Learning Outcomes Based Curriculum Framework

(With effect from 2020-21)

For

M.Sc. (Microbiology)

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. (Microbiology)

In the increasingly globalized society, it is important that the students are equipped with knowledge, skills, mindsets and behaviors which may enable them to perform their duties in such a way that they become important contributors to the development of the society and are capable of earning a decent living so that the overall standard of their families and surroundings improve leading to development of human welfare. To achieve this goal, it is imperative that their educational training is improved such that it incorporates the use of newer technologies, use of newer assessment tools for mid-course corrections to make sure that they become competitive individuals. In the face of this need, the educational curricula, teaching learning processes, training, assessment methods all need to be improved or even re-invented. Keeping this in view, learning outcomes-based course curriculum framework for M.Sc. (Microbiology) is designed to persuade the subject specific knowledge as well as relevant understanding in the emerging areas of microbiology. The curriculum envisions that the student, after completing postgraduate degree in microbiology, may enter into job market as trained microbiologist wherever required in the academia and industry or may initiate start-up and develop it into a commercial enterprise.

Hallmark attributes of M.Sc. (Microbiology) 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 semester the students are exposed to the basic subjects of genetics, microbiology, physiology and biochemistry. Subsequently, they are made to learn instrumentation techniques, bioinformatics, fermentation and recombinant DNA technology followed by advanced specialized aspects such as molecular biology, enzymology, immunology and nanotechnology along with industry and clinically oriented courses. 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 microbiology and possess the ability to use these tools in industry, healthcare, community and institutes or other professions they wish to pursue.
- **Breadth**: There is a great demand for microbiologists in countless diversified industries and sectors such as Pharmaceutical-Biotech Industries, Academia, Clinical/Diagnostic Laboratories, Research Organizations, Environmental Agencies, Food Industry, Beverage Industry and Chemical Industries
- **Professionalism**: The students who have acquired a graduate degree in microbiology can easily find a suitable position in a number of industries engaged in processing and developing biological and fermented 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 Microbiology is 104 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. 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 MMD-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 EXAMINATION FOR M.Sc. (Microbiology)

M.Sc. (Microbiology) Sem. I

Sr.	Course No.	Title	Type	L	P	Credits
1	MML-511	Principles of Microbiology	PC	4	0	4
2	MML-512	Principles of Biochemistry	PC	4	0	4
3	MML-513	Microbial Physiology and Metabolism	PC	4	0	4
4	MML-514	Microbial Genetics	PC	4	0	4
5	MML-515	Soil and Environmental Microbiology	PC	4	0	4
6	MMP-516	Lab I (Microbiology)	PC	0	6	3
7	MMP-517	Lab II (Biochemistry)	PC	0	6	3
		TOTAL		**20**	**12**	**26**

M.Sc. (Microbiology) Sem. II

Sr. No	Course No.	Title	Type	L	P	Credits
1	MML-521	Instrumentation Techniques	PC	4	0	4
2	MML-522	Molecular Biology	PC	4	0	4
3	MML-523	Immunology	PC	4	0	4
4	MML-524	Industrial Microbiology	PC	4	0	4
5	MML-525	Research Methodology and Scientific Communication Skills	PC	2	0	2
6	MMP-526	Lab III (Immunology and Instrumentation Techniques)	PC	0	6	3
7	MMP-527	Lab IV (Industrial Microbiology)	PC	0	6	3
8	Open	Open Elective offered by other department	OE	4	0	4
		TOTAL		**22**	**12**	**28**

M.Sc. (Microbiology) Sem. III

Sr. No.	Course No.	Title	Type	L	P	Credits
1	MML-531	Recombinant DNA Technology	PC	3	0	3
2	MML-532	Microbial Enzyme Technology	PC	3	0	3
3	MML-533	Bioinformatics	PC	3	0	3
4	MML-534	Food Microbiology	PC	3	0	3
5	MML-535	Medical Microbiology	PC	3	0	3
6	MML-536	Nanoparticles in Microorganisms and Biosystems	PC	3	0	3
7	MML-537	Project Proposal Preparation and Presentation	PC	2	0	2
8	MMP-538	Lab V (Recombinant DNA Technology and Bioinformatics)	PC	0	6	3
9	MMP-539	Lab VI (Food and Medical Microbiology)	PC	0	6	3

		TOTAL		**20**	**12**	**26**

M.Sc. (Microbiology) Sem. IV

Sr. No.	Course No.	Title	Type	L	P	Credits
1.	MML-541	Critical Analysis of Classical Papers	PC	2	0	2
2.	MML 542-547	Program Elective-I	PE	2	0	2
3.	MMD-600	Dissertation	PC	0	20	20
		TOTAL		2	20	**24**

Program Elective-I
MML-542 Plant-Pathogen Interactions
MML-543 Virology
MML- 544 Bioentrepreneurship, Biosafety and IPR
MML- 545 Vaccines
MML-546 Metabolic Engineering
MML- 547 Any MOOCs Courses offered by SWAYAM/NPTEL

Semester	Credits
I	**26**
II	**28**
III	**26**
IV	**24**
TOTAL	**104**

Program core (PC)	Program Elective (PE)	Open Elective (OE)	Total Credits
98	**2**	**4**	**104**

MML 511: Principles of 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, growth and nutrition; methods for control of microbes and viruses.	**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. Identify and demonstrate major types of viruses, their properties and replication**

UNIT I [15 Lectures]

Introduction to Microbiology: Introduction to microbiology and microorganisms, Historical development and scope of Microbiology, Ubiquitous nature of microorganisms, Impact of microorganisms on human affairs, Structure of prokaryotic and eukaryotic cell, Differences between Eubacteria, Archaebacteria and Eukaryotes, Salient features of different groups of microorganisms such as bacteria, fungi, protozoa and algae including their morphological features, mode of reproduction and cell cycle.

UNIT II [15 Lectures]

Microbial Diversity and Classification: Microbial taxonomy and evolution of diversity, Classification of microorganisms, criteria for classification, New approaches of bacterial classification, classification of bacteria, Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria, Mycobacteria and Mycoplasma. Archaea: Halophiles, Methanogens, Hyperthermophilic archae, Thermoplasm, eukarya: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes.

UNIT III [15 Lectures]

Microbial Growth & Nutrition: The definition of microbial growth, Growth in batch culture, Mathematical representation of bacterial growth, Bacterial generation time, Specific growth rate, Monoauxic, Diauxic and synchronized growth curves, Measurement of microbial growth, Factors affecting microbial growth. Brief account of growth in fungi, Culture collection and maintenance of microbial cultures, Principles of microbial nutrition-Chemoautotrophs, chemoheterotrophs, photoautotrophs and photo heterotrophs.

UNIT IV [15 Lectures]

Control of Microorganisms: Control of Microorganisms by physical and chemical agents- Antiseptics and disinfectants, Narrow and broad-spectrum antibiotics, Antifungal antibiotics, Mode of action of antimicrobial agents; Antibiotic resistance mechanisms.

Viruses: General characteristics, structure, and classification of plant, animal and bacterial viruses, Replication of viruses- Lytic and lysogenic cycle in bacteriophages. A Brief account of Retroviruses, Viroids, Virusoids, Prions and emerging pandemics caused by Viruses such as HIV, SARS, Avian flu, Swine flu, Ebola, Corona virus-19 etc.

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.
6. Sequeira, M., Kapoor, K.K., Yadav, K.S. & Tauro, P., An Introduction to Microbiology (3rd Ed.). New Age International Publishers. 2019.

MML 512: Principles of Biochemistry (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.

MML 513: Microbial Physiology 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 major objective of this course is to develop clear understanding of various aspects of microbial physiology along with diverse metabolic pathways existing in bacteria in relation to its survival and propagation.	**Upon successful completion of the course, the student should be able to:-** **1. Demonstrate significant knowledge and understanding of microbial physiology, metabolism and ecology.** **2. Describing the growth characteristics of the microorganisms which require different nutrient for growth and the associated mechanisms of energy generation for their survival like autotrophs, heterotrophs, chemolithoautotrophs etc.** **3. Differentiating concepts of aerobic and anaerobic respiration and how these are manifested in the form of different metabolic pathways in microorganisms.** **4. Acquired knowledge in engineering metabolic pathways for developing industrially useful strains.**

UNIT I [15 Lectures]

Cellular Organization of Microorganisms: Structure, function, biosynthesis and assembly of various cellular components of Prokaryotes- Capsule and slime layers, peptidoglycan, outer membrane, cytoplasmic membrane, flagella, axial filaments, pili and fimbriae, nuclear material, and storage molecules. Bacterial Permeation-Transport of solutes across the membrane. Chemotaxis. Cell cycle of *E. coli*, and Yeast *S. cerevisiae*. Structure of fungal cell.

UNIT II [15 Lectures]

Differentiation in Bacteria: Endospore and cyst forming bacteria. Molecular architecture of spores, induction and stages of sporulation cycle. Influence of different factors on sporulation. Cytological and macromolecular changes during sporulation. Spore germination and out growth. Micro cycle sporulation. Differentiation in *Caulobacter* and myxobacteria. Sporulation in fungi-biochemical and macromolecular changes.

UNIT III [15 Lectures]

Fermentation and Energy Generation: Metabolism of lactic acid bacteria, coliforms, yeast, clostridia, and propionic acid bacteria. Metabolism of methanogens.

Bacterial Photosynthesis: Photosynthetic bacteria, photosynthetic pigments, and generation of reducing power by cyclic and non-cyclic photophosphorylation, electron transport chain in photosynthetic bacteria, Carbon dioxide fixation pathways. Cyanobacterial photosynthesis.

UNIT IV [15 Lectures]

Bacterial Respiration: Bacterial aerobic respiration, components of electron transport chain, free energy changes and electron transport, oxidative phosphorylation and theories of ATP formation, inhibition of electron transport chain. Electron transport chain in some chemolithotrophic bacteria such as nitrifiers and Sulphur oxidizers. Oxidation of molecular hydrogen by *Hydrogenomonas* species. Bacterial anaerobic respiration- Nitrate and sulphate as electron acceptors. Electron transport chains in some anaerobic bacteria. Catalase, super oxide dismutase, mechanism of oxygen toxicity.

Recommended Textbooks and References:

1. Madigan, MT, Bender, K.S., Buckley, D.H., Sattley, W.M. & Stahl, D.A., Brock Biology of Microorganisms (15th Ed.). Pearson/ Benjamin Cummings. 2018.
2. Singh, R.P., Microbiology. Kalyani Publisher. 2009.
3. Caldwell, D.R., Microbial Physiology and Metabolism, Brown Publishers. 1995.
4. Moat, A.G. & Foster, J. W. , Microbial Physiology. Wiley., NY.1999.
5. Brun, Y.V. & Shimkets L.J., Prokaryotic Development. ASM Press, Wisconsin. 2000.
6. Doelle, H.W., Bacterial Metabolism. Academic Press, NY. 1969.
7. Gottschalk, G., Bacterial Metabolism.Springer Verlag, Berlin. 1979.
8. Sokatch, J.R., Bacterial Physiology and Metabolism. Academic Press, NY. 1969.
9. Srivastava, B., Microbial Physiology and Metabolism, LAP Lambert Academic Publishing, USA. 2011.
10. Warner B. Bair, W.R., Tortora, G.J., Funke, B.R., Case, C.L. & Weber, D., Microbiology an Introduction (13th Ed.). Pearson. 2018.

MML 514: Microbial 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 objective of this course is to understand the use of microorganisms as tools to understand various biological phenomena. The student will become familiar with methods of transfer of genetic material in bacteria, and will understand the biology of lytic and lysogenic phages. The student will be acquainted with the different modes of gene regulation in bacteria, and the importance of bacterial transposition and its applications.	**Upon successful completion of the course, the student:** **1. Can discuss the importance of mutation analysis.** **2. Is able to explain conjugation-based method, compare and contrast generalized versus specialized transduction,** **3. Is able to list the events in the lytic and lysogenic phases of lambda phage life cycle and the regulatory factors and events involved.** **4. Can list the outcomes of transposition events, differentiate between positive and negative regulation of gene expression, inducible and repressible systems.** **5. Will have learnt about the model organisms used in biological studies.**

UNIT I [15 Lectures]

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

UNIT II [15 Lectures]

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

Lytic Bacteriophages and Gene Transfer by Transduction and Transformation: Lytic development cycle using phages T4 and T7 as models. Regulation of expression of genes in phage T4 and phage T7. Replication of T4 versus T7 phages. Genetic analysis of phages – complementation and recombination tests with phages. Genetic experiments with the rII genes of phage T4. Natural transformation and competence. Molecular basis of natural

transformation – DNA uptake competence systems in gram positive and gram negative bacteria. Regulation of competence in *B. subtilis*. Importance of natural transformation. Artificially induced competence. Generalized versus specialized transduction: T4, lambda phage. Mapping bacterial genes by transduction.

UNIT III [15 Lectures]

Lysogenic Phages: Lambda phage – gene and promoter organization. Lambda lytic cycle – regulation of gene expression – very early, early and late gene expression. Establishment and maintenance of lysogeny. Regulation of gene expression in lysogenic phase - role of cI, cII and cIII proteins. Lambda immunity region and immunity to superinfection. Events leading to induction – role of cI and cro repressors in regulating the events.

UNIT IV [15 Lectures]

Transposons: Discovery of transposition. Classes of bacterial transposons. Regulation of transposition activity. Effects of transposition in bacteria. Assays to analyze transposition events – suicide vectors and mating out assays. Molecular mechanisms of transposition – genetic evidence supporting the mechanisms. Conjugative transposons. Transposon mutagenesis.

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

Model organisms Used in Genetic Studies: Yeast (Saccharomyces cerevisiae), fruitfly (Drosophila melanogaster), nematode worm (*Caenorhabditis elegans*), mouse (*Mus musculus*), Arabidopsis (*Arabidopsis thaliana*).

Model Microorganisms Used in Genetic Studies: Yeast (*Saccharomyces cerevisiae*), *E.coli*, *Bacillus* spp. and *Neurospora crassa*

Recommended Textbooks and References:

1. Snyder, L., Peters, J., Henkin, T. & Champness, W., Molecular Genetics of Bacteria (4th Ed.) ASM Press. 2013.
2. Trun, N. & Trempy, J., Fundamental Bacterial Genetics. Wiley-Blackwell Publishing. 2004.
3. Streips, U.N. & Yasbin, R.E., Modern Microbial Genetics edited (2nd Ed.). Wiley-Liss Publishers. 2002.
4. Maloy, S.R., Cronan, J.E. Jr., Freifelder, D., Microbial Genetics (2nd Ed.). Jones and Bartlett Publishers. 1994.
5. Singh, R.P., Microbiology. Kalyani Publisher. 2009
6. Warner B. Bair, W.R., Tortora, G.J., Funke, B.R., Case, C.L. & Weber, D., Microbiology an Introduction (13th Ed.). Pearson. 2018.
7. Krebs, J.E., Lewin, B., Kilpatrick, S.T. & Goldstein, E.S., Lewin's Genes XII. Burlington, MA: Jones & Bartlett Learning. 2017.

MML 515: Soil and Environmental 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 major objective of this course is to impart knowledge about structure, composition and functioning of microbial communities of diverse environments including soil air and water. The use of microbial population in agriculture, biogeochemical cycles, microbial interactions in soil and other soil activities, mineral recovery, waste and pollution management.	**Upon successful completion of the course, the student:** **1. Will have an overview of developments in the field of soil & environmental microbiology with special emphasis on the role of microbes in mitigating environment pollution.** **2. Will have become acquainted with various cultural, biochemical and molecular techniques used in understanding microbial diversity and its biotechnological application** **3. Will be knowledgeable about the diversity, adaptations and biotechnological applications of microbes of extreme environment.** **4. Understands the role of microbes in management of waste plant biomass and can apply knowledge in designing microbe-based processes for pulp, textile, biofuel and animal feed production industries.** **5. Is able to describe the role of microbes in solid and liquid waste management. Understands the role of microbes in bioremediation of environmental pollutants.**

UNIT I [15 Lectures]

Environmental Microbiology: Development of microbial ecology and emergence of field of environmental microbiology, significant applications of microbes in solving environmental pollution problems.

Soil and Water Microbiology: Importance of soil microorganisms, Distribution of various groups of microorganisms in soil, such as bacteria, fungi, protozoa, algae and viruses, nutrient transformation processes, plant-microbe symbiosis, microbial antagonism, biofilms and their biotechnological applications, drinking water microbiology and quality control.

UNIT II [15 Lectures]

Microbial Transformations: Carbon cycle. Biodegradation of soil organic constituents-Degradation of cellulose, hemicelluloses and lignin. Humic substances in soil-Genesis, structure, composition and role in agriculture and environment. Role of microorganisms in

cycling of nitrogen, phosphorus, sulphur, iron and manganese in soil-plant system. Environmental impact of biogeochemical cycles.

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

UNIT III [15 Lectures]

Microbial Interactions in Soil: Positive and negative interactions. Microbiology of rhizosphere. Biological nitrogen fixation. Symbiotic associations- Legume-rhizobial symbiosis, actinorhizal symbiosis, and associative symbiosis. Mycorrhizal associations and P nutrition.

Microbial Control and Bioinoculants: Microorganisms involved in biological control of plant diseases. Biocontrol agents and mechanisms of disease suppression. Plant growth promoting rhizobacteria. Biological control of insects and nematodes. Production and use of microbial inoculants.

UNIT IV [15 Lectures]

Microbial Diversity in Extreme Environments: Occurrence, diversity, adaptations and potential applications of oligotrophs, thermophiles, psychrophiles, acidophiles, alkaliphiles and halophiles.

Bioremediation of Environmental Pollutants: Biological indicators of soil health. Biodegradation of pesticides& xenobiotic compounds, Heavy metals etc. Phytoremediation, Role of microorganisms in sustainable agriculture and organic farming, use of biosensors for their detection.

Biomass Waste Management of Plant Residues: Lignocellulolytic microorganisms, enzymes and their biotechnological applications in: (i) biopulping, (ii) biobleaching, (iii) textiles (iv) biofuels, (v) animal feed production. Challenges in waste management.

Recommended Textbooks and References:

1. Alexander, M., Introduction to Soil Microbiology. John Wiley, New York. 1977.
2. Paul, E.A., Soil Microbiology, Ecology and Biochemistry (3rd Ed.). Academic Press, New York. 2007.
3. Sylvia D.M., Fuhrmann, J.J., Hartel, P.G. & Zuberer, D.A., Principles and Applications of Soil Microbiology (2nd Ed.). Pearson Edu. 2004.
4. Van Elsas, J.D., Trevors, J.T. & Wellington, E.M.H., Modern Soil Microbiology. Marcel Dekker., NY. 1997.
5. Tate, R.L., Soil Microbiology, Wiley-Blackwell., NY. 2012.
6. Dixon G.R. & Tilston, E.L., Production. Springer, Heidelberg. 2010.
7. Coyne, M., Introduction to Soil Microbiology. Delmar Cengage Learning, NY. 1999.
8. Bloem, J., Hopkins, D.W. & Benedetti, A., Microbiological Methods for Assessing Soil Quality, CABI, Wallingfard. 2008.
9. Maier, R.M., Pepper, I.L. & Gerba, C.P., Environmental Microbiology (2nd Ed.) Ed. Academic Press. 2009.
10. Wicket, L.P. & Hershberger, C.D., Biocatalysis and Biodegradation: Microbial transformation of organic compounds. ASM Publications. 2000.
11. Forster, C.F. & Wase, D.A.J., Environmental Biotechnology. Ellis Harwood Ltd. Publication. 2001.

MMP 516: Lab I (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, techniques used in microbial genetics and soil microbiology.	**Upon successful completion of the course, the 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.
5. Preparation of bacterial smear and Gram's staining.
6. Enumeration of bacteria: standard plate count.
7. Growth – Factors affecting growth. Sporulation, Growth curve of bacteria in batch culture.
8. Antimicrobial sensitivity test and demonstration of drug resistance.
9. Maintenance of stock cultures: slants, stabs and glycerol stock cultures
10. Determination of phenol co-efficient of antimicrobial agents.
11. Determination of Minimum Inhibitory Concentration (MIC)
12. Methods of isolation, purification and maintenance of microorganisms from different environments (air, water, soil, milk and food).
13. Enrichment culture technique – isolation of asymbiotic, symbiotic nitrogen fixing bacteria.
14. Determination of viable and total number of cells.
15. Measurement of cell size. and spore germination in bacteria.
16. Protoplasts formation.
17. Inactivation of microorganisms by different mutagens. Production, isolation and characterization of mutants. Determination of mutation rate.
18. Determination of soil microbial population; Soil microbial biomass; Decomposition studies in soil, Soil enzymes; Study of rhizosphere effect.

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.

MMP 517: Lab II (Biochemistry) (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 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.	**On 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 of aliphatic, aromatic and polar amino acids by paper chromatography.
5. Separation of lipids by thin layer chromatography.
6. Purification and characterization of an enzyme from a natural / recombinant 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.

MML 521: Instrumentation Techniques (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 microbiology.** **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.

MML 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 an in-depth knowledge of molecular mechanisms of DNA replication, DNA repair, transcription, translation, and gene regulation in prokaryotic and eukaryotic organisms	**Upon successful completion of the 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 eukaryotic RNA 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.

MML 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.	**Upon completion of the 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.

MML 524: Industrial 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 educate students about the fundamental concepts of industrial microbiology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of fermentation industry.	**Upon successful completion of the course, the students: -** **1. Will have gained insight on industrially important microbes, recent developments in fermentation processes and various optimization strategies at fermenter level.** **2. Attains knowledge about designing of industrial strains and various media optimization strategies** **3. Learns about the design, types of fermenters and various critical components of bioreactors** **4. Acquire knowledge about various industrially relevant microbial products and their production process**

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 for increased yield and other desirable characteristics; Principles of overproduction of primary and secondary metabolites with relevant examples, Culture collection, cataloguing of cultures.
Fermentation Systems: Batch and Continuous system, Fed batch culture, multistage systems, Feedback systems, Solid substrate fermentation. Instrumentation and control of fermentation processes, Monod kinetics of microbial growth, growth and non-growth associated product formation, product formation kinetics.

UNIT II [15 Lectures]

Fermenter Design: Bioreactor configuration, design features, Criteria in Fermenter design, Requirement for aeration and mixing, Energy Transfer. Otherfermenter designs- Tube reactors, packed bed reactors, fluidized bed reactors, cyclone reactors, trickle flow reactors.
Production and Recovery of Primary and Secondary Metabolites: Industrial Alcohol, Beer, Wine, Citric Acid, Acetic acid, Baker's Yeast, Single Cell Protein, Amino acids-

Lysine & Glutamic acid production, Industrial enzymes- Proteases, Antibiotics- Penicillin, vaccines (BCG& Covid-19), vitamins (B12), Bioinsecticides, Biopolymers and steroids.

UNIT III [15 Lectures]

Fermentation Upstream Processing: Media for industrial fermentation, Criteria used in media formulation, fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.

Downstream Processing: Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: Liquid-liquid extractions, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.

UNIT IV [15 Lectures]

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

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.

MML 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.	**Upon successful completion of the 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 softwares.

Recommended Textbooks and References:

1. Valiela, I. Doing Science: Design, Analysis, and Communication of Scientific Research. Oxford: Oxford University Press. 2001
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.

MMP 526: Lab III (Immunology and Instrumentation Techniques) (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.	**Upon 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.

MMP 527: Lab IV (Industrial 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 related to techniques used in industrial and environmental microbiology.	**Upon successful completion of this course, the students should be able to:** **1. Learn practical exercises related to industrial fermentation organisms and conduct of fermentation experiments.** **2. Quantify the fermentation organisms.** **3. Learn microbial technology for waste management.**

List of Experiments:

1. Sterilization, general methods and safety in Industrial microbiology laboratory.
2. Industrially important microorganisms: Isolation and screening- Isolation of yeast, lactic acid bacteria, Acetobacter; Isolation of Amylase producers from soil, Isolation of Cellulase producing organisms, Isolation of Protease producers from soil.
3. Production of Industrial alcohol.
4. Production of Lactic acid.
5. Production of Grape wine
6. Production of cellulase.
7. Production of Citric acid
8. Analytical assays in fermentations: Estimation of Ethanol, lactic acid, sugars, total acids, volatile fatty acids, protein assay etc
9. Analysis of BOD, COD, DO in wastewater.
10. Estimation of hardness in water sample.
11. Treatment of sewage and wastewater.
12. Estimation of Heavy metals in soil/water sample.

Recommended Textbooks and References:

1. Kulandaivel, S. & Janarthanan, S., Practical Manual on Fermentation Technology, IK Books. 2012.
2. Mathur, N., & Singh, A., Industrial Microbiology: A Laboratory Manual. Aavishkar. 2007

MML 531: Recombinant DNA Technology (Credits: 3+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 / industries.	**Upon 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 practical 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 [12 Lectures]

Introduction and Tools of Recombinant DNA Technology (RDT) : Impact of RDT 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.

UNIT II [11 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: Sequencing 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 Solexagenome analyzer platform. Whole genome sequencing and functional genomics (a brief account), Applications of genomics and Proteomics with special reference to *E.coli*, Phage lambda and SV40.

UNIT III [11 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; Principles for maximizing gene expression, Protein purification; His-tag; GST-tag etc.; Protein-DNA interactions.

UNIT IV [11 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. 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.

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.

MML 532: Microbial Enzyme Technology (Credits: 3+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 the principles & role of enzymes, their specificity, kinetics, regulation and applications in industry.	**Upon completion of this course, students should be able to:** **1. Gain fundamental knowledge about enzymes and their specificity;** **2. Understand the enzyme kinetics, enzyme regulation and applications of isolated enzymes in industry.**

UNIT I [12 Lectures]

Basic Enzymology: Historical background, Enzymes vs Chemical catalyst, Enzyme nomenclature and classification, Units of activity, Methods for enzyme assays, Extraction and purification of enzymes, Cofactors and coenzymes.

UNIT II [11 Lectures]

Enzyme Specificity: Substrate and reaction specificity, Lock & key hypothesis, Induced Fit hypothesis, Wrong way binding hypothesis, Three-point attachment hypothesis, Mechanism of action of selected enzymes i.e. chymotrypsin, trypsin, papain, Lysozyme, ribonuclease.

UNIT III [11 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, Multi-reactant enzymes, Enzymes inhibition i.e., reversible and irreversible inhibition, Competitive, Non-competitive and Uncompetitive inhibition.

UNIT IV [11 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.

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

MML 533: Bioinformatics (Credits: 3+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.	**Upon successful completion of this course, the students should be able to: -** **1. Develop an understanding of basic theory of 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 [11 Lectures]

Bioinformatics Basics: Computers in biology and medicine; Database concepts; Protein and nucleic acid databases; Structural databases; Biological 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 [11 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.

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 [11 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 **[12 Lectures]**

Protein Structure Prediction : Protein folding and model generation; secondary structure prediction; analyzing secondary structures; protein loop searching; loop generating methods; homology modelling: 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.

MML 534: Food Microbiology (Credits: 3+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 will enable students to understand the food associated molds, yeasts, yeast-like fungi and bacteria. The course will teach the strategies to develop fermented and non-fermented food products. The role of microbes in food spoilage, preservation and various food borne diseases will be discussed.	**Upon successful completion of this course, the student:** **1. Will know about production and evaluation of the quality of starter cultures and fermented food products** **2. Gathers information regarding microbes causing food intoxications and food-borne infections.** **3. Knows traditional food preservation and recent development in food preservation techniques** **4. Understands the relevance of microbial standards for food safety, quality assurance programs that revolutionize food safety.**

UNIT I [12 Lectures]

An Overview of Microbes in Food: Brief historical aspects of microorganism in foods; source, types and role of microorganisms in foods; intrinsic and extrinsic factors affecting microbial growth. Microbiome of food material.

Microbial Spoilage of Foods: Types and causes of spoilage of cereals and cereals products, spoilage of vegetables and fruits, Meat and meat products, Milk and milk products, canned foods.

Food Preservation: General principles of food preservation, various classical, physical, chemical, and biological methods of preservation. New developments in food preservation techniques. Analysis of practical implementation of such techniques. Hurdle technology in food preservation, Bacteriocins and their applications; Probiotic bacteria in foods.

UNIT II [11 Lectures]

Fermented Food Products: Microorganisms involved in food fermentations, Starter Cultures, Fermented meats and sausages; Fermented milk products- Acidophilus and Bulgarian milk, yoghurt, cheese, Kefir, Koumiss; Fermented grains and vegetable products - Sauerkraut, Soy sauce, Tempeh, Miso, Olive, and Kimchi, Nutraceuticals & Nanonutraceuticals.

Protein Engineering: Protein engineering in food technology-objectives, methods, targets, potential applications in food industry and limitations.

UNIT III [11 Lectures]

Food Borne Infections and Intoxications: Types of Food Poisonings, Role of microorganisms and their toxins in food poisoning. Common food borne pathogens: *Bacillus cereus*, *Staphylococcus aureus*, *Vibrio*, *Campylobacter jejuni*, *Clostridium botulinum*, *Clostridium perfringens*, *Escherichia coli*, *Listeria monocytogenes*, *Salmonellosis*, *Shigellosis*, *Yersinia enterocolitica*. Mycotoxins, Enteric viruses and algal toxins. Summary of prevention of microbial food infections. Identification and first aid for specific types of infections.

UNIT IV [11 Lectures]

Food Safety and Quality Assurance in Foods: Microbial testing of foods-traditional methodology and new approaches: Microbiological, Physical, Chemical methods, Immunological methods, Use of gene probes and PCR, bioluminescence, BAX system, Riboprinter and Real Time PCR based approaches, Microbiological quality standards for food industry. Biosensors in food. Concept of HACCP for quality assurance and food safety in food industry.

Recommended Textbooks and References:

1. Ray, B. & Bhunia, A., Fundamental Food Microbiology (5th Ed.). CRC Press Inc. 2013.
2. Frazier, W.C. & Westhoff, D.C., Food Microbiology (3rd Ed.). Tata McGraw Hill. 1991.
3. Banwart, G.J, Basic Food Microbiology. AVI. Pp.462. 1989.
4. Jay, J.M., Loessner, M.J. & Golden, D.A., Modern Food Microbiology (7th Ed.) Springer-Verlag New York. 2005.
5. Montville, T., Matthews, K. & Kniel, K., Food Microbiology: An Introduction (4th Ed.). ASM press. 2017.
6. Doyle, M.P. & Buchanan, R.L., Food Microbiology. ASM Press, Washington. 2012.
7. Joshi, V.K. & Pandey, A., Biotechnology: Food Fermentation Vol. 1 & 2, Education Publisher and Distributor, New Delhi. 1999.
8. Rayand, B. & Bhunia, A., Fundamental Food Microbiology (5th Ed.). CRC press. 2013.
9. Adams, M.R., Moss, M.O. & McClure, P., Food Microbiology (4th Ed.). Royal Society of Chemistry. 2015.

MML 535: Medical Microbiology (Credits: 3+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 will enable students to understand the infection process and diseases caused by pathogenic bacteria, pathogenic protozoa & fungi and pathogenic viruses.	**Upon successful completion of the course, the student:** **1. Will acquire a good understanding of infection process, common diseases caused by bacteria, viruses and other microbes.** **2. Knows about pathogenesis, laboratory diagnosis and rapid methods of pathogenic bacteria, pathogenic fungi and viruses**

UNIT I [11 Lectures]

Infection Process: Process of infection-Types, stages of infection, Establishment of pathogenic microorganisms: Entry, spread and tissue damage. Mechanism of bacterial adhesion, colonization and invasion of mucous membranes of respiratory, enteric and urogenital tracts. Aggresssins and toxins.

UNIT II [11 Lectures]

Pathogenic Bacteria: Morphological characteristics, pathogenesis and laboratory diagnosis including rapid methods of following pathogenic bacteria; *Staphylococcus, Streptococcus, Neisseria, Klebsiella, Proteus, Salmonella, Shigella, Virbrio, Campylobacter, Pseudomonas, Acinetobacter, Yersinia, Francisella, Pasteurella, Haemophilus, Bordetella, Bacillus, Clostridium, Mycobacterium, Actinomyces, Nocardia, Bacteroides, Fusobacterium, Listeria, Legionella. Mycoplasma, Rickettsiae, Chlamydiae,* Spirochetes.

UNIT III [12 Lectures]

Pathogenic Fungi: Morphological characteristics, pathogenesis and laboratory diagnosis of following pathogenic fungi; - Microsporum*; Trichophyton; Histoplasmacapsulatum; Blastomycesdermatitidis; Candida albicans; Cryptococcus neoformans; Pneumocystis carinii.*

Protozoal Pathogens: General description, biological properties and diseases caused by Protozoa- *Plasmodium* spp, *Giardia intestinalis, Entamoebahistolytica, Pneumocystis jiroveci, Leishmaniatropica.*

UNIT IV [11 Lectures]

Viral diseases: Structure, cultivation, pathogenicity, lab diagnostics, prevention and control of viral diseases-Hepatitis, Herpes, Measles, Rabies, Polio, Rubella, Rotaviruses, Japanese Encephalitis, HIV, SARS, Ebola, Avian Flu, Swine Flu, Covid-19 and future pandemics.

Recommended Textbooks and References:

1. Atlas, R.M., Principles of Microbiology, McMillan, New York. 2006.
2. Tortora, G.J., Funke, B.R., Case, C.L., Microbiology -An Introduction, 8thEdition, Pearson education Pvt. Ltd. Singapore. 2004.
3. Walsh, G., Biopharmaceuticals: Biochemistry and Biotechnology, John Wiley & Sons, New York. 1998.
4. Benjamin, E., Immunology-A short course (6th Ed.). John Wiley, New York. 2009.
5. Punt, J., Stranford, S., Jones, P. & Owen, J.A., Kuby Immunology (8th Ed.). Macmillan International Higher Education. 2018.
6. Ryan, K.J., Sherris Medical Microbiology (5th Ed.). McGraw-Hill. 2010.

MML 536: Nanoparticles in Microorganisms and Biosystems (Credits: 3+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 nanometer 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 [11 Lectures]

Nanotechnology: An Overview, Insights and intervention into the Nano world, Historical Developments, Applications of Nanotechnology in different areas of Food, Agriculture, Cosmetics & Consumer products, Textile and Medical Sciences. Nanomaterial's: Various classes, properties & applications, Concept of Bionanotechnology & Nanobiotechnology, Biomimicking.

UNIT II [11 Lectures]

Biological Methods of Synthesis: Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Synthesis process and application, Role of plants in nanoparticle synthesis.
Microorganisms for Toxicity Detection: Safety & Toxicological aspects related to nanomaterials and Ethical issues. Nanotoxicity assessment.

UNIT III [12 Lectures]

Nano-composite Biomaterials, Teeth and Bone Substitution: Natural Nano-composite systems such as spider silk, bones, shells; organic-inorganic Nano-composite formation through self-assembly. Biomimetic synthesis of Nano-composite material; Use of synthetic nano-composites for bone, teeth replacement, Nano-phase Materials Coatings, Advantages of Nanomaterial's Used as Implants, Nano phase Materials in Tissue Engineering Applications

UNIT IV **[11 Lectures]**

Engineering: The status of tissue engineering of specific organs, including bone marrow, skeletal muscle, and cartilage. Cell biological fundamentals of tissue engineering. Nano-regenerative medicine towards clinical outcome of stem cell and tissue engineering in humans, carbon nanotubes in healthcare, nanomedicine & Cancer therapy.

Recommended Textbooks and References:

1. Goodsell, D.S., Bionanotechnology: Lessons from Nature, Wiley-Liss Inc. 2004.
2. Mahendra, R. & Nelson, D., Metal Nanoparticles in Microbiology. Springer. 2011.
3. Nicola, C. & Mahendra, R., Nano-Antimicrobials. Springer. 2012.
4. Freitas, R.A., Nanomedicine, Vol. IIA: Biocompatibility, Landes Bioscience. 2003.
5. Nalwa, H.S., Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology, American Scientific Publishers. 2005.
6. Mirkin, C.A. & Niemeyer, C.M. Nanobiotechnology II. Wiley-VCH Verlag GmbH & Co. KGaA. 2007.
7. Ventra, M.D., Introduction to Nanoscale Science and Technology (Nanostructure Science and Technology). 2009.
8. Ramakrishna, S., Murugan, R. & Kumar, T.S.S., Biomaterials: A nano approach, CRC Press/Taylor & Francis. 2010.

MML 537: Project Proposal Preparation and 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.	**Upon 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 [7 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 [8 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.

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.

MMP 538: Lab V (Recombinant DNA Technology and Bioinformatics) (Credits:0+3)

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

Course Objectives	Student Learning Outcomes
The objectives of this course are to provide students with experimental knowledge of molecular biology and genetic engineering. This practical course is also aim to impart training in bioinformatic methods by various software packages.	**Upon successful completion of this course, students should be able to:** **1. Gain hands-on experience in gene cloning, protein expression and purification.** **2. Describe contents and properties of most important bioinformatics databases.** **3. Perform text- and sequence-based searches and analyze and discuss results in light of molecular biological knowledge.** **4. Explain major steps in pairwise and multiple sequence alignment, explain principle and execute pairwise sequence alignment by dynamic programming.** **5. Predict secondary and tertiary structures of protein sequences.**

List of Experiments:

Section A) Recombinant DNA Technology:

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

b) Southern hybridization.

Section B) Bioinformatics

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.

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.
2. Mount, D.W., 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, andGenomics. Oxford: Oxford University Press. 2004.

MMP 539: Lab VI (Food and Medical Microbiology) (Credits: 0+3)

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

Course Objectives	Student Learning Outcomes
The aim of this course is to provide practical training in food and medical microbiology.	**On completion of this course, students should be able to:** **1. Learn microbial analysis of food products- cereals, water, milk and milk products, vegetables.** **2. Acquaint learners about new methods in food diagnostics.** **3. Learn practical exercises related to medical microbiology examination and identification of resident microflora of skin, oral cavity, nasal swabs, sterility testing and rapid methods.**

List of Experiments:

Section A) Food Microbiology:

1. Microbial analysis of food products: The Bacterial Count
2. Microbiological standards in foods-Statutory, recommended and supplementary tests for microbiological analysis of various foods: Baby foods, meat, vegetables, fruits, cereals, surfaces, containers and water.
3. Microbial analysis of milk: The Reductase Test
4. Direct microscopic count of microscopic in Milk
5. Standard Plate Count of Milk
6. Microbiological analysis of water- Most probable number, SPC of water, coliform count of water
7. New methods, One step method for detection of microorganisms in foods/water.

Section B) Medical Microbiology:

1. Safety aspects while working in medical microbiology laboratory
2. TCBS agar; Hektoen Enteric agar; XLD agar; Endo agar; Salmonella-Shigella agar; Deoxycholate citrate agar
3. To study pathogenicity of Staphylococcus aureus by coagulase test
4. To perform sterility testing of a sample.
5. Normal Human Microbiota;, microscopic examination of resident microflora of skin swab, dental plaque by negative, simple and Gram staining
6. To study resident microflora of oral and nasal cavity.
7. Rapid Diagnostics Tests- lateral Flow Assays
8. Acid fast staining for identification of mycobacteria
9. Antibiotic sensitivity assay
10. Media for Isolation and Rapid Identification of Bacteria.- Antigen Detection and Identification.

Recommended Textbooks and References:

1. Matthews, K.R., Kniel K.E. & Montville, T.J., Food Microbiology: An Introduction (4th Ed.). ASM Press, Washington, DC. 2019.
2. Goldberg I. & Williams R., Biotechnology and Food Ingredients, Van Nostrant., Reinhold, New York. 1991.
3. Ricke, S., Donaldson, J.R. & Phillips, C.A., Food Safety: Emerging Issues, Technologies and Systems. Academic Press. 2015.
4. Carroll, K.C., Morse, S.A., Butel, J.S., & Mietzner, T.A. Jawetz, Melnick and Adelberg's Medical Microbiology (27th Ed.). McGraw Hill Publication. 2017.
5. Goering, R., Dockrell, H., Zuckerman, M. & Chiodini, P., Mims' Medical Microbiology (6th Ed.). Elsevier. 2018.
6. Willey, J.M., Sherwood, L., Woolverton, C.J., Prescott, L.M. & Willey, J.M. Prescott's Microbiology. New York: McGraw-Hill. 2011.

MML 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.

MML 542: Plant-Pathogen Interactions (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 will facilitate in understanding of how pathogens interact with various plants and effect plant physiology, photosynthesis, respiration, transpiration and translocation. The course covers the novel molecular diagnostic approaches and correct forecasting of plant diseases.	**Upon successful completion of the course, the student should be able to: -** **1. Gain in-depth knowledge about cause of plant diseases and effect of microbial infections on plant.** **2. Will have gained insight into genetics of host-pathogen interactions, resistance mechanism in plants.** **3. Understand genetic basis of plant disease and physical, chemical & biological methods of disease control.** **4. Attained knowledge about designing of molecular diagnosis of plant disease and development of transgenic plants with applications and constraints.**

UNIT I [8 Lectures]

Concepts- Physiology & Biochemical basis of plant diseases: Causes of disease, pathogenesis, pathogenesis in relation to environment, effect of microbial infections on plant physiology, photosynthesis, respiration, transpiration, translocation, Enzymes and toxins in plant diseases, phytoalexins.

UNIT II [7 Lectures]

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

Microorganisms for toxicity detection: Safety & Toxicological aspects related to nanomaterials and Ethical issues. Nanotoxicity assessment.

UNIT III [8 Lectures]

Genetic Basis of Plant Diseases: Genetics of host-pathogen interactions, resistance genes, resistance mechanisms in plants.

Disease control: Principles of plant disease control, physical and chemical methods of disease control, biocontrol agents - concepts and practices, fungal agents, Trichoderma as biocontrol agent.

UNIT IV [7 Lectures]

Molecular Approach: Molecular diagnosis, transgenic approach for plant protection, Disease forecasting: Important milestones in disease control, Relevance of forecasting in Indian farming.

Recommended Textbooks and References:

1. Agrios, G.N., Plant Pathology (5th Ed.). Academic Press. 2005
2. Mehrotra, R.S. & Aggarwal, A., Plant Pathology (3rd Ed.). Tata McGraw Hill. 2017.
3. Sigee, D.C., Bacterial plant pathology: cell and molecular aspects. Cambridge University Press. 1993.
4. Dickinson, M., Molecular plant pathology. BIOS Scientific Publishers, London. 2003.
5. Basu, A.N. & Giri, B.K., The essentials of Viruses, Vectors and Plant diseases. Wiley Eastern Limited.1993.
6. Mukerji, K.G. & K.L.Garg, K.L., Biocontrol of Plant Diseases (Vol. I). CRC Press Inc., USA.1988.
7. Stahl, U. & Tudzyski, P., Molecular Biology of Filamentous Fungi. VCH VerlagsgesellschaftmbH. 1992.

MML 543: Virology (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 will facilitate in understanding of virology by examining common processes and principles in viruses to illustrate viral complexity, to understand viral propagation and replication. It covers the pathogenicity of viruses and addresses the interplay between viruses and their host organisms	**Upon successful completion of the course, the student should be able to:-** **1. Understand basis of viral classification, characterization and propagation.** **2. Describe steps in virus infection and transmission** **3. Describe some important viral diseases**

UNIT I [8 Lectures]

Introduction and History: Introduction to viruses. Discovery of viruses and development of virology. Nature, origin and evolution of viruses.

Virus Architecture and Nomenclature: Structure of plant, animal and bacterial viruses. Criteria used for virus nomenclature and classification. Current ICTV classification of viruses of bacteria, plants and animals and humans.

UNIT II [7 Lectures]

Propagation and characterization viruses: General methods of propagation of plant, bacterial and animal viruses. Purification of viruses using centrifugation, and electrophoresis techniques. Quantization of viruses: Infectivity assay methods (plaque, pock, end point, local / systemic assay of plant viruses), physical (EM), serological and chemical (viral protein and nucleic acid based) approaches.

UNIT III [8 Lectures]

Virus Replication Cycles: Viral genomes, Mechanisms of viral entry and multiplication. Replication of plant, animal and bacterial viruses. Lytic and lysogenic cycles in bacteriophages. Development and maintenance of lysogeny.

UNIT IV [7 Lectures]

Pathogenesis of viral infection: Stages of infection, Patterns of some important viral diseases- epidemiology, transmission, infection, symptoms, risk, transformation and oncogenesis, emerging viruses, Algal, fungal and protozoan viruses.

Recommended Textbooks and References:

1. Flint, S.J., Racaniello, V.R., Rall, G.F. & Skalka, A.M. Principles of Virology (4th Ed.). Science Publishers. New York. 2015.
2. Richman, D.D., Whitley, R. & Hayden, F., Clinical Virology (New edition). American Society for Microbiology. Washington DC. 2017.
3. Dimmock, N.J., Easton, A.J. & Leppard, K.N., Introduction to Modern Virology (7th Ed.). John Wiley & Sons, New York. 2016.
4. Wagner, E.K., Hewlett, M.J., Bloom, D.C. & Camerini, D., Basic Virology (3rd Ed.). John Wiley & Sons Ltd; New York. 2007.
5. Cann, A.J., Principles of Molecular Virology (3rd Ed.). Elsevier Academic Press. 2001.
6. Hull, R., Plant Virology (4th Ed.). Academic press. 2002.

MML 544: Bioentrepreneurship, Biosafety and IPR (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 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.**	**On 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 [8 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 [7 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 microbes, gene, process and products. Commercialization of patented innovations.

UNIT III [8 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; Risk management issues - Containment; Problem formulation – protection goals, compilation of relevant information.

UNIT IV [7 Lectures]

Bioethics: Introduction, ethical conflicts in biological sciences - interference with nature, bioethics in health care - 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.

Mandatory: It is mandatory to attend one workshop/conference / lecture series on IPR /Patenting/ Technology Commercialization organized by the IPR 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.

MML 545: Vaccines (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 provide students with an overview of current developments in different areas of vaccines.	**By the end of this course, students should be able to: -** **1. Understand fundamental concepts of human immune system.** **2. Differentiate and understand immune responses in relation to infection and vaccination;** **3. Understand requirement and designing of different types of vaccines;** **4. Understand importance of conventional and new emerging vaccine technologies.**

UNIT I [7 Lectures]

Fundamentals of Immune System: Overview of Immune system; Human Immune system: Effectors of immune system; Innate & Adaptive Immunity; Activation of the Innate Immunity; Adaptive Immunity; T and B cells in adaptive immunity; Immune response in infection; Correlates of protection.

UNIT II [8 Lectures]

Immune Response to Infection : Protective immune response in bacterial; viral and parasitic infections; Primary and Secondary immune responses during infection; Antigen presentation and Role of Antigen presenting cells: Dendritic cells in immune response; Innate immune response; Humoral (antibody mediated) responses; Cell mediated responses: role of CD4+ and CD8+ T cells; Memory responses: Memory and effector T and B cells, Generation and Maintenance of memory T and B cells.

UNIT III [7 Lectures]

Immune Response to Vaccination: Vaccination and immune response; Adjuvants in Vaccination; Modulation of immune responses: Induction of Th1 and Th2 responses by using appropriate adjuvants and antigen delivery systems - Microbial adjuvants, Liposomal and Microparticles as delivery systems; Chemokines and cytokines; Role of soluble mediators in vaccination; Oral immunization and Mucosal Immunity.

UNIT IV [8 Lectures]

Vaccine Types & Design and Vaccine Technologies: 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. 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. Janeway, C.A., Travers, P., Walport, M., & Shlomchik, M.J., Immuno Biology: the Immune System in Health and Disease. USA: Garland Science Pub. 2005.
2. Punt, J., Stranford, S., Jones, P. & Owen, J.A., Kuby Immunology (8th Ed.). Macmillan International Higher Education. 2018
3. Kenneth, M. & Weaver, C., Janeway's Immunobiology (9th Ed.). Garland Science. 2016.
4. Kaufmann, S.H., Novel Vaccination Strategies. Weinheim: Wiley-VCH. 2004.
5. Journal Articles (relevant issues) from: Annual Review of Immunology, Annual Review of Microbiology, Current Opinion in Immunology, Nature Immunology, Expert review of vaccines.

MML 546: 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.**	**Upon 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 [7 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 labelled, NMR and MS based methods for flux determination.

UNIT II [8 Lectures]

Flavanoid and Terpenoid Pathways: The basic structure of flavonoid 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 microbial cell culture for production of

secondary metabolites, Bioreactors systems and models for mass cultivation of microbial 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. & Wilhelm, A., Metabolic Engineering of Plant Secondary Metabolism, Springer. 2010.
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MML- 547 Any MOOCs Courses offered by SWAYAM/NPTEL

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

MMD 600: Dissertation (Credits: 20+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.