Lewin's GENES XII. United States: Jones & Bartlett Learning.
11. Kalia V. C. (2016). Microbial Factories: Biodiversity, Biopolymers, Bioactive Molecules: Volume 2. India: Springer India.
12. Kolpashchikov D. M. and Gerasimova Y. V. (2016). Nucleic acid detection: methods

and protocols. United States: Humana Press.
13. Kurnaz I. A. (2015). Techniques in Genetic Engineering. United Kingdom: CRC Press.
14. Leblanc B. and Moss T. (2010). DNA-Protein Interactions: Principles and Protocols. Third Edition. United States: Humana Press.
15. Lilley D. M. J. and Eckstein F. (2012). Nucleic Acids and Molecular Biology. Germany: Springer Berlin Heidelberg.
16. Lodish H., Berk A., Kaiser C. A., Krieger M., Bretscher A., Ploegh H., Amon A. and Martin K. C. (2016). Molecular Cell Biology. United States: Macmillan Learning.
17. Müller U. R. and Nicolau D. V. (2006). Microarray technology and its applications. Germany: Physica-Verlag.
18. Rice P. A. and Correll C. C. (Editors). (2008). Protein-Nucleic Acid Interactions: Structural Biology. United Kingdom: Royal Society of Chemistry.
19. Seitz H. (Editor). (2007). Analytics of Protein-DNA Interactions. Germany: Springer.
20. Sharp D., Sikorski E. and Plopper G. (2013). Lewin's CELLS. United States: Jones & Bartlett Learning.
21. Stanbury P. F., Whitaker A. and Hall S. J. (2016). Principles of Fermentation Technology. Netherlands: Elsevier Science.
22. Stormo G. (2013). Introduction to Protein-DNA Interactions: Structure, Thermodynamics and Bioinformatics. United States: Cold Spring Harbor Laboratory Press.
23. Strohl L. M. and Strohl W. R. (2012). Therapeutic Antibody Engineering: Current and Future Advances Driving the Strongest Growth Area in the Pharmaceutical Industry. United Kingdom: Elsevier Science.
24. Travers A. A. and Buckle M. (2000). DNA-protein Interactions: A Practical Approach. United Kingdom: Oxford University Press.
25. Voet D. and Voet J. G. (2011). Biochemistry. United Kingdom: Wiley. ISBN: 9780470570951
26. Walsh G. (2013). Pharmaceutical Biotechnology: Concepts and Applications. Germany: Wiley.

MB 560 MJP -Practicals based on MB 560 MJ

Group I Major Elective Practical

Total: 2 Credits Workload: - 15 hours /credit

(Total Workload:-2 credits x30 hours=60 hours in semester)

Course outcomes COs
After studying the course learners will be able to

CO1	Basic experimental aspects of recombinant DNA technology and cloning
CO2	Use of microbial systems in cloning
CO3	To appreciate the application of primers and their design for DNA amplification along with technical details of PCR
CO 4	To use electrophoretic technique for identification / characterization of molecules
CO 5	To analyze and interpret the FTIR data of biomolecules
CO 6	The techniques for production of gum and polyhydroxyalkanoates by the recombinant microbes in a fermentation process

MB 560 MJP -Practicals based on MB 560 MJ

Group I Major Elective Practical

Total: 2 Credits Workload: - 15 hours /credit

(Total Workload:-2 credits x30 hours=60 hours in semester)

Credit Title and Contents	Number of Hours
1. Cloning/ transformation using plasmid vectors- GFP gene cloning/ blue and white screening: i. Vector and Insert Ligation ii. Preparation of competent cells iii. Transformation of *E. coli* with standard plasmids, iv. Calculation of transformation efficiency 2. PCR amplification 3. Purification of 16S rRNA gene 4. PCR Primer Design 5. Protoplast fusion 6. Activity staining analysis (Zymograms) (NATIVE PAGE) 7. FTIR analysis of a biomolecule/recombinant molecule (at least five different molecules) 8. Production by recombinant strain and estimation of Biopolymers: i. Gum ii. Polyhydroxyalkanoates (PHB)	60

Suggested References: MB 560 MJP -Practicals based on MB 560 MJ

Group I Major Elective Practical

1.a) Green Fluorescence Protein cloning (GFP):

- Banerjee S., Kumar J., Apte-Deshpande A. and Padmanabhan S. (2010). A novel prokaryotic vector for identification and selection of recombinants: Direct use of the vector for expression studies in *E. coli.* Microb Cell Fact 9, 30 https://doi.org/10.1186/1475-2859-9-30

- Slama R. A. and Ziada A. S. (2016). Initial stages of construction of a plasmid to study the kinetics of gene expression at a single cell level following uptake of DNA into *Escherichia coli*. Journal of experimental microbiology and immunology. (JEMI). 20: 86-91

1.b) Blue and white screening:

- Julin D. A. (2018) Blue/White Selection. In: Wells R. D., Bond J. S., Klinman J. Masters B.S.S. (eds). Molecular Life Sciences. Springer, New York, NY. https://doi.org/10.1007/978-1-4614-1531-2_94
- Liu J., Chang W., Pan L., Liu X., Su L., Zhangn W., Li Q., and Zheng Y. (2018). An improved method of preparing high efficiency transformation *Escherichia coli* with both plasmids and larger DNA fragments. Indian Journal of Microbiology, 58(4): 448–456. https://doi.org/10.1007/s12088-018-0743-z
- Zhang Y. S. (2016). Blue-white screening liquid can eliminate false positives in blue-white colony screening Genetics and Molecular Research 15 (2): gmr.15027925. http://dx.doi.org/10.4238/gmr.15027925

2 and 3 PCR amplification and purification of 16S rRNA gene:

- Rosselli R., Romoli O., Vitulo, N. Vezzi A., Campanaro S., de Pascale F., Schiavon R., Tiarca M., Poletto F., Concheri G., Valle G. and Squartini A. (2016). Direct 16S rRNA-seq from bacterial communities: a PCR-independent approach to simultaneously assess microbial diversity and functional activity potential of each taxon. Sci Rep 6:32165 https://doi.org/10.1038/srep32165
- Sabat G., Rose P., Hickey W. J., Harkin J. M. (2000). Selective and sensitive method for PCR amplification of *Escherichia coli* 16S rRNA genes in soil. Appl Environ Microbiol. 66(2):844-849. doi: 10.1128/AEM.66.2.844-849.2000.

4. PCR Primer Design:

- Miyazaki K., Sato M. and Tsukuda M. (2017). PCR primer design for 16S rRNAs for experimental horizontal gene transfer test in *Escherichia coli*. Front. Bioeng. Biotechnol. 5:14. doi: 10.3389/fbioe.2017.00014
- Ye J., Coulouris G., Zaretskaya I., Zaretskaya I., Cutcutache I., Rozen S. and Madden T. L. (2012). Primer-BLAST: A tool to design target-specific primers for polymerase.chain reaction. BMC Bioinformatics.13: 134. https://doi.org/10.1186/1471-2105-13-134

5. Protoplast fusion:

- Guon J. L., Gongn D. C., Li Z. J., and Zheng Z. (2013). Construction of yeast strain capable of co-fermenting pentose and hexose by protoplast fusion. Advanced Materials Research. 781–784: 847–851. https://doi.org/10.4028/www.scientific.net/amr.781-784.847
- Shalsh F. J., Ibrahim N. A., Arifullah M. and Hussin A. S. M. (2016). Optimization of the protoplast fusion conditions of *Saccharomyces cerevisiae* and *Pichia stipitis* for improvement of bioethanol production from biomass. Asian Journal of Biological Sciences, 9: 10-18. DOI: 10.3923/ajbs.2016.10.18

6. Activity staining analysis (Zymograms) (NATIVE PAGE):

- Deshmukh A. A., Weist J. L. and Leight J. L. Detection of Protease Activity by Fluorescent Peptide Zymography. J. Vis. Exp. (143), e58938, doi:10.3791/58938 (2019).

- Lanka S. and Latha J. (2015). Purification and characterization of a new cold active lipase, EnL A from *Emericella nidulans* NFCCI 3643. African Journal of Biotechnology. 14:1897-1909
- Wechselberger C., Doppler C. and Bernhard D. (2019). An Inexpensive Staining Alternative for Gelatin Zymography Gels. Methods Protoc. 2: 61. doi:10.3390/mps2030061

7. FTIR analysis of a biomolecule/recombinant molecule (at least five different molecules):

7.a.i) Tannins

- Arianna Ricci, Kenneth J. Olejar, Giuseppina P. Parpinello, Paul A. Kilmartin & Andrea Versari (2015) Application of Fourier Transform Infrared (FTIR) Spectroscopy in the Characterization of Tannins, Applied Spectroscopy Reviews, 50:5, 407-442, DOI: 10.1080/05704928.2014.1000461
- https://spectrabase.com/spectrum/KPLVhGlArJg

7.a.ii**) Indole acetic acid**

- https://spectrabase.com/spectrum/LE3GWjvqQ0

7.b.) **Recombinant molecules**

7.b.i) **Colistin-peptide antibiotic.** (Colistimethanesulfonic Acid injection):

- Pacheco T, Bustos RH, González D, Garzón V, García JC, Ramírez D. An Approach to Measuring Colistin Plasma Levels Regarding the Treatment of Multidrug-Resistant Bacterial Infection. Antibiotics (Basel). 2019 Jul 24;8(3):100. doi: 10.3390/antibiotics8030100.
- https://spectrabase.com/spectrum/6sovrQr8OR

7.b.ii) Polymyxin B –peptide antibiotic (Polymyxin B Sulphate Injection):

- Marwan Y. Hussain, Adnan A. Ali-Nizam and Samir M. Abou-Isba. (2017). Antibacterial activities (bacitracin a and polymyxin b) of lyophilized extracts from indigenous *Bacillus subtilis* against *Staphylococcus aureus*. 10(3): 205-212. ISSN 1995-6673
- https://spectrabase.com/spectrum/BfcQ8Se5jz

7.b.iii)Ascorbic acid:

- Andrei A. Bunaciu, Elena Bacalum, Hassan Y. Aboul-Enein, Gabriela Elena Udristioiu & Şerban Fleschin (2009) FT-IR Spectrophotometric Analysis of Ascorbic Acid and Biotin and their Pharmaceutical Formulations, Analytical Letters, 42:10, 1321-1327, DOI: 10.1080/00032710902954490
- https://spectrabase.com/spectrum/47mQ0uyEFIP

8. Production by recombinant strain and estimation of Biopolymers:

8.i) Gum:

- Dai X., Gao G., Wu M., Wei W., Qu J., Li G. and Ma T. (2019). Construction and application of a Xanthomonas campestris CGMCC15155 strain that produces white xanthan gum. Microbiology Open. 8:e631. https://doi.org/10.1002/mbo3.631
- Sukumar S., Arockiasamy S., Moothona M. C. (2021). Optimization of cultural conditions

of gellan gum production from recombinant Sphingomonas paucimobilis ATCC 31461 and its characterization. Journal of Applied Biology & Biotechnology. 9(1):58-67. DOI: 10.7324/JABB.2020.9108

8.ii) Polyhydroxyalkanoates (PHB):

- Li R., Zhang H. and Qi Q. (2007). The production of polyhydroxyalkanoates in recombinant Escherichia coli. Bioresource Technology. 98(12): 2313-2320. https://doi.org/ 10.1016/j.biortech.2006.09.014.
- Nikel P. I., de Almeida, A., Melillo, E. C., Galvagno M. A., and Pettinari M. J. (2006). New recombinant Escherichia coli strain tailored for the production of poly (3-hydroxybutyrate) from agroindustrial by-products. Applied and Environmental Microbiology, 72(6), 3949–3954. https://doi.org/10.1128/AEM.00044-06

MB 561 MJ- Nitrogen Metabolism, Respiration and Photosynthesis

Group II Major Elective Theory

Total: 2 Credits Workload:-15 hours. /credit
(Total Workload:-2 credits x 15 hrs. = 30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	Understand of biological nitrogen fixation and it's regulation.
CO2	Gain knowledge of enzymes involved in nitrogen metabolism.
CO3	Knowledge of anaerobic respiration with respect to chemolithotrophs
CO 4	Differentiate between oxygenic and unoxygenic photosynthesis mechanism

MB 561 MJ -Nitrogen Metabolism, Respiration and Photosynthesis

Group II Major Elective Theory

Total: 2 Credits Workload:-15 hours. /credit
(Total Workload:-2 credits x 15 hrs.= 30 hours in semester)

Credits	**Credit Title and Contents**	**Number of Lectures**
I	**Nitrogen fixation and amino acid degradation:** 1. Biochemistry of biological nitrogen fixation, properties of nitrogenase and its regulation 2. Ammonia assimilation, glutamine synthetase, glutamate dehydrogenase, glutamate synthetase, their properties and regulation 3. Protein turnover and amino acid degradation	15
II	**Respiration and photosynthesis:** 1. Respiration: Respiration in chemolithotrophs, sulphur oxidisers, nitrate reducers with respect to electron transport chain and energy generation, Biochemistry of methanogens.	15

	2. Photosynthesis: i. Overview: Plant Photosynthesis. ii. Bacterial photosynthesis: photolithotrophs, scope, photosystems, iii. Bacterial (cyclic, noncylic) photophosphorylation in various groups of phototrophic bacteria (photoautotrophs and photoheterotrophs) iv. Electron donors other than water in anoxygenic photosynthetic bacteria	

Suggested References: MB 561 MJ -Nitrogen Metabolism, Respiration and Photosynthesis
Group II Major Elective Theory

Nitrogen Metabolism

1. Blackstock J. C. (2014). Guide to Biochemistry. United Kingdom: Elsevier Science.
2. Garrett R. H. and Grisham C. M. (2013). Biochemistry. 5th Edition. Brooks/Cole, Publishing Company, California. ISBN-13: 978-1-133-10629-6
3. Madigan M. T., Sattley W. M., Bender, K. S., Stahl D. A. and Buckley D. H. (2018). Brock Biology of Microorganisms. United Kingdom: Pearson.
4. Mandelstam J. and Dawes I. W. and McQuillen K. (1982). Biochemistry of Bacterial Growth. United Kingdom: Wiley.
5. Moat A. G. Foster J. W. and Spector M. P. (2003). (Microbial Physiology. Germany: Wiley.
6. Nelson D. L. and Cox M. M. (2021). Lehninger's Principles of Biochemistry.8th Edition. Mac Millan Worth Pub. Co. New Delhi. ISBN: 9781319228002
7. Satyanarayana U. and Chakrapani U. (2017). Biochemistry - E-Book. India: Elsevier Health Sciences.
8. Voet D. and Voet J. G. (2011). Biochemistry. United Kingdom: Wiley
9. White D., Drummond J. T., Drummond J. and Fuqua C. (2012).The Physiology and Biochemistry of Prokaryotes. United Kingdom: Oxford University Press.

Respiration and Photosynthesis:

1. Doelle H. W. (2014). Bacterial Metabolism. United States: Elsevier Science.
2. Govindjee. (2012). Photosynthesis Volume1. Energy Conversion by Plants and Bacteria. Unit Kingdom: Elsevier Science.
3. Kim B. H. and Gadd G. M. (2019). Prokaryotic Metabolism and Physiology. United Kingdo Cambridge University Press.
4. Madigan M. T., Sattley W. M., Bender, K. S., Stahl D. A., Buckley, D. H. (2018). Brock Biology Microorganisms. United Kingdom: Pearson.
5. Moat A. G. Foster J. W. and Spector M. P. (2003). (Microbial Physiology. Germany
6. Nelson D. L. and Cox M. M. (2005) Lehninger's Principles of Biochemistry, Fourth edition, W. Freeman & Co. New York
7. Nelson D. L. and Cox M. M. (2021). Lehninger's Principles of Biochemistry.8th Edition. Mac Mill Worth Pub. Co. New Delhi. ISBN:9781319228002
8. Renger G., Irrgang K.D., Govindjee, Singhal G. S. and Sopory S. K. (2012). Concepts in Photobiolog Photosynthesis and Photomorphogenesis. Netherlands: Springer Netherlands.
9. Woese C. R. (2004). The archaeal concept and the world it lives in: a retrospective. Photosynthesis

Research. 80: 361–372.

MB 561 MJP -Practical based on Nitrogen Metabolism, Respiration and Photosynthesis
Group II Major Elective Practical

Total: 2 Credits Workload:-30 hours /credit
(Total Workload:-2 credits x 30hrs=60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	Methods used for isolation of microbes able to produce the metabolites such as indole acetic acid, siderophores and techniques for their detection.
CO2	Techniques used for isolation of microbial system that are able to fix the atmospheric nitrogen.
CO3	Characterization technique for polyphenols and tannins
CO 4	Microbial methods for isolation and characterization of microbes able to degrade biomolecules such as xylan/lignin
CO 5	Microbial methods required for isolation of sulfur reducing microbes / methanogens
CO 6	Microbial methods for photosynthetic microbes such as cyanobacteria and biochemical method to determine its chlorophyll content

MB 561 MJP -Practical based on Nitrogen Metabolism, Respiration and Photosynthesis
Group II Major Elective Practical

Total: 2 Credits Workload:-30 hours /credit
(**Total Workload:-2 credits x 30hrs=60 hours in semester**)

Credit Title and Contents	**Number of Hours**
1. Isolation of IAA producing organism, Detection of Indole acetic acid production by microorganism. 2. Detection of siderophore production by microorganisms 3. Enrichment, Isolation and characterization of nitrogen fixing bacteria. 4. Extraction and estimation by Folin Ciocalteu method of a) polyphenols b) tannins 5. Enrichment and isolation of lignin/xylan degraders from Soil. 6. Enrichment, Isolation, and characterization of Sulphur reducing bacteria/ Methanogens. 7. Enrichment, Isolation, and characterization of Cyanobacteria. 8. Detection of chlorophyll-a of Cyanobacteria.	60

Suggested References: MB 561 MJP -Practical based on Nitrogen Metabolism, and Photosynthesis

Group II Major Elective Practical Respiration

1. Isolation and Detection of Indole acetic acid production bymicroorganisms: -

- Gang S., Sharma, S., Saraf M., Buck M. and Schumacher J. (2019). Analysis of Indole-3-acetic Acid (IAA) Production in Klebsiella by LC-MS/MS and the Salkowski Method .Bio-protocol. 9(9): e3230. DOI: 10.21769/BioProtoc.3230.
- Mohite B. (2013). Isolation and characterization of indole acetic acid (IAA) producingbacteria from rhizospheric soil and its effect on plant growth. Journal of Soil Science andPlantNutrition, 13(3):638-649.

2. Detection of siderophore production by microorganisms:-

- Ferreira C. M. H., Vilas-Boas Â, Sousa C. A., Soares H. M. V. M. and Soares E. V.(2019) Comparison of five bacterial strains producing siderophores with ability to chelate iron under alkaline conditions. AMB Express. 9(1): 78. doi:10.1186/s13568-019-0796-3.
- Senthilkumar M., Amaresan N. and Sankaranarayanan A. (2021). Detection of Siderophore producing microorganisms. In: Plant-Microbe Interactions. Springer Protocols Handbooks. Humana, NewYork, NY. https://doi.org/10.1007/978-1-0716-1080-0_47

3. Enrichment, Isolationandcharacterizationofnitrogenfixingbacteria:-

- Jiménez D. J., Montaña J. S. and Martínez M. M. (2011). Characterization of free nitrogen fixing bacteria of the genus Azotobacter in organic vegetable-grown Colombian soils. Brazilian Journal of Microbiology .42(3): 846-858. https://doi.org/10.1590/S1517-83822011000300003.
- Muangthong A.,Youpensuk S. and Rerkasem B. (2015). Isolation and characterisation of endophytic nitrogen fixing bacteria in sugarcane. Tropical life sciences research.26(1):41-51.

4. Extraction and estimation of:-

4.a.)Polyphenols:

- Aryal S.,Baniya M.K., Danekhu K.,Kunwar P., Gurung R.and Koirala N.(2019).Total phenolic content, flavonoid content and antioxidant potential of wild vegetables from western Nepal. Plants (Basel). 18(4): 96. doi: 10.3390/plants8040096.
- PouraliA., Afrouziyeh M. and Moghaddaszadehahrabi S. 2014. Extraction of Phenolic compounds and quantification of the total phenol of grape pomace. European Journal of Experimental Biology. 4(1):174-176.

4. b) Tannins by Folin Danis method:

- Chandran K. and Indria G. (2016). Quantitative estimation of total phenolic, flavonoids, tannin and chlorophyll content of leaves of StrobilanthesKunthiana (Neelakurinji). Journal of Medicinal Plants Studies, 4(4): 282-286.
- Rhazi N., Hannache H., Oumam M., Sesbou A., Charrier B., Pizzi A., Charrier-El Bouhtoury F. (2019). Green extraction process of tannins obtained from Moroccan Acacia mollissima barks by microwave: Modeling and optimization of the process using the response surface methodology RSM. Arabian Journal of Chemistry. 12(8): 2668- 2684. https://doi.org/10.1016/j.arabjc.2015.04.032.

5. Enrichment and isolation of lignin/xylan degraders from Soil:-

5.a) Lignin degraders:

- DeAngelis K. M., Allgaier M., Chavarria Y., Fortney J. L., Hugenholtz P., Simmons B., Sublette K., Silver W. L. and Hazen T. C.. (2011). Characterization of trapped lignin-degrading microbes in tropical forest soil. PLoS ONE 6(4): e19306. https://doi.org/10.1371/journal.pone.0019306
- Kambale R. and Jadhav A. (2012). Isolation, purification, and characterization of xylanase produced by a new species of bacillus in solid state fermentation. International J of Microbiology.volume- 2012. Article ID 683193 doi: 10.1155/2012/683193
- Yang, C.-X., Wang, T., Gao, L.-N., Yin, H.-J. and Lü, X. (2017), Isolation, identification and characterization of lignin-degrading bacteria from Qinling, China. J Appl Microbiol, 123: 1447-1460. https://doi.org/10.1111/jam.13562 5. b) Xylan degraders:
- Zerva I., Remmas N. and Ntougias S. (2019). Diversity and biotechnological potential of xylan-degrading microorganisms from orange juice processing waste. Water.11(2): 274. https://doi.org/10.3390/w11020274

5. b) Xylan degraders:

- Kambale R. and Jadhav A. (2012). Isolation, purification, and characterization of xylanase produced by a new species of bacillus in solid state fermentation. International J of Microbiology.volume- 2012. Article ID 683193 doi: 10.1155/2012/683193
- Zerva I., Remmas N. and Ntougias S. (2019). Diversity and biotechnological potential of xylan-degrading microorganisms from orange juice processing waste. Water.11(2): 274. https://doi.org/10.3390/w11020274

6. Enrichment, Isolation and characterization of :-

6. a) Sulphur reducing bacteria:

- Sass H. and Cypionka H. (2004). Isolation of sulfate-reducing bacteria from the terrestrial deep subsurface and description of Desulfovibrio cavernae sp. nov. Systematic and Applied Microbiology. 27(5): 541-548. https://doi.org/10.1078/0723202041748181.
- Simankova M. V., Kotsyurbenko O. R., Lueders T., Nozhevnikova A. N., Wagner B., Conrad R. and Friedrich M. W. (2003). Isolation and characterization of new strains of methanogens from cold terrestrial habitats. Systematic and Applied Microbiology. 26(2): 312-318. https://doi.org/10.1078/072320203322346173.

6. b) Methanogens:

- Kumar S., Dagar S. S. and Puniya A. K. (2012). Isolation and characterization of methanogens from rumen of Murrah buffalo. Ann Microbiol 62, 345–350 https://doi.org/10.1007/s13213-011-0268-8
- Simankova M. V., Kotsyurbenko O. R., Lueders T., Nozhevnikova A. N., Wagner B., Conrad R. and Friedrich M. W. (2003). Isolation and characterization of new strains of methanogens from cold terrestrial habitats. Systematic and Applied Microbiology. 26(2): 312-318. https://doi.org/10.1078/072320203322346173.

7. Enrichment, Isolation and characterization of Cyanobacteria:-

- Pramanik, A., Sundararaman, M., Das, S., Ghosh, U. and Mukherjee, J. (2011). Isolation and characterization of cyanobacteria possessing antimicrobial activity from the Sundarbans, the world's largest tidal mangrove forest1. Journal of Phycology, 47: 731-743. https://doi.org/10.1111/j.1529-8817.2011.01017.x
- Urmeneta, J., Navarrete, A., Huete, J. and Guerrero R. (2003). Isolation and characterization of cyanobacteria from microbial mats of the Ebro Delta, Spain. CurrMicrobiol 46, 0199–0204 https://doi.org/10.1007/s00284-002-3856-9

8. Detection of chlorophyll-a activity of Cyanobacteria:-

- Johan F., Jafri M. Z., Lim H. S. and Wan Maznah W. O. (2014). "Laboratory measurement: Chlorophyll-a concentration measurement with acetone method using spectrophotometer." IEEE International Conference on Industrial Engineering and Engineering Management. 744-748, doi: 10.1109/IEEM.2014.7058737.
- Zavřel T, Sinetova M and Červený J. 2015. Measurement of Chlorophyll a and Carotenoids Concentration in Cyanobacteria. Bio-protocol. 5. www.bioprotocol.org/e1467

……

MB 562 MJ -Molecular Biophysics

Group III Major Elective Theory

Total: 2 Credits Workload:-15 hours/credit

(Total Workload:-2 credits x 15 hrs= 30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	Learn fundamental concept of nuclear magnetic resonance spectroscopy
CO2	Understand principle, technical details and applications of NMR in biological field
CO3	To appreciate the methods of protein purification pertaining to X-ray crystallography
CO 4	Learn technical details of instrumentation and application of technique in biology
CO 5	Understand basic aspects of phenomenon of radioactivity
CO 6	To recognize the significance of radioisotopes in biology along with techniques used
CO 7	Learn technical details of confocal microscopy and its application in biology

MB 562 MJ -Molecular Biophysics
Group III Major Elective Theory

Total: 2 Credits Workload:-15 hours/credit

(Total Workload:-2 credits x 15 hrs= 30 hours in semester)

Credits	**Credit Title and Contents**	**Number of Lectures**
I	**Biophysical Techniques**	15

	1. NMR spectroscopy: Basic Principles of NMR, Chemical shift, Intensity, Line width, Relaxation parameters, Spin coupling, Nuclear Over hauser Effect Spectroscopy, Correlation Spectroscopy, Approach to structure determination by 2D-NMR 2. X-ray crystallography: Purification of proteins, Crystallization of proteins, Instrumentation, acquisition of the diffraction pattern, basic principles of X-ray diffraction, Crystal Structures (Bravais Lattices), Crystal planes and Miller Indices, Fourier Transform and Inverse Fourier, Direct Lattice and Reciprocal lattice, Ewald sphere, Electron density Maps, Phase determination	
II	**Radioisotopes in Biology and Confocal Microscopy** **1. Radioisotopes in Biology:** Principles and applications of radiotracers in medicine, agriculture, industry, and fundamental research. Radiation and Radioactive isotopes: Types, Quantities, and units of estimation, the half-life of isotopes. Detection and measurement of radioactivity- Autoradiography, Liquid scintillation counting. Effect of Radiation on a biological system **2. Confocal Microscopy:** Scanning optical microscope, confocal principle, resolution and point spread function, light source: gas lasers and solid-state, primary beam splitter; beam scanning, pinhole, and signal channel configurations, detectors; pixels and voxels; contrast, spatial sampling: temporal sampling: signal-to-noise ratio, multichannel images	15

Suggested References MB 563 MJ -Molecular Biophysics
Group III Major Elective Theory

1. Boyer R. F. (2000). Modern experimental biochemistry. India: Pearson Education.
2. Chakravarty R., Goel S. and Cai W. (2014). Nanobody: the "magic bullet" for molecular imaging? Theranostics. 4(4): 386-398. doi:10.7150/thno.8006
3. Dennison C. (2013). A guide to protein isolation. Netherlands: Springer Netherlands.
4. Desiderio D. M., Kraj A. and Nibbering N. M. (2009). Mass spectrometry: instrumentation, interpretation and applications. United Kingdom: Wiley.
5. Feldheim D. L. and Foss C. A., Jr. (Editors). (2002) Metal nanoparticles synthesis and characterization and applications. Taylor & Francis
6. Hofmann A., Walker J. M., Wilson K. and Clokie S. (2018). Wilson and Walker's Principles and techniques of biochemistry and molecular biology. United Kingdom: Cambridge University Press.
7. Mirkin C. A. and Niemeyer C. M. (2006). Nanobiotechnology: Concepts, Applications and Perspectives. Germany: Wiley.

8. Mirkin C. A. and Niemeyer C. M. (2007). Nanobiotechnology II: More Concepts and Applications. Germany: Wiley.
9. Mount D. W. (2005). Bioinformatics: sequence and genome analysis. India: CBS Publishers & Distributors.
10. Narayanan P. (2007). Essentials of biophysics. India: New Age International.
11. Nölting B. (2013). Methods in modern biophysics. Germany: Springer Berlin Heidelberg.
12. Pattabhi V. and Gautham N. (2002). Biophysics. India: Springer Netherlands.
13. Rai M. and Duran N. (2011). Metal nanoparticles in microbiology. Germany: Springer Berlin Heidelberg.
14. Rutherford T. (2019). Principles of analytical biochemistry. Alexis Press LLC. New York.
15. Segel I. H. (2010). Biochemical calculations. 2nd Edition. India: Wiley India Pvt.Ltd
16. Sohier J. S., Laurent C., Chevigné A., Pardon E., Srinivasan V., Wernery U., Lassaux P., Steyaert J. and Galleni M. (2013). Allosteric inhibition of VIM metallo-β-lactamases by a camelid nanobody. Biochem J. 450(3): 477-86. doi: 10.1042/BJ20121305.
17. Webster D. M. (2000). Protein Structure Prediction: Methods and Protocols. Ukraine: Humana Press.

MB 563 MJP - Molecular Biophysics
Group III Major Elective Practical

Total: 2 Credits Workload:-30 hours/credit
(Total Workload:-2 credits x 30 hrs= 60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	Use of virtual simulation for obtaining the data pertaining to radioisotopes, Bravais lattices and NMR
CO2	To use simulation for thorough understanding of the instrumentation pertaining to radioisotopes, Bravais lattices and NMR
CO3	To interpret the data obtained from above experiments
CO 4	To obtain the X-ray diffraction pattern and crystallographs of the biomolecules using virtual lab / simulation
CO 5	To interpret the data obtained from above exercise
CO 6	To obtain the confocal microscopic images through virtual lab and interpretation of same

MB 563 MJP -Molecular Biophysics Group III Major Elective Practical Total: 2 Credits Workload:-30 hours/credit (Total Workload:-2 credits x 30 hrs= 60 hours in semester)		
Credits	**Credit Title and Contents**	**Number of Hours**
I	1. Virtual lab problem-based exercise to understand the instrumentation, experimentation and interpretation of data obtained using Radioisotopes in experiment 2. Virtual lab problem-based exercise to understand the instrumentation, experimentation and interpretation of Bravais Lattices 3. Virtual lab problem-based exercise to understand the instrumentation, experimentation and interpretation of data obtained using NMR	30
II	1. Virtual lab problem-based exercise to understand the instrumentation, experimentation and interpretation of data obtained using X-ray diffraction pattern 2. Virtual lab problem-based exercise to understand the instrumentation, experimentation and interpretation of data obtained using, X-Ray crystallography 3. Virtual lab problem-based exercise to understand the instrumentation, experimentation and interpretation of data obtained using Confocal Microscope	30

Suggested References: MB 563 MJP -Molecular Biophysics Group III Major Elective Practical
1. Use of reference, use of reference management tools (e.g. Zotero). https://aut.ac.nz.libguides.com/managingreferences https://aut.ac.nz.libguides.com/c.php?g=843515&p=6028899
2. Virtual lab exercise to understand the instrumentation, experimentation and interpretation of data obtained using HPLC, FACS, FTIR, GC-MS, NMR, X-Ray crystallography MALDI TOF, SEM, TEM, AFM, Confocal Microscope (representative websites)
3. Virtual proteomics laboratory IIT Bombay: http://pe-iitb.vlabs.ac.in/

MB 564 MJ -Bioinformatics

Group IV Major Elective Theory

Total: 2 Credits Workload:-15 hours/credit

(Total Workload:-2 credits x 15 hrs= 30 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	Study of bioinformatics as the collection, classification, storage, and analysis of biochemical and biological information using computers
CO2	Study methods of sequencing and various databases for microorganisms
CO3	Understand submission of Sequences to databases
CO 4	Learn tools and softwares in bioinformatics

Credits	**Credit Title and Contents**	**Number of Lectures**
I	1. Introduction to Bioinformatics 2. Overview of Bioinformatics resources on the web - NCBI/EBI/EXPASY etc. 3. Nature of biological data and formats 4. Literature databases (searching and downloading) 5. Nucleic acid sequence databases – GenBank, EMBL, DDBJ, RefSeq, dbSTS, dbEST 6. Protein sequence databases i. UniProtKB ii. UniRef, UniParc, Proteomes, NextProt	15
II	1. Nucleic acid and Protein sequence analysis- pairwise sequence alignment, multiple sequence alignment 2. Database Searches – Introduction to BLAST and FASTA 3. Structure databases – PDB, NDB 4. Molecular Phylogeny Concept and overview 5. Distance-based methods: UPGMA & NJ 6. Character-based methods: Maximum Parsimony	15

Suggested References: MB 564 MJ-Bioinformatics
Group III Major Elective Theory

1. Ajawatanawong P. (2017). Molecular Phylogenetics: Concepts for a Newcomer. Adv Biochem Eng Biotechnol.160:185-196. doi: 10.1007/10_2016_49. PMID: 27783136.
2. Benson D. A., Boguski M. S., Lipman D. J., Ostell J. and Ouellette B. F. F. (1998).

GenBank. *Nucleic Acids Res*. 26(1):1-7. doi:10.1093/nar/26.1.1.

3. Berman H. M., Gelbin A., Clowney L., Hsieh S. H., Zardecki C. and Westbrook J. (1996). The Nucleic Acid Database: Present and Future. J Res Natl Inst Stand Technol. 101(3): 243-257. doi: 10.6028/jres.101.026. PMID: 27805162; PMCID: PMC4963143
4. Coimbatore Narayanan B., Westbrook J., Ghosh S., Petrov A. I., Sweeney B., Zirbel C. L., Leontis N. B. and Berman H. M. (2014). The Nucleic Acid Database: new features and capabilities. Nucleic Acids Res. 42(Database issue): D114-22. doi: 10.1093/nar/gkt980. Epub 2013 Oct 31. PMID: 24185695; PMCID: PMC3964972.
5. https://pediaa.com/difference-between-upgma-and-neighbor-joining-tree/
6. Kannan L. and Wheeler W. C. Maximum Parsimony on Phylogenetic networks. *Algorithms Mol Biol* **7**. 9 (2012). https://doi.org/10.1186/1748-7188-7-9
7. NCBI Resource Coordinators. (2013) Database resources of the National Center for Biotechnology Information. Nucleic Acids Res. 41(Database issue): D8-D20. doi: 10.1093/nar/gks1189. Epub 2012 Nov 27. PMID: 23193264; PMCID: PMC3531099.
8. Suzek B., Huang H., Mcgarvey P., Mazumder R. and Wu C. (2007). UniRef: Comprehensive and Non-Redundant UniProt Reference Clusters. Bioinformatics (Oxford, England). 23:1282-1288. 10.1093/bioinformatics/btm098.
9. Wang Y., *et al* (2017). GSA: Genome Sequence Archive. *Genomics Proteomics Bioinformatics.* 15(1):14-18. doi:10.1016/j.gpb.2017.01.001.

MB 564 MJP -Bioinformatics
Group IV Major Elective Practical

Total: 2 Credits Workload:-30 hours/credit
(Total Workload:-2 credits x 30 hrs= 60 hours in semester)

Course outcomes COs	
After studying the course learners will be able to	
CO1	Isolation of bacterial chromosomal DNA and its detection through agarose gel electrophoresis
CO2	To use the 16SrDNA sequences of bacteria for identification purpose through its analysis using appropriate technique
CO3	To recognize the significance of A260/A280 ratio of bacterial chromosomal DNA and its analysis through same
CO 4	Methodology to amplify 16SrDNA through PCR and characterize PCR product
CO 5	To use the computational method such as BLAST for sequence matching of 16SrDNA
CO 6	Appreciate the use of appropriate software like Phylip, Mega for construction of

	phylogenetic tree

MB 564 MJP - Bioinformatics **Group IV Major Elective Practical** Total: 2 Credits Workload:-30 hours/credit **(Total Workload:-2 credits x 30 hrs= 60 hours in semester)**	
Credit Title and Contents	**Number of Hours**
1. 16S rRNA gene sequencing analysis of bacteria: Isolation, purity checking using A260/A280 ratio and Agarose gel electrophoresis of isolated chromosomal DNA of bacteria 2. PCR amplification and purification of 16S rRNA gene 3. Demonstration of the following steps, if not possible to perform in your lab: PCR product sequencing using automated sequencer -Sequence matching by BLAST analysis. 4. Drawing phylogenetic tree using related sequences (Using standard software like Phylip, Mega etc)	60

Suggested References: MB 564 MJP -Bioinformatics
Group III Major Elective Practical

1. Janda J. M. and Abbott S. L. (2007).16S rRNA gene sequencing for bacterial identification in the diagnostic laboratory: pluses, perils, and pitfalls. J Clin Microbiol. 45(9): 2761-2764. doi: 10.1128/JCM.01228-07. Epub 2007 Jul 11. PMID: 17626177; PMCID: PMC2045242.
2. https://assets.thermofisher.com/TFS-Assets/CAD/Product-Bulletins/T123-NanoDrop-Lite-Interpretation-of-Nucleic-Acid-260-280-Ratios.pdf
3. https://www.biotech.cornell.edu/sites/default/files/2020-07/Full_service_Sanger_Handbook.pdf
4. Wilson K. H., Blitchington R. B. and Greene R C. (1990). Amplification of bacterial 16S ribosomal DNA with polymerase chain reaction. J Clin Microbiol. 28(9): 1942-1946. doi: 10.1128/jcm.28.9.1942-1946.1990. Erratum in: J Clin Microbiol 1991 Mar;29(3):666. PMID: 2095137; PMCID: PMC268083.
5. Kumar S., Nei M., Dudley J. and Tamura K. (2008). MEGA: a biologist-centric software for evolutionary analysis of DNA and protein sequences. Brief Bioinform. 9(4):299-306. doi: 10.1093/bib/bbn017. EpubApr 16. PMID: 18417537; PMCID: PMC2562624.
6. https://blast.ncbi.nlm.nih.gov/Blast.cgi
7. https://www.youtube.com/watch?v=HXEpBnUbAMo
8. https://www.ncbi.nlm.nih.gov/genbank/fastaformat/

9. Following linux software tools can be used for practicals

Bioconductor	Analysis and comprehension of high-throughput genomic data
Biopython	Tools for biological computation written in Python
BioPerl	Perl tools for computational molecular biology
InterMine	Integrate biological data sources
UGENE	Set of integrated bioinformatics software
IGV	High-performance visualization genome browser tool
BioJava	Provides Java tools for processing biological data
GROMACS	Versatile package to perform molecular dynamics
Taverna Workbench	For designing and executing bioinformatics workflows
EMBOSS	The European Molecular Biology Open Software Suite
Clustal Omega	Multiple sequence alignment program
BLAST	Algorithm for comparing primary biological sequence information
bedtools	Powerful toolset for genome arithmetic
geWorkbench	Software platform for integrated genomic data analysis
Bioclipse	Rich-client platform chemistry and biology workbench