Learning Outcomes Based Curriculum Framework

(With effect from 2020-21: Sem-I M.Sc. (Biotechnology) /

Sem VII Dual Degree

B.Sc. (Hons. Biotechnology)-M.Sc. (Biotechnology)

For

M.Sc. (Biotechnology)

BASED ON

CHOICE BASED CREDIT SYSTEM

Department of Bio and Nano Technology

Guru Jambheshwar University of Science & Technology,

Hisar-125 001, Haryana

Learning Outcome based Curriculum Framework for M.Sc. (Biotechnology)

The National Biotechnology Development Strategy (2015 – 2020) and National Education Policy (2020) envisions a quality education system to produce graduates equipped with the knowledge, skills, attitudes and values that are required to lead a productive life and participate in the country's development process. Improving employability in this sector is heavily dependent on the overall curriculum of the educational programs. In view of the scientific advancements taking place globally in the field of biotechnology, it was highly desirable to update the current course accordingly and modify it based on the needs of both research and industry.

Learning Outcome based approach to curriculum planning (LOCF) is a paradigm shift in the whole gamut of higher education such that it is based on first and foremost identifying the outcomes of the learning required for a particular subject of study, and then planning all components of higher education so as to achieve these outcomes. The learning outcomes-based course curriculum framework for M.Sc. (Biotechnology) is designed to persuade the subject specific knowledge as well as relevant understanding in the emerging areas of biotechnology. The curriculum envisions that the student, after completing postgraduate degree in Biotechnology, may enter into job market as trained biotechnologist wherever required in the academia and industry or may initiate start-up and develop it into a commercial enterprise.

Hallmark attributes of M.Sc. (Biotechnology) Program under the outcome-based teaching/ learning framework may encompass the following:

- **Preparation**: The curriculum is designed in such a way that in the first year the students are exposed to the basic subjects of genetics, microbiology and biochemistry. Subsequently, they are made to learn analytical, tissue culture, bioinformatics and genetic engineering techniques followed by advanced specialized aspects such as molecular biology, genomics, proteomics, genetic engineering, bioprocess engineering, immunology etc. along with their practical applications. The students will be exposed to the subject of bioentrepreneurship in the 3rd semester to make them aware about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards. In the fourth semester, a separate course on critical analysis of classical papers has been introduced to familiarize students with classic literature to make them appreciate how ground-breaking discoveries were made without, necessarily, use of high-end technologies. The students are required to undertake dissertation comprising of 14-16 weeks and shall be required to submit an Investigation Report in the form of Thesis.
- **Knowledge**: The students acquire strong theoretical background along with necessary skills and techniques in biological sciences and possess the ability to use these tools in industry, healthcare, community and institutes or other professions they wish to pursue.
- **Breadth**: Biotechnology assimilates in itself a number of disciplines. There is a great demand for biotechnologists in countless diversified industries and sectors such as, Agriculture, Animal

Husbandry, Environmental Conservation, Ecology, Genetic Engineering, Healthcare, Pharmaceutical, Medicine, Academia, Industrial Research and Development.

- **Professionalism**: The students who have acquired a graduate degree in biotechnology can easily find a suitable position in a number of industries engaged in processing and developing agricultural and biological products, bio-processing, pharmaceutics and biochemicals.
- **Evaluation**: Academic performance evaluation of a student comprises of Continuous Internal Evaluation (CIE) as well as Semester End Examination (SEE).

STRUCTURE / GUIDELINES FOR EXECUTION OF CURRICULUM

- The minimum credit requirement for the M.Sc. degree in Biotechnology is 102 credits including 04 credits for Open Elective courses and 02 for Program Elective. As per MHRD guidelines student may opt one MOOC course through SWAYAM /NPTEL to earned total credit. List of offered MOOC courses will be notified by the department in the beginning of semester.
- Among the Program Electives Courses the student is required to opt only one course of 2 credits out of the six courses (Program Elective I) in Semester IV including MOOC.
- No Program Elective Course will run unless a number of students registered for the Program Elective Course are less than five.
- Student should opt one Open Elective Course of 04 credits (Offered by any other Department of University) in 2nd semester.
- For theory courses, one hour per week is assigned as one credit and for practical courses one hour per week is assigned as half credit.
- Practical component has been included in every core subject offered during the programme. As biotechnology practical require individual attention for imparting correct and adequate hands – on training to the students, each practical batch would not have more than 20 students. The list of experiments to be performed has been provided alongside each of such courses. The marks (100 marks) for the practical examination will be split as follows:

S. No.	Type of Test		Marks
1	**External Evaluation**		**70**
	Major Test		20
	Performance of Practical		20
	Practical record/ notebook		10
	Viva voce		20
2	**Internal Assessment**		**30**
	A	Minor Test (Internal)	20
	B	Co-curricular Activities (Including Lab Manners and Discipline)	6
	C	Classroom Attendance Incentive	4

- A total of 100 marks have been allocated to each theory course. The distribution of marks will be as follows:

S.No.	Type of Test		Marks
1	**Major Test (External)**		**70**
2	**Internal Assessment**		**30**
	A	Minor Test (Internal)	20
	B	Co-curricular Activities (Including assignment)	6
	C	Classroom Attendance Incentive	4

- **Classroom Attendance Incentive**: The candidates who have greater than 65% attendance will be awarded Internal Assessment Marks as follows:
  a. 65% to 70 % = 1 Marks
  b. 71% to 75 % = 2 Marks
  c. 76% to 80 % = 3 Marks
  d. 81 % onwards = 4 Marks

- Each theory paper examination will be of 3 hours duration and practical examination will be of 4 hours duration.
- In the fourth semester the students are required to undertake Dissertation MBD-600 comprising of 14-16 weeks and shall be required to submit an Investigation Report in the form of Thesis. Outside external expert will evaluate the thesis by conducting viva voce examination and award marks out of 100 on the basis of quality of research work.

SCHEME OF EXAMINATIONFOR M.Sc. (BIOTECHNOLOGY) / DUAL DEGREE B.Sc. (BIOTECHNOLOGY)-M.Sc. (BIOTECHNOLOGY)

M.Sc. (Biotechnology) Sem. I / Dual Degree B.Sc. (Biotechnology)-M.Sc. (Biotechnology) Sem. VII

Sr. No.	Course No.	Title	Type	L	P	Credit
1.	MBL-511	Plant and Animal Biotechnology	PC	4	0	4
2.	MBL-512	Biomolecules and Metabolism	PC	4	0	4
3.	MBL-513	Principles of Genetics	PC	4	0	4
4.	MBL-514	General and Applied Microbiology	PC	4	0	4
5	MBL-515	Biophysics, Biomathematics and Biostatistics	PC	4	0	4
5.	MBP-516	Lab I (Biochemistry)	PC	0	6	3
6.	MBP-517	Lab II (Microbiology)	PC	0	6	3
		TOTAL		**20**	**12**	**26**

M.Sc. (Biotechnology) Sem. II / Dual Degree B.Sc. (Biotechnology)-M.Sc. (Biotechnology) Sem. VIII

Sr. No	Course No.	Title	Type	L	P	Credit
1	MBL-521	Emerging Technologies	PC	4	0	4
2	MBL-522	Molecular Biology	PC	4	0	4
3	MBL-523	Immunology	PC	4	0	4
4	MBL-524	Bioprocess Technology	PC	4	0	4
5	MBL-525	Research Methodology and Scientific Communication Skills	PC	2	0	2
6	MBP-526	Lab III (Immunology and Emerging Technologies)	PC	0	6	3
7	MBP-527	Lab IV (Bioprocess Technology)	PC	0	6	3
8	Open	Open Elective offered by other department/ MOOC	OE	4	0	4
		TOTAL		**22**	**12**	**28**

M.Sc. (Biotechnology) Sem. III / Dual Degree B.Sc. (Biotechnology)-M.Sc. (Biotechnology) Sem. IX

Sr. No.	Course No.	Title	Type	L	P	Credit
1.	MBL-531	Genetic Engineering	PC	4	0	4
2.	MBL-532	Enzymology and Enzyme Technology	PC	4	0	4
3.	MBL-533	Bioinformatics	PC	4	0	4
4.	MBL-534	Nanobiotechnology	PC	4	0	4
5	MBL-535	Bioentrepreneurship, Intellectual Property Rights and Biosafety	PC	4	0	4
5	MBL-536	Project Proposal Preparation and Presentation	PC	2	0	2
5	MBP-537	Lab V (Genetic Engineering)	PC	0	6	3
6	MBP-538	Lab VI (Bioinformatics)	PC	0	6	3
		TOTAL		**22**	**12**	**28**

M.Sc. (Biotechnology) Sem. IV / Dual Degree B.Sc. (Biotechnology)-M.Sc. (Biotechnology) Sem. X

Sr. No .	Course No.	Title	Type	L	P	Credit
1	MBL-541	Critical Analysis of Classical Papers	PC	2	0	2
2.	MBL 542-547	Program Elective-I	PE	2	0	2
3	MBD-600	Dissertation	PC	0	16	16
		TOTAL		4	16	**20**

Program Elective-I
MBL-542 Molecular Diagnostics
MBL-543 Drug Discovery and Vaccines Development
MBL- 544 Genomics and Proteomics
MBL- 545 Metabolic Engineering
MBL- 546 Environmental Biotechnology
MBL-547 MOOC Any one MOOC through SWAYAM/NPTEL

Semester	Credit
I	**26**
II	**28**
III	**28**
IV	**20**
TOTAL	**102**

Program core (PC)	Program Elective (PE)	Open Elective (OE)	Total Credit
96	**2**	**4**	**102**

MBL 511: Plant and Animal Biotechnology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students to fundamental knowledge of animal and plant biotechnology and their applications.	**After successful completion of this course, students should be able to learn the principles, practices and applications of animal biotechnology, plant tissue culture, plant and animal genomics, genetic transformation and molecular breeding of plants and animals.**

UNIT I [15 Lectures]

Plant Tissue Culture: Historical perspective; totipotency; organogenesis; Somatic embryogenesis; Establishment of cultures – callus culture, cell suspension culture, Media preparation – nutrients and plant hormones; Sterilization techniques; Applications of tissue culture - micropropagation; somaclonal variation; androgenesis and its applications; Germplasm conservation and cryopreservation; Synthetic seed production; Protoplast culture and somatic hybridization - protoplast isolation; culture and usage; Somatic hybridization - methods and applications; Cybrids; Plant cell cultures for secondary metabolite production.

Animal Cell Culture: Brief history of animal cell culture; Cell culture media; Primary culture, Secondary culture, Continuous cell lines, Suspension cultures; Application of animal cell culture for virus isolation and *in vitro* testing of drugs.

UNIT II [15 Lectures]

Genetic Engineering: *Agrobacterium*-plant interaction; Virulence; Ti and Ri plasmids; Opines and their significance; T-DNA transfer; disarmed Ti plasmid; Genetic transformation - *Agrobacterium*-mediated gene delivery; Cointegrate and binary vectors and their utility; direct gene transfer - PEG-mediated, electroporation, particle bombardment and alternative methods; Screenable and selectable markers; Advanced methodologies - cisgenesis, intragenesis and genome editing; Molecular pharming - concept of plants as biofactories, production of industrial enzymes and pharmaceutically important compounds.

UNIT III [15 Lectures]

Animal Reproductive Biotechnology: Structure of sperms and ovum; Cryopreservation of sperms and ova of livestock; Artificial insemination; Super ovulation, Embryo recovery and *in vitro* fertilization; Culture of embryos; Cryopreservation of embryos; Embryo transfer technology; Animal cloning - basic concept, cloning for conservation for conservation endangered species.

Vaccinology: History of development of vaccines, Introduction to the concept of vaccines, Conventional methods of animal vaccine production, Recombinant approaches to vaccine production, Modern vaccines.

UNIT IV **[15 Lectures]**

Genomics: Overview of genomics – definition, complexity and classification; Need for genomics level analysis; Methods of analyzing genome at various levels – DNA, RNA, protein, metabolites and phenotype; Genome projects and bioinformatics resources for genome research – databases; Overview of forward and reverse genetics for assigning function for genes.

Molecular Markers: Molecular markers - hybridization and PCR based markers RFLP, RAPD, STS, SSR, AFLP, SNP markers; DNA fingerprinting-principles and applications; Introduction to mapping of genes/QTLs; Marker-assisted selection - strategies for introducing genes of biotic and abiotic stress resistance in plants.

Recommended Textbooks and References:

1. Bhojwani, S.S. & Rajdan, M.K., Plant Tissue Culture: Theory and Practice: A Revised Edition, Reed Elsevier, India, New Delhi. 2004.
2. Razdan, M.K. (2003). Introduction to Plant Tissue Culture. Enfield, NH: Science.
3. Slater, A., Scott, N.W. & Fowler, M.R., Plant Biotechnology: an Introduction to Genetic Engineering. Oxford: Oxford University Press. 2008.
4. Buchanan, B.B., Gruissem, W. & Jones, R.L., Biochemistry & Molecular Biology of Plants. Chichester, West Sussex: John Wiley & Sons. 2015.
5. Umesha, S., Plant Biotechnology. The Energy and Resources. 2013.
6. Glick, B.R. & Pasternak, J.J., Molecular Biotechnology: Principles and Applications of Recombinant DNA. ASM Press, Washington, D.C. 2010.
7. Brown, T. A., Gene cloning and DNA analysis: An Introduction (7th Ed.). Wiley-Blackwell. 2016.
8. Primrose, S.B. & Twyman, R.M. Principles of Gene Manipulation and Genomics (7th Ed.). Malden, MA: Blackwell Publisher. 2006.
9. Slater, A., Scott, N. W. & Fowler, M. R. Plant Biotechnology: The Genetic Manipulation of Plants. Oxford: Oxford University Press. 2003.
10. Gordon, I., Reproductive Techniques in Farm Animals. Oxford: CAB International. 2005.
11. Levine, M.M., New Generation Vaccines. New York: M. Dekker. 2004.
12. Pörtner, R., Animal Cell Biotechnology: Methods and Protocols. Totowa, NJ: Humana Press. 2007.

MBL 512: Biomolecules and Metabolism (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways.	**After successful completion of this course, students should be able to:** **1. Gain fundamental knowledge on structure, functions and metabolism of biomolecules;** **2. Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.**

UNIT I [15 Lectures]

Chemical Basis of Life: Chemical basis of life; Miller-Urey experiment, Abiotic formation of amino acid oligomers. Composition of living matter; Water – properties of water, Essential role of water for life on earth.

Biomolecules: An introduction, General structure and important features of biomolecules, Fundamental principles governing structure of biomolecules, Importance of covalent and non-covalent bonds.

Glycobiology: Structure and function of biologically important mono, di and poly-saccharides, glycoproteins & glycolipids. Metabolism of Carbohydrates-Glycolysis, Feeder pathways, Citric acid cycle, Gluconeogenesis and their regulations, Glycogen metabolism, Reciprocal control of glycogen synthesis and breakdown, Roles of epinephrine and glucagon and insulin in glycogen metabolism; Starvation responses and insulin signalling. Glyoxylate and Pentose phosphate pathways.

UNIT II [15 Lectures]

Structure and Functions of Proteins: Structure of amino acids, non-protein and rare amino acids, Structural organization of proteins, Reverse turns and Ramachandran plot, Structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; Protein folding: Anfinsen's Dogma, Levinthal paradox, Cooperativity in protein folding, Free energy landscape of protein folding and pathways of protein folding.

Amino Acid Metabolism: A brief account of amino acid biosynthesis and degradation, Urea cycle and its regulation. Chemical synthesis of peptides and small proteins. Protein sequencing.

UNIT III [15 Lectures]

Structure and Functions of Lipids: Structure of fatty acids, Classification of lipids, Structure and functions of major lipid subclasses- Acylglycerols, Phospholipids, Glycolipids, Sphingolipids, Waxes, Terpenes and Sterols.

Lipid Metabolism: Fatty acids biosynthesis, degradation and their regulations, Hormone trigger mobilization of stored triacylglycerol, Oxidation of fatty acids-saturated (odd and even carbon) and unsaturated, Ketone bodies synthesis. Biosynthesis of TAG, Phospholipids and Glycolipids. Mevalonate pathway.

UNIT IV **[15 Lectures]**

Structure and Metabolism of Nucleic acids: Structure and properties of nucleic acid bases, Nucleosides and nucleotides. Biosynthesis and degradation of purines and pyrimidines, Salvage pathway.

Central Metabolism: Logic and integration of central metabolism; Entry/ exit of various biomolecules from central pathways; Principles of metabolic regulation; Steps for regulation; Elucidation of metabolic pathways.

Vitamins and Coenzymes: Structure and biochemical roles of fat and water-soluble vitamins and their coenzymes

Recommended Textbooks and References:

1. Stryer, L., Biochemistry. (8th Ed.) New York: Freeman. 2015.
2. Nelson, D.L. & Cox, M.M. Lehninger, A.L. Lehninger Principles of Biochemistry (7th Ed.). New York, NY: Worth. 2017.
3. Voet, D. & Voet, J.G., Biochemistry (5th Ed.). Hoboken, NJ: J. Wiley & Sons.
4. Dobson, C.M. (2003). Protein Folding and Misfolding. Nature, 426(6968), 884-890. doi:10.1038/nature02261. 2016.
5. Richards, F.M., The Protein Folding Problem. Scientific American, 264(1), 54-63. doi:10.1038/scientificamerican0191-54. 1991.

MBL 513: Principles of Genetics (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to take students through basics of genetics and classical genetics covering prokaryotic/phage genetics to yeast and higher eukaryotic domains. On covering all classical concepts of Mendelian genetics across these life-forms, students will be exposed to concepts of population genetics, quantitative genetics encompassing complex traits and plant genetics.	**After successful completion of this course, students should be able to:** **1. Describe fundamental molecular principles of genetics** **2. Understand relationship between phenotype and genotype in human genetic traits** **3. Describe the basics of genetic mapping** **4. Understand how gene expression is regulated**

UNIT I [15 Lectures]

Introductory Genetics: Introduction to Genetics, Mitosis and Meiosis, Mendelian Genetics, Mendelian inheritance in humans, Pedigree analysis, Extensions of Mendelian Genetics, Chromosome Mapping in Eukaryotes, Sex Determination and Sex Chromosomes, Quantitative inheritance, Extranuclear Inheritance.

UNIT II [15 Lectures]

DNA organization, Gene Regulation and Modern Genetics: DNA Organization in prokaryotes, DNA organization in chromosomes, DNA complexity in eukaryotes, Regulation of Gene Expression in Prokaryotes, Regulation of Gene Expression in Eukaryotes, DNA Forensics, Genomics and Personalized Medicine, Epigenetics, Stem Cells.

UNIT III [15 Lectures]

Linkage, Crossing over and Gene Mapping: Mapping of genes in bacterial and phage chromosomes; genetic complementation**,** Linkage and recombination of gene, gene conversion, Gene mapping by three-point test cross, Tetrad analysis, Positive and negative interference, Molecular mechanism of crossing over, Post-meiotic segregation, Mapping through somatic cell hybridization.

UNIT IV [15 Lectures]

Mutation: Molecular mechanism of spontaneous mutations, Molecular mechanism of mutations induced by known chemical mutagens, Types of DNA repair, Molecular mechanism of suppression, Somatic mutations., Transposons in Eukaryotes and Prokaryotes.
Population Genetics: Genetic variation, Genetic drift, Hardy Weinberg law, Natural selection, Linkage disequilibrium, Population bottlenecks.
Quantitative Genetics of Complex Traits (QTLs): Complex traits, mapping QTLs, Yeast genetics to understand biology of QTLs.

Plant Genetics: Laws of segregation in plant crosses, inbreeding, Selfing, heterosis, Maintenance of genetic purity, Gene pyramiding.

Recommended Textbooks and References:

1. Hartl, D.L. & Jones, E.W., Genetics: Principles and Analysis. Sudbury, MA: Jones and Bartlett. 1998.
2. Pierce, B.A., Genetics: a Conceptual Approach. New York: W.H. Freeman. 2005.
3. Tamarin, R.H. & Leavitt, R.W., Principles of Genetics. Dubuque, IA: Wm. C. Brown. 1991.
4. Klug, W.S., Cummings, M.R., Spencer, C.A., Palladino, M.A. & Killian, D., Concepts of Genetics (12th Ed.). Pearson Education Limited: London. 2019.
5. Gardner, E.J. Simmonns, M.J. Snustad, D.P., Principles of Genetics (8th Ed.). Wiley India. 2008.

MBL 514: General and Applied Microbiology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce field of microbiology with special emphasis on microbial diversity, morphology, physiology and nutrition; methods for control of microbes and host-microbe interactions.	**After successful completion of this course, students should be able to:** **1. Identify major categories of microorganisms and analyze their classification, diversity, and ubiquity;** **2. Identify and demonstrate structural, physiological, genetic similarities and differences of major categories of microorganisms;** **3. Identify and demonstrate how to control microbial growth;** **4. Demonstrate and evaluate interactions between microbes, hosts and environment**

UNIT I [15 Lectures]

Microbial Characteristics: Introduction to microbiology and microorganisms; History and scope of microbiology, morphology; Structure, growth and nutrition of bacteria; Bacterial culture methods; Bacterial growth: Different types of growth, measurement of microbial growth. Bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation, antimicrobial resistance.

UNIT II [15 Lectures]

Microbial Diversity: Microbial taxonomy and evolution of diversity, classification of microorganisms, criteria for classification; classification of bacteria; Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria, Mycobacteria and Mycoplasma. Unculturable microorganisms. Archaea: Halophiles, Methanogens, Hyperthermophilic archae, Thermoplasma, Eukarya: algae, fungi, slime molds and protozoa; unculturable microbes

UNIT III [15 Lectures]

Control of Microorganisms and Virology: Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, biological control of microorganisms.

Viruses and Bacteriophages: General properties of viruses, Viral structure, Taxonomy of viruses, Replication of plant, animal and bacterial viruses: Cultivation and identification of viruses; Sub-viral particles – Viroids, Virusoids and Prions.

UNIT IV [15 Lectures]

Host-Microbes Interaction: Host-pathogen interaction, ecological impact of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); Microbes and nutrient cycles; Microbial communication and sensing system; Bacterial quorum sensing; Prebiotics and probiotics.

Recommended Textbooks and References:

1. Pelczar, M.J., Reid, R.D. & Chan, E. C. Microbiology (5th Ed.). New York: McGraw-Hill. 2001.
2. Matthai, W., Berg, C.Y. & Black, J.G. Microbiology, Principles and Explorations. Boston, MA: John Wiley & Son. 2005.
3. Willey, J.M., Sherwood, L., Woolverton, C.J., Prescott, L.M. & Willey, J.M., Prescott's Microbiology. New York: McGraw-Hill. 2011.
4. Madigan, MT, Bender, K.S., Buckley, D.H., Sattley, W.M. & Stahl, D.A., Brock Biology of Microorganisms (15th Ed.). Pearson/ Benjamin Cummings. 2018.
5. Pommerville, J.C., Alcamo's Fundamentals of Microbiology (10th Ed.) Jones and Bartlett Learning. 2013.

MBL 515: Biophysics, Biomathematics and Biostatistics (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objective of this course is to give conceptual exposure of essential contents of biophysics, mathematics and statistics to students.	**After successful completion of this course, students should be able to:** **1. Understand the basic physical parameters of cells or biological processes and basic methods used to study these.** **2. Develop a firm foundation in fundamentals and application of current physical scientific theories.** **3. Acquaint basic concepts of mathematics and statistics as applied to biological phenomenon.**

UNIT I [15 Lectures]

Biophysics: Fundamental postulates of Statistical mechanics, Random walk, Mean free path, Diffusion and Brownian motion; Langevin equation, diffusion equation, Einstein Relation. Biological applications - Sedimentation, bacterial metabolism, pattern formation. Concept of charge, Coulomb's law, Gauss's law. Electric field and potential. Conductors, capacitors, dielectrics, dielectric polarization, volume and surface charges, electrostatic energy. Electrostatic interactions - Poisson-Boltzmann eqn and its solution. Crystals; Types of lattices and symmetry, Physical Techniques and related biology - X-ray diffraction, Bragg's diffraction law, and neutron scattering, Fluorescence Spectroscopy: Jablonski diagram; fluorescence resonance energy transfer (FRET) and biological applications.

UNIT II [15 Lectures]

Biomathematics: Sets and their representations. Venn diagrams. Union and Intersection of sets. Difference of sets. Complement of a set. Properties of Complement of Sets. Functions and their graphs: polynomial, linear, power, periodic, exponential and logarithmic functions, real valued functions. Sum, difference, product and quotient of functions. Imaginary numbers, complex numbers, adding-subtracting-multiplying complex numbers; Basic idea of differentiation. Derivative of composite functions, chain rule. Derivatives of logarithmic, trigonometric, exponential functions and problems based on them. Basic idea of integration, Integration as inverse process of differentiation. Some examples of evaluation of simple integrals and problems based on them.

UNIT III [15 Lectures]

Biostatistics: Aims and applications of biostatistics, methods of classification of data, differences between classification and tabulation, formation of frequency distribution. Tabular and graphic representation of data, line diagram, histogram, frequency polygon, frequency curve, cumulative frequency curve or Ogive, scatter, bar, pie diagram, pictogram and cartogram, statistical methods: applications and scope of statistics, principles of statistical analysis of biological data. Sampling parameters. Difference between sample and population, sampling errors, censoring, difference between parametric and non-parametric statistics; Mean and Variance of discrete and continuous distributions namely binomial, Poisson and normal distribution. Fitting of distributions. Measures of Mean, Median Mode, central tendency, dispersion, standard deviation and variance; Correlation and Types of Correlation, Measures of Simple Correlation and Simple regression. Regression Equation, Emphasis on examples from biological systems.

UNIT IV [15 Lectures]

Statistics: Important Terms and Concepts, Sample point, Sample space, Trial and Event; Classical Definition of Probability, Frequency Definition of Probability, Rules of Probability (Addition Rule and Multiplication Rule); Sampling size determination, testing of hypothesis, Level of significance and degree of freedom; Large sample test based on normal distribution; Small sample test based on *t*-test, Z test and F test; Confidence interval; Distribution free test; Chi-square test; Basic introduction to multivariate statistics, analysis of variance(ANOVA).

Recommended Textbooks and References:

1. Wilson, K. & Walker, L., Principles and Techniques in Practical Biochemistry (5th Ed.). Cambridge University Press. 2000.
2. Khan, I.A. & Khan, I. A., Fundamentals of Biostatistics. Ukaaz Publications. 1994.
3. Beckner, W.M., Kleinsmith L.J & Hardin J., The world of cell (4th Ed.). Benjamin/Cummings. 2000.
4. Samuels, M.L., Witmer, J.A. & Schaffner, A.A., Statistics for the life sciences (4th Ed.). Pearson. 2010.
5. Arya, J. & Lardner, R.W., Mathematics for the Biological Sciences. Prentice Hall New Jersey. 1979.
6. Le, C.T. & Eberly, L.E., Introductory Biostatistics 2nd Edition. Wiley. 2016.
7. Phillips, R., Theriot, J. & Garcia, H. & Kondev, J., Physical Biology of the Cell (2nd Ed.). Garland Science. 2012.
8. Lakowicz, J.R., Principles of Fluorescence Spectroscopy (3rd Ed.). Springer. 2006.
9. Nearing, J., Mathematical Tools for Physics. Dover Publications. 2010.
10. Bloomfield, V., Computer Simulation and Data Analysis in Molecular Biology and Biophysics. Springer. 2009.
11. Jackson, M.B., Molecular and Cellular Biophysics. Cambridge University Press. 2006.

MBP 516: Lab I (Biochemistry) (Credits: 0+3)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**4H**

Course Objectives	Student Learning Outcomes
The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach students the utility of set of experimental methods in biochemistry in a problem-oriented manner.	**After successful completion of this course, students should be able to:** **1. Elaborate concepts of biochemistry with easy to run experiments.** **2. Familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in biochemistry.**

List of Experiments:

1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer- Lambert's Law.
4. Separation and identification of amino acids by paper chromatography.
5. Separation and identification of amino acids / lipids by thin layer chromatography.
6. Purification and characterization of an enzyme from a recombinant / natural source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of choice).
    a) Preparation of cell-free lysates
    b) Ammonium Sulfate precipitation
    c) Ion-exchange Chromatography
    d) Gel Filtration Chromatography
    e) Affinity Chromatography
    f) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method.
    g) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
    h) Enzyme Kinetic Parameters: Km, Vmax and Kcat.
7. Experimental verification that absorption at OD_{260} is more for denatured DNA as compared to native double stranded DNA. Reversal of the same following DNA renaturation. Kinetics of DNA renaturation as a function of DNA size.
8. Identification of an unknown sample as DNA, RNA or protein using available laboratory tool.

Recommended Textbooks and References:

1. Sawhney, S.K. & Singh, R., Introductory Practical Biochemistry, Narosa Publishing House. 2009.
2. Plummer, D., An Introduction to Practical Biochemistry (3rd Ed.). McGraw Hill Education.2017.
3. Sadasivam, S., Biochemical Method (3rd Ed.). New Age International Pvt Ltd Publishers. 2018.
4. Jayaraman, J., Laboratory Manual in Biochemistry. New Age International Private Limited. 2011.

MBP 517: Lab II (Microbiology) (Credits: 0+3)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**4 H**

Course Objectives	Student Learning Outcomes
The objective of this laboratory course is to provide practical skills on basic microbiological techniques.	**After successful completion of this course, students should be able to:** **1. Know the basic organization of microbiology laboratory.** **2. Isolate, characterize and identify common microorganisms.** **3. Determine bacterial load of different samples.** **4. Perform antimicrobial sensitivity tests.** **5. Preserve microbial cultures.**

List of Experiments:

1. Sterilization, disinfection and safety in microbiological laboratory.
2. Media Preparation for cultivation of microorganisms.
3. Isolation of bacteria in pure culture by streak plate method.
4. Study of colony and growth characteristics of some common bacteria: *Bacillus, E. coli, Staphylococcus*etc.
5. Preparation of bacterial smear and Gram's staining
6. Light compound microscope and its handling
7. Microscopic observation of bacteria (Gram +ve bacilli and cocci, Gram –ve bacilli), cyanobacteria, algae, and fungi.
8. Calibrations of microscopic measurements (Ocular, stage micrometers)
9. Measuring dimensions of fungal spores
10. Simple and differential staining (Gram staining).
11. Spore staining, capsule staining and negative staining.
12. Enumeration of bacteria: standard plate count.
13. Growth curve of bacteria in batch culture.
14. Antimicrobial sensitivity test and demonstration of drug resistance.
15. Maintenance of stock cultures: slants, stabs and glycerol stock cultures.
16. Determination of phenol co-efficient of antimicrobial agents.
17. Determination of Minimum Inhibitory Concentration (MIC)
18. Isolation of Rhizobium from root nodules

Recommended Textbooks and References:

1. Cappuccino, J.G., & Welsh, C., Microbiology: a Laboratory Manual. Benjamin-Cummings Publishing Company. 2016.
2. Collins, C.H., Lyne, P.M., Grange, J.M., & Falkinham III, J. Collins and Lyne's Microbiological Methods (8th Ed.). Arnolds. 2004.
3. Tille, P.M., Bailey & Scott's Diagnostic Microbiology (14th Ed.). Elsevier. 2017.
4. Kapoor, K.K. & Paroda, S., Experimental Soil Microbiology. CBS Publishers. 2007.
5. Garg, F.C., Experimental Microbiology. CBS Publishers & Distributors. 2005.

MBL 521: Emerging Technologies (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
This course is broad-based in nature encompassing several new technologies that current experimental researchers are employing to probe complex system biology questions in life-sciences. The objectives of this course are to teach basics of the new principles to students so as to appreciate current-day research tool-kit better.	**After successful completion of this course, students should be able to: -** **1. Learn history, theoretical basis and applications of latest technologies in the advanced area of biotechnology.** **2. Gain fundamental knowledge about the light spectrum, absorption, fluorescence, NMR, mass spectroscopy.** **3. Acquire knowledge on the different. chromatographic methods for separation of biological products.**

UNIT I [15 Lectures]

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

UNIT II [15 Lectures]

Microscopy: Basics of microscopy: image formation, magnification, resolution, Biological applications and instrumentation of various kinds of microscopy: Optical Microscopy, Fluorescence, Confocal and Electron Microscopy, Probe Microscopy-Atomic Force Microscopy, Flow Cytometry.

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

UNIT III [15 Lectures]

Separation Techniques I (Chromatography): Basics principles and applications of various chromatography methods: Partition and Absorption chromatography, gel filtration, ion-exchange and affinity chromatography. Theory and biological applications of GC, HPLC and FPLC.

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

UNIT IV **[15 Lectures]**

Radioactive Methods: Basics of radioactive isotopes and radioactive decay, sample preparation, counting, Safety precautions during handling, biological applications, Liquid Scintillation counter, HPGe.

Nanobodies: Introduction to nanobodies, nanobody as a tool for protein structure-function studies, use of nanobodies for molecular imaging.

Other Emerging Techniques: Theory, principle and applications of PSA cum Zeta sizer, CRISPR-Cas, Flow Cytometry, DSC-TGA etc.

Recommended Textbooks and References:

1. Banwell, C., Fundamentals of Molecular Spectroscopy (4th Ed.) McGraw Hill. 2017.
2. Lakowicz, J. & Joseph, R., Principles of Fluorescence Spectroscopy (3rd Ed.) Springer. 2006.
3. Valeur, B., Molecular Fluorescence: Principles and Applications (2nd Ed.) Wiley. 2013.
4. Rupp, B., Biomolecular Crystallography: Principles, Practice and Application to Structural Biology (1st Ed.). Garland Science. 2009.
5. Wilson, K. & Walker, L., Principles and Techniques in Practical Biochemistry (5th Ed.). Cambridge University Press. 2000.
6. Dash, U.N., Textbook of Biophysical Chemistry. Macmillan Publishers India. 2006.
7. Cantor, C.R. Schimmel, P.R., Biophysical Chemistry: Part 2: Techniques (1st Ed.). W.H Freeman and Co. 2008.
8. Campbell, I.D., Biophysical Techniques. Oxford: Oxford University Press. 2012.
9. Serdyuk, I.N., Zaccai, N.R., & Zaccai, G., Methods in Molecular Biophysics: Structure, Dynamics, Function. Cambridge: Cambridge University Press. 2007.
10. Chakravarty, R., Goel, S. & Cai, W., Nanobody: The “Magic Bullet” for Molecular Imaging? Theranostics, 4(4), 386-398. doi:10.7150/thno.8006. 2014.

MBL 522: Molecular Biology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The purpose of this course is to introduce the student to the advanced concepts in molecular biology. Student will gain in-depth knowledge of molecular mechanisms of DNA replication, DNA repair, transcription, translation, and gene regulation in prokaryotic and eukaryotic organisms.	**After successful completion of this course, students should be able to:** **1. Describe the structure of DNA and RNA, organization of prokaryotic and eukaryotic genomes.** **2. Identify the principles of DNA replication, transcription and translation and explain how they relate to each other.** **3. Explain various levels of gene regulation in both prokaryotic and eukaryotic organisms.** **4. Articulate applications of molecular biology in the modern world.**

UNIT I [15 Lectures]

The Nature of Genetic material: DNA as genetic material; Chemical structure and base composition of nucleic acids; Double helical structures; Different forms of DNA; Forces stabilizing nucleic acid structure; Super coiled DNA; Properties of DNA; Renaturation and denaturation of DNA. Tm and Cot curves, Structure of RNA. Organization of prokaryotic and eukaryotic genomes- chromatin arrangement, nucleosome formation, satellite DNA.

UNIT II [15 Lectures]

DNA replication: General features of DNA replication, Enzymes and proteins of DNA replication, Models of replication, Prokaryotic and eukaryotic replication mechanism, relationship between DNA replication and cell cycle, DNA copy number maintenance. Replication in phages, Reverse transcription.

Recombination and Repair of DNA: DNA repair and recombination, DNA mismatch repair, Double strand break repair, Recombination as a molecular biology tool, CRISPR-Cas systems for editing, Regulating and targeting genomes.

UNIT III [15 Lectures]

Transcription: Mechanism of transcription in prokaryotes and eukaryotes, Structure and assembly of prokaryotic and eukaryoticRNA polymerases, promoters and enhancers, Transcription factors as activators and repressor, Transcription- initiation, elongation and termination, Effect of chromatin structure, Regulation of transcription.

Post-transcriptional Processes: Co- and post-transcriptional modifications, Post-transcriptional processing of tRNA, rRNA and mRNA (5' capping, 3' polyadenylation and splicing), mRNA flow through nuclear envelop into cytoplasm, RNA Editing; RNAi and

miRNAs, Antisense RNA, Posttranscriptional gene regulation, RNA as an enzyme-Ribozyme.

UNIT IV **[15 Lectures]**

Genetic code: Genetic code, General features, Deciphering of genetic code, Wobble hypothesis, mitochondrial genetic code.

Translation: Translational mechanism in prokaryotes and eukaryotes. Ribosome composition and assembly, Regulation of translation, RNA instability, Antibiotic inhibitors and translation, stringent response in bacteria, Non ribosomal polypeptide synthesis.

Post-translational Processes: Post translational modification, Transport, Folding, Chaperones. Protein targeting, The Signal Hypothesis.

DNA Binding Protein Motifs: Zinc finger, Leucine zipper, Helix-turn-helix and other motifs.

Recommended Textbooks and References:

1. Adams, R.L.P., Knowler, J.T. & Leader, D.P., The Biochemistry of Nucleic Acids (11th Ed.), Chapman and Hall, New York. 1992.
2. Kreb, J.E. & Goldstein, E.S., Lewin's GENE XII, Jones and Bartlett Publishers. 2017.
3. Karp, G., Iwasa, J. & Marshall, W., Karp's Cell and Molecular Biology (9th Ed.). John Wiley & Sons. 2020.
4. Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A. & Martin, K.C., Molecular Cell Biology (8th Ed.). W. H. Freeman & Co. 2016.
5. Malacinski, G.M., Freifelder's Essentials of Molecular Biology (3rd Ed.). John and Bartlett Publishers. 2015.
6. Buchanan, B.B., Gruissem, W. & Jones, R.L., Biochemistry and Molecular Biology of Plants. Wiley. 2015.
7. Watson, J.D., Baker T.A., Bell, S.P., Gann, A., Levine, M., & Losick, R., Molecular Biology of the Gene (7 Ed.). Pearson Pub. 2013.
8. Klug, W.S., Cummings, M.R., Spencer C.A., Palladino, M.A. & Killian, D., Concept of Genetics (12th Ed.). Pearson Education, Singapore. 2019.
9. Krebs, J.E., Lewin, B., Kilpatrick, S.T. & Goldstein, E.S., Lewin's Genes XII. Burlington, MA: Jones & Bartlett Learning. 2017.
10. Alberts, B., Johnson, A.D., Lewis, J., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2014). Molecular Biology of the cell (6th Ed.). Garland Science.

MBL 523: Immunology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students about structural features of components of immune system as well as their function This will be imperative for students as it will help them to predict about nature of immune response that develops against bacterial, viral or parasitic infection.	**On successful completion of this course, the students should be able to: -** **1. Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in the setting of infection (viral or bacterial).** **2. Well versed with immunity to infection of microbes, hypersensitivity, autoimmune disease, tumour immunology and primary and secondary immunodeficiency disease** **3. Evaluate usefulness of immunology in pharmaceutical and bio-based companies.**

UNIT I [15 Lectures]

Innate Immunity: Components of innate and acquired immunity; Important organs and cells of immune responses, complement and inflammatory responses; Pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); Interferon, Inflammation, ADCC, Acute Phase protein, Innate immune response; Mucosal immunity; Immune dysfunction and its consequences; Antigens - immunogens, Haptens, adjuvant; Antigenic determinants.

UNIT II [15 Lectures]

Immune Responses Generated by B and T Lymphocytes: Immunoglobulins-basic structure, classes & subclasses of immunoglobulins; Hybridoma technology and its application; Multigene organization of immunoglobulin genes; B cell receptor; Immunoglobulin superfamily; Principles of cell signaling; Basis of self, non-self-discrimination; Kinetics of immune response, memory; Generation of antibody diversity. Processing and presentation of antigen: Antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens, Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility, HLA typing.

UNIT III [15 Lectures]

Antigen-antibody Interactions: Precipitation, agglutination and complement mediated immune reactions; Advanced immunological techniques- RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immune electron microscopy; Surface Plasmon resonance, Biosensor assays for assessing ligand –receptor interaction, CMI techniques- lymphoproliferation assay, Mixed lymphocyte reaction, Cell Cytotoxicity assays, Apoptosis, microarrays, transgenic mice, gene knock outs.

Vaccine and its type, Active and passive immunization; live, killed, attenuated, subunit vaccines; recombinant DNA and protein-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines. Success stories in vaccinology e.g. Hepatitis, Polio, Small pox, DPT.

UNIT IV [15 Lectures]

Clinical Immunology Immunity to Infection: Bacteria, viral, fungal and parasitic infections (with examples from each group); Hypersensitivity – Type I-IV; Autoimmunity; Types of autoimmune diseases; Mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; Treatment of autoimmune diseases; Cytokines-properties, receptors and therapeutic uses; Tumor immunology –Tumor antigens; Immune response to tumors and tumor evasion of the immune system, Cancer immunotherapy; Immunodeficiency Primary immune deficiencies, Acquired or secondary immune deficiencies.

Recommended Textbooks and References:

1. Punt, J., Stranford, S., Jones, P. & Owen, J.A., Kuby Immunology (8th Ed.). Macmillan International Higher Education. 2018.
2. Delves, P.J., Martin, S.J., Burton, D.R. & Roitt, I.M., Roitt's Essential Immunology (13th Ed.). Wiley-Blackwell. 2017.
3. Kenneth, M. & Weaver, C., Janeway's Immunobiology (9th Ed.). Garland Science. 2016.

MBL 524: Bioprocess Technology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.	**On successful completion of this course, the students should be able to: -** **1. Understand relevance of microorganisms from industrial context.** **2. Give an account of design and operations of various fermenters.** **3. Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products.** **4. Critically analyze any bioprocess from market point of view.** **5. Give an account of important microbial/enzymatic industrial processes in food, fuel and pharma industry.**

UNIT I [15 Lectures]

Introduction to Fermentation Technology: Fermentation overview, Introduction to fermentation processes, Industrially important microorganisms-Isolation, screening, and preservation of industrially important microorganisms. Strain Improvement: Natural selection, mutation and screening of improved cultures, random and strategic screening methods, Use of recombinant DNA technology, protoplast fusion etc. Principles of overproduction of primary and secondary metabolites with relevant examples.

UNIT II [15 Lectures]

Fermentation Systems: Batch and Continuous system, Fed batch culture, Multi-stage systems, Feedback systems, Solid substrate fermentation. Bioprocess kinetics and controls of fermentation processes. Production and Recovery of Primary and Secondary Metabolites: Industrial Alcohol, Beer, Wine, Citric Acid, Acetic acid, lactic acid, Acetone- Butanol fermentation, Amino acids- Lysine and Glutamic acid production, Industrial enzymes, Antibiotics- Penicillin and Tetracycline, Bioinsecticides, Biopolymers, vitamins and steroids. Large scale animal and plant cell cultivation.

UNIT III [15 Lectures]

Fermentation Raw Materials: Media for industrial fermentation, Criteria used in media formulation, sterilization, raw materials and process control. Downstream processing-Separation processes and recovery methods for fermentation products: filtration, centrifugation, sedimentation, flocculation. Cell disruption; separation of soluble products:

liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration,

UNIT IV [15 Lectures]

Fermenter Design: Bioreactor configuration, design features, Criteria in Fermenter design, Requirement for aeration and mixing, Energy Transfer. Other fermenter designs- Tube reactors, packed bed reactors, fluidized bed reactors, cyclone reactors, trickle flow reactors. Waste Treatment: Waste Treatment systems, Aerobic and anaerobic waste treatment systems for waste treatment in fermentation industry.

Recommended Textbooks and References:

1. Stanbury, P.F., Hall, S., Whitaker, A., Principles of Fermentation Technology (3rd Ed.). Butterworth Heinemann Ltd., Elsevier. 2016.
2. Ward, O.P., Fermentation Biotechnology - Principles, Process and Products. Prentice Hall Publishing, New Jersey. 1999.
3. Rehm, H.J., Reed, G.B., Puehler, A. & Stadler, Biotechnology, Vol. 1-8, VCH Publication. 1993.
4. Prescott, S.C. & Dunn, G.C., Prescott and Dunn's Industrial Microbiology (4th Ed.). CBS Publication, New Delhi. 1992
5. Demain, A.I. & Davies, J. E., Manual of Industrial Microbiology and Biotechnology (2nd Ed.), ASM Press, Washington D.C. 1999.
6. Glazer, A.N. & Nikaido, H., Microbial Biotechnology: Fundamentals of Applied Microbiology. WH Freeman & Company, New York. 1998.
7. Cruger, W. & Kruger, A., Biotechnology -A Textbook of Industrial Microbiology (2nd Ed.). Panima Publishing Corporation, New Delhi. 2002.
8. Clarke, W., Industrial Microbiology. CBS Publisher and Distributors PVT .LTD New Delhi. 2016.

MBL 525: Research Methodology and Scientific Communication Skills

(Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to give background on history of science, emphasizing methodologies used to do research, use framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics.	**On successful completion of this course, the students should be able to: -** **1. Understand history and methodologies of scientific research, applying these to recent published papers.** **2. Understand and practice scientific reading, writing and presentations.** **3. Appreciate scientific ethics through case studies.**

UNIT I [7 Lectures]

History of Science and Science Methodologies: Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.

Preparation of Research: Choosing a mentor, lab and research question; maintaining a lab notebook.

UNIT II [8 Lectures]

Process of Communication: Concept of effective communication- setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using over-head projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

UNIT III [7 Lectures]

Scientific Communication: Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific

papers - peer review process and problems, recent developments such as open access and nonblind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

UNIT IV **[8 Lectures]**

Biostatistics: Probability: counting, conditional probability, discrete and continuous random variables; Error propagation; Populations and samples, expectation, parametric tests of statistical significance, nonparametric hypothesis tests, linear regression, correlation & causality, analysis of variance, factorial experiment design. Introduction and applications of SPSS and R software.

Recommended Textbooks and References:

1. Valiela, I. (2001). Doing Science: Design, Analysis, and Communication of Scientific Research. Oxford: Oxford University Press.
2. On Being a Scientist: a Guide to Responsible Conduct in Research, Washington, D.C.: National Academies Press. 2009.
3. Gopen, G.D. & Smith, J.A. The Science of Scientific Writing. American Scientist, 78 (Nov-Dec 1990), 550-558. 1990.
4. Mohan, K. & Singh, N.P., Speaking English Effectively. Delhi: Macmillan India. 5. Movie: Naturally Obsessed, The Making of a Scientist. 2010.
5. Rosner, B., Fundamentals of Biostatistics. Boston, MA: Duxbury Press. 2000.
6. Daniel, W.W., Biostatistics, a Foundation for Analysis in the Health Sciences. New York: Wiley. 1987.

MBP 526: Lab III (Immunology and Emerging Technologies)

(Credits: 0+3)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**4 H**

Course Objectives	Student Learning Outcomes
The objectives of this laboratory course are to develop an understanding about practical aspects of components of immune system as well as their function. The practical course will also help the budding technocrats to get working experience of advanced biophysical and biochemical techniques	**After successful completion of this practical course, the students should be able to:** **1. Evaluate usefulness of immunology and emerging technologies in different biotech companies.** **2. Gain working experience in advanced biophysical and biochemical techniques.** **3. Identify proper research lab working in area of their own interests.**

List of Experiments:

Section A: Immunology

1. Selection of animals, preparation of antigens, immunization and methods of blood collection, serum separation and storage.
2. Antibody titre by ELISA method.
3. Double diffusion, Immuno-electrophoresis and Radial Immuno diffusion.
4. Complement fixation test.
5. Isolation and purification of IgG from serum or IgY from chicken egg.
6. Immunoblotting, Dot blot assays.
7. Blood smear identification of leucocytes by Giemsa stain.
8. Separation of leucocytes by dextran method.
9. Demonstration of Phagocytosis of latex beads and their cryopreservation.
10. Separation of mononuclear cells by Ficoll-Hypaque and their cryopreservation.
11. Demonstration of ELISpot.
12. Demonstration of FACS.

Section B: Emerging Technologies:

1. Study of the size of nanobodies using dynamic light scattering.
2. Study of stability of synthesized nanobodies using zeta potential
3. Identification of functional groups using FTIR spectroscopy
4. Synthesis/preparation of nanobodies of metals, metal oxides and their hybrids
5. Synthesis of different morphologies of carbon-based structures

6. Sample preparation for estimation of size and morphological features using electron microscopy.
7. Study of different morphological and surface features using atomic force microscopy
8. Study of the crystalline information of sample (either solid or thin film) using X-ray diffraction.
9. Quantification of the metal ion concentrations in aqueous samples using atomic adsorption spectroscopy (AAS)/inductively coupled plasma mass spectrometry (ICP-MS).
10. Study of the spectrum of pure and complex samples using mass spectroscopy.
11. Study of the variation of properties of substance with heat using Differential Scanning Calorimetry (DSC) and Thermogravimetric analysis (TGA).

Recommended Textbooks and References:

1. Punt, J., Stranford, S., Jones, P. & Owen, J.A., Kuby Immunology (8th Ed.). Macmillan International Higher Education. 2018.
2. Delves, P.J., Martin, S.J., Burton, D.R. & Roitt, I.M., Roitt's Essential Immunology (13th Ed.). Wiley-Blackwell. 2017.
3. Kenneth, M. & Weaver, C., Janeway's Immunobiology (9th Ed.). Garland Science. 2016.
4. Green, M.R. & Sambrook, J., Molecular Cloning: a Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. 2012.
5. Wilson, K. & Walker, L., Principles and Techniques in Practical Biochemistry (5th Ed.). Cambridge University Press. 2000.
6. Banwell, C., Fundamentals of Molecular Spectroscopy (4th Ed.) McGraw Hill. 2017.
7. Lakowicz, J. & Joseph, R., Principles of Fluorescence Spectroscopy (3rd Ed.) Springer. 2006.
8. Valeur, B., Molecular Fluorescence: Principles and Applications (2nd Ed.) Wiley. 2013.
9. Serdyuk, I.N., Zaccai, N.R., & Zaccai, G., Methods in Molecular Biophysics: Structure, Dynamics, Function. Cambridge: Cambridge University Press. 2007.

MBP 527: Lab IV (Bioprocess Technology) (Credits : 0+3)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**4 H**

Course Objectives	Student Learning Outcomes
The objectives of this laboratory course are to provide hands-on training to students in upstream and downstream unit operations.	**After successful completion of this practical course, the students should be able to:** **1. Investigate, design and conduct experiments, analyze and interpret data, and apply the laboratory skills to solve complex bioprocess engineering problems.** **2. Design various bioreactors used in bioprocess industries.** **3. Apply skills and knowledge gained will be useful in solving problems typical of bio industries and research**

List of Experiments:

1. Isolation purification and screening of industrially important microorganisms from natural sources such as soils/ food processing waste/ and animal droppings.

a) Isolation of antibiotic producing microorganisms
b) Isolation of enzyme producing microorganisms
c) Isolation of organic acid producing microorganisms
d) Isolation of xenobiotic degrading microorganisms

2. To evaluate the production of alcohol/Lactic acid/Citric acid/bioactive compound.
3. Microbial biomass production (fungi/bacteria/yeast), batch /continuous culture.
4. Production of extra cellular enzymes (amylases/ proteases/ xylanases/phytase) by thermophilic/mesophilic fungal/Bacterial culture.
5. Scale up from frozen vial to agar plate to shake flask culture.
6. To study the BOD, COD, TDS, TSS, TS levels of different water systems.
7. Bacteriological analysis of water by presumptive, confirmatory and completed tests.
8. Industrially important product production and quality evaluation: Yogurt production/ wine preparation/Milk quality testing/ fermentation of vegetables etc.
9. Instrumentation: Microplate reader, spectrophotometer, microscopy.
10. Anatomy of fermenter: Anatomy of fermenter whereby the students are required to dismantle and identify the various components of the fermenter and study the various systems making up the fermenter. Cleaning and operation of fermenter: Students are required to learn the importance of cleaning the fermenter properly and to carry out COP cleaning and operation of laboratory fermenter.
11. Visit to any fermentation industry/ Waste water treatment plant. (Optional)
12. Unit operations
    a. Microfiltration: Separation of cells from broth.
    b. Bioseparations: Various chromatographic techniques and extractions.
13. Bioanalytics: Analytical techniques like HPLC, GC, LC/GC-MS *etc.* for measurement of amounts of products/substrates.

Recommended Textbooks and References:

1. Shuler, M.L. & Kargi, F., Bioprocess Engineering: Basic Concepts. Upper Saddle River, NJ: Prentice Hall. 2002.
2. Stanbury, P.F. & Whitaker, A., Principles of Fermentation Technology. Oxford: Pergamon Press. 2010.
3. Blanch, H.W. & Clark, D.S., Biochemical Engineering. New York: M. Dekker. 1997.
4. Bailey, J.E. & Ollis, D.F., Biochemical Engineering Fundamentals. New York: McGraw-Hill. 1986.
5. El-Mansi, M. & Bryce, C.F., Fermentation Microbiology and Biotechnology. Boca Raton: CRC/Taylor & Francis. 2007.

MBL 531: Genetic Engineering (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to acquaint students with various approaches of recombinant DNA technology and their applications in biological research as well as in biotechnology industries.	**After successful completion of this course, students should be:** **1. Endowed with strong theoretical knowledge of recombinant DNA technology and its applications in the genetic manipulation of organism for the industrial, agriculture and pharmaceutical industries.** **2. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.**

UNIT I [15 Lectures]

Introduction and Tools of Genetic Engineering: Impact of genetic engineering in modern society; General requirements for performing a genetic engineering experiment; Restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, Polynucleotide kinase, Alkaline phosphatase; Cohesive and blunt end ligation; Linkers; adaptors; homopolymeric tailing; labeling of DNA: nick translation, random priming, radioactive and non-radioactive probes, Hybridization techniques: northern, southern, south-western and far-western and colony hybridization, Fluorescence *in situ* hybridization.

Cloning and Expression Vectors: Vehicles for gene cloning, Plasmids, Bacteriophages, Cosmids and Phagemids as vectors, P1 vectors, F- factor based vectors, Plant and animal viruses as vector, Artificial chromosomes as vectors (YAC, BAC, PAC and MAC vectors), Expression vectors- use of promoters and expression cassettes, Baculovirus and Pichia vectors system, Plant based vectors, Ti and Ri as vectors, yeast vectors, Binary and shuttle vectors, Intein-based vectors; Inclusion bodies; Methodologies to reduce formation of inclusion bodies.

UNIT II [15 Lectures]

PCR Techniques: Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; Types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, Touchdown PCR, Hot start PCR, Colony PCR, Asymmetric PCR, Cloning of PCR products; T-vectors; Proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; Viral and bacterial detection.

Sequencing Techniques: **S**equencing methods; Enzymatic DNA sequencing; Chemical sequencing of DNA; Automated DNA sequencing; RNA sequencing; Chemical synthesis of

oligonucleotides; Mutation detection: SSCP, DGGE, RFLP, Next Generation sequencing methods: 454 FLX Roche genome analyzer platform, Illumina Solexa genome analyzer platform, Pacific Biosciences SMRT sequence analyzer platform, Ion torrent platform, Oxford Nanopore sequencing platform. Whole genome sequencing and functional genomics (A brief account), Applications of genomics and proteomics with special reference to *Arabidopsis* and Rice.

UNIT III **[15 Lectures]**

Gene Manipulation and Protein-DNA Interaction: Insertion of foreign DNA into host cells; transformation, electroporation, transfection; Construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; Construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; Study of protein-DNA interactions: electrophoretic mobility shift assay; DNase footprinting; Methyl interference assay, Chromatin immunoprecipitation; Principles for maximizing gene expression, Protein purification; His-tag; GST-tag etc.; Protein-DNA interactions. Protein-protein interactions using yeast two-hybrid system; Phage display.

UNIT IV **[15 Lectures]**

Gene Silencing and Genome Editing Technologies: Gene silencing techniques; Introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; Principle and application of gene silencing; Gene knockouts and gene therapy; Creation of transgenic plants; Debate over GM crops; Introduction to methods of genetic manipulation in different model systems e.g. fruit flies (*Drosophila*), worms (*C. elegans*), frogs (*Xenopus*), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; Creation of transgenic and knock-out mice; disease model; Genome editing by CRISPR-Cas with specific emphasis on Chinese and American clinical trials, DNA chip Technology (a brief account).

Recommended Textbooks and References:

1. Clark DP and Pazdernik NJ. (2009). Biotechnology-Applying the Genetic Revolution. Elsevier Academic Press, USA.
2. Brown T.A., Gene Cloning & DNA Analysis (6th Ed.) Wiley-Blackwell, New York. 2010.
3. Watson J.D., A Passion for DNA: Genes, Genomes & Society, Cold Spring Harbor Laboratory press (CSHL). 2009.
4. Primrose, S.B. & Twyman, R.M. Principles of Gene Manipulation and Genomics (7th Ed.). Malden, MA: Blackwell Publisher. 2006.
5. Green, M.R. & Sambrook, J., Molecular Cloning: a Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. 2012.
6. Alcamo, I.E., DNA Technology: The Awesome Skill. Harcourt Academic Press. 2001.

MBL 532: Enzymology and Enzyme Technology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objective of the course is to provide a deeper insight into the fundamentals of enzyme structure, function, mechanism and kinetics of soluble and immobilized enzymes. Also, it deals with current applications and future potential of enzyme process.	**After successful completion of this course, the students should be able to: -** **1. Distinguish the fundamentals of enzyme properties, nomenclatures, characteristics and mechanisms.** **2. Apply biochemical calculation for enzyme kinetics.** **3. Compare methods for production, purification, characterization and immobilization of enzymes.** **4. Discover the current and future trends of applying enzyme technology for the commercial purpose of biotechnological products.**

UNIT I [15 Lectures]

Introduction to Enzyme: Historical background, Enzymes vs Chemical catalyst, Enzyme nomenclature and classification, Enzyme activity and units, Specific activity, Transition state, Arrhenius Equation, Cofactors and coenzymes.

Enzyme Specificity: Substrate and reaction specificity, Lock & key hypothesis, Induced fit hypothesis, Wrong way binding hypothesis, Three-point attachment hypothesis.

UNIT II [15 Lectures]

Enzyme Purification: Methods for enzyme assays, Methods of Extraction of enzymes, Enzyme purification techniques- salt fractionation, gel filtration chromatography, ion exchange chromatography, affinity chromatography etc., Testing of enzyme purity.

Enzyme Catalysis: Sequencing methods; Enzymatic DNA sequencing; Chemical sequencing of DNA; Automated Mechanism of enzyme catalysis, Acid-Base catalysis, Covalent catalysis, Metal ion catalysis, Electrostatic catalysis, Catalysis through proximity and orientation effects, Catalysis by transition state binding. Catalysis in model enzymes – Ribonuclease A, Chymotrypsin, Carbonic anhydrase, Carboxypeptidase A, Lysozyme.

UNIT III [15 Lectures]

Enzyme Kinetics: Factors affecting velocity of enzyme catalyzed reactions, Michaelis-Menten hypothesis, Transformation of Michaelis- Menten equation and determination of Km and Vmax, Haldane relationship, Enzyme inhibition i.e., reversible and irreversible

inhibition, competitive, non-competitive and uncompetitive inhibition – Michaelis- Menten equation, Determination of Km, Vmax and Ki.
Bi-substrate Reactions- Sequential – Ping-Pong reactions- rate equations, examples – Differentiating Bi-substrate mechanisms.

UNIT IV [15 Lectures]

Regulatory Enzymes: Allosteric enzymes, Sequential and symmetry models, Covalently regulated enzymes.
Enzyme Technology: Large scale production of enzymes, Uses of isolated enzymes in food and chemical industries, Therapeutic & medicinal use of enzymes.
Protein Engineering: Concept and Methods, Site directed mutagenesis, Active site mapping, Nature of the active site, Identification of functional groups at the active site,
Immobilized enzymes–Methods and Applications.

Recommended Textbooks and References:

1. Palmer, T. & Bonner, P., Enzymes: Biochemistry, Biotechnology and Clinical Chemistry (2nd Ed.). Howood Publishing Chishester, England. 2008.
2. Okotore, R.O. (2015) Essentials of Enzymology Xlibris, USA. 2015.
3. Marangoni, A.G., Enzyme Kinetics-A Modern Approach. 2003.
4. Engel, P.C., Enzyme Kinetics: The Steady State Approach, Springer Illustrated Edition. 2014.
5. Bisswanger, H., Enzyme Kinetics: Principles and Methods (3rd Ed.). Willey-VCH. 2017.
6. Rocha-Martin, J., Immobilization of Enzymes and Cells: Methods and Protocols, Springer US. 2020.
7. Price, N.C. & Stevens, L., Fundamentals of Enzymology (3rd Ed.). Oxford University Press, New York. 1999.
8. Phillips, J., Fundamentals of Enzymology Ed-Tech Press, United Kingdom. 2019.
9. Dixon, M. & Webb, E.C., Enzyme (3rd Ed.). Academic Press, New York. 1979.
10. Uhlig, H., Industrial Enzymes and Their Applications, Jone Wiley, New York. 1998

MBL 533: Bioinformatics (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to provide theory and practical experience of the use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.	**After successful completion of this course, the students should be able to: -** **1. Develop an understanding of basic theory of these bioinformatics tools.** **2. Gain working knowledge of these bioinformatics tools and methods.** **3. Appreciate their relevance for investigating specific contemporary biological questions.** **4. Critically analyze and interpret results of their study.**

UNIT I [15 Lectures]

Bioinformatics Basics: Bioinformatics basics: Computers in biology and medicine; Introduction to Unix and Linux systems and basic commands; Database concepts; Protein and nucleic acid databases; Structural databases; Biological XML DTD's; pattern matching algorithm basics; databases and search tools: biological background for sequence analysis; Identification of protein sequence from DNA sequence; searching of databases similar sequence; NCBI; publicly available tools; resources at EBI; resources on web; database mining tools.

UNIT II [15 Lectures]

DNA Sequence Analysis: Gene bank sequence database; submitting DNA sequences to databases and database searching; sequence alignment; pairwise alignment techniques; motif discovery and gene prediction; local structural variants of DNA, their relevance in molecular level processes, and their identification; assembly of data from genome sequencing.

Multiple Sequence Analysis: Multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTALW and CLUSTALX for multiple sequence alignment; submitting DNA protein sequence to databases: where and how to submit, SEQUIN, genome centres; submitting aligned sets of sequences, updating submitted sequences, methods of phylogenetic analysis.

UNIT III [15 Lectures]

Protein Modelling: Introduction; force field methods; energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; fitting monomers; RMS fit of conformers; assigning secondary structures; sequence alignment- methods, evaluation, scoring; protein completion: backbone construction and side

chain addition; small peptide methodology; software accessibility; building peptides; protein displays; substructure manipulations, annealing.

UNIT IV [15 Lectures]

Protein Structure Prediction: Protein folding and model generation; secondary structure prediction; analyzing secondary structures; protein loop searching; loop generating methods; homology modeling: potential applications, description, methodology, homologous sequence identification; align structures, align model sequence; construction of variable and conserved regions; threading techniques; topology fingerprint approach for prediction; evaluation of alternate models; structure prediction on a mystery sequence; structure aided sequence techniques of structure prediction; structural profiles, alignment algorithms, mutation tables, prediction, validation, sequence based methods of structure prediction, prediction using inverse folding, fold prediction; significance analysis, scoring techniques, sequence-sequence scoring; protein function prediction; elements of *in silico* drug design; Virtual library: Searching PubMed, current content, science citation index and current awareness services, electronic journals, grants and funding information.

Recommended Textbooks and References:

1. Lesk, A.M., Introduction to Bioinformatics. Oxford: Oxford University Press. 2002.
2. Mount, D.W. (2001). Bioinformatics: Sequence and Genome Analysis. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. 2001.
3. Baxevanis, A.D. & Ouellette, B.F., Bioinformatics: a Practical Guide to the Analysis of Genes and Proteins. New York: Wiley-Interscience. 2001.
4. Pevsner, J., Bioinformatics and Functional Genomics. Hoboken, NJ: Wiley-Blackwell. 2015.
5. Bourne, P. E. & Gu, J., Structural Bioinformatics. Hoboken, NJ: Wiley-Liss. 2009.
6. Lesk, A.M., Introduction to Protein Science: Architecture, Function, and Genomics. Oxford: Oxford University Press. 2004.
7. Mount, D.W., Bioinformatics: Sequence and Genome Analysis (2^{nd} Ed.). CSHL Press. 2004.
8. Bloomfield, V., Computer Simulation and Data Analysis in Molecular Biology and Biophysics. Springer. 2009.

MBL 534: Nanobiotechnology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The course aims at providing a general and broad introduction to multi-disciplinary field of nanotechnology and its applications.	**On successful completion of this course, students should be able to:-** **1. Describe basic science behind the properties of materials at nanometre scale and the principles behind advanced experimental and computational techniques for studying nanomaterials.** **2. Describe synthesis methods of nanomaterials especially biological synthesis and nanocomposite biomaterials for biological applications**

UNIT I [15 Lectures]

Introduction to Nanobiotechnology: Introduction to Nanotechnology Nanobiotechnology; Concepts, historical perspective, Insights and intervention into the Nanoworld, Historical Background, Applications of Nanotechnology in different fields- Agriculture, medical applications, Environmental applications, Space, Food processing, consumer durables, textiles, cosmetics etc, Natural nanomaterials: Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures.

UNIT II [15 Lectures]

Nanomaterials: Nanomaterials- Types, Properties and applications; Synthesis methods- Physical, Chemical and Biological methods of synthesis; Carbon Nanotubes – Synthesis methods and applications; Nanowires- synthesis methods, properties and applications.
Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

UNIT III [15 Lectures]

Applications of Nanoparticles: Nanoparticles for diagnostics and imaging (theranostics); implications in cancer therapy, Nanomaterials in Sensing applications, Nanodevices-MEMS & NEMS, Microfluidics and Lab-on-a-chip concept. Carbon nanotubes in healthcare applications. Novel materials for healthcare applications- Graphene, Quantum dots etc.; Nano-based smart formulations for agriculture applications. Nanonutraceuticals, Polymeric nanocomposites for healthcare and agriculture applications- Nanovesicles; Nanospheres; Nano capsules etc.

UNIT IV [15 Lectures]

Nano-materials and Nano Toxicity: Nanomaterials for catalysis-Nano biocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates. Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different strata's of environment; Ecotoxicity models.

Recommended Textbooks and References:

1. GeroDecher, J., & Schlenoff, B., Multilayer Thin Films: Sequential Assembly of Nanocomposite Materials, Wiley-VCH Verlag GmbH & Co. KGaA. 2003.
2. Goodsell, D.S., Bionanotechnology: Lessons from Nature; Wiley-Liss. 2004.
3. Malsch, N.H., Biomedical Nanotechnology, CRC Press. 2005.
4. Hermanson, G.T., Bioconjugate Techniques (3rd Ed.). Elsevier. 2013.
5. Kulkarni, S.K., Nanotechnology- Principles and Practices (3rd Ed.). Capital Publishing Company. 2014.
6. Vajtai, R., Handbook of Nanomaterials, Springer. 2013.
7. Nalwa, H.S., Encyclopedia of Nano Science & Nanotechnology. American Scientific Publishers. 2011.
8. Balzani, V., Credi, A. & Verturi, M., Molecular Devices and Machines- A Journey into Nanoworld. Wiley-VCH Verlag. 2003.
9. Wolfson, J.R., Social and Ethical Issues in Nanotechnology: Lessons from Biotechnology and Other High Technologies. Biotechnology Law Report, **22**, no 4, 376-96. 2003.
10. Bharat, B., Handbook of Nanotechnology. Springer. 2004.

MBL 535: Bioentrepreneurship, Intellectual Property Rights and Biosafety

(Credits : 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are: - **1. To teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.** **2. To provide basic knowledge on intellectual property rights and their implications in biological research and product development.** **3. To become familiar with ethical issues, biosafety and risk assessment of products derived from biotechnology and regulation of such products.**	**After successful completion of this course, students should be able to:** **1. Gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies.** **2. Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents.** **3. Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;** **4. Understand ethical aspects related to biological, biomedical, health care and biotechnology research.**

UNIT I [15 Lectures]

Innovation and Entrepreneurship in Bio-business: Introduction and scope in Bio-entrepreneurship, Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make in India etc.), Strategic dimensions of patenting & commercialization strategies.

Financing of Biofirms: Business plan preparation including statutory and legal requirements, Business feasibility study, Arrangement of risk capital: From Angeles, High net worth individuals, venture capital and other informal sources, Deal structuring, Negotiation.

UNIT II [15 Lectures]

Intellectual Property Right: Introduction to intellectual property; types of IP: patents, trademarks, copyright rights, industrial design, geographical indications, protection of new

GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act, patent databases - country-wise patent searches (USPTO, EPO, India).

Patenting: Basics of patents: types of patents; Indian Patent Act 1970; Procedure for filing a patent application; International harmonization of patent laws. Patenting of biological materials, Patenting of life forms−plant, animals, microbes, gene, process and products, Commercialization of patented innovations.

UNIT III [15 Lectures]

Biosafety: Biosafety and Biosecurity - introduction; historical background; biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; GMOs & LMOs; Principles of safety assessment of transgenic plants – sequential steps in risk assessment; environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops *vs* cisgenic plants or products derived from RNAi and genome editing tools.

UNIT IV [15 Lectures]

Bioethics: Introduction, ethical conflicts in biological sciences - interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research – cloning and stem cell research, Human and animal experimentation, animal rights/welfare, Agricultural Biotechnology-Genetically engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – biopiracy.

Mandatory: It is mandatory to attend one workshop/conference / lecture series on IPR /Patenting/ Technology Commercialization organized by the IPR & TC Cell of University. Three marks in lieu of participation will be counted towards internal assessment.

Recommended Textbooks and References:

1. Adams, D.J. & Sparrow, J.C., Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences. Bloxham: Scion. 2008.
2. Karhad, P., How to Patent an Idea in India: From Idea to Granted Patent in Quickest Time, Saving Costs and Making Money with Your Patented Invention; A Step by step guideline on Intellectual Property in India. 2018.
3. Chopra, R.K., Indian Patent System. Himalaya Publishing House. 2010.
4. Patzelt, H. & Brenner, T., Handbook of Bioentrepreneurship: 4 (International Handbook Series on Entrepreneurship). Springer. 2010.
5. Shimasaki, C.D. Biotechnology Entrepreneurship: Starting, Managing, and Leading Biotech Companies. Amsterdam: Elsevier. Academic Press is an imprint of Elsevier. 2014.
6. Jordan, J.F., Innovation, Commercialization, and Start-Ups in Life Sciences. London: CRC Press. 2014.
7. Desai, V., The Dynamics of Entrepreneurial Development and Management. New Delhi: Himalaya Pub. House. 2009.
8. Ganguli, P., Intellectual Property Rights: Unleashing the Knowledge Economy. New Delhi. 2001.

9. Kuhse, H., Bioethics: an Anthology. Malden, MA: Blackwell. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/. 2010.
10. World Intellectual Property Organisation. http://www.wipo.int
11. Wolt, J.D., Keese, P., Raybould, A., Fitzpatrick, J.W., Burachik, M., Gray, A., Wu, F. Problem Formulation in the Environmental Risk Assessment for Genetically Modified Plants. Transgenic Research, 19(3), 425-436. doi:10.1007/s11248-009-9321-9. 2009.

MBL 536: Project Proposal Preparation & Presentation (Credits: 2+0)

Internal Marks	**100**
Total Marks	**100**

Note: Three Teachers of the department including the Supervisor will evaluate the preparation of synopsis, poster and research proposal of the student and award marks based on oral presentation.

Course Objectives	Student Learning Outcomes
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.	**After successful completion of this course, students should be able to:** **1. Formulate a scientific question.** **2. Present scientific approach to solve the problem.** **3. Interpret, discuss and communicate scientific results in written form.** **4. Gain experience in writing a scientific proposal.** **5. Learn how to present and explain their research findings to the audience effectively.**

UNIT I [8 Lectures]

Selection of Research Lab and Research Topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven. Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

UNIT II [8 Lectures]

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

UNIT III [7 Lectures]

Poster Presentation: Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic

UNIT IV [7 Lectures]

Oral Presentation: At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

MBP 537: Lab V (Genetic Engineering) (Credits: 0+3)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**4H**

Course Objectives	Student Learning Outcomes
The objectives of this course are to provide students with experimental knowledge of molecular biology and genetic engineering	**After successful completion of this practical course, students should be able to gain hands-on experience in gene cloning, protein expression and purification. This experience would enable them to begin a career in industry that engages in genetic engineering as well as in research laboratories conducting fundamental research.**

List of Experiments:

1. Concept of lac-operon:
   a) Lactose induction of β-galactosidase.
   b) Glucose Repression.
   c) Diauxic growth curve of *E.coli*
2. Phage titre with epsilon phage/M13
3. Genetic Transfer-Conjugation, gene mapping
4. Plasmid DNA isolation and quantification
5. Restriction Enzyme digestion of plasmid DNA
6. Agarose gel electrophoresis
7. Isolation of RNA from plant tissue
8. Synthesis of cDNA using RNA
9. Polymerase Chain Reaction and analysis by agarose gel electrophoresis
10. Vector and Insert Ligation.
11. Preparation of competent cells.
12. Transformation of *E. coli* with standard plasmids, Calculation of transformation efficiency.
13. Confirmation of the insert by Colony PCR and Restriction mapping
14. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in *E. coli*, SDS-PAGE analysis
15. Purification of His-Tagged protein on Ni-NTA columns

a) Random Primer labeling

b) Southern hybridization.

Recommended Textbooks and References:

1. Green, M.R. & Sambrook, J., Molecular Cloning: a Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. 2012.

MBP 538: Lab VI (Bioinformatics) (Credits: 0+3)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**4H**

Course Objectives	Student Learning Outcomes
The aim of this course is to provide practical training in bioinformatic methods including accessing major public sequence databases, use of different computational tools to find sequences, analysis of protein and nucleic acid sequences by various software packages.	**On successful completion of this course, students should be able to:** **1. Describe contents and properties of most important bioinformatics databases.** **2. Perform text- and sequence-based searches and analyze and discuss results in light of molecular biological knowledge.** **3. Explain major steps in pairwise and multiple sequence alignment, explain principle and execute pairwise sequence alignment by dynamic programming.** **4. Predict secondary and tertiary structures of protein sequences.**

List of Experiments:

1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
3. Sequence information resource: Using NCBI, EMBL, Genbank, Entrez, Swissprot/ TrEMBL, UniProt.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
6. Phylogenetic analysis of protein and nucleotide sequences.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
12. Homology modeling of proteins.
13. Use of tools for mutation and analysis of the energy minimization of protein structures.
14. Use of miRNA prediction, designing and target prediction tools.

Recommended Textbooks and References:

1. Mount, D.W., Bioinformatics: Sequence and Genome Analysis. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. 2001.
2. Baxevanis, A.D., & Ouellette, B.F., Bioinformatics: a Practical Guide to the Analysis of Genes and Proteins. New York: Wiley-Interscience. 2001.
3. Pevsner, J., Bioinformatics and Functional Genomics. Hoboken, NJ.: Wiley-Blackwell. 2015.
4. Bourne, P. E., & Gu, J., Structural Bioinformatics. Hoboken, NJ: Wiley-Liss. 2009.

MBL 541: Critical Analysis of Classical Papers (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Internal Assessment: Students will be divided in groups and each group will be responsible for one classical paper. Each week there will be a one-hour presentation cum discussion for each of the papers. At the end of the semester each student will be asked to write a mini-review (2-3 pages long) on any one classical paper, other than the one he/she presented/discussed.

Course Objectives	Student Learning Outcomes
The objectives of this course are to familiarize students with classic literature to make them appreciate how ground-breaking discoveries were made without, necessarily, use of high-end technologies	**Students should be able to train in the exercise of hypothesis building and methods of addressing the hypothesis with readily available technology.**

UNIT I

Molecular Biology:

1. Studies on the chemical nature of the substance inducing transformation of Pneumococcal types: Induction of transformation by a deoxyribonucleic acid fraction isolated from *Pneumococcus* type III. Avery OT, Macleod CM, McCarty M.; J Exp Med. 1944 Feb 1;79(2):137-58.
   Note: This paper demonstrates that DNA is the transforming principle originally described by Fredrick Griffith.
2. Independent functions of viral protein and nucleic acid in growth of bacteriophage Hershey AD and Chase M.; J Gen Physiol. 1952 May;36(1):39-56.
   Note: This paper demonstrates that DNA, and not protein, component of phages enters bacterial cells.
3. Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid Watson JD and Crick FH; Nature. 1953 Apr 25;171(4356):737-8
   Note: In this one-page paper Watson and Crick first described the structure of DNA double helix
   Study help - Watson_Crick_Nature_1953_annotated
4. Transposable mating type genes in *Saccharomyces cerevisiae* James Hicks, Jeffrey N. Strathern & Amar J.S. Klar; Nature 282, 478-483,1979

Note: This paper provided evidence for 'cassette hypothesis' of yeast mating type switches *i.e.* interconversion of mating types in yeast *(S. cerevisiae)* occurs by DNA rearrangement.

5. Messelson & Stahl experiment demonstrating semi-conservative replication of DNA. Meselson M and Stahl FW.; Proc Natl Acad Sci U S A. 1958 Jul 15;44(7):671-82
   Note: The experiment demonstrating semi-conservative mode of DNA replication is referred to as "the most beautiful experiment in biology"
6. *In vivo* alteration of telomere sequences and senescence caused by mutated *Tetrahymena* telomerase RNAs Guo-Liang Yu, John D. Bradley, Laura D. Attardi & Elizabeth H. Blackburn; Nature 344, 126-132, 1990
   Note: This paper demonstrates that the telomerase contains the template for telomere synthesis.

UNIT II

Cell Biology:

1. A protein-conducting channel in the endoplasmic reticulum Simon SM AND Blobel G.; Cell. 1991 May 3;65(3):371-80
   Note: This paper demonstrates the existence of a protein conducting channel
   Study help - A brief history of Signal Hypothesis
2. Identification of 23 complementation groups required for post-translational events in the yeast secretory pathway Novick P, Field C, Schekman R.; Cell. 1980 Aug; 21(1):205-15
   Note: In this groundbreaking paper Randy Schekman's group used a mutagenesis screen for fast sedimenting yeast mutants to identify genes involved in cell secretion
3. A yeast mutant defective at an early stage in import of secretory protein precursors into the endoplasmic reticulum Deshaies RJ and Schekman R.; J Cell Biol. 1987 Aug;105(2):633-45
   Note: Using another yeast mutation screen Schekman lab identifies Sec61, a component of ER protein Conducting Channel (PCC)
   Suggested reference paper - A biochemical assay for identification of PCC.
4. Reconstitution of the Transport of Protein between Successive Compartments of the Golgi Balch WE, Dunphy WG, Braell WA, Rothman JE.; Cell. 1984 Dec;39(2 Pt 1):405-16
   Note: This paper describes setting up of an *in vitro* reconstituted system for transport between golgi stacks which eventually paved the way for identification of most of the molecular players involved in these steps including NSF, SNAP *etc.*
5. A complete immunoglobulin gene is created by somatic recombination Brack C, Hirama M, Lenhard-Schuller R, Tonegawa S.; Cell. 1978 Sep;15(1):1-14
   Note: This study demonstrates DNA level molecular details of somatic rearrangement of immunoglobulin gene sequences leading to the generation of functionally competent antibody generating gene following recombination.
6. A novel multigene family may encode odorant receptors: a molecular basis for odor recognition Buck L and Axel R; Cell. 1991 Apr 5;65(1):175-87

Note: This paper suggests that different chemical odorants associate with different cell-specific expression of a transmembrane receptor in *Drosophila* olfactory epithelium where a large family of odorat receptors is expressed.

7. Kinesin walks hand-over-hand Yildiz A, Tomishige M, Vale RD, Selvin PR.; Science. 2004 Jan 30;303(5658):676-8
   Note: This paper shows that kinesin motor works as a two-headed dimeric motor walking hand-over-hand rather than like an inchworm on microtubule tract using the energy of ATP hydrolysis.

UNIT III

Developmental Biology/ Genetics:

1. Mutations affecting segment number and polarity in *Drosophila* Christiane Nusslein-Volhard and Eric Weischaus; Nature 287, 795-801, 1980
   Note: This single mutagenesis screen identified majority of the developmentally important genes not only in flies but in other metazoans as well.
2. Information for the dorsal--ventral pattern of the *Drosophila* embryo is stored as maternal mRNA Anderson KV and Nüsslein-Volhard C; Nature. 1984 Sep 20-26;311(5983):223-7
   Note: This landmark paper demonstrated that early dorsal-ventral pattern information is stored as maternal mRNA in flies and devised the method of identifying genes encoding such genes
3. Hedgehog signalling in the mouse requires intraflagellar transport proteins Huangfu D, Liu A, Rakeman AS, Murcia NS, Niswander L, Anderson KV.; Nature. 2003 Nov 6;426(6962):83-7
   Note: One of the architects of original fly mutagenesis screens conducted a mouse mutagenes screen which identified a gene Kif3a as a major component of hedgehog signaling pathway. Eventually this discovery revolutionizes our understanding of mechanisms of action of signaling pathways by demonstrating central role of cillia in it.

Immunology:

The Nature Milestones in Antibodies supplement available at **http://www.nature.com/milestones/antibodies** includes a Timeline listing each breakthrough according to the year in which the first relevant primary paper was published and a collection featuring six key historic antibody-related papers that were published in Nature. The following Milestone topics and papers were selected that aim to highlight outstanding technological developments and scientific discoveries that have helped to define a particular field in immunology.

Milestone-1

Blood is very unusual fluid. Nature Immunology.11: S5.2016

Note: This paper highlights how infected animals could be cured and healthy animals could be pre-treated to prevent infection.

Original Research Papers:

a) Behring, E. & Kitasato, S. Ueber das Zustandekommen der Diphtherie-Immunität und der Tetanus-Immunität bei Thieren**.** Dtsch. Med. Wschr 16, 1113–1114 .1890
b) Behring, E. Untersuchungen über das Zustandekommen der Diphtherie-Immunität bei Thieren. Dtsch. Med. Wschr. 16, 1145–1147.1890

Further Reading:
De Kruif, P. The Microbe Hunters 2nd ed (Harcourt, Brace and Jovanovich, San Diego, 1954

Milestone-2

The many sides of Paul Ehrlic. Nature Immunology.11: S6.2016

Note: This paper explained that during infection the side chain would bind to microbial toxin instead of nutrients and would thereby block the physiological function of the side chain.

Original Research Papers:
a. Ehrlich, P. Experimentelle Untersuchungen über Immunität. *Dtsch. Med. Wschr*.17, 976 .1891
b) Ehrlich, P. Die Seitenkettentheorie und ihre Gegner. *Münch. Med. Wschr.* 18, 2123.1901
c) Ehrlich, P. Die Schutzstoffe des Blutes. *Dtsch. Med. Wschr.* 27, 865. 1901

Further Reading:
i. Silverstein, A. M. The most elegant immunological experiment of the XIX century. *Nat. Immunol.* 1, 93–94 .2000
ii. Winau, F., Westphal, O. & Winau, R. Paul Ehrlich—in search of the magic bullet. *J. Mic. Inf.* 6, 786–789. 2004|
iii. Silverstein, A. M. Paul Ehrlich, archives and the history of immunology. *Nat. Immunol.* 6, 639. 2005
iv. Kaufmann, S. H. E. Immunology's foundation: the 100-year anniversary of the Nobel Prize to Paul Ehrlich and Elie Metchnikoff. *Nat. Immunol.* 9, 705–712. 2008|

Milestone -3

Putting antibodies into shape. Nature immunology.11: S11.2016

Note: This paper explained that how X-ray crystallography and electron microscopy studies have provided a wealth of structural details on immunoglobulin.

Original Research Papers:
a) Porter, R. R. The hydrolysis of rabbit γ-globulin and antibodies with crystalline papain. *Biochem. J.* 73, 119–127.1959
b) Edelman, G. M. & Poulik, M. D. Studies on structural units of the γ-globulin. *J. Exp. Med.* 113, 861–884. 1961
c) Fleischman, J. B. *et al.* The arrangement of the peptide chains in γ-globulin. *Biochem. J.* 88, 220–228.1963
d) Edelman, G. M. *et al.* The covalent structure of an entire γG immunoglobulin molecule. *Proc. Natl. Acad. Sci. USA* 63, 78–85. 1969
e) Wu, T. T. & Kabat, E. A. An analysis of the sequences of the variable regions of Bence Jones proteins and myeloma light chains and their implications for antibody complementarity. *J. Exp. Med.* 132, 211–250 .1970

f) Silverton, E. W., Navia, M. A. & Davies, D. R. Three-dimensional structure of an intact human immunoglobulin. *Proc. Natl. Acad. Sci. USA* 74, 5140–5144 .1977

Further Reading:

i. Bence Jones, H. On the new substance occurring in the urine of a patient with mollities ossium. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 138, 55–62 .1847

ii. Edelman, G. M. & Gally, J. A. The nature of Bence-Jones proteins. Chemical similarities to polypetide chains of myeloma globulins and normal γ-globulins. *J. Exp. Med.* 116, 207–227 .1962

Milestone-4

The birth of monoclonal antibodies. Nature immunology.11: S13.2016

Note: This paper reviewed method for generating large amounts of monoclonal antibodies of a predefined specificity.

Original Research Papers:

a) Cotton, R. G. H. & Milstein, C. Fusion of two immunoglobulin-producing myeloma cells. *Nature* 244, 42–43 (1973)

b) Klinman, N. R. Antibody with homogeneous antigen binding produced by splenic foci in organ culture. *Immunochemistry* 6, 757–759 (1969)

c) Köhler, G. & Milstein, C. Continuous cultures of fused cells secreting antibody of predefined specificity. *Nature* 256, 495–497 (1975)

Further Reading http://www.whatisbiotechnology.org/ exhibitions/milstein/antibodies

UNIT IV

Recombinant DNA Technology:

1. DNA restriction enzyme from *E. coli*. Meselson M, Yuan R; 1968 Nature. 217(5134): 1110-4

   Note: This paper demonstrates the isolation of a restriction endonuclease enzyme from *E. coli* which degrade foreign DNA

   Further Reading:

   a) Highlights of the DNA cutters: A short history of the restriction enzymes. Loenen WA, Dryden DT, Raleigh EA, Wilson GG, Murray NE 2014 Jan. Nucleic Acids Research 42 (1): 3–19

   b) History: The servant with the scissors. Konforti, B. 2000 Feb. Nature Structural Biology. **7** (2): 99–100

   Note: These reviews trace the discovery of restriction enzymes I, II, III, and IV and their continuing impact on molecular biology and medicine

2. Nucleotide sequence of bacteriophage phi X174 DNA. Sanger, F., Air, G, M., Barrell, B.G.N., et al.1977, Nature. 265: 687–69.

   Note: This paper shows DNA sequence for the genome of bacteriophage φX174 using the rapid and simple 'plus and minus' method.

   Further Reading: DNA sequencing with chain-terminating inhibitors. Sanger, F. Nicklen, S. & Coulson A.R. Proc. Nat. Acad. Sci. USA. 74 (12). 5463-5467.

   Note: This paper describes a classical method for determining nucleotide sequences in DNA with chain-terminating inhibitors.

3. Maxam, A.M. and Gilbert, W. 1977. A new method for sequencing DNA. Proc. Natl. Acad. Sci. U.S.A. 74
   Note: This paper describes that DNA can be sequenced by a chemical procedure that breaks a terminally labeled DNA molecule partially at each repetition of a base.
4. Next-generation sequencing transforms today's biology. Stephan C Schuster.2008 Nature Methods **5** : 16–18
   Note: This paper emphasizes how a new generation of non-Sanger-based sequencing technologies has delivered on its promise of sequencing DNA at unprecedented speed, thereby enabling impressive scientific achievements and novel biological applications.
5. The unusual origin of the polymerase chain reaction. Mullis KB 1990 April. Scientific American. **262** (4): 56–61, 64–5
   Note: This paper describes how a surprisingly simple method for making unlimited copies of DNA fragments was conceived by Kary B.Mullis under unlikely circumstances-during a moonlit drive through the mountains of California
6. A bacterial clone synthesizing proinsulin. Villa-Komaroff L, Efstratiadis A, Broome S, Lomedico P, Tizard R, Naber SP, et al 1978 Aug. Proceedings of the National Academy of Sciences of the United States of America. 75 (8): 372731
   Note: This paper demonstrates the cloning of double-stranded cDNA of a rat preproinsulin messenger RNA in *Escherichia coli*
7. Potent and specific genetic interference by double-stranded RNA in *Caenorhabditis elegans.* Fire A, Xu A, Montgomery MK, Kostas SA Driver AD, Samuel E Mello CC 1998 . Nature 391(6669):806-811.
   Note: This paper describes how the phenomenon dubbed "RNA interference was discovered by Andrew Fire and Craig Mello through their studies of the roundworm *C. elegans*.
8. A Programmable Dual-RNA-Guided DNA Endonuclease in Adaptive Bacterial Immunity. Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J. A., & Charpentier, E. 2012 Aug. Science, 337(6096), 816-821.
   Note: This paper demonstrates remarkable DNA interference mechanism involving a dual-RNA structure that directs a Cas9 endonuclease to introduce site-specific double-stranded breaks in target DNA
   Further Reading:
   a) The Unsung Heroes of CRISPR. Ledford, H. 2016.Nature, 535(7612), 342-344.
   b) The Heroes of CRISPR. Lander, E. 2016. Cell, 164(1-2), 18-28
   Note: These papers describe an inspiring ensemble of a dozen or so scientists who—with their collaborators and other contributors whose stories are not elaborated—discovered the CRISPR system, unraveled its molecular mechanisms, and repurposed it as a powerful tool for biological research and biomedicine. Together, they are the Heroes of CRISPR.

MBL 542: Molecular Diagnostics (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to sensitize students about recent advances in genome biology and various facets of molecular medicine	**Students should be able to understand various facets of molecular procedures and basics of genomics and metabolomics that could be employed in early diagnosis and prognosis of human diseases.**

UNIT I [7 Lectures]

Genome Biology in Health and Disease: DNA, RNA, Protein: An overview; chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs.

UNIT II [8 Lectures]

Genome - Resolution, Detection &Analysis: PCR: Real-time; ARMS; Multiplex; ISH; FISH; ISA; RFLP; DHPLC; DGGE; CSCE; SSCP; Nucleic acid sequencing: new generations of automated sequencers; Microarray chips; EST; SAGE; microarray data normalization & analysis; molecular markers: 16S rRNA typing; Diagnostic proteomics: SELDI-TOF-MS; Bioinformatics data acquisition & analysis.

UNIT III [7 Lectures]

Diagnostic Metabolomics: Metabolite profile for biomarker detection the body fluids/tissues in various metabolic disorders by using LCMS & NMR technological platforms.

Detection and Identity of Microbial Diseases: Direct detection and identification of pathogenic-organisms that are slow growing or currently lacking a system of *in vitro* cultivation as well as genotypic markers of microbial resistance to specific antibiotics.

UNIT IV [8 Lectures]

Detection of Inherited Diseases: Exemplified by two inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: Fragile X Syndrome: Paradigm of new mutational mechanism of unstable triplet repeats, von-Hippel Lindau disease: recent acquisition in growing number of familial cancer syndromes.

Molecular Oncology: Detection of recognized genetic aberrations in clinical samples from cancer patients; types of cancer-causing alterations revealed by next-generation sequencing of clinical isolates; predictive biomarkers for personalized onco-therapy of human diseases such

as chronic myeloid leukemia, colon, breast, lung cancer and melanoma as well as matching targeted therapies with patients and preventing toxicity of standard systemic therapies. Quality oversight; regulations and approved testing.

Recommended Textbooks and References:

1. Campbell, A.M. & Heyer, L.J., Discovering Genomics, Proteomics, and Bioinformatics. San Francisco: Benjamin Cummings. 2006.
2. Brooker, R.J., Genetics: Analysis & Principles. New York, NY: McGraw-Hill. 2009.
3. Glick, B.R., Pasternak, J.J. & Patten, C. L., Molecular Biotechnology: Principles and Applications of Recombinant DNA. Washington, DC: ASM Press. 2010.
4. Coleman, W.B. & Tsongalis, G.J., Molecular Diagnostics: for the Clinical Laboratorian. Totowa, NJ: Humana Press. 2010.

MBL 543: Drug Discovery and Vaccines Development (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
This course will give a broad overview of research and development carried out in industrial setup towards drug discovery and vaccines development.	**After successful completion of this course, students should be able to: -** **1. Understand basics of R&D in drug discovery and vaccines development.** **2. Apply knowledge gained in respective fields of pharmaceutical industry.**

UNIT I [7 Lectures]

Target Identification: Identification of target or drug leads associated with a particular disease by a number of different techniques including combinations of molecular modeling, combinatorial libraries and high-throughput screening (HTS); Rational drug design, based on understanding the three-dimensional structures and physicochemical properties of drugs and receptors.

Molecular Modelling: Modelling drug/receptor interactions with the emphasis on molecular mechanisms, molecular dynamics simulations and homology modeling; Conformational sampling, macromolecular folding, structural bioinformatics, receptor-based and ligand-based design and docking methods, in silico screening of libraries, semi-empirical and ab-initio methods, QSAR methods, molecular diversity, design of combinatorial libraries of drug-like molecules, macromolecular and chemical databases.

UNIT II [8 Lectures]

Lead Optimization: Identification of relevant groups on a molecule that interact with a receptor and are responsible for biological activity; Understanding structure activity relationship; Structure modification to increase potency and therapeutic index; Concept of quantitative drug design using Quantitative structure–activity relationship models (QSAR models); Bioanalytical assay development in support of *in vitro* and *in vivo* studies (LC/MS/MS, GC/MS and ELISA).

Preclinical Development: Principles of drug absorption, drug metabolism and distribution - intestinal absorption, metabolic stability, drug-drug interactions, plasma protein binding assays, metabolite profile studies, Principles of toxicology, Experimental design for preclinical and clinical PK/PD/TK studies, Selection of animal model; Regulatory guidelines for preclinical PK/PD/TK studies.

UNIT III [7 Lectures]

Drug Manufacturing: Requirements of GMP implementation, Documentation of GMP practices, CoA, Regulatory certification of GMP, Quality control and Quality assurance,

concept and philosophy of TQM, ICH and ISO 9000; ICH guidelines for Manufacturing, Understanding Impurity Qualification Data, Stability Studies.

Clinical Trial Design: Objectives of Phase I, II, III and IV clinical studies, Clinical study design, enrollment, sites and documentation, Clinical safety studies: Adverse events and adverse drug reactions, Clinical PK, pharmacology, drug-drug interaction studies, Statistical analysis and documentation.

UNIT IV [8 Lectures]

Vaccine Types & Design: History of vaccines, Conventional vaccines; Bacterial vaccines; Viral Vaccines; Vaccines based on routes of administration: parenteral, oral, mucosal; Live attenuated and inactivated vaccine; Subunit Vaccines and Toxoids; Peptide Vaccine.

Vaccine Technologies: New Vaccine Technologies; Rationally designed Vaccines; DNA Vaccination; Mucosal vaccination; New approaches for vaccine delivery; Engineering virus vectors for vaccination; Vaccines for targeted delivery (Vaccine Delivery systems); Disease specific vaccine design: Tuberculosis Vaccine; Malaria Vaccine; HIV/AIDS vaccine; New emerging diseases and vaccine needs (Ebola, Zika).

Recommended Textbooks and References:

1. Stromgaard, K., Krogsgaard-Larsen, P. & Madsen, U., Textbook of Drug Design and Discovery (4th Ed.). CRC Press. 2016.
2. Kuhse, H., Bioethics: an Anthology. Malden, MA: Blackwell. 2010.
3. Nally, J.D., GMP for Pharmaceuticals (6th Ed.). CRC Press. 2006.
4. Brody, T., Clinical Trials: Study Design, Endpoints and Biomarkers, Drug Safety, and FDA and ICH Guidelines. Academic Press. 2016.
5. Kaufmann, S.H., Novel Vaccination Strategies. Weinheim: Wiley-VCH. 2004.
6. Blass, B., Basic principles of drug discovery and development. Elsevier. 2015.
7. Brunt, L.L., Hilal-Dandan, R. & Knollmann, B.C., Goodman and Gilman's The Pharmacological Basis of Therapeutics (13th Ed.). McGraw Hill Education. 2017.
8. Tozer, T.N. & Rowland, M., Introduction to Pharmacokinetics and Pharmacodynamics (4th Ed.). Lippincott Williams & Wilkins. 2006.

MBL 544: Genomics and Proteomics (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to provide introductory knowledge concerning genomics, proteomics and their applications.	**After successful completion of this course, students should be able to acquire knowledge and understanding of fundamentals of genomics and proteomics, transcriptomics and metabolomics and their applications in various applied areas of biology.**

UNIT I [7 Lectures]

Basics of Genomics and Proteomics: Brief overview of prokaryotic and eukaryotic genome organization; Extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.

Genome Mapping: Genetic and physical maps; Markers for genetic mapping; Methods and techniques used for gene mapping, Physical mapping, Linkage analysis, Cytogenetic techniques, FISH technique in gene mapping, Somatic cell hybridization, Radiation hybrid maps, *in situ* hybridization, Comparative gene mapping.

UNIT II [8 Lectures]

Genome Sequencing Projects: Human Genome Project, Genome sequencing projects for microbes, plants and animals, Accessing and retrieving genome project information from the web.

Comparative Genomics: Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; Use of genomes to understand evolution of eukaryotes, Track emerging diseases and design new drugs; Determining gene location in genome sequence.

UNIT III [7 Lectures]

Proteomics: Aims, strategies and challenges in proteomics; Proteomics technologies: 2D-PAGE, Isoelectric focusing, Mass spectrometry, MALDI-TOF, Yeast 2-hybrid system, Proteome databases.

UNIT IV [8 Lectures]

Functional Genomics and Proteomics: Transcriptome sequencing for identification and functional annotation of gene, Contig assembly, Chromosome walking and characterization of chromosomes, Mining functional genes in genome, Gene function- forward and reverse genetics, Gene ethics; Protein-protein and protein-DNA interactions; Protein chips and functional proteomics; Clinical and biomedical applications of proteomics; Introduction to metabolomics, Lipidomics, Metagenomics and systems biology.

Recommended Textbooks and References:

1. John, P., Genomics and Proteomics: Functional and Computational Aspects, Westbury Publishing Ltd. 2020.
2. Sandor, S., Genomics and Proteomics: Functional and Computational Aspects, Springer. 2009.
3. Devarajan, T. & Jeyabalan, S., Genomics and Proteomics: Principles, Technologies, and Applications. Apple Academic Press. 2015.
4. Rudolph, M., Genomics and Proteomics: Functional and Computational Aspects, Syrawood Publishing House. 2019.
5. Cullis, C.A. Plant Genomics and Proteomics, Wiley-Blackwell. 2004.
6. Bagchi, D. & Swaroop, A., Genomics, Proteomics and Metabolomics in Nutraceuticals and Functional Foods, Wiley. 2015.
7. Primrose, S.B. & Twyman, R.M., Principles of Genome Analysis and Genomics (7th Ed.). Blackwell Publishing. 2006.
8. Edward, C., Genomics. Apple Academics. 2010.

MBL 545: Metabolic Engineering (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are: - **1. To develop skills in the area of metabolic engineering to alter the existing metabolic pathway.** **2. To introduce novel metabolic pathways in microorganisms using r-DNA technology.** **3. To learn molecular techniques in order to enhance the product yield.**	**After successful completion of this course, students should be able to: -** **1. Comprehend modern biology with engineering principles and recall the basic principles and regulation of metabolic pathways.** **2. Adapt suitable metabolic control analysis to identify important steps in pathway control.** **3. Demonstrate different methods to obtain improved production strains and bioconversion process.** **4. Apply the concept of metabolic engineering in chemical, medical, and environmental fields.**

UNIT I [8 Lectures]

Secondary Metabolites: Concept of secondary metabolites, Historical and current views, Importance of secondary metabolites in medicine and agriculture, Introduction to metabolic pathways. Metabolic flux, ^{13}C labeled, NMR and MS based methods for flux determination.

UNIT II [7 Lectures]

Flavanoid and Terpenoid Pathways: The basic structure of flavanoid and terpenoid, Stereochemistry, Chemical synthesis of different intermediates, The biochemical pathway, Different regulatory points, Intermediate pools and their significance in horticulture, agriculture and medicine, Regulatory genes, Regulation of gene expression.

UNIT III [7 Lectures]

Saponin and Polyketide Pathways: The basic structure of saponin and polyketide, Stereochemistry, Chemical synthesis of different intermediates, The biochemical pathway, Different regulatory points, Intermediate pools and their significance in horticulture, agriculture and medicine, Regulatory genes, Regulation of gene expression.

UNIT IV [8 Lectures]

Industrial Applications: Pathway engineering strategies for overproduction of secondary metabolites, Strain selection and improvement, Modification of existing or the introduction of entirely new metabolic pathways Technology of plant cell culture for production of secondary metabolites, Bioreactors systems and models for mass cultivation of plant cells.

Bioconversion: Methods of bioconversion, Applications and factors affecting bioconversion

Recommended Textbooks and References:

1. Himmel, M.E. & Bomble, Y.J., Metabolic Pathway Engineering, Humana. 2020.
2. Challacombe, J.F., Metabolic Pathway Engineering: Analysis and Applications in the Life Sciences, Enny Stanford Publishing. 2020.
3. Verpoorte, R. & Alfermann, A.W., Metabolic Engineering of Plant Secondary Metabolism, Springer. 2010.
4. Stephanopoulos, G.N., Aristidou, A.A. & Nielsen, J., Metabolic Engineering - Principles and Methodologies, CBSPD Publisher. 2005.
5. Cortassa, S., Aon, M.A., Iglesias, A.A. & Llyod, D., An Introduction to Metabolic and Cellular Engineering World Scientific Publishing Co. Pte. Ltd. 2002.
6. Lehninger, A.L, Nelson D.L & Cox, M.M., Principles of Biochemistry (7th Ed.). Freeman Publishers, New York. 2017.

MBL 546: Environmental Biotechnology (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The course aims to introduce the specific roles of chemical, biological and molecular sciences to identify and address the emerging environmental issues.	**After the successful completion of this course, the students will be able to; -** **1. Acquire knowledge on scope of biotechnology in environmental applications.** **2. Explain the various global and regional environmental concerns due to natural causes and/or human activities.** **3. Describe existing and emerging technologies that are important in the area of environmental biotechnology.** **4. Demonstrate an awareness of emerging concerns such as climate change, waste management or reductions in fossil fuels, and new technologies for addressing these.**

UNIT I [8 Lectures]

Introduction to Environment: Introduction to environment; pollution and its control; pollution indicators; waste management: domestic, industrial, solid and hazardous wastes; strain improvement; Biodiversity and its conservation; Role of microorganisms in geochemical cycles; microbial energy metabolism, microbial growth kinetics and elementary chemostat theory, relevant microbiological processes, microbial ecology.

UNIT II [7 Lectures]

Bioremediation: Bioremediation: Fundamentals, methods and strategies of application (biostimulation, bioaugmentation) – examples, bioremediation of metals (Cr, As, Se, Hg), radionuclides (U, Te), organic pollutants (PAHs, PCBs, Pesticides, TNT etc.).

Role of Microorganisms in Bioremediation: Application of bacteria and fungi in bioremediation: White rot fungi vs specialized degrading bacteria: examples, uses and advantages vs disadvantages.

UNIT III [7 Lectures]

Bioinsecticides: Bacillus thuringiensis, Baculoviruses, uses, genetic modifications and aspects of safety in their use.

Biofungicides: Description of mode of actions and mechanisms (e.g. Trichoderma, Pseudomonas fluorescens);

Biofertilizers: A symbiotic system between plants – microorganisms (nitrogen fixing symbiosis, mycorrhiza fungi symbiosis), Plant growth promoting rhizobacteria (PGPR) – uses, practical aspects and problems in application

UNIT IV [8 Lectures]

Biofuels: Environmental Biotechnology and biofuels: biogas; bioethanol; biodiesel; biohydrogen; Description of the industrial processes involved, microorganisms and biotechnological interventions for optimization of production; Microbiologically enhanced oil recovery (MEOR); Bioleaching of metals; Production of bioplastics; Production of biosurfactants: bioemulsifiers; Paper production: use of xylanases and white rot fungi.

Recommended Textbooks and References:

1. Evans, G.N. & Furlong, J.C., Environmental Biotechnology: Theory and Applications. Wiley Publishers. 2003.
2. Ritmann, B. & McCarty, P.L., Environmental Biotechnology: Principle & Applications (2nd Ed.). McGraw Hill Science. 2000.
3. Scragg, A., Environmental Biotechnology. Pearson Education Limited. 2005.
4. Devinny, J.S., Deshusses, M.A. & Webster, T.S., Biofiltration for Air Pollution Control, CRC Press. 1998.
5. Rehm, J.H. & Reed, G., Biotechnology-A Multi-volume Comprehensive Treatise, Vol. 11, 2nd Ed., VCH Publishers Inc. 2001.
6. Peavy, H.S, Rowe, D.R. & Tchobanoglous, G., Environmental Engineering, McGraw-Hill Inc. 2013.

MBL 547 Any MOOCs Courses offered by SWAYAM/NPTEL

Maximum Marks (External only)	**100**
Total Marks	**100**

MBD 600: Dissertation (Credits: 16+0)

Maximum Marks	**100**
Total Marks	**100**

Note: Members of the Departmental Research Committee and an outside subject expert will evaluate the thesis submitted by the student at the end of the fourth semester and award marks based on quality of research carried out.

Course Objectives	Student Learning Outcomes
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.	**Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:** **1. In-depth knowledge of the chosen area of research.** **2. Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.** **3. Competence in research design**

Planning & Performing Experiments:

Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

Thesis writing:

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.