Savitribai Phule Pune University

(Formerly University of Pune)

Two Year Degree Program in Microbiology

(Faculty of Science and Technology)

Revised Syllabi for

M.Sc. (Microbiology) Part-I

(For Colleges
Affiliated to Savitribai Phule Pune University)

Choice Based Credit System Syllabus

To be implemented from Academic Year 2019-2020

Title of the Course: M.Sc. (Microbiology)

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, micro-organisms from extreme environments, Archaebacteria, etc.
- **Mathematical approach for Biologists**: Numerical Microbiology Problem solving, Concept of mathematical models, Application of Mathematical models to microbiologicalprocesses
- **Advanced Biochemistry and Molecular Biology Techniques**: Chromatography techniques, next generation sequencing methods (Pyrosequencing, Ion torrent, Nanopore sequencing)
- **Morphogenesis and organogenesis in plants**
- **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 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
- Techniques in Bio-nanotechnology
- 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 technological 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 post-graduate student can start work directly in applied fields (industry or institutions), without any additional training.

Thus, the university / college itself will be developing the 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 Sciences would be of 80 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 3 core compulsory theory courses (4 credits each) and one core compulsory Practical course (4 credits). In addition to this, choice based optional paper means elective course (departmental course) is offered consisting of 2 theory credits course and allied 2 practical credit course.

II. Workload:

Each theory credit is equivalent to 15 clock hours of teaching (12 hrs classroom + 3 hrs of tutorials-active learning method) and each practical credit is equivalent to 30 clock hours of teaching in a semester.

1. For the purpose of computation of workload, the following mechanism may be adopted as per UGC guidelines:
   i) 1 Credit = 1 Theory period of one-hour duration per week
   ii) 1 Credit = 1 Tutorial period of one-hour duration per week
   iii) 1 Credit = 1 Practical period of two-hour duration per week
2. Each theory lecture time is of 1hour=60min.
3. Each practical session time for Compulsory Practical Paper is of 8 hour=480 min.
4. Each practical session time for Choice Based Practical Optional paper is of 4 hour =240min.

III : M. Sc. First year Microbiology syllabus, equivalence with 2013 Pattern and assessment of credits:

III. A) M. Sc. First year Semester I syllabus and equivalence with 2013 Pattern

Course Type	2013 Pattern Course Code	2013 Pattern Course Name	2019 Pattern Course Code		2019 Pattern Course Name	2019 Pattern Corrected Course Code
Core Compulsory Theory Papers	MB 501	Microbial Diversity and Taxonomy	MB 501		Microbial Systematics	MBCT 111
	MB 502	Quantitative Biology	MB 502		Quantitative Biology	MBCT 112
	MB 503	Cell organization and Biochemistry	MB 503		Biochemistry and Metabolism	MBCT 113
Core Compulsory Practical paper	MB 511	Practical Course 1: Microbial Diversity & Systematics	MBCP1		Biochemical Techniques (Practical based oncompulsory theory credits)	MBCP 114
	MB 512	Practical Course 2: Cell Biology & Biochemistry	--		--	--
Choice Based Optional Papers Elective/ Departmental Course **Any one group**	--	--	Group I	MBTE 11	Fungal Systematics and Extremophiles	MBET 115
	--	--		MBPE 11	Practicals Based on Fungal Systematics and Extremophiles	MBEP 115
	OR					
	--	--	Group II	MBTE12	Experimental Design and Quantitative approaches for Biologist	MBET 116
	--	--		MBPE12	Practical's based on Experimental Design and Quantitative approaches for Biologist	MBEP 116
	OR					
	--	--	Group III	MBTE13	Microbial communication, Membrane transport and signal transduction	MBET 117
	--	--		MBPE13	Practicals Based on Microbial communication, Membrane transport and signal transduction	MBEP 117

MB: Microbiology; CT: Core Compulsory Theory; CP: Compulsory Practical; EP: Elective Practical; ET: Elective Theory

III. B) M. Sc. First year Microbiology Semester I assessment of Credits: -

Course Type	CourseCode		Course Name	Credit	Assessment		
					IA	UE	Total
Core Compulsory Theory Papers	MBCT111		Microbial Systematics	4	30	70	100
	MBCT112		Quantitative Biology	4	30	70	100
	MBCT113		Biochemistry and Metabolism	4	30	70	100
Core Compulsory Practical paper	MBCP114		Biochemical Techniques (Practical based on compulsory theory credits)	4	30	70	100
Choice Based Optional Papers Elective/ Departmental Course **Any one group**	Group I	MBET 115	Fungal Systematics and Extremophiles	2	15	35	50
		MBEP 115	Practicals Based on Fungal Systematics and Extremophiles	2	15	35	50
	OR						
	Group II	MBET 116	Experimental Design and Quantitative approaches for Biologist	2	15	35	50
		MBEP 116	Practicals based on Experimental Design and Quantitative approaches for Biologist	2	15	35	50
	OR						
	Group III	MBET 117	Microbial communication, Membrane transport and signal transduction	2	15	35	50
		MBEP 117	Practicals Based on Microbial communication, Membrane transport and signal transduction	2	15	35	50

III. C) Course Structure: M. Sc. First year Microbiology Semester II syllabus and equivalence with 2013 Pattern: -

Course Type	2013 Pattern Course Code	2013 Pattern Course Name	2019 Pattern Course Code		2019 Pattern Course Name	2019 Pattern Corrected Course Code
Core Compulsory Theory Papers	MB 601	Instrumentation and Molecular Biophysics	MB 601		Instrumentation and Molecular Biophysics	MBCT 121
	MB 602	Virology	MB 602		Molecular Biology	MBCT 122
	MB 603	Microbial Metabolism	MB 603		Enzymology, Bioenergetics and Metabolism	MBCT 123
Core Compulsory Practical paper	MB 611	Practical Course 1: Biophysics and Virology	MBCP 2		Molecular biology, Enzymology and Instrumentation Techniques (Practical basedon compulsory theory credits)	MBCP 124
	MB 612	Practical Course 2: Enzymology and Microbial Metabolism	--		--	--
Choice Based Optional Papers Elective/ Departmental Course **Any one group**	--	--	Group I	MBTE 21	Bioinformatics and Bio-nanotechnology	MBET 125
	--	--		MBPE 21	Practicals based on Bioinformatics and Bio-nanotechnology	MBEP 125
	OR					
	--	--	Group II	MBTE 22	Molecular Biology tools and applications	MBET 126
	--	--		MBPE 22	Practical based on Molecular Biology tools and applications	MBEP 126
	OR					
	--	--	Group III	MBTE 23	Nitrogen Metabolism, Respiration and Photosynthesis	MBET 127
	--	--		MBPE 23	Practicals Based on Nitrogen Metabolism, Respiration and Photosynthesis	MBEP 127

MB: Microbiology; CT: Core Compulsory Theory; CP: Compulsory Practical; EP: Elective Practical; ET: Elective Theory

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

Course Type	Course Code		Course Name	Credit	Assessment		
					IA	UE	Total
Core Compulsory Theory Papers	MBCT 121		Instrumentation and Molecular Biophysics	4	30	70	100
	MBCT 122		Molecular Biology	4	30	70	100
	MBCT 123		Enzymology, Bioenergetics and Metabolism	4	30	70	100
Core Compulsory Practical paper	MBCP 124		Molecular biology, enzymology and instrumentation Techniques (Practical based oncompulsory theory credits)	4	30	70	100
Choice Based Optional Papers Elective/ Departmental Course **Any one group**	Group I	MBET 125	Bioinformatics and Bio-nanotechnology	2	15	35	50
		MBEP 125	Practicals based on Bioinformatics and Bio-nanotechnology	2	15	35	50
	OR						
	Group II	MBET 126	Molecular Biology tools and applications	2	15	35	50
		MBEP 126	Practical based on Molecular Biology tools and applications	2	15	35	50
	OR						
	Group III	MBET 127	Nitrogen Metabolism, Respiration and Photosynthesis	2	15	35	50
		MBEP 127	Practicals Based on Nitrogen Metabolism, Respiration and Photosynthesis	2	15	35	50

IV. M. Sc. Second year Microbiology syllabus, equivalence with 2013 Pattern and assessment of credits:

IV. A) M. Sc. Second year Microbiology Semester III syllabus and equivalence with 2013 Pattern :-

Course Type	2013 Pattern Course Code	2013 Pattern Course Name	2019 Pattern Course Code		2019 Pattern New Course Name	2019 Pattern Corrected Course Code
Core Compulsory Theory Papers	MB 701	Immunology	CCTP 7 (MB 701)		Immunology	MBCT 231
	MB 702	Molecular Biology-I	CCTP 8 (MB 702)		Molecular Biology	MBCT 232
	MB 703	Industrial Waste Water Treatment	CCTP 9 (MB 703)		Clinical Microbiology	MBCT 233
Core Compulsory Practical paper	MB 711	Practical course based on Immunology, Pharmaceutical Microbiology and Environmental Microbiology	MBCP 3		Practicals based on Compulsory Theory Credits.	MBCP 234
	MB 712	Practical course based on Molecular Biology (I and II) and Microbial Technology	--		--	--
Choice Based Optional Papers Elective/ Departmental Course **Any one group**	--	--	Group I	MBTE 31	Cell Culture Techniques	MBET 235
	--	--		MBPE 31	Practicals based on Cell Culture Techniques	MBEP 235
	OR					
	--	--	Group II	MBTE 32	Bioremediation and Biomass utilization	MBET 236
	--	--		MBPE 32	Practicals based on Bioremediation and Biomass utilization	MBEP 236
	OR					
	--	--	Group III	MBTE 33	Microbial Virus Technology	MBET 237
	--	--		MBPE 33	Practicals based on Clinical Microbiology and Microbial Virus Technology	MBEP 237

IV. B) M. Sc. Second year Microbiology syllabus semester III assessment of credits: -

Course Type	Course Code	Course Name	Credit	Assessment		
				IA	UA	Total
Core Compulsory Theory Papers (CCTP)	MBCT 231	Immunology	4	30	70	100
	MBCT 232	Molecular Biology	4	30	70	100
	MBCT 233	Clinical Microbiology	4	30	70	100
Core Compulsory Practical Paper	MBCP 234	Practicals based on Compulsory TheoryCredits.	4	30	70	100
Choice Based Optional Papers (CBOP) Elective /Departmental Course	MBET 235	Cell Culture Techniques	2	15	35	50
	MBEP 235	Practicals based on Cell CultureTechniques	2	15	35	50
	OR					
	MBET 236	Bioremediation and Biomass utilization	2	15	35	50
	MBEP 236	Practicals based on Bioremediation and Biomass utilization	2	15	35	50
	OR					
	MBET 237	Microbial Virus Technology	2	15	35	50
	MBEP 237	Practicals based on Clinical Microbiology and Microbial VirusTechnology	2	15	35	50

IV. C) M. Sc. Second year Microbiology Semester IV syllabus and equivalence with 2013

Pattern: -

Course Type	2013 Pattern Course Code	2013 Pattern Course Name	2019 Pattern Course Code		2019 Pattern Course Name	2019 Pattern Corrected Course Code
Core Compulsory Theory Papers	MB 801	Pharmaceutical and medical Microbiology	CCTP 10 (MB 801)		Pharmaceutical Microbiology	MBCT 241
	MB 802	Molecular Biology II	-		-	-
	MB 803	Microbial Technology	CCTP 11 (MB 802)		Microbial Technology	MBCT 242
Core Compulsory Practical paper	MB 811	Dissertation I	MBCP 4		Dissertation	MBCP 243
	MB 812	Dissertation II	--		--	--
Choice Based Optional Papers Elective/ Departmental Course **Any two group**	--	--	Group I	MBTE 41	Quality Assurance and Validation in Pharmaceutical Industry and Development of Anti-infectives	MBET 244
	--	--		MBPE 41	Practicals based on quality assurance and validation in pharmaceutical industry and development of anti-infectives	MBEP 244
	OR					
	--	--	Group II	MBTE 42	Advances in Microbial Technology	MBET 245
	--	--		MBPE 42	Practicals based on Advances in Microbial Technology	MBEP 245
	OR Continued on next page					
	2013 Pattern Course	**2013 Pattern Course Name**		**2019 Pattern Course**	**2019 Pattern Course Name**	**2019 Pattern Corrected Course Code**

	Code			**Code**		
	--	--	**Group III**	MBTE 43	Industrial Waste Water Treatment and Industrial Production of Vaccines	MBET 246
	--	--		MBPE 43	Practicals based on Industrial Waste Water Treatment and Industrial Production of Vaccines	MBEP 246
	OR					
	--	--	**Group IV**	MBTE 44	Bioethics, Biosafety, Quality Control and Quality Assurance	MBET 247
	--	--		MBPE 44	Practicals based on Bioethics, Biosafety, Quality Control and Quality Assurance	MBEP 247

IV. D). ***M. Sc. Second year Microbiology Semester IV assessment of credits*****:-**

Course Type	Course Code	Course Name	Credit	Assessment		
				IA	UA	Total
Core Compulsory Theory Papers (CCTP)	MBCT 241	Pharmaceutical Microbiology	4	30	70	100
	MBCT 242	Microbial Technology	4	30	70	100
Core Compulsory Practical Paper	MBCT 243	Dissertation	4	30	70	100
Any Two: Choice Based Optional Papers (CBOP) Elective /Departmental Course	MBET 244	Quality Assurance and Validation in Pharmaceutical Industry and Development of Anti-infectives	2	15	35	50
	MBEP 244	Practicals based on quality assurance and validation in pharmaceutical industry and development of anti-infectives	2	15	35	50
	OR					
	MBET 245	Advances in Microbial Technology	2	15	35	50
	MBEP 245	Practicals based on Advances in Microbial Technology	2	15	35	50
	OR					
	MBET 246	Industrial Waste Water Treatment and Industrial Production of Vaccines	2	15	35	50
	MBEP 246	Practicals based on Industrial Waste Water Treatment and Industrial Production of Vaccines	2	15	35	50
	OR					
	MBET 247	Bioethics, Biosafety, Quality Control and Quality Assurance	2	15	35	50
	MBEP 247	Practicals based on Bioethics, Biosafety, Quality Control and Quality Assurance	2	15	35	50

V. Course Evaluation:

Each course will be evaluated for 25 marks per credit of which 30% will be based on

continuous / internal evaluation.

VI. Examination Results:

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

VII. 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 80 credit hours. Total credit hours mean sum of credit hours of the courses which a student has passed.

VIII. Rules and University Guidelines:

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

IX. 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 80 credits (20 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 takeplace. 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
5. Short Quizzes
6. Assignments
7. Extension work
8. An open book test (with the respective subject teacher deciding what books are to be allowed for this purpose)
9. 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 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 principle 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. In case he/she wants to repeat internal assessment he/she can do so only by registering for the said course during the 5^{th} / 6^{th} semester and onwards up to 8^{th} semester.

Students who have failed semester-end exam may reappear for semester-end examination only twice in subsequent period. 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 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. Result 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.

M. Sc. Microbiology First Year Semester I syllabus

	Semester I	
Credits	**MBCT 111: Microbial Systematics** Core Compulsory Theory Paper Total: 4 Credits; Workload: -15 hrs /credit (Total Workload: - 4 credits x 15 hrs = 60 hrs in semester)	**Lectures**
Credit I	**Bacterial Systematics** 1. Species concept in prokaryotes and eukaryotes 2. 5-Kingdom classification system 3. 3-Domain classification system 4. Determinative Bacteriology (Phenetic Approach) 5. Systematic Bacteriology (Phylogenetic Approach) 6. Polyphasic Approach 7. Molecular clocks, phylogeny and molecular distances	**15**
Credit II	**Microbial Diversity** 1. Facets of microbial diversity: morphological, structural, metabolic, ecological, behavioraland evolutionary 2. Species divergence and measurement of microbial diversity 3. Measures and indices of diversity; alpha, beta and gamma diversity	**15**
Credit III	**Exploration of Un-culturable 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**
Credit 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 gene. 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 ageing, evolutionary trade-offs, r and k selection	**15**

Suggested References: MBCT 111: Microbial Systematic Semester I

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	Semester I	

Credits	**MBCT 112: Quantitative Biology** Core Compulsory Theory Paper Total: 4 Credits Workload: -15 hrs /credit (Total Workload: - 4 credits x 15 hrs = 60 hrs in semester)	Lectures
Credit I	**Descriptive Statistics** 1. Fundamental concepts –Sample Statistics and Population parameter, data (qualitative and quantitative data, discrete and continuous series data), data sources, variables, measurement scales (nominal, ordinal, interval and ratio), variability and uncertainty in measurements 2. Measures of central tendency – Mean Mode, median 3. Measures of dispersion – Mean deviation Standard deviation and Variance 4. Data presentation-Tables and Graphs (Histogram, bar, pie and line) 5. Simple linear Regression and correlation (significance testing not necessary) *(Sr. No. 1: - only theory questions to be asked in exam.* *Sr. No. 2 – 5: - only problem-solving questions to be asked in exam.)*	**15**
Credit II	**Inferential Statistics-1** 1. Uncertainty: Variation, Probability and inference 2. Central Limit Theorem, Standard deviation of the means standard error and confidence interval 3. The concepts of null hypothesis, Test statistics, P-value significance level, type I and type II errors, one tailed and two tailed tests, degrees of freedom, Parametric and nonparametric test, statistical decision tree, Parametric statistical test: Z-test, t-test and F-test *(Sr. No 1 – 3: - only theory questions to be asked in exam except Z-test, T-test and F-test.)*	**15**
Credit III	**Inferential Statistics-2** 1. Test of Significance: Chi square test (Goodness of fit and Independence), 2. Comparison of 3 or more samples – ANOVA One way and two-way, Post Hoc test (Tukey's) 3. Nonparametric Tests: comparison to parametric tests, Sign test, Wilcoxon's signed rank testand Mann-Whitney U test	**15**
Credit IV	**Probability and Probability Distribution** 1. Concept of experiment, event (mutually exclusive & non-exclusive events, dependent &independent events); 2. Laws of probability (addition and multiplication); 3. Probability distribution – Normal (x-scale and z-scale), Binomial and Poisson distributions	**15**

Suggested References: MBCT 112: Quantitative Biology Semester I

1. Bailey N. T. J. (1981). Statistical Methods in Biology. United Kingdom: Hodder and Stoughton. ISBN: 9780340247563,
2. Brown D. and Rothery P. (1993). Models in biology: mathematics, statistics, and computing. United Kingdom: Wiley. ISBN: 9780471933229. Digitized 20th June 2009
3. Chetwynd A., Chetwynd A. G. and Diggle P. J. (2011). Statistics and Scientific Method: An Introduction for Students and Researchers. Italy: OUP Oxford. ISBN:9780199543182
4. Daniel W. W. and Cross C. L. (2018). Biostatistics: A Foundation for Analysis in the Health Sciences. United Kingdom: Wiley. ISBN: 9781119282372
5. Doran P. M. (2013). Bioprocess Engineering Principles. Netherlands: Elsevier Science. ISBN: 9780122208515
6. Gupta S. P. (2021). Statistical Methods. 46th edition. Sultan Chand & Sons Publisher, New Delhi. ISBN13: 9789351611769
7. Haefner J. W. (2012). Modeling Biological Systems: Principles and Applications. United States: Springer US. ISBN: 9781461541196
8. Harvey L. and McNeil B. (2008). Practical Fermentation Technology. Germany: Wiley. ISBN: 9780470014349
9. Khan I. A. and Khanum A. (2016). Fundamentals of Biostatistics. 5th Edition. Ukaaz, Publications, Hyderabad. ISBN-13: 9788190044103
10. Lindgren B. (2017). Statistical Theory. United Kingdom: CRC Press. ISBN: 9781351414173
11. Montgomery D. C. (2013). Design and Analysis of Experiments. Italy: Wiley. ISBN: 9781118097939
12. Newman S. C. (2003). Biostatistical Methods in Epidemiology. Germany: Wiley. ISBN: 9780471461609
13. Petrie A. and Sabin C. (2019). Medical Statistics at a Glance. United Kingdom: Wiley. ISBN: 9781119167815
14. Rosner B. (2016). Fundamentals of Biostatistics. United States: Cengage Learning. ISBN:9781305268920

	Semester I	
Credit	**MBCT 113: Biochemistry and Metabolism** Core Compulsory Theory Paper Total: 4 Credits Workload: -15 hrs /credit (Total Workload: - 4 credits x 15 hrs = 60 hrs in semester)	**Lectures**
Credit 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-terminal determination, methodof 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 &hemoglobin)	**15**
Credit II	**Biochemistry and Molecular Biology Techniques:** 1. Chromatography: Principles and applications of gel filtration, Ion exchange, affinitychromatography 2. Electrophoresis: Agarose, Native PAGE, SDS PAGE 3. Polymerase chain reaction: Principle, variations of PCR (Hot start, Nested, Reverse transcription, real time PCR) and its applications. 4. Sequencing methods: a) RNA-sequencing methods and applications, b) DNA sequencing: Classical and next generation sequencing methods (Pyro-sequencing, Ion torrent, Nano-pore sequencing).	**15**

Credit 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**
Credit IV	**Cell biology:** 1. Structural organization and function of Endoplasmic Reticulum, Golgi apparatus, Nucleus, Mitochondrion, chloroplast, Lysosomes, peroxisomes; Cytoskeleton and function of Molecularmotors. 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	**15**

Suggested References: MBCT 113 Biochemistry and Metabolism

Credit I and II : Protein Chemistry, Biochemistry and Molecular Biology Techniques

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, PublishingCompany, 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 Kingdom: 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

Semester I

MBCP 114: Biochemical Techniques

Core Compulsory Practical Paper

Total: 4 Credits Workload: -30 hrs /credit

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

1. Safety rules in Laboratory: Laboratory safety, hazard from chemicals, handling of chemicals, disposal of chemicals and cultures, recording of scientific experiments. Standardization of laboratory procedures, calibration and validation instruments, preparing / designing SOP for the same, maintenance of instruments
2. Buffer: Determination of pKa of a monoprotic weak organic acid;

   Preparation of buffers using KH_2PO_4 and K_2HPO_4, acetic acid and sodium acetate, K_2HPO_4 and H_3PO_4.
3. Computer applications: Using data sheets, and sorting data with different parameters, plotting graphs – bar charts, line graphs, pie charts, adding error bars. (Using Microsoft Excel Statistical analysis of data – Students t test, ANOVA, Chi square test, F test using computer softwares (Using Microsoft Excel)
4. Enrichment, Isolation and identification of the following extremophiles from natural samples: Alkaliphiles and Thermophiles

   Identification 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)
5. Studying the stages mitosis in growing tip of onion root cells and to observe polyploidy induced by colchicine treatment on root tip. Demonstration of mounting of embryos (frog and fruit fly) at various developmental stages on permanent slides
6. Demonstration of mounting of embryos (frog and fruit fly) at various developmental stages on permanent slides
7. Extraction of Protein and Exo-polysaccharide from bacterial culture (may use TCA and ethanol method)
8. Colorimetry and spectrophotometry: estimation of above sample: Bradford and UV Spectrophotometry (purity using A_{280} method).
9. Chromatography: Separation of hydrolyzed protein and EPS sample (above) using paper and thin layer chromatography. (*Explain concept of two-dimensional chromatography and descending chromatography*)

10. Electrophoresis: SDS-PAGE of above proteins / To determine the ion-exchange capacity and nature of given resin using anion exchange chromatography
11. Interpretation of Ramachandran Plot and study of conformations of protein molecule using Molecular Graphics Visualization Tool (e.g., Swiss PDB)

Suggested references MBCP 114: Biochemical Techniques Semester I

1. Safety rules in Laboratory: Laboratory safety, hazard from chemicals, handling of chemicals, disposal of chemicals and cultures, recording of scientific experiments. Standardization of laboratory procedures, calibration and validation instruments, preparing / designing SOP for the same, maintenance of instruments
   - 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
2. Buffer: Determination of pKa of a monoprotic weak organic acid;

   Preparation of buffers using KH_2PO_4 and K_2HPO_4, acetic acid and sodium acetate, K_2HPO_4 and H_3PO_4.
   - 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.

3. a. Computer applications: Using data sheets, and sorting data with different parameters, plotting graphs – bar charts, line graphs, pie charts, adding error bars. (Using Microsoft Excel

- 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. Pearson Education.
- https://www.britannica.com/technology/spreadsheet

3.b. Statistical analysis of data – Students t test, ANOVA, Chi square test, F test using computer softwares (Using Microsoft Excel)

- 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.

4. Enrichment, Isolation and identification of the following extremophiles from natural samples: Alkaliphiles and Thermophiles

   Identification 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)

- Bhosle S., Desai R. S., Krishnamurthy N. K. and Mavinkurve S. (2004). Alkalophiles in estuarine mangrove regions of Goa. Indian Journal of Marine Sciences. 33(2):178-180.
- Horikoshi K. (1999). Alkaliphiles: some applications of their products for biotechnology. Microbiol. Mol. Biol. Rev. 63:735–750. doi: 10.1128/MMBR.63.4.735-750.1999.
- 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 as potential producers of thermostable enzymes". International Journal of Microbiology. 2017: Article ID 6943952. 1-12. https://doi.org/10.1155/2017/6943952
- Merino N., Aronson H. S., Bojanova D. P., Feyhl-Buska J., Wong M. L., Zhang S.

and Giovannelli D. (2019). Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Front. Microbiol. 10:780. doi: 10.3389/fmicb.2019.00780

- Nakatsu C. H., Miller R. V., Yates M. V. and Pillai S. D. (2020). Manual of Environmental Microbiology. United States: Wiley. ISBN:9781555818821

5. Studying the stages 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.

6. Demonstration of mounting of embryos (frog and 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

7. Extraction of Protein and Exo-polysaccharide from bacterial culture (may use TCA and ethanol method)

- 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

8. Colorimetry and spectrophotometry: estimation of above sample: Bradford and UV Spectrophotometry (purity using A_{280} method).

- 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

9. Chromatography: Separation of hydrolysed protein and EPS sample (above) using paper and thin layer chromatography. (*Explain concept of two-dimensional chromatography and descending chromatography*)
   - 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
   - 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.
10. Electrophoresis: SDS-PAGE of above proteins / To determine the ion-exchange capacity and nature of given resin using anion exchange chromatography
    - 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.
11. Interpretation of Ramachandran Plot and study of conformations of protein molecule using Molecular Graphics Visualization Tool (e.g., Swiss PDB)
    - 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.

	Semester I	
Credits	**MBET 115: Fungal Systematics and Extremophiles** **Choice based Optional Theory Paper (Elective)** Total: 2 Credits Workload: -15 hrs /credit (Total Workload: - 2 credits x 15 hrs = 30 hrs in semester)	**Lectures**
Credit I	**Fungal Systematics:** 1. Six Classes of Fungi 2. Differentiating characters among different Classes of fungi 3. Importance of morphological characters in fungal differentiation and classification	**15**
Credit II	**Extremophiles** 1. Enrichment, isolation, classification, properties and application of extremophiles: Thermophiles, Psychrophiles, Halophiles, Acidophiles, Methanogens **2.** Adaptation mechanisms of extremophiles	**15**

Suggested References: MBET 115: Fungal Systematics and Extremophiles Semester I

Credit I : Fungal Systematics:

1. Athearn Bessey E. (2020). Morphology and Taxonomy of Fungi. India: Alpha Editions. ISBN: 9789354009730,
2. Barnett H. L. and Hunter, B. B. 1960. Illustrated Genera of Imperfect Fungi. Burgess Publishing Co., Minnesota.
3. Carlile M. J., Watkinson S. C. and Gooday G. W. (2001). The Fungi. Netherlands: Elsevier Science. ISBN: 9780127384467
4. Lodder J. (1974). The Yeasts: A Taxonomic Study, North Holland Publishing Co. Amsterdam
5. Manoharachary C. and Mukerji K. G. (2010). Taxonomy and Ecology of Indian Fungi. India: I.K. International Publishing House Pvt. Limited. ISBN:9789380026923

Credit II : Extremophiles

1. Gerday C. and Glansdorff N. (2009). Extremophiles. United Kingdom: Eolss Publishers. ISBN: 9781905839933
2. Horikoshi K., Stetter K. O., Antranikian G., Robb F. and Bull A. (2010). Extremophiles Handbook. Germany: Springer.
3. Sharma V. and Salwan R. (2020). Physiological and Biotechnological Aspects of Extremophiles. Netherlands: Elsevier Science. ISBN: 9780128183236
4. Stan-Lotter H., Oren A. and Seckbach J. (2013). Polyextremophiles: Life Under Multiple Forms of Stress. Netherlands: Springer Netherlands.
5. Subba Rao D. V. and Durvasula R. V. (2018). Extremophiles: From Biology to Biotechnology. United States: CRC Press. ISBN: 9781351650731

	Semester I	
Credits	**MBEP 115: Practicals Based on Fungal Systematics and Extremophiles** **Choice based Optional Practical Paper (Elective)** Total: 2 Credits Workload: -30 hrs /credit (Total Workload: - 2 credits x 30 hrs = 60 hrs in semester)	**Lectures**
Credit I	**Isolation and identification of yeasts and saprophytic molds from natural samples.** The identification key must be designed for each isolated and identified fungus. Students are expected to isolate at least one Genus from Mold and Yeast each *(Varied types of samples should be processed to obtain representative isolate of the groups)*	**30**
Credit II	**Isolation and identification of the following extremophiles from natural samples: Acidophiles and Halophiles** Identification 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)*	**30**

Suggested References: MBEP 115: Practicals Based on Fungal Systematics and Extremophiles Semester I

Credit I : Isolation and identification of yeasts and saprophytic molds from natural samples.

- Alexopoulos C. J., Mims C. W. and Blackwell M. (2007). Introductory Mycology, 4th Edition. India: Wiley India Pvt. Limited.
- Bills G. F., Mueller G. M. and Foster M. S. (2011). Biodiversity of Fungi: Inventory and Monitoring Methods. Netherlands: Elsevier Science.
- Deacon J. W. (2013). Fungal Biology. Germany: Wiley.
- Hudson H. J. (1992). Fungal Biology. United Kingdom: Cambridge University Press.
- Kreger-Van Rij N. J. W. (2013). The Yeasts: A Taxonomic Study. Netherlands: Elsevier Science.

Credit II : Isolation and identification of the following extremophiles from natural samples:

Acidophiles: -

- Joe S. J., Suto K., Inoie C. and Chida T. (2007). Isolation and characterization of acidophilic heterotrophic iron-oxidizing bacterium from enrichment culture obtained from acid mine drainage treatment plant. J Biosci Bioeng. 104(2):117-123. doi: 10.1263/jbb.104.117.
- Ňancucheo I., Rowe O. F., Hedrich S. and Johnson D. B. (2016). Solid and liquid media for isolating and cultivating acidophilic and acid-tolerant sulfate-reducing bacteria, FEMS Microbiology Letters, 363: 10, fnw083. https://doi.org/10.1093/femsle/fnw083
- Sánchez-Andrea I., Stams A. J., Amils R. and Sanz J. L. (2013). Enrichment and isolation of acidophilic sulfate-reducing bacteria from Tinto River sediments. Environ Microbiol Rep. 5(5): 672-678. doi: 10.1111/1758-2229.12066

Halophiles: -

- 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
- Kumar S., Karan R., Kapoor S., Singh S. P. and Khare S. K. (2012). Screening and isolation of halophilic bacteria producing industrially important enzymes. Braz J Microbiol. 43(4): 1595–1603. doi: 10.1590/S1517-838220120004000044
- 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.

	Semester I	
Credit	**MBET 116: Experimental Design and Quantitative approached for Biologist** **Choice based Optional Theory Paper (Elective)** Total: 2 Credits Workload: -15 hrs /credit (Total Workload: - 2 credits x 15 hrs = 30 hrs in semester)	**Lectures**
Credit I	**Designing of Experiments:** 1. Research Methodology 2. Sampling methods, sampling errors 3. Survey design, DOE in Agriculture (randomization, replication and local control), designs- CRD, RCBD and LSD 4. Factorial design (Full, Fractional and Plackett Burman) 5. Epidemiological Study designs: Case control, cohort, concurrent, cross-sectional, retrospective/prospective 6. Clinical/field trials-Randomization, Bias removal (Blinding – single and double), controlled and uncontrolled trials	**15**
Credit II	**Mathematical approach for Biologists** *(Basic rules and application of limits, derivative and integration need to be discussed)* 7. Presentation of experimental data (Tables, graphs and equations) 8. Data Analysis (Trends, Testing mathematical models, Goodness of fit: Least Square Analysis, Linear and Non-linear models) 9. Concept of mathematical model, need, modeling the system of interest, modeling the data Deterministic Vs Stochastic model, Cyclic processes of model construction, verification and applications	**15**

Suggested References: Experimental Design and Quantitative approached for Biologist
Semester I

1. Bailey N. T. J. (1995). Statistical Methods in Biology. United Kingdom: Cambridge University Press.
2. Gupta S. P. (2021). Statistical Methods. 46th edition. Sultan Chand & Sons Publisher, New Delhi. ISBN13: 9789351611769
3. Haaland P. D. (2020). Experimental Design in Biotechnology. United States: CRC Press.
4. Jaberi-Douraki M. and Moghadas S. M. (2018). Mathematical Modelling: A Graduate Textbook. Germany: Wiley.
5. Khan I. A. and Khanum A. (2016). Fundamentals of Biostatistics. 5th Edition. Ukaaz, Publications, Hyderabad. ISBN-13: 9788190044103
6. Locker A. and Krüger F. (2014). Quantitative Biology of Metabolism: Models of Metabolism, Metabolic Parameters, Damage to Metabolism, Metabolic Control. United States: Springer Berlin Heidelberg.
7. Montgomery D. C. (2013). Design and Analysis of Experiments. Italy: Wiley. ISBN: 9781118097939
8. Müller J. and Kuttler C. (2015). Methods and Models in Mathematical Biology: Deterministic and Stochastic Approaches. Germany: Springer Berlin Heidelberg.
9. Newman S. C. (2003). Biostatistical Methods in Epidemiology. Germany: Wiley.
10. Petrie A. and Sabin C. (2019). Medical Statistics at a Glance. United Kingdom: Wiley.
11. Reid N., Reid N. and Cox D. (2000). The Theory of the Design of Experiments. United States: CRC Press.
12. Rosner B. (2016). Fundamentals of Biostatistics. United States: Cengage Learning.
13. Voss D., Draguljić D. and Dean A. (2017). Design and Analysis of Experiments. Germany: Springer International Publishing.

	Semester I	
Credit	**MBEP 116: Practicals Based on Experimental Design and Quantitative approached for Biologist** **Choice based Optional Practical Paper (Elective)** Total: 2 Credits Workload: -30 hrs /credit (Total Workload: - 2 credits x 30 hrs = 60 hrs in semester)	**Lectures**
Credit I	**Practicals based on theory credit Designing of experiments** 1. Designing of 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 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*)	**30**

	4. Factorial Study Design (Placket barmen, Fractional Factorial and full factorial) forOptimization of Media conditions a) Data collection from Research Papers/ Dissertations /Journals b) Data Treatment using Statistical Software's (Mini tab, SPSS and Design Expert)	
Credit II	**Practicals based on theory credit Mathematical approach for Biologists** 1. Numerical Microbiology Problem solving: Unit conversion, 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. (*Using Statistical Packages other than Microsoft Excel)* 3. Statistical analysis of data – Students t test, ANOVA, Chi square test, F test using computer software (*Using Statistical Packages other than Microsoft Excel*)	**30**

Suggested References: MBEP 116: Semester I
Practicals Based on Experimental Design and Quantitative approached for Biologist

Credit I : Practicals based on theory credit Designing of experiments

1. Designing of Mock Research Proposal which includes:
   - Gastel B. and Day R. A. (2016). How to Write and Publish a Scientific Paper. United States: ABC-CLIO, LLC.
   - Kothari C. R. (2004). Research methodology methods and techniques. 2nd revised edition. New age international publisher.
2. Epidemiological study Proposal *(Mini Project)*
   - Brown D. and Rothery P. (1993). Models in biology: mathematics, statistics, and computing. United Kingdom: Wiley. ISBN: 9780471933229. Digitized 20th June 2009
   - Newman S. C. (2003). Biostatistical Methods in Epidemiology. Germany: Wiley.

ISBN: 9780471461609

3. Statistical Survey
   - Acharya R. and Roy T. K. (2016). Statistical Survey Design and Evaluating Impact. India: Cambridge University Press.
   - Nardi P. M. (2018). Doing Survey Research: A Guide to Quantitative Methods. United Kingdom: Taylor & Francis.
   - Singh Y. K. (2006). Fundamental of Research Methodology and Statistics. India: New Age International (P) Limited.
4. Factorial Study Design (Placket barmen, Fractional Factorial and full factorial) for Optimization of Media conditions
   - Harvey L. and McNeil B. (2008). Practical Fermentation Technology. Germany: Wiley.
   - Montgomery D. C. (2013). Design and Analysis of Experiments. Italy: Wiley. ISBN: 9781118097939

Credit II : Practicals based on Theory Mathematical approach for Biologists

1. Numerical Microbiology Problem solving: Unit conversion, 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

- Aneja K. R. (2007). Experiments In Microbiology, Plant Pathology and Biotechnology. India: New Age International.
- Cappuccino J. G. and Welsh C. T. (2017). Microbiology: A Laboratory Manual. eBook, Global Edition. United Kingdom: Pearson Education.
- Green L. H. and Goldman E. (2008). Practical Handbook of Microbiology. United States: CRC Press.
- Pommerville J. C. (2010). Alcamo's Laboratory Fundamentals of Microbiology. United States: Jones & Bartlett Learning, LLC.
- Tate R. L. (1986). Microbial Autecology: A Method for Environmental Studies. Digitized 2009. United Kingdom: Wiley.

2. Computer applications: Using data sheets, and sorting data with different parameters, plotting graphs – bar charts, line graphs, pie charts, adding error bars. (*Using Statistical Packages other than Microsoft Excel*)

- Boslaugh S. (2012). Statistics in a Nutshell. Germany: O'Reilly Media Incorporated. ISBN: 9781449316822

- 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. Pearson Education.
- https://www.britannica.com/technology/spreadsheet

3. Statistical analysis of data – Students t test, ANOVA, Chi square test, F test using computer software (*Using Statistical Packages other than Microsoft Excel*)

- Boslaugh S. (2012). Statistics in a Nutshell. Germany: O'Reilly Media Incorporated. ISBN: 9781449316822
- Khan I. A. and Khanum A. (2016). Fundamentals of Biostatistics. 5th Edition. Ukaaz, Publications, Hyderabad. ISBN-13: 9788190044103
- 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

	Semester I	
Credit	**MBET 117: Microbial communication, Membrane transport and signal transduction** **Choice based Optional Theory Paper (Elective)** Total: 2 Credits Workload: -15 hrs /credit (Total Workload: - 2 credits x 15 hrs = 30 hrs in semester)	**Lectures**
Credit I	**Communication and Coordination among microorganisms** 1. Life cycle of *Dictyostelium discoideum*, Molecular mechanism of quorum sensing in slime molds, 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	**15**
Credit II	**Membrane transport and signal transduction** 6. The composition and architecture of membranes, Membrane dynamics, 7. Solute transport across membranes: Passive diffusion, facilitated transport, primary and secondary active transport using P, V and F type ATPases 8. Ionophores, Ion mediated transport, transport of ions across membranes (ion pumps), ligand and voltage gated ion channels 9. Liposomes and model membrane 10. Signal transduction pathways in bacteria, second messengers, regulation of signaling pathways,bacterial two-component systems, chemotaxis.	**15**

Suggested References : MBET 117: Microbial communication, Membrane transport and signal transduction

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 Multicellular Morphogenesis, Cold Spring Harb Perspect Biol 2010; 2: a000380
4. Toole 'O' G., Kaplan H. B. and Kolter R. (2000) Biofilm formation as microbial development 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. (2015) Molecular Biology of the Cell. 6th edition. Garland Science; Taylor and Francis Group. New York. ISBN: 9781317563754
2. Cantley L. C., Sever R. and Hunter T. (2014). Signal Transduction: Principles, Pathways, and Processes. United States: Cold Spring Harbor Laboratory Press.
3. Changeux J., Comoglio, P., Sandhoff, K., Schatz G., Pinna L., Tager J., Orrenius S., Jaenicke R. (2012). Biochemistry of Cell Membranes: A Compendium of Selected Topics. Switzerland: Springer Basel AG.
4. Evangelopoulos A.E., Changeux J.P., Wirtz K.W.A., Packer L. and Sotiroudis T.G. (2013). Receptors, Membrane Transport and Signal Transduction. Germany: Springer Berlin Heidelberg.
5. Fairweather I. Cell Signalling 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.

Semester I

MBEP 117: Practicals Based on Microbial communication, Membrane transport and signal transduction

Choice based Optional Practical Paper (Elective)

Total: 2 Credits Workload: -30 hrs /credit

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

Practicals Based on Credit I: Communication And Coordination among microorganisms

1. Crystal violet assay for estimation of biofilm formation
2. Bioassay for determination of quorum sensing signals produced by bacteria.
3. Determination of chemo-taxis responses shown by bacteria using agar plate or capillarytube method.

Practicals 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)
5. Different methods of cell disruption.
6. Swab evaluation with respect to transport of bacterial sample.

Suggested references MBEP 117: Semester I

Practicals Based on Microbial communication, Membrane transport and signal transduction

Practical based on Credit I : 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.

	Semester II	
Credit	**MBCT 121: Instrumentation and Molecular Biophysics** **Core Compulsory Theory Paper** **Total: 4 Credits Workload: -15 hrs /credit** **(Total Workload: - 4 credits x 15 hrs = 60 hrs in semester)**	**Lectures**
Credit I	**Separation and analysis of biomolecules:** 1. Techniques for sample preparation: Dialysis, ultra-filtration, centrifugal vacuum concentration 2. Chromatography- i. Partition Coefficient, Selectivity, Resolution, Column Efficiency, Van Deemter equation, Interpretation of chromatograms, ii. Principle, instrumentation and applications of High Performance Liquid Chromatography (HPLC), iii. Fast Protein Liquid Chromatography (FPLC), iv. Supercritical Fluid Chromatography v. Reversed Phase Chromatography and Gas chromatography. 3. Electrophoresis Methods: Pulse field gel electrophoresis, capillary electrophoresis, isoelectric focusing, 2-dimensional electrophoresis, immune-electrophoresis	**15**
Credit II	**Spectroscopy** 4. Introduction: Electromagnetic spectrum, Atomic orbitals, Molecular orbitals, Electronic, Rotational and Vibrational transitions in spectroscopy, Interpretation of spectra. 5. UV/Visible spectroscopy- Instrumentation, Molar Absorptivities, Beer and Lamberts Law, Bathochromic and hypochromic shifts. 6. Fluorescence spectroscopy- Instrumentation, Quantum Yield, Quenching, FRET, Binding and Folding studies, Flow cytometry and FACS 7. Infrared spectroscopy- Principle, Instrumentation, Absorption bands, FTIR and its applications 8. Mass spectroscopy- Principles of operation, Ionization, Ion fragmentation, Mass Analysers, GC- MS, MALDI-TOF	**15**

Credit III	**Biophysical Techniques** 1. NMR spectroscopy: i. Basic Principles of NMR, Chemical shift, Intensity, Line width, Relaxationparameters, Spin coupling, ii. Nuclear Overhauser Effect Spectroscopy, Correlation Spectroscopy, Approach to structure determination by 2D-NMR 2. X-ray crystallography: i. Purification of proteins, Crystallization of proteins, Instrumentation, ii. acquisition of the diffraction pattern, basic principles of x-ray diffraction, iii. Crystal Structures (Bravais Lattices), Crystal planes and Miller Indices, Direct Lattice and Reciprocal lattice, iv. Fourier Transform and Inverse Fourier, v. Ewald sphere, Electron density Maps, Phase determination	**15**
Credit IV	**Radioisotopes in Biology and Confocal Microscopy** 3. Radioisotopes in Biology: i. Principles and applications of radio tracers in medicine, agriculture, industry, and fundamental research ii. Radiation and Radioactive isotopes: Types, Quantities and units of estimation, half-life of isotopes iii. Detection and measurement of radioactivity- Autoradiography, Liquid scintillation counting. iv. Effect of radiation on biological system 4. Confocal Microscopy: i. Scanning optical microscope, confocal principle, ii. Resolution and point spread function, light source: gas lasers & solid-state, primary beam splitter; beam scanning, iii. Pinhole and signal channel configurations, detectors; pixels and voxels; contrast, iv. Spatial sampling: temporal sampling: signal-to noise ratio, multichannel images	**15**

Suggested References: MBCT 121: Instrumentation and Molecular Biophysics

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 andcharacterization 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 Private. Limited.
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.

	Semester II	
Credit	**MBCT 122: Molecular Biology** Core Compulsory Theory Paper Total: 4 Credits Workload: -15 hrs /credit (Total Workload: - 4 credits x 15 hrs = 60 hrs in semester)	**Lectures**
Credit I	**RNA processing &Molecular Techniques** 1. 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. Pi RNA (Piwi interacting RNAs) 2. Molecular Techniques: Knockout mice, phage display system, expressed sequence tags, yeast two and three hybrid assay, Activity gel assay, DNA helicase assay, Chromatin Immuno-precipitation (ChIP), Designing probe, Epitope tagging	**15**
Credit II	**Tools for Genetic engineering** 3. i. Enzymes: Restriction endonucleases and methylases DNA ligase, klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; ii. Cohesive and blunt end ligation, linkers; adaptors; homopolymeric tailing labeling of DNA: iii. Nick translation, random priming, radioactive and non-radioactive probes iv. Hybridization techniques: Northern, Southern, south-western and far-western and colony hybridization, fluorescence *in situ* hybridization. 4. 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:	**15**

	types (pMal, GST, pET-based vectors), ii. Protein tagging and purification (His-tag, GST-tag, MBP-tag) 5. Construction of genomic DNA and cDNA libraries	
Credit III	**Genome projects** 6. i. Concept and meaning of genome projects ii. Techniques used in deciphering genome (blotting, sequencing) iii Applications of genome projects 7. Introduction to Genome projects of *E. coli*, yeast (*Saccharomyces cerevisia*), *Plasmodium*, Mouse (*Mus musculus*), *Drosophila*, Rice (*Oryza sativa*) and comparative genomics 8. Gene annotation 9. Human Genome project and its applications	**15**
Credit IV	**Molecular diagnostics and applications** 11. Introduction to protein array, protein arrays to detect polygenic diseases, Immunoassay for protein confirmation in specific disorders 12. Detection of diseases-associated changes in gene expression using microarray 13. Detection of RNA signatures of 'Antibiotic Resistance' in bacteria 14. Detection of micro RNA (miRNA): A signature of cancer diagnostics	**15**

Suggested References: MBCT 122: Molecular Biology Semester II

1. Alberts B. (2017). Molecular Biology of the Cell. Sixth Edition. United States: W.W. Norton.
2. Amon A., Berk A., Martin K. C., Lodish H., Kaiser, C. A., Ploegh H., Krieger M., Bretscher A. (2016). Molecular Cell Biology. United States: Macmillan Learning.
3. Cooper G. M. and Hausman R. E. (2007). The Cell: A Molecular Approach. United Kingdom: ASM Press.
4. Farrell Jr. R. E. (2017). RNA Methodologies: Laboratory Guide for Isolation and Characterization. United Kingdom: Elsevier Science.
5. Garg N. and Kumar A. (2005). Genetic engineering. New York: Nova Biomedical Books.
6. Glick B. R. and Patten C. L. (2017). Molecular Biotechnology: Principles and

Applications of Recombinant DNA. United Kingdom: Wiley.

7. Goldstein E. S., Kilpatrick S. T. and Krebs J. E. (2017). Lewin's GENES XII. United States: Jones & Bartlett Learning.
8. Goldstein E. S., Krebs J. E. and Kilpatrick S. T. (2017). Lewin's GENES XII. United States: Jones & Bartlett Learning.
9. Goot J. M. and. Emeson R. B. (2000). Functions and Mechanics of RNA editing. Annual Review of Genetics. 34:499-531. https://doi.org/10.1146/annurev.genet.34.1.499
10. Hwang H. W. and Mendell J. T. (2006). MicroRNAs in cell proliferation, cell death and tumorigenesis. Br J Cancer. 94(6): 776-80. doi: 10.1038/sj.bjc.6603023.
11. Karp G. (2010). Cell and Molecular Biology: Concepts and Experiments. United Kingdom: Wiley. 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.
12. Kloc M., Zearfoss N. R., Etkin L. D. (2002). Mechanisms of subcellular mRNA localization. Cell. 108(4): 533-544. doi: 10.1016/s0092-8674(02)00651-7.
13. Klug W. S., Cummings M. R. Spencer C. A., Killian D. and Palladino M. A. (2019). Concepts of Genetics. United States: Pearson.
14. 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.
15. Lodish H., Berk A., Kaiser C. A., Krieger M., Bretscher, A. Ploegh H., Amon A. and Martin K. C., (2016). Molecular Cell Biology. United Kingdom: W. H. Freeman.
16. Nakanishi K. and Nureki O. (2005). Recent progress of structural biology of tRNA processing and modification. Mol Cells. 19(2): 157-66
17. Reece R. J. (2004). Analysis of Genes and Genomes. United Kingdom: John Wiley & Sons.
18. Taft R. J., Pang K. C., Mercer T. R., Dinger M. and Mattick J. S. (2010). Non-coding RNAs: regulators of disease. J Pathol. 220(2): 126-139. doi: 10.1002/path.2638.
19. Twyman R. and Primrose S. B. (2009). Principles of Genome Analysis and Genomics. Germany: Wiley.
20. Voet J. G. and Voet D. (2011). Biochemistry. United Kingdom: Wiley.
21. 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
22. Weaver R. F. (2008). Molecular Biology. Singapore: McGraw-Hill.

	Semester II	
Credit	**MBCT 123: Enzymology, Bioenergetics and Metabolism** Core Compulsory Theory Paper Total: 4 Credits Workload: -15 hrs /credit (Total Workload: - 4 credits x 15 hrs = 60 hrs in semester)	**Lectures**
Credit I	**Enzymology:** 1. Purifications of enzyme, purification chart, 2. Kinetics of reversible inhibitions: Competitive, uncompetitive, non-competitive, mixed, substrate. Primary and secondary plots, Determination of Ki using secondary plots. Significance of inhibitors 3. King Altman approach to derive – two substrate enzyme catalysed reactions 4. Concept of allosterism, positive and negative co-operativity, models of allosteric enzymes (Monad, Wyamann and Changuax and Koshland, Nemethy and Filmer model), kinetics of allosteric enzyme, Hill plot, examples of allosteric enzymes and their significance in regulation.	**15**
Credit II	**Bioenergetics:** 1. Laws of thermodynamics, entropy, enthalpy, free energy, free energy and equilibrium constant Gibbs free energy equation with reference to biological significance. 2. Determination of free energy of hydrolytic and biological oxidation reduction reactions under standard and non-standard conditions 3. High energy compounds 4. Coupled reactions 5. Determination of feasibility of reactions 6. Problems based on 2 and 4. 7. Atkinson's energy charge.	**15**
Credit III	**Lipid Chemistry and Metabolism:** 1. Classification of lipids according to chemical structure, 2. Fatty acids, saturated, unsaturated, branched, nomenclature system,	**15**

	3. Structure and function of: triglycerides, phospholipids, sphingolipids, terpenes, prostaglandins,waxes, and steroids. 4. Synthesis of storage lipids: Fatty acids and triacylglycerols, 5. Synthesis of membrane lipids: Glycerophospholipids, sphingolipids, sterols, 6. Degradation of fatty acids (beta oxidation and unsaturated fatty sacid) and fats in animals 7. Lipids as signal molecules (eg. phosphatidyl inositol, eicosanoids).	
Credit IV	**Carbohydrate Chemistry and Metabolism:** 1. Mono, di, oligosaccharides and polysaccharides, with examples 2. Isomerism in sugars: asymmetric centres in sugars, dextro, leavo-rotatory, sugar anomers (reducing and non-reducing sugars), sugar epimers 3. Sugar derivatives such as sugar alcohols, amino sugars, sugar acids, deoxy sugars 4. Glycolysis and gluconeogenesis, Regulation of glycolysis and gluconeogenesis, 5. Synthesis of microbial exopolysaccharides (alginate) 6. Cellulose synthesis and breakdown 7. Regulation of Glycogen synthesis; breakdown, 8. Metabolic flux and its regulation by various metabolic intermediates 9. TCA cycle- regulation, role in energy generation, Role in generating biosynthetic intermediates and glyoxylate cycle	**15**

Suggested References MBCT 123: Enzymology, Bioenergetics and Metabolism.
Semester II

1. Cornish-Bowden A. (2014). Fundamentals of Enzyme Kinetics. Netherlands: Elsevier Science.
2. Farrell S. O., Bettelheim F. A., Torres O., Brown W. H. and Campbell M. K. (2015). Introduction to General, Organic and Biochemistry. United States: Cengage Learning.
3. Ferguson S. J. and Nicholls D. G. (2014). Bioenergetics 2. United Kingdom: Elsevier Science.
4. Frayn K. N., Gurr M. I. and Harwood J. L. (2008). Lipid Biochemistry: An Introduction. Germany: Wiley.
5. Garrett R. H. and Grisham C. M. (2013). Biochemistry. 5th Edition. Brooks/Cole, Publishing Company, California. ISBN-13: 978-1-133-10629-6
6. Hervé G., Yon-Kahn J. (2011). Molecular and Cellular Enzymology. Germany: Springer Berlin Heidelberg.
7. Kim B. H. and Gadd G. M. (2019). Prokaryotic Metabolism and Physiology. United Kingdom: Cambridge University Press.
8. Leskovac V. (2007). Comprehensive Enzyme Kinetics. Netherlands: Springer US.
9. Madigan M. T., Sattley W. M., Bender, K. S., Stahl D. A., Buckley, D. H. (2018). Brock Biology of Microorganisms. United Kingdom: Pearson.
10. McQuillen K., Dawes I. W. and Mandelstam J. (1982; Digitized 2010). Biochemistry of bacterial growth. United Kingdom: Wiley.
11. Meena Kumari S. (2019). Microbial Physiology. United Kingdom: MJP Publisher.
12. Moat A. G. Foster J. W. and Spector M. P. (2003). (Microbial Physiology. Germany: Wiley.
13. Nelson D. L. and Cox M. M. (2021). Lehninger's Principles of Biochemistry.8th Edition. Mac Millan Worth Pub. Co. New Delhi. ISBN: 9781319228002
14. Palmer T. and Bonner P. L. (2007). Enzymes: Biochemistry, Biotechnology, Clinical Chemistry. United Kingdom: Elsevier Science.
15. Punekar N. (2018). ENZYMES: Catalysis, Kinetics and Mechanisms. Germany: Springer Singapore.
16. Segel I. H. (2010). Biochemical Calculations. 2nd Ed. Wiley India Pvt. Ltd.
17. Tymoczko J. L., Berg J. M., Stryer L., Gatto G. J. (2015). Biochemistry. United States: W. H. Freeman.
18. Vance D. E. and Vance J. (Editors). Biochemistry of Lipids, Lipoproteins and Membranes. (2002). Netherlands: Elsevier Science.
19. White D., Fuqua C., Drummond J. and Drummond J. T. (2012). The physiology and biochemistry of prokaryotes. United Kingdom: Oxford University Press.

Semester II

MBCP 124: Molecular Biology, Enzymology and Instrumentation TechniquesCore Compulsory Practical Paper

Total: 4 Credits Workload: -30 hrs /credit

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

1. Concept of lac-operon: Lactose induction of Beta galactosidase; Glucose Repression;Diauxic growth curve of *E. coli.*
2. Plasmid DNA isolation, DNA quantitation and characterization by gel electrophoresis.
3. Construction of restriction digestion map of plasmid DNA
4. Curing of bacterial Plasmid
5. Gene annotation
6. Purification of enzymes (Amylase/Invertase): (ammonium sulphate precipitation, organic solvent precipitation, gel filtration (any two methods); Establishment of enzyme purification chart
7. Determination of Km, Vmax and Kcat values of enzyme
8. Determination of molecular extinction coefficient of biomolecule
9. Isolation of Aflatoxin producing organism. Extraction and detection of Aflatoxin in food.
10. Isolation and characterization of lipase/cellulase/chitinase producing microbe.
11. Scientific Communication and Research Methodology

    Concept of effective communication: Presentation skills, formal scientific presentation skills; Preparing power point presentation, Presenting the work, Scientific poster preparation and oral presentation; Participating in group discussions. Technical writing skills: Types, Formats of scientific reports, scientific writing skills, Significance of communicating science, ethical issues, copyrights and plagiarism, Components of a research paper, publishing scientific papers - peer review process and problems. Use of search engines for scientific data mining, use of reference, use of reference management tools (e.g. Zotero). (Assignment/activity-based teaching method may be used)
12. 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)
13. Visit to any lab or institute to understand the principle and working of the bio-analytical instrument studied in theory courses(optional)

Suggested References MBCP 124: Semester II
Molecular Biology, Enzymology and Instrumentation Techniques

1. Concept of lac-operon:

   Lactose induction of Beta galactosidase; Glucose Repression; Diauxic growth curve of *E. coli*:

- Borralho T., ChangY., Jain P., Lalani M. and Parghi K. (2002). Lactose Induction of the lac operon in *Escherichia coli* B 23 and its effect on the o-nitrophenyl galactoside Assay. Journal of Experimental Microbiology and Immunology (JEMI). 2: 117-123
- Cappuccino J. and Sherman N. (2002). Microbiology: A Laboratory Manual. 6th edition. Pearson Education,
- Chu D. and Barnes D. (2016). The lag-phase during diauxic growth is a trade-off between fast adaptation and high growth rate. Sci Rep 6, 25191 https://doi.org/10.1038/srep25191
- Marbach A. and Bettenbrock K. (2012). Lac operon induction in *Escherichia coli*: Systematic comparison of IPTG and TMG induction and influence of the transacetylase LacA. J Biotechnol. 157(1):82-8. doi: 10.1016/j.jbiotec.2011.10.009.
- http://rothlab.ucdavis.edu/protocols/beta-galactosidase-3.shtml

2. Plasmid DNA isolation, DNA quantitation and characterization by gel electrophoresis:

- 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
- Sambrook J. and Russell D. (2001) Molecular Cloning: A Laboratory Manual, 3rd edition. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.

3. Construction of restriction digestion map of plasmid DNA:

- Russell P. J. (2010). iGenetics: A Molecular Approach. 3rd edition. Pearson Education, Inc., publishing as Pearson Benjamin Cummings, San Francisco
- 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

4. Curing of bacterial Plasmid:

- 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
- Trevors J. T. (1986). Plasmid curing in bacteria**.** FEMS Microbiology Reviews 32:149-157

5. Gene annotation:
   - 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
   - Webster D. M. (Editor). Protein Structure Prediction: Methods and Protocols. In: Methods in Molecular Biology; Volume 143. Humana Press.
6. Purification of enzymes (Amylase/Invertase): Aammonium sulphate precipitation, organic solvent precipitation, gel filtration (any two methods); Establishment of enzyme purification chart.
   - 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
   - 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.
   - Scopes R. K. (1994) Protein Purification Principles and Practice. Third Edition, Springer
   - 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
7. Determination of Km, Vmax and Kcat values of enzyme:
   - 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.

- Palmer T. and Bonner P. L. (2007). Enzymes: Biochemistry, Biotechnology, Clinical Chemistry. United Kingdom: Elsevier Science.

8. Determination of molecular extinction coefficient of biomolecule:

- Miranda-Hernández M. P., Valle-González E. R., Ferreira-Gómez D., Pérez N. O., Flores-Ortiz L. 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
- Wilson K. and Walker J. (2005) Principles and Techniques of Biochemistry and Molecular Biolog. 6th edition. Cambridge University Press, New York.

9. Aflatoxins:

9. a) Isolation of Aflatoxin producing organism.

- 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
- 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.b) Extraction and detection of Aflatoxin in food:

- Braicu C., Puia C., Bodoki E. and Socaciu C. (2008). Screening and quantification of aflatoxins and ochratoxin a in different cereals cultivated in Romania using thin-layer chromatography-densitometry. Journal of Food Quality. 31: 108-120. https://doi.org/10.1111/j.1745-4557.2007.00187.x
- 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

10. Isolation and characterization of lipase/ cellulase / chitinase producing microbe:

10.i) Lipase:

- 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.
- 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.

10.ii) Cellulase:

- 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.
- 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.

10.iii) Chitinase:

- 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
- 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

11. Scientific Communication and Research Methodology:

(*Assignment/activity-based teaching method may be used*):

11.a) Concept of effective communication: Presentation skills, formal scientific presentation skills; Preparing power point presentation, Presenting the work, Scientific poster preparation &oral presentation; Participating in group discussions. Technical writing skills: Types, Formats of scientific reports, scientific writing skills, Significance of communicating science, ethical issues, copyrights and plagiarism, Components of a research paper, publishing scientific papers - peer review process and problems. Use of search engines for scientific data mining.

- Day R. A. and Gastel B. (2011) How to write an publish a scientific paper, seventh Edition. Greenwood, California
- Kotahri C. R. 2004. Research Methodology - Methods & Techniques. New age International (p) Limited, Publishers.New Delhi, India.
- Van Cleemput O. and Saso L. (2017). Manual on Scientific Communication for Postgraduate Students and Young Researchers in Technical, Natural, and Life Sciences. DOI: 10.5772/intechopen.69870. Available from: https://www.intechopen.com/chapters/56191

11.b) 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

12. 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)

- Virtual proteomics laboratory IIT Bombay: http://pe-iitb.vlabs.ac.in/

13. Visit to any lab or institute to understand the principle and working of the bio-analytical instrument studied in theory courses(optional)

	Semester II	
Credit	**MBTE 125: Bioinformatics and Bio-nanotechnology** **Choice based Optional Theory Paper (Elective)** **Total: 2 Credits Workload: -15 hrs /credit** **(Total Workload: - 2 credits x 15 hrs = 30 hrs in semester)**	**Lectures**
Credit I	**Bioinformatics** 1. Introduction and biological databases Nucleic acid, proteins, genomes— structure data bases, search engines, sequence data forms and submission tools, scoring matrices for sequence alignments, algorithms pairwise sequence alignments, database similarity searches-BLAST, FASTA 2. Gene bank sequence database; submitting DNA sequences to databases and database searching;sequence alignment; pairwise alignment techniques, Multiple sequence alignment, phylogenetic analysis and tree building methods, motif searches, epitope prediction, data mining tools and applications, promoter and gene prediction, comparative analysis 3. Demonstration of databases (GENBANK, PDB, OMIM) and software (RASMOL, Ligand Explorer)	**15**
Credit II	**Techniques in Bio-nanotechnology** 4. Biogenic nanoparticles – Synthesis and applications. Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Role of plants in nanoparticle synthesis. 5. Significance of the physical properties of nanoparticles 6. Characterization of nanoparticles Dynamic Light Scattering (DLS), EDAX analysis, Zeta analysis 7. Imaging techniques to characterize nanoparticles: Principle, instrumentation and applications of: i. TEM (Transmission Electron Microscope) ii. SEM (Scanning Electron Microscope) iii. Scanning Probe Microscopy (SPM) iv. AFM (Atomic Force Microscopy)	**15**

Suggested References: MBTE 125: Bioinformatics and Bionanotechnolog Semester II

Credit I : Bioinformatics

1. Bal H. P. (2003). Perl Programming for Bioinformatics. India: Tata McGraw-Hill. Ingvar
2. Baxevanis A. D., Ouellette B. F. F. (2009). Bioinformatics: a practical guide to the analysis of genes and proteins. 3rd Edition. India: Wiley India Pvt. Limited.
3. Eidhammer I., Taylor W. R., Jonassen I., Taylor W. R., Taylor W. R. (2004). Protein bioinformatics: an algorithmic approach to sequence and structure analysis. United Kingdom: Wiley.
4. Mallick B. and Ghosh Z. (2008). Bioinformatics: Principles and Applications. India: Oxford University Press.
5. Mount D. W. (2005). Bioinformatics: Sequence and Genome Analysis.India: CBS Publishers & Distributors.
6. Narayanan P. (2007). Essentials of Biophysics. India: New Age International.
7. Orengo C., Jones D. and Thornton J. (Editors). (2003).Bioinformatics: Genes, Proteins and Computers. United Kingdom: CRC Press.
8. Ramsden J. J. (2012). Bioinformatics: An Introduction. Netherlands: Springer Netherlands.
9. Rastogi S. C., Rastogi P. and Mendiratta N. (2013). Bioinformatics: Methods and Applications: (Genomics, Proteomics and Drug Discovery). India: PHI Learning.
10. Shaik N. A., Banaganapalli B., Elango R. and Hakeem K. R. (2019). Essentials of Bioinformatics, Volume I: Understanding Bioinformatics: Genes to Proteins. Germany: Springer International Publishing.
11. Webster D. M. (2000). Protein Structure Prediction: Methods and Protocols. Ukraine: Humana Press.
12. Womble D. D. and Krawetz S. A. (2003). Introduction to Bioinformatics: A Theoretical And Practical Approach. United Kingdom: Humana Press.

Credit II : Techniques in Bio-nanotechnology

1. Feldheim D. L. and Foss C. A. Jr. (2002). Metal nanoparticles synthesis and characterization and applications Marcel Dekker, Inc.
2. Mishra P. (Serial editor). Blackman J. A. (Editor). Metallic Nanoparticles. (2008). Netherlands: Elsevier Science.

3. Nasrollahzadeh M., Isaabadi Z., Sajadi M. S. and Atarod M. (2019). An Introduction to Green Nanotechnology.United Kingdom: Elsevier Science.
4. Niemeyer C. M. and Mirkin C. A. (2006). Nanobiotechnology. John Wiley & Sons.
5. Omran B. A. (2020). Nanobiotechnology: A Multidisciplinary Field of Science. Germany: Springer International Publishing.
6. Prashanthi M., Sundaram R., Jeyaseelan A. and Kaliannan T. (Editors). (2021). Bioremediation and Green Technologies: Sustainable approaches to mitigate environmental impacts. Germany: Springer International Publishing. Environmental Science and Engineering. DOI 10.1007/978-3-319-48439-6_11
7. Rai M. and Duran N. (2011). Metal nanoparticles in Microbiology. Springer Verlag Berlin Heidelberg.
8. Schmid G. (Editor). (2006). Nanoparticles: From Theory to Application. Germany: Wiley.
9. Thyagarajan L. P., Sudhakar S. and Meenambal T. (2017). Bioremediation of congo-red dye by using silver nanoparticles synthesized from *Bacillus* sps. © Springer International Publishing AG 2017.

Semester II		
Credit	**MBEP 125: Practicals based on Bioinformatics and Bio-nanotechnology** **Choice based Optional Practical Paper (Elective)** **Total: 2 Credits Workload: -30 hrs /credit** **(Total Workload: - 2 credits x 30 hrs = 60 hrs in semester)**	**Lectures**
Credit I	**Bioinformatics** 16S rRNA gene sequencing analysis of bacteria: 1. 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 4. Sequence matching by BLAST analysis. 5. Drawing phylogenetic tree using related sequences (Using standard software like Phylip, Mega etc)	**30**
Credit II	**Bio-nanotechnology** 1. Biological synthesis of nanoparticles (at least 2 types) using actinomycetes /fungi /yeast and their characterization by UV-VIS spectroscopy 2. Characterization of nanoparticles, antimicrobial activity, dye decolorization activity. 3. Biological synthesis of nanoparticles (at least 2 types) using plant material/plant extract: i. Extract preparation ii. Synthesis of nanoparticles iii. Characterization by UV-VIS spectroscopy iv. Antimicrobial activity, dye decolorization activity 4. Nanoparticle characterization data analysis (data to be obtained from scientific literature) SEM/TEM/AFM images, FTIR scan, DLS, zeta potential, etc.	**30**

Suggested References: MBEP 125: Semester II
Practicals based on Bioinformatics and Bio-nanotechnology

Credit I : Bioinformatics

16S rRNA gene sequencing analysis of bacteria:

1. Isolation, purity checking using A260/A280 ratio and Agarose gel electrophoresis of isolated chromosomal DNA of bacteria
   - Kheyrodin H. and Ghazvinian K. (2012). DNA purification and isolation of genomic DNA from bacterial species by plasmid purification system. African Journal of Agricultural Research, 7(3): 433-442.
   - Olson N. D. and Morrow J. B. (2012). DNA extract characterization process for microbial detection methods development and validation. BMC research notes. 5. 668. https://doi.org/10.1186/1756-0500-5-668
2. PCR amplification and purification of 16S rRNA gene:
   - Giangacomo C., Mohseni M., Kovar L. and Wallace J. G. (2021).Comparing DNA Extraction and 16S rRNA Gene Amplification Methods for Plant-Associated Bacterial Communities. Phytobiomes Journal. 5(2):190-201
   - 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
   - Srinivasan R., Karaoz U., Volegova M., MacKichan J., Kato-Maeda M., Miller S., Nadarajan R., Brodie E. L. and Lynch S. V. (2015). Use of 16S rRNA gene for identification of a broad range of clinically relevant bacterial pathogens. PLoS ONE 10(2): e0117617. https://doi.org/10.1371/journal.pone.0117617
3. Demonstration of the following steps, if not possible to perform in institute laboratory

a) PCR product sequencing using automated sequencer:
   - https://www.youtube.com/watch?v=jFCD8Q6qSTM
   - https://www.youtube.com/watch?v=8lAVfKbRK3I

b) Sequence matching by BLAST analysis:
   - https://www.youtube.com/watch?v=HXEpBnUbAMo
   - https://www.youtube.com/watch?v=JKD5laNtwSc

4. Drawing phylogenetic tree using related sequences (Using standard software like Phylip, Mega etc)

4.a) Phylip:

https://www.youtube.com/watch?v=9mqHkkSLbIw

https://www.youtube.com/watch?v=7t34HU1guiI

4.b) Mega:

https://www.youtube.com/watch?v=wPRCLnF2NYk

https://www.youtube.com/watch?v=encRU80nOHg

Credit II : Bio-nanotechnology

1. Biological synthesis of nanoparticles (at least 2 types) using actinomycetes /fungi /yeast.

- Ranjitha V. R. and Rai V. R. (2017). Actinomycetes mediated synthesis of gold nanoparticles from the culture supernatant of *Streptomyces griseoruber* with special reference to catalytic activity. 3 Biotech. 7(5): 299. doi:10.1007/s13205-017-0930-3
- Sabir S., Zahoor M.A., Waseem M., Siddique M. H., , Shafique M., Imran M.,
- Hayat S., Malik I. R., and Muzammil S. (2020). Biosynthesis of ZnO nanoparticles using *Bacillus subtilis*: characterization and nutritive significance for promoting plant growth in *Zea mays* L. Dose-Response. doi:10.1177/1559325820958911

2. Characterisation of nanoparticles by UV-VIS spectroscopy, Antimicrobial activity and dye decolorization activity (photocatalytic activity)

- San Keskin N. O., Koçberber Kılıç N., Dönmez G. andTekinay T. (2016). Green synthesis of silver nanoparticles using cyanobacteria and evaluation of their photocatalytic and antimicrobial activity. JNanoR. 40: 120–127. https://doi.org/10.4028/www.scientific.net/jnanor.40.120
- Thyagarajan L. P., Sudhakar S. and Meenambal T. (2017). Bioremediation of congo-red dye by using silver nanoparticles synthesized from *Bacillus* sps. © Springer International Publishing AG 2017. M. Prashanthi et al. (eds.), Bioremediation and Sustainable Technologies for Cleaner Environment, Environmental Science and Engineering. DOI 10.1007/978-3-319-48439-6_11
- Yehia R. S. and Ali A. M. (2020). Biosynthesis and characterization of iron nanoparticles produced by *Thymus vulgaris* L. and their antimicrobial activity. Acta Botanica Croatica, 79(2). Retrieved from http://www.abc.botanic.hr/index.php/abc/article/view/2724

3. Biological synthesis of nanoparticles (at least 2 types) using plant material/plant extract

- Chand K., Cao D., Fouad D. E., Shah A. H., Dayo A. Q., Zhu K., Lakhan N. M., Mehdi G. and Dong S. (2020). Green synthesis, characterization and photocatalytic application of silver nanoparticles synthesized by various plant extracts. Arabian Journal of Chemistry. 13(11): 8248-8261. https://doi.org/10.1016/j.arabjc.2020.01.009.
- Yasmin S., Nouren S., Bhatti H. N., Iqbal D. N., Iftikhar S., Majeed J., Mustafa R., Nisar N., Nisar J., Nazir A., Iqbal M. and Rizvi H. (2020). "Green synthesis, characterization and photocatalytic applications of silver nanoparticles using Diospyros lotus". Green Processing and Synthesis. 9(1): 87-96. https://doi.org/10.1515/gps-2020-0010

4. Nanoparticle characterization data analysis (data to be obtained from scientific literature):

SEM/TEM/AFM images, FTIR scan, DLS, zeta potential.:

- Lin P. C., Lin S., Wang P. C. and Sridhar, R. (2014). Techniques for physicochemical characterization of nanomaterials. Biotechnology advances, 32(4), 711–726. https://doi.org/10.1016/j.biotechadv.2013.11.006
- Mourdikoudis S., Pallares R. M. and Thanh N. T. K. (2018). Characterization techniques for nanoparticles: comparison and complementarity upon studying nanoparticle properties. Nanoscale. 10; 12871-12934. https://doi.org/10.1039/C8NR02278J
- Santhoshkumar J., Rajeshkumar S. and Venkat Kumar S. (2017). Phyto-assisted synthesis, characterization and applications of gold nanoparticles – A review. Biochemistry and Biophysics Reports. 11: 46-57. https://doi.org/10.1016/j.bbrep.2017.06.004.

	Semester II	
Credit	**MBTE 126: Molecular Biology tools and applications** **Choice based Optional Theory Paper (Elective)** Total: 2 Credits Workload: -15 hrs /credit (Total Workload: - 2 credits x 15 hrs = 30 hrs in semester)	**Lectures**
Credit 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 system; 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 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, **5.** CRISPR-Cas system: Technology and Applications	**15**
Credit 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, polyhydroxyalkanoates. 4. Un-conventional microbial systems for production of high-quality protein drugs	**15**

Suggested References: MBTE 126: Molecular Biology tools and applications

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. Kolpashchikov D. M. and Gerasimova Y. V. (2016). Nucleic acid detection: methods and protocols. United States: Humana Press.
7. 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.
8. Fu H. (2004). Protein-protein Interactions: Methods and Applications. Ukraine: Humana Press.
9. García-Cañas V., Simó C. and Cifuentes A. (2014). Fundamentals of advanced omics technologies: from genes to metabolites. Netherlands: Elsevier Science.
10. Glick B. R. and Patten C. L. (2017). Molecular Biotechnology: Principles and Applications of Recombinant DNA. India: Wiley.
11. Goldstein E. S., Krebs J. E. and Kilpatrick S. T. (2017). Lewin's GENES XII. United States: Jones & Bartlett Learning.
12. Kalia V. C. (2016). Microbial Factories: Biodiversity, Biopolymers, Bioactive Molecules: Volume 2. India: Springer India.
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.

Semester II

MBEP 126: Practical Based on Molecular Biology tools and applications

Choice based Optional Practical Paper (Elective)

Total: 2 Credits Workload: -30 hrs /credit

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

1. Cloning and 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 and purification of 16S rRNA gene
3. PCR Primer Design
4. Protoplast fusion
5. Activity staining analysis (Zymograms) (NATIVE PAGE)
6. FTIR analysis of a biomolecule/recombinant molecule (at least five different molecules)
7. Production by recombinant strain and estimation of Biopolymers:
   i. Gum
   ii. Polyhydroxyalkanoates (PHB)

Suggested References: MBEP 126: Semester II
Practical Based on Molecular Biology tools and applications

1. Cloning and transformation using plasmid vectors- GFP gene cloning or blue and white screening:

1.a) Green Florescence 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. 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.

3. 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

4. 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

5. 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
6. FTIR analysis of a **biomolecule/recombinant molecule** (at least five different molecules);

6.a) **Biomolecule:**

6.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

6.a.ii**) Indole acetic acid:**

- Lobayan RM, Schmit MC, Jubert AH, Vitale A. Theoretical studies and vibrational spectra of 1H-indole-3-acetic acid. Exploratory conformational analysis of dimeric species. J Mol Model. 2011 Jun;17(6):1381-92. doi: 10.1007/s00894-010-0833-2.
- https://spectrabase.com/spectrum/LE3GWjvqQg0

6.b.) **Recombinant molecules:**

6.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/6sovrQrG8OR

6.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/BfcQ8Se5jNz

6.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

7. Production by recombinant strain and estimation of Biopolymers:

7.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

7.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

Semester II		
Credit	**MBET 127: Nitrogen Metabolism, respiration and Photosynthesis** **Choice based Optional Theory Paper (Elective)** Total: 2 Credits Workload: -15 hrs /credit (Total Workload: - 2 credits x 15 hrs = 30 hrs in semester)	**Lectures**
Credit I	**Nitrogen Metabolism** 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. Biosynthesis of five families of amino acids and histidine, 4. Biosynthesis of purine and pyrimidine bases	**15**
Credit II	**Respiration and photosynthesis:** 5. Respiration: Concept of anaerobic respiration, oxidized sulfur compounds and nitrate as electron acceptor with respect to electron transport chain and energy generation, Biochemistry of methanogenes. 6. Photosynthesis: a) Organization of photosystem I and II, cyclic and non-cyclic flow of electrons, Z scheme, Hill reaction, photolysis of water b) C3, C4 CAM plants, Photorespiration, Regulation of photosynthesis	**15**

Suggested References: MBET 127: Semester II
Nitrogen Metabolism, respiration and Photosynthesis

Credit I : 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., 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.

Credit II : 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. United Kingdom: Elsevier Science.
3. Kim B. H. and Gadd G. M. (2019). Prokaryotic Metabolism and Physiology. United Kingdom: Cambridge University Press.
4. Madigan M. T., Sattley W. M., Bender, K. S., Stahl D. A., Buckley, D. H. (2018). Brock Biology of 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. H. Freeman & Co. New York
7. Nelson D. L. and Cox M. M. (2021). Lehninger's Principles of Biochemistry.8th Edition. Mac Millan Worth Pub. Co. New Delhi. ISBN:9781319228002
8. Renger G., Irrgang K.D., Govindjee, Singhal G. S. and Sopory S. K. (2012). Concepts in Photobiology: 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.

Semester II

MBEP 127: Practicals based on Nitrogen Metabolism, respiration and Photosynthesis

Choice based Optional Practical Paper (Elective)

Total: 2 Credits Workload: -30 hrs /credit

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

1. Isolation of IAA producing organism, Detection of Indole acetic acid production bymicroorganism
2. Detection of siderophore production by microorganism
3. Enrichment ,Isolation and characterisation of nitrogen fixing activity of bacteria
4. Extraction and estimation of polyphenols and tannins by Folin Danis method
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 activity of Cyanobacteria

Suggested references: MBEP 127: Semester II
Practicals based on Nitrogen Metabolism, respiration and Photosynthesis

1. Isolation of IAA producing organism, Detection of Indole acetic acid production by microorganisms: -

- 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) producing bacteria from rhizospheric soil and its effect on plant growth. Journal of Soil Science and Plant Nutrition, 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, New York, NY. https://doi.org/10.1007/978-1-0716-1080-0_47

3. Enrichment, Isolation and characterization of nitrogen fixing activity of bacteria: -

- 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.
- Pourali A., Afrouziyeh M. and Moghaddaszadeh-ahrabi 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 *Strobilanthes Kunthiana* (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
- 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:

- 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. Curr Microbiol 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.bio-protocol.org/e1467

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