Learning Outcome based Curriculum Framework (LOCF)

For

Choice Based Credit System (CBCS)

Syllabus

B.Sc. (Honours) in Microbiology

w.e.f. Academic Session 2020-21

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Preamble:

Microbiology is the study of microorganisms or microbes such bacteria, viruses, fungi, algae, cyanobacteria, protozoa and prions. They are extremely important as their diverse activities range from causation of deadly diseases in humans, animals and plants to production of highly useful products like antibiotics, enzymes, alcohol, fermented foods, and recycling of dead and decaying organic matter in the nature. Thus, the science of microbiology has an important role to play in health, agriculture, environment and industry. Several discoveries in the last two to three decades, which significantly impact these areas have put Microbiology on the centre stage of teaching, research and development all over the globe.

The Choice Based Credit System (CBCS) curriculum for Microbiology at the undergraduate level has now been developed into a new system called Learning Outcome Curriculum Framework (LOCF) under the recommendations and guidance of University Grants Commission (UGC). The LOCF approach first envisioned the programme learning outcomes of the B.Sc. (Hons) program in Microbiology as well as the learning outcomes of the courses being taught under this programme, keeping in view the graduate attributes of the subject. The curriculum was then developed in tune with the learning outcomes. It is envisaged that the students trained under this curriculum will have the required attributes of knowledge, skills, temperament and ethics related to the subject of Microbiology. Besides the contents of the curriculum, the teaching learning processes have also been designed to achieve these attributes. A variety of learning assessment tasks have been included in the curriculum. Besides assessing the knowledge/skills acquired by the students, these tasks would also help to supplement the teaching learning processes.

There are 14 core courses (CC1 - 14) which encompass all important aspects of the discipline of Microbiology and are all compulsory courses. The choice-based Discipline Specific Elective (DSE) courses are designed to enhance the expanse of the subject. DSE also give the students a chance to apply their knowledge of microbiology to study societal problems and suggest solutions in the form of small project under the mentorship of their teachers. These are also designed to expose the students to leaders / innovators in the areas related to microbiology for inspiration. The Generic Elective Courses (GEC) are designed to impart comprehensive understanding of Microbiology to students from other disciplines. The Microbiology students will have the choice to select courses from other disciplines depending on their interest and passion besides Microbiology. The CC, DSE and GEC are all 6 credit (4 Credit Theory and 2 Credit Laboratory work) courses. A number of Skill based Elective Courses (SEC), 4 Credits each would give the students option to develop skills in areas which have direct relevance to employability in diagnostics, health, food and pharmaceutical industries, agriculture and environment-related job opportunities in Microbiology. The focus of the Ability Enhancement Compulsory Courses (AECC) which are 2 Credits each, is to develop communication skills and awareness about our environment.

Course Summary

Semester	Course Name		Course Type	Course Code	Course Details	Page No.
I	Microbial World and Principles of Microbiology		C	BSCHMCBC101	CC-1	3
	Bacteriology and Systematics			BSCHMCBC102	CC-2	4
	Generic Elective Courses		GE		GEC-1	
	Environmental Studies		AE	AEE101	AECC-1	
II	Basic Biochemistry		C	BSCHMCBC201	CC-3	9
	Microbial Techniques and Instruments			BSCHMCBC202	CC-4	11
	Generic Elective Courses		GE		GEC-2	
	English/MIL Communication		AE	See Pool	AECC-2	
III	Virology		C	BSCHMCBC301	CC-5	15
	Microbial Physiology and Metabolism			BSCHMCBC302	CC-6	16
	Cell and Molecular Biology			BSCHMCBC303	CC-7	18
	Generic Elective Courses		GE		GEC-3	
	Microbial Quality Control in Food & Pharmaceutical Industries	(Any One)	SE	BSCHMCBSE301	SEC-1	20
	Microbial Diagnostics and Public Health			BSCHMCBSE302		21
IV	Microbial Genetics		C	BSCHMCBC401	CC-8	24
	Environmental Microbiology and Microbial Ecology			BSCHMCBC402	CC-9	26
	Industrial Microbiology			BSCHMCBC403	CC-10	27
	Generic Elective Courses		GE		GEC-4	
	Food Fermentation Techniques	(Any One)	SE	BSCHMCBSE401	SEC-2	29
	Microbial Products			BSCHMCBSE402		30
V	Medical & Veterinary Microbiology and Immunology		C	BSCHMCBC501	CC-11	33
	Agriculture, Food and Dairy Microbiology			BSCHMCBC502	CC-12	35
	Biophysics, Biomathematics & Biostatistics	(Any Two)	DSE	BSCHMCBDSE501	DSEC-1 & DSEC-2	36
	Heredity and Evolution			BSCHMCBDSE502		37
	Microbial Biotechnology			BSCHMCBDSE503		39
VI	Advanced Microbiology		C	BSCHMCBC601	CC-13	41
	Recombinant DNA Technology			BSCHMCBC602	CC-14	42
	Project Work on Microbiology of Societal Importance	(Any Two)	DSE	BSCHMCBDSE601	DSEC-3 & DSEC-4	44
	Basic Computer and Bioinformatics			BSCHMCBDSE602		45
	Mycology and Phycology			BSCHMCBDSE603		46

Pool of Generic Elective Courses offered by Microbiology for other Disciplines

Semester	Course Name	Course Type	Course Code	Course Details	Page No.
I	Microbial World and Diversity	GE	BSCHMCBGE101	GEC-1	6
II	Bacteriology and Virology		BSCHMCBGE201	GEC-2	12
III	Industrial and Food Microbiology		BSCHMCBGE301	GEC-3	22
IV	Genetic Engineering and Biotechnology		BSCHMCBGE401	GEC-4	31

Abbreviations: C= Core; CC=Core Course; AE= Ability Enhancement; AECC= Ability Enhancement Compulsory Course; GE= Generic Elective; GEC= Generic Elective Course; SE= Skill Enhancement; SEC= Skill Enhancement Course; DSE= Discipline Specific Elective; DSEC= Discipline Specific Elective Course; CA= Continuous Assessment, ESE= End Semester Examination, L= Lecture Hour; T= Tutorial Hour and P= Practical Hour/ Field Work and NA= Not Applicable

Course Details

Semester-I

Course Name: Microbial World and Principles of Microbiology
Course Code: BSCHMCBC101

Course Type: **C**	Course Details: **CC-1**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *After the completion of this course, the students will –*

1. *Develop a good knowledge of the development of the discipline of Microbiology and the contributions made by prominent scientists in this field.*

2. *Develop a very good understanding of the characteristics of different types of microorganisms, methods to organize/classify these into and basic tools to study these in the laboratory.*

3. *Able to explain the useful and harmful activities of the microorganisms.*

4. *Able to perform basic experiments to grow and study microorganisms in the laboratory.*

Course Content:

Theory

Unit – 1: History of Microbiology and introduction to the microbial world. Germ theory of disease, golden era of microbiology. Contributions of Antony von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming, Martinus W. Beijerinck, Sergei N. Winogradsky,

Unit – 2: Binomial Nomenclature, Whittaker's five kingdom and Carl Woese's three kingdom classification systems and their utility. General characteristics of Cellular microorganisms, wall-less forms - MLO (mycoplasma and spheroplasts) with emphasis on distribution and occurrence,

Unit – 3: General concept of phytoplanktons and zooplanktons. General characteristics, structure, mode of reproduction and economic importance of actinomycetes General characteristics, occurrence, structure, reproduction and importance of protozoa.

Unit – 4: Methods of studying microorganism; Staining techniques: simple staining, Gram staining, negative staining and acid-fast staining. Sterilization techniques (physical & chemical sterilization). Culture media & conditions for microbial growth. Pure culture isolation: Streaking, serial dilution and plating methods; cultivation, maintenance and preservation of pure cultures.

Unit – 5: Beneficial and harmful microbes and their role in daily life.

Practical

1. Microbiology Good Laboratory Practices and Bio-safety.
2. To study the principle and applications of important instruments (biological safety cabinets, autoclave, incubator, BOD incubator, hot air oven, light microscope, pH meter) used in the microbiology laboratory.
3. Preparation of culture media (liquid & solid) for bacterial cultivation.
4. Handling and care of laboratory equipment - autoclave, hot air oven, incubator, and laminar airflow.
5. Sterilization of media using autoclave and assessment of sterility.
6. Sterilization of glassware using hot air oven.
7. Sterilization of heat sensitive material by membrane filtration.
8. Demonstration of the presence of microflora in the environment by exposing nutrient agar plates to air.
9. Study of microbes using temporary / permanent mounts- *Rhizopus*, *Penicillium*, *Aspergillus*, *Spirogyra*, *Chlamydomonas*, *Volvox*, *Amoeba*.

Reference Books

1. Prescot, M.J., Harley, J.P. and Klein, D.A. Microbiology. 5th Edition WCB McGraw Hill, New York, (2002).
2. Ganguly, K.K. Science and Technology, History and Evolution. Chapter-History of Microbiology, July 2020, pg: 221-237, Publisher: Kumud Publications, ISBN:978-81-945060-3-4.

Course Name: Bacteriology and Systematics
Course Code: BSCHMCBC102

Course Type: **C**	Course Details: **CC-2**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *At the completion of this course, the students will be able to –*

1. *Describe characteristics of bacterial cells, cell organelles, cell wall composition and various appendages like capsules, flagella or pili.*

2. *Differentiate a large number of common bacteria by their salient characteristics; classify bacteria into groups.*

3. *Describe the nutritional requirements of bacteria for growth; developed knowledge and understanding that besides common bacteria there are several other microbes which grow under extreme environments.*

4. *Perform basic laboratory experiments to study microorganisms; methods to preserve bacteria in the laboratory; calculate generation time of growing bacteria.*

Course Content:

Theory

Unit – 1: Cell size, shape and arrangement, capsule, flagella, fimbriae and pili. Cell-wall: Composition and detailed structure of Gram-positive and Gram-negative cell walls, archaebacterial cell wall, Gram and acid-fast staining mechanisms, lipopolysaccharide (LPS), sphaeroplasts, protoplasts, and L-forms. Effect of antibiotics and enzymes on the cell wall. Cell Membrane: Structure, function and chemical composition of bacterial and archaeal cell membranes. Cytoplasm: Ribosomes, mesosomes, inclusion bodies, nucleoid. Endospore: Structure, formation, stages of sporulation.

Unit – 2: Gram negative and Gram positive bacteria: characteristics and examples. Study of typical eubacteria (Bacillus, Clostridium, Staphylococcus, Streptococcus, Mycobacterium, Escherichia,

Unit – 3: Nutritional requirements in bacteria and nutritional categories. Culture media: components of media, natural and synthetic media, chemically defined media, complex media, selective, differential, enriched and enrichment media. Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation. Chemical methods of microbial control: disinfectants, types and mode of action.

Unit – 4: Aim and principles of classification, systematics and taxonomy, concept of species, taxa, strain; conventional, molecular and recent approaches to evolutionary chronometers, rRNA oligonucleotide sequencing and its importance. Differences between eubacteria and archaebacteria.

Unit – 5: General characteristics, phylogenetic overview of archaebacteria. Introduction to *Nanoarchaeota* (*Nanoarchaeum), Crenarchaeota (Sulfolobus, Thermoproteus)* and *Euryarchaeota [Methanogens (Methanobacterium, Methanocaldococcus), thermophiles (Thermococcus, Pyrococcus, Thermoplasma), and Halophiles (Halobacterium, Halococcus)].*

Practical

1. Preparation of different media: synthetic media, complex media- Nutrient agar, McConkey agar, EMB agar.
2. Simple staining
3. Negative staining
4. Gram staining
5. Capsule staining
6. Endospore staining.

7. Isolation of pure cultures of bacteria by streaking method.
8. Preservation of bacterial cultures by various techniques.
9. Estimation of CFU count by spread plate method/pour plate method.
10. Motility by hanging drop method.

Reference Books

1. Prescott, M.J., Harley, J.P. and Klein, D.A. Microbiology. 5th Edition WCB McGrawHill, New York, (2002).
2. Tortora, G.J., Funke, B.R. and Case, C.L. Microbiology: An Introduction. Pearson Education, Singapore, (2004).
3. Alcomo, I.E. Fundamentals of Microbiology. VI Edition, Jones and Bartlett Publishers. Sudbury. Massachusetts, (2001).
4. Black J.G. Microbiology-Principles and Explorations. John Wiley & Sons Inc. New York, (2002)
5. Tom Besty, D.C Jim Koegh. Microbiology Demystified McGraw-Hill.
6. Ray A . and Mukherjee R. Basic Lab Manual of Microbiology, Biochemistry and Molecular Biology. Taurean Publications, India.

Course Name: Microbial World and Diversity
Course Code: BSCHMCBGE101

Course Type: GE	**Course Details: GEC-1**			**L-T-P: 4-0-4**	
Credit: 6	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will -*

1. Acquire a fairly good understanding of the Diversity of the microbes

2. Acquire a fairly good understanding of the activities/ importance of microbes.

3. Acquire practical skills of handing microorganisms in the laboratory for study.

Course Content:

Theory

Unit – 1: Introduction to microbial world, Physiochemical and biological characteristics; Characteristics of Acellular microorganisms (Viruses); Baltimore classification, general structure with special reference to viroids and prions. Binomial Nomenclature, Whittaker's

five kingdom and Carl Woese's three kingdom classification systems and their utility. Difference between prokaryotic and eukaryotic microorganisms

Unit – 2: General characteristics of Cellular microorganisms, types - archaebacteria, eubacteria, wall-less forms - MLO (mycoplasma and spheroplasts) with emphasis on distribution and occurrence, morphology, mode of reproduction and economic importance. Structure, reproduction and economic importance of Mycoplasma.

Unit – 3: General concept of Phytoplanktons and Zooplanktons. Characteristics, occurrence, thallus organization and classification of Algae. Cyanobacteria - occurrence, thallus organization, cell ultra-structure, reproduction and economic importance. Applications of algae in agriculture, industry, environment and food.

Unit – 4: Historical developments in the field of Mycology including significant contributions of eminent mycologists. General characteristics of fungi including habitat, distribution, nutritional requirements, fungal cell ultrastructure, thallus organization and aggregation, mode of reproduction and Economic importance of fungi with examples in agriculture, environment, Industry, medicine and food.

Unit – 5: General characteristics, structure, mode of reproduction and economic importance of Actinomycetes with special reference to its application in medicine and industry. General characteristics, occurrence, classification structure, reproduction and economic importance of Protozoa.

Practical

1. Microbiology Good Laboratory Practices and Bio-safety.
2. To study the principle and applications of important instruments (biological safety cabinets, autoclave, incubator, BOD incubator, hot air oven, light microscope, pH meter) used in the microbiology laboratory.
3. Preparation of laboratory Glass wares (Chemical washing, cleaning and drying).
4. Preparation of culture media (Liquid & solid). For bacterial cultivation.
5. Handling and care of laboratory equipment- Autoclave, Hot air oven, Incubator, pH meter, High speed centrifuge, Laminar air flow.
6. Sterilization of medium using Autoclave.
7. Sterilization of glass ware using Hot Air Oven and assessment for sterility.
8. Sterilization of heat sensitive material by membrane filtration and assessment for Sterility
9. Demonstration of the presence of microflora in the environment by exposing nutrient agar plates to air.
10. Observation of microorganisms - Bacteria, Cyanobacteria Protozoa, Fungi, Yeasts, and Algae from Natural habitats.
11. Study of common fungi, algae and protozoan using temporary mounts

References/ Suggested Readings

1. Singh, R.P. General Microbiology. Kalyani Publishers, New Delhi (2007).
2. Aneja, K.R. Experiments in Microbiology, Plant pathology and Biotechnology, Fourth edition, New Age International publishers.

3. Dubey, R.C. and Maheshwary, D.K. Text book of Microbiology. S. Chand and company (1999).
4. Powar, C.B. and Daginawal, H.F. General Microbiology. Vol-I and Vol-II, Himalaya Publishing House.
5. Chakraborty P.A Text book of Microbiology. New central book Agency (2005).
6. Prescott, M.J., Harley, J.P. and Klein, D.A. Microbiology. 5th Edition WCB McGrawHill, New York, (2002).
7. Tortora, G.J., Funke, B.R. and Case, C.L. Microbiology: An Introduction. Pearson Education, Singapore, (2004).

Semester-II

Course Name: Basic Biochemistry
Course Code: BSCHMCBC201

Course Type: **C**	Course Details: **CC-3**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the end of this course the students will -*

1. *Develop a very good understanding of various biomolecules which are required for development and functioning of a bacterial cell.*

2. *Understand how the carbohydrates make the structural and functional components such as energy generation and as storage food molecules for the bacterial cells*

3. *Conversant about multifarious function of proteins; are able to calculate enzyme activity and other quantitative and qualitative parameters of enzyme kinetics; also knowledge about lipids and nucleic acids.*

4. *Able to make buffers, study enzyme kinetics and calculate V_{max}, K_m, K_{cat} values.*

Course Content:

Theory

Unit – 1: Concept of bio-molecules - Building blocks of life, Macromolecules. Basic concept on structure of water molecule, forces in molecules. Concept of pH and buffers and Numerical problems to explain the concepts.
Concept of Bioenergetics - First and second laws of Thermodynamics. Definitions of Gibb's Free Energy, enthalpy and Entropy and mathematical relationship among them, Standard free energy change and equilibrium constant. Coupled reactions and additive nature of standard free energy change, Energy rich compounds, ATP.

Unit - 2: Carbohydrate: Basic idea on carbon atom structure. Stereo isomerism of monosaccharides, epimers, mutarotation and anomers of glucose. Families of monosaccharides – aldoses and ketoses, trioses, tetroses, pentoses, and hexoses. Furanose and pyranose forms of glucose and fructose, Haworth projection formulae for glucose; chair and boat forms of glucose, sugar derivatives, glucosamine. Disaccharides; concept of reducing and non-reducing sugars, occurrence and Haworth projections of maltose, lactose, and sucrose, polysaccharides, storage polysaccharides, starch and glycogen. Structural polysaccharides, cellulose, peptidoglycan and chitin.

Unit - 3: Protein: Amino acids the building blocks of proteins. Titration curve of amino acid and its Significance, Classification, biochemical structure and notation of standard protein amino acids Ninhydrin reaction. General formula of amino acid and concept of zwitterion. Natural modifications of amino acids in proteins hydrolysine, cystine and hydroxyproline, Non

protein amino acids: Gramicidin, beta-alanine, D-alanine and D-glutamic acid. Primary, secondary, tertiary and quaternary structures. Enzymes: General concept of enzyme, Apoenzyme and cofactors, prosthetic group- TPP, coenzyme - NAD, metal cofactors, Classification of enzymes (IUBMB), Mechanism of action of enzymes: active site, transition state complex and activation energy. Lock and key hypothesis, and Induced Fit hypothesis. Significance of hyperbolic, double reciprocal plots of enzyme activity, Km, and allosteric mechanism. Definitions of terms – enzyme unit, specific activity and turnover number, Effect of pH and temperature on enzyme activity. Enzyme inhibition: competitive- sulfa drugs; non-competitive- heavy metal salts and Uncompetitive. Feedback inhibition. Cooperativity.

Unit - 4: Lipids: Definition and major classes of storage and structural lipids. Storage-lipids. Fatty acids structure and functions. Essential fatty acids. Triacylglycerols structure, functions and properties. Saponification, Iodine number. Structural lipids. Phosphoglycerides: Building blocks, general structure, functions and properties. Structure of phosphatidylethanolamine and phosphatidylcholine. Sphingolipids: building blocks, structure of sphingosine, ceramide. Special mention of sphingomyelins, cerebrosides and gangliosides. Lipid functions: cell signals, cofactors, prostaglandins, Introduction to lipid micelles, monolayers, bilayers, liposome.

Unit - 5: Nucleic acids and vitamins: Base composition: Purine, pyrimidine bases, nucleoside, nucleotide- structure, properties. Types, structure and function of DNA & RNA. Model of DNA structure. Superhelicity in DNA, linking number, topological properties. Vitamin: Classification and characteristics with suitable examples, sources and importance.

Practical

1. Preparation of buffer- Phosphate buffer, Tris buffer.
2. Qualitative/Quantitative tests for carbohydrates, reducing sugars (DNS), non-reducing sugars (Anthrone).
3. Qualitative/Quantitative tests for amino acid (Ninhydrin), protein (Lowry).
4. Qualitative tests for lipids- Sudan.
5. Study of enzyme kinetics– calculation of *V*max, Km, Kcat values.
6. Study effect of temperature, pH on enzyme activity.
7. Estimation of vitamin- Ascorbic acid.

Reference Books

1. Tortora, G.J., Funke, B.R and Case, C.L. Microbiology: An Introduction. Pearson Education, Singapore, (2004).
2. Stanbury, Biochemistry
3. Voet & Voet. Fundamentals of biochemistry Wiley
4. M.M. Cox, D.L. Nelson. Lehninger's principles of biochemistry. WH Freeman
5. Stryer. Biochemistry WH Freeman
6. Fundamentals of Biochemistry (2016) by J L Jain, Sunjay Jain, Nitin Jain. S. Chand

Course Name: Microbial Techniques and Instruments
Course Code: BSCHMCBC202

Course Type: **C**	Course Details: **CC-4**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the end of this course the students will -*

1. *Understand principles which underlies sterilization of culture media, glassware and plastic ware to be used for microbiological work.*
2. *Understand principles of a number of analytical instruments which the students have to use during the study and also later as microbiologists for performing various laboratory manipulations.*
3. *Learned handling and use of microscopes for the study of microorganisms which are among the basics kills expected from a practicing microbiologist. They also get introduced a variety of modifications in the microscopes for specialized viewing.*
4. *Understand several separation techniques which may be required to be handled by microbiologists.*

Course Content:

Theory

Unit - 1: Microscopy**:** Principle, mechanism and application of photo optical instruments (different types of Microscopes), Phase contrast microscope, Bright Field Microscope, Dark Field Microscope, Fluoresence microscopy, Confocal microscopy, Atomic Force Microscopy, Scanning and Transmission Electron Microscopy, Cryoelectron Microscopy. Micrometry.

Unit - 2: Purification and separation techniques: Principle and techniques with applications (Partition, adsorption, ion exchange, size exclusion, 2-D, HPLC, GLC and affinity chromatography). Electrophoretic technique (agarose and polyacrylamide gel) its Components, working and applications. Principles of Centrifugation and Ultracentrifugation techniques and its applications. Basic idea of salting out, Dialysis.

Unit - 3: Biophysical Principles: Osmosis, osmotic pressure, Donan equilibrium, diffusion potential, diffusion coefficient, endocytosis & exocytosis, gradient of chemical potential as driving force in transport, membrane potential & ionophores.

Unit - 4: Principle, mechanism and application of instruments used in Spectrophotometric techniques (UV, visible, IR, Fluorescence, NMR, ESR). Basic concept of CD, ORD.

Unit - 5: Radioactivity: Laws of Radioactivity, Half-life & Average life, types of radiation (α, β, γ radiations) application of radioactive isotopes in biology. Radioisotope dilution technique and Autoradiography.

Practical

1. Ray diagrams of phase contrast microscopy and Electron microscopy.
2. Separation of mixtures by paper/ thin layer chromatography- Amino acid, Sugar
3. Separation of protein mixtures by Polyacrylamide Gel Electrophoresis (PAGE).
4. Determination of extinction coefficient. For an unknown sample.
5. Separation of components of a given mixture using a laboratory scale centrifuge.
6. Understanding density gradient centrifugation with the help of pictures.

Reference Books:

1. Wilson & Walker. Principles and Techniques in Practical Biochemistry. 5th Edition. Cambridge University Press (2000).
2. Murphy D.B. Fundamental of Light Microscopy & Electron Imaging. 1st Edition. Wiley- Liss. (2001).
3. K L Ghatak. Techniques And Methods In Biology PHI Publication (2011)
4. Pranav Kumar. Fundamentals and Techniques of Biophysics and Molecular Biology (2016).
5. Aurora Blair. Laboratory Techniques & Experiments In Biology. Intelliz Press
6. D.T Plummer. An Introduction to Practical Biochemistry. McGraw Hill Publication 1987
7. Beckner, W.M., Kleinsmith L.J and Hardin J. The world of cell. IV edition. Benjamin Cummings (2000)
8. Biophysical Chemistry by Upadhyay, Upadhyay, Nath. Himalaya Publishing House.

Course Name: Bacteriology and Virology
Course Code: BSCHMCBGE201

Course Type: **GE**	Course Details: **GEC2**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course learning outcomes: *By the conclusion of this course, the students will -*

1. Acquired a fairly good understanding of the different types of bacteria and viruses.

2. Acquired a fairly good understanding of the structure and other salient characteristics of bacteria and viruses.

3. *Acquired skills of visualizing bacteria by staining, using a microscope and culturing bacteria in microbiological media to describe the features of bacterial colonies.*

Course Content:

Theory

Unit – 1: Virology: Discovery of viruses, concept of viroids, virusoids, satellite viruses and Prions. Structure of Viruses. Viral taxonomy- Classification and nomenclature of different groups of viruses. Diversity, classification of bacteriophages, lytic and lysogenic phages (lambda phage) concept of early and late proteins, regulation of transcription in lambda phage.

Unit – 2: Modes of viral transmission: Persistent, non-persistent, vertical and horizontal. Salient features of viral Nucleic acid : Unusual bases (TMV,T4 phage), overlapping genes (ϕX174, Hepatitis B virus), alternate splicing (HIV), terminal redundancy (T4 phage), terminal cohesive ends (lambda phage), partial double stranded genomes (Hepatitis B), long terminal repeats (retrovirus), segmented (Influenza virus), and non-segmented genomes (picornavirus), capping and tailing (TMV) Viral multiplication and replication strategies: Interaction of viruses with cellular receptors and entry of viruses. Replication strategies of viruses as per Baltimore classification (phiX174, Retroviridae).

Unit – 3: Bacteria: Cell size, shape and arrangement, glycocalyx, capsule, flagella, endoflagella, fimbriae and pili. Cell-wall: Composition and detailed structure of Gram-positive and Gram- negative cell walls, Archaeal cell wall, lipopolysaccharide (LPS), sphaeroplasts, protoplasts, and L-forms. Cell Membrane: Structure, function and chemical composition of bacterial and archaeal cell membranes. Cytoplasm- Ribosomes, mesosomes, inclusion bodies, nucleoid, genome and plasmids Endospore: Structure, formation, stages of sporulation.

Unit – 4: Nutritional requirements in bacteria and nutritional categories; Culture media: natural and synthetic media, chemically defined media, complex media, selective, differential, indicator, enriched and enrichment media. Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation. Asexual methods of reproduction, logarithmic representation of bacterial populations, phases of growth, calculation of generation time and specific growth rate

Unit – 5: Aim and principles of classification, systematics and taxonomy, concept of species, taxa, strain; conventional, molecular and recent approaches to polyphasic bacterial taxonomy, evolutionary chronometers, rRNA oligonucleotide sequencing, signature sequences, and protein sequences. Differences between eubacteria and archaebacteria.

Practical

1. Preparation of different media: synthetic media, Complex media Nutrient- agar, McConkey agar, EMB agar.
2. Gram staining
3. Isolation of pure cultures of bacteria by streaking method.
4. Preservation of bacterial cultures by various techniques.

5. Estimation of CFU count by spread plate method/ pour plate method.
6. Motility by hanging drop method.
7. Study of the structure of important animal viruses (influenza, hepatitis B and retroviruses) using models, videos, and electron micrographs
8. Study of the structure of important plant viruses (tobacco mosaic viruses) using electron micrographs
9. Isolation and enumeration of bacteriophages (PFU) from water/sewage sample using double agar layer technique

Semester-III

Course Name: Virology
Course Code: BSCHMCBC301

Course Type: **C**	Course Details: **CC-5**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will -*

1. *Understood what are viruses and the chemical nature of viruses, different types of viruses infecting animals, plants and bacteria (bacteriophages)*

2. *Understand about the biology of bacteriophages.*

3. *Gained knowledge of a variety of plant viruses and animal viruses.*

4. *Gained ability to describe role of viruses in the causation of the cancer*

Course Content:

Theory

Unit – 1: Virology: Discovery of viruses, nature and definition of viruses, general properties, Theories of viral origin; Structure of Viruses. Modes of viral infection: Persistent, non-persistent; viral transmission: vertical and horizontal. Concept of viroids, virusoids, satellite viruses and Prions. Viral taxonomy- Classification and nomenclature of different groups of viruses- ICTV & Baltimore system of classification.

Unit - 2: Isolation, purification and cultivation of bacterial viruses. Study of one step growth curve of bacterial viruses. Types of bacteriophages, lytic and lysogenic phages (lambda phage) concept of early and late proteins, regulation of transcription in lambda phage, T4.

Unit - 3: Replication Assembly, maturation and release of viruses. Salient features of viral, Nucleic acid : Unusual bases (TMV, T4 phage), overlapping genes (ϕX174, Hepatitis B virus), alternate splicing (HIV), terminal redundancy (T4 phage), terminal cohesive ends (lambda phage), partial double stranded genomes (Hepatitis B), long terminal repeats (retrovirus), segmented (Influenza virus), and non-segmented genomes (picornavirus), capping and tailing (TMV) Viral multiplication and replication strategies: Interaction of viruses with cellular receptors and entry of viruses. Replication strategies (ϕX174, Retroviridae, M13).

Unit - 4: Introduction to oncogenic viruses. Types of oncogenic DNA and RNA viruses: Concepts of oncogenes, proto-oncogenes and viral origin onco-proteins.

Unit - 5: Antiviral compounds and their mode of action Interferon and their mode of action; viral vaccines. Viral outbreaks- SARS, MARS and SARS-CoV2

Practical

1. Study of the structure of important animal viruses (rhabdo, influenza, paramyxo) using electron micrographs.
2. Study of the structure of important plant viruses (Gemini, tobacco mosaic, and alpha-alpha mosaic viruses) using electron micrographs.
3. Study of the structure of important bacterial viruses (M13, T4)using electron micrograph.
4. Isolation and enumeration of bacteriophages (PFU) from water/ sewage sample using double agar layer technique.
5. Purifications of virus from plant lesion and local lesion assay in plant.

Reference Books

1. Pelczar M., Chan E.C.S. and Krieg, N.R. Microbiology. Tata McGrew Hill Publishing, Co. Ltd., New Delhi.
2. Stainier R.V., Ingraham, J.L., Wheelis, M.L. and Painter P.R. The Microbial World. Printice-Hall of India (Pvt.) Ltd., New Delhi
3. Ellen Strauss, James Strauss. Viruses and Human Disease 2nd Edition. Academic Press
4. Christopher Burrell Colin Howard Frederick Murphy. Fenner and White's Medical Virology 5th Edition. Academic Press

Course Name: Microbial Physiology and Metabolism
Course Code: BSCHMCBC302

Course Type: **…C**	Course Details: **CC-6**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will be capable of-*

1. Describing the growth characteristics of the microorganisms capable of growing under unusual environmental condition of temperature, oxygen, and solute and water activity.

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.

Course Content:

Theory

Unit – 1: Definitions of growth, measurement of microbial growth, Phases of growth, Batch culture, Continuous culture, generation time and specific growth rate, synchronous growth, diauxic growth curve. Microbial growth in response to environment - Temperature (*psychrophiles, mesophiles, thermophiles, extremophiles, thermodurics, psychrotrophs*), pH (*acidophiles, alkaliphiles*), solute and water activity (*halophiles, xerophiles, osmophilic*), Oxygen (*aerobic, anaerobic, microaerophilic, facultative aerobe, facultative anaerobe*), barophilic.

Unit - 2: Microbial growth in response to nutrition and energy – Autotroph/ Phototroph, heterotrophy, *Chemolithoautotroph, Chemolithoheterotroph, Chemoheterotroph, Chemolithotroph, photolithoautotroph, Photoorganoheterotroph*. Passive and facilitated diffusion. Primary and secondary active transport, concept of uniport, symport and antiport Group translocation, Iron uptake.

Unit - 3: Concept of aerobic metabolism, anaerobic metabolism and fermentation - Sugar degradation pathways i.e. EMP, ED, Pentose phosphate pathway, TCA cycle. Electron transport chain: components of respiratory chain, comparison of mitochondrial and bacterial ETC, electron transport phosphorylation, uncouplers and inhibitors. Fermentation - Alcohol fermentation and Pasteur effect; Lactate fermentation (homofermentative and heterofermentative pathways). Account of beta-oxidation of even and odd number, saturated and unsaturated fatty acids.

Unit - 4: Introduction to aerobic and anaerobic chemolithotrophy with an example each. Hydrogen oxidation (definition and reaction) and methanogenesis (definition and reaction). Introduction to phototrophic metabolism - groups of phototrophic microorganisms, anoxygenic vs. oxygenic photosynthesis with reference to photosynthesis in green bacteria, purple bacteria and Cyanobacteria.

Unit - 5: Anaerobic respiration with special reference to dissimilatory nitrate. Reduction (Denitrification; nitrate/nitrite and nitrate/ammonia respiration; fermentative nitrate reduction). Concept & mechanism of biological nitrogen fixation, Ammonia assimilation. Assimilatory nitrate reduction, dissimilatory nitrate reduction, denitrification. Concept and reaction of Transamination, Deamination, Transmethylation and decarboxylation, Urea cycle in connection to amino acid catabolism.

Practical

1. Study and plot the growth curve of *E.coli* by turbidometric - Calculations of generation time and specific growth rate of bacteria from the graph plotted with the given data.
2. Effect of temperature on growth of *E.coli.*
3. Effect of pH on growth of *E.coli.*
4. Effect of deprivation of carbon and nitrogen sources on growth of *E.coli.*
5. Effect of salt on growth of *E.coli.*
6. Demonstration of alcoholic fermentation.
7. Demonstration of the thermal death time and thermal death point of *E.coli.*

Reference Books

1. Voet &Voet. Fundamentals of biochemistry Wiley
2. M.M. Cox, D. L. Nelson. Lehninger's principles of biochemistry. W H Freeman
3. Stryer. Biochemistry W H Freeman
4. Fundamentals of Biochemistry (2016) by J L Jain, Sunjay Jain, Nitin Jain. S. Chand
5. Madigan, Martinko, Bender, Buckley, Stahl. Brock Biology of Microorganisms. Pearson
6. Prescott, M.J., Harley, J.P. and Klein, D.A. Microbiology. 5th Edition WCB McGrawHill, New York.

Course Name: Cell and Molecular Biology
Course Code: BSCHMCBC303

Course Type: **…C**	Course Details: **CC-7**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will capable of –*

1. Describing importance and mechanism of central dogma of life

2. Describing the structure and function of different components of cell.

3. Differentiating the cellular and molecular processes between prokaryotes and eukaryotes.

Course Content:

Theory

Unit – 1: Concepts of cell- Comparison of Prokaryotic & Eukaryotic cells. Cell organelles-structure and function. Eukaryotic cells - cell wall & plasma membrane; Cell Wall: Eukaryotic cell wall, Extra cellular matrix and cell matrix interactions, Cell-Cell Interactions - adhesion junctions, tight junctions, gap junctions, and plasmodesmata (only structural aspects). Cytoskeleton: Structure and organization of actin filaments, microtubules. Nuclear envelope, nuclear pore complex and nuclear lamina Chromatin structure – Molecular organization, Nucleolus.

Unit - 2: Modes & Models of DNA replication. Enzymes, proteins and other factors involved in DNA replication. Mechanism of DNA replication in prokaryotes and comparison with eukaryotes. Properties, mechanism of action of topoisomerases.

Unit - 3: Eukaryotic cell cycle and its regulation, Mitosis and Meiosis. Development of cancer, Programmed cell death. Basic idea of Stem cells and pleuripotency. Basic idea and function of

signaling molecules and their receptors. Pathways of intra-cellular receptors – Cyclic AMP pathway, cyclic GMP and MAP kinase, Integrin pathway.

Unit - 4: Transcription: promoter- concept and strength of promoter RNA Polymerase and the transcription unit. Transcription in Eukaryotes: RNA polymerases, general Transcription factors. Translational machinery, charging of tRNA, aminoacyl tRNA synthetases, Mechanisms of initiation, elongation and termination of polypeptides in both prokaryotes and eukaryotes, Fidelity of translation, Inhibitors of protein synthesis in prokaryotes and eukaryote. Protein Sorting and Transport- targeting and insertion of proteins in the ER, protein folding and processing, export of proteins and lipids. Protein glycosylation, protein sorting and export from Golgi, Apparatus, Lysosomes.

Unit-5: Split genes, concept of introns and exons, RNA splicing, spliceosome machinery**,** concept of alternative splicing, Polyadenylation and capping, RNA interference: siRNA, miRNA and its significance. Principles of transcriptional regulation, regulation at initiation with examples from *lac* and *trp* operons, Sporulation in Bacillus, Epigenetics - DNA methylation and Histone Acetylation mechanisms.

Practical

1. Study a representative plant and animal cell by microscopy.
2. Study of the structure of cell organelles through electron micrographs.
3. Identification and study of cancer cells by photomicrographs.
4. Pictorial Study of different stages of Mitosis.
5. Estimations of DNA and RNA using diphenylamine and orcinol reagent, and UV Spectrophotometer (A260 measurement).

Reference Books

1. Benjamin Lewin, Gene VII, Oxford University Press, (2000).
2. Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter, Molecular biology of the Cell, 4th Edition. Garland publishing Inc. (2002).
3. Darnell, Lodish and Baltimore, Molecular Cell Biology, Scientific American Publishing Inc. (2000).
4. Watson. J.D, Baker. T.A, Bell. S.P, Gann. A. Levine. M. Losick. R, Molecular Biology of Gene, 5th Edition. The Benjamin/Cummings Pub. Co. Inc. (2003).
5. Brown T.A., Gene Cloning and DNA analysis. 2nd Edition, A S Mpress. (2004).
6. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
7. Glick BR and Pasternak JJ, Molecular Biotechnology, 2nd Ed.ASM press. (2003).

Course Name: Microbial Quality Control in Food & Pharmaceutical Industries

Course Code: BSCHMCBSE301

Course Type: **SE**	Course Details: **SEC-1**			L-T-P: **4 - 0 - 0**	
Credit: **4**	Full Marks: 50	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		--	10	--	40

Course learning outcomes: *By the conclusion of this course, the students will -*

1. *Developed a very good understanding of practical aspects of microbiological safety, various detection methodologies and use of different microbiological media in food industries.*
2. *Developed a very good understanding of practical aspects of microbiological safety, various detection methodologies and toxicological testing of products in the pharmaceutical industries*

Course Content:

Theory

Unit-1: Microbiological Laboratory and Safe Practices: Good laboratory practices - Good laboratory practices, Good microbiological practices. Biosafety cabinets – Working of biosafety cabinets, using protective clothing, specification for BSL-1, BSL-2, BSL-3. Discarding biohazardous waste – Methodology of Disinfection, Autoclaving & Incineration

Unit-2: Determining Microbes in Food / Pharmaceutical Samples: Culture and microscopic methods - Standard plate count, Most probable numbers, Direct microscopic counts, Biochemical and immunological methods: Limulus lysate test for endotoxin, gel diffusion, sterility testing for pharmaceutical products

Unit-3: Molecular methods to determine microbes in samples- Nucleic acid probes, PCR based detection, biosensors. Enrichment culture technique, Detection of specific microorganisms- on XLD agar, *Salmonella Shigella* Agar, Manitol salt agar, EMB agar, McConkey Agar, Saboraud Agar

Unit-4: Ascertaining microbial quality of milk by MBRT, Rapid detection methods of microbiological quality of milk at milk collection centers (COB, 10 min Resazurin assay)

Unit-5: HACCP for Food Safety and Microbial Standards: Hazard analysis of critical control point (HACCP) - Principles, flow diagrams, limitations Microbial Standards for Different Foods and Water – BIS standards for common foods and drinking water

Reference Books

1. Quality Control in the Food Industry V1, S Herschdoerfer, ISBN**:** 9780323152068,**:** Academic Press, 1967
2. Principles of Sensory Evaluation of Food- 1965 MA Amerine, RM , Pangborn and EB Roessler, Elsevier.

Course Name: Microbial Diagnostics and Public Health

Course Code: BSCHMCBSE302

Course Type: **SE**	Course Details: **SEC-1**			L-T-P: **4 - 0 - 0**	
Credit: **4**	Full Marks: 50	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		--	10	--	40

Course learning outcomes: *By the conclusion of this course, the students will -*

1. *Developed a very good understanding of practical aspects of collection of different clinical samples, their transport, culture and examination by staining, and molecular and immunological diagnostic methods for diagnosis of microbial diseases.*

2. *Developed a very good understanding of practical aspects of antibiotic sensitivity testing, water and food testing skills using kits available in the market.*

Course Content:

Theory

Unit-1: Importance of Diagnosis of Diseases: Bacterial, Viral, Fungal and Protozoan Diseases of various human body systems, Disease associated clinical samples for diagnosis.

Unit-2: Collection of Clinical Samples: How to collect clinical samples (oral cavity, throat, skin, Blood, CSF, urine and faeces) and precautions required. Method of transport of clinical samples to laboratory and storage.

Unit-3: Direct Microscopic Examination and Culture. Examination of sample by staining-Gram stain, Ziehl-Neelson staining for tuberculosis, Giemsa- stained thin blood film for malaria. Preparation and use of culture media- Blood agar, Chocolate agar, Lowenstein-Jensen medium, MacConkey agar, Distinct colony properties of various bacterial pathogens.

Unit-4: Serological and Molecular Methods: Serological Methods-Agglutination, ELISA, immunofluorescence, Nucleic acid based methods- PCR, Nucleic acid probes. Kits for Rapid Detection of Pathogens: Typhoid, Dengue and HIV, Swine flu.

Unit-5: Testing for Antibiotic Sensitivity in Bacteria: Importance, Determination of resistance/ sensitivity of bacteria using disc diffusion method, Determination of minimal inhibitory concentration (MIC) of an antibiotic by serial double dilution method.

Reference books

1. Ananthanarayan R and Paniker CKJ. Textbook of Microbiology. 7th Edition. University Press Publication. (2005).

Course Name: Industrial and Food Microbiology

Course Code: BSCHMCBGE301

Course Type: **GE**	Course Details: G**EC-3**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course learning outcomes: *By the conclusion of this course, the students-*

1. *Has acquired a fairly good knowledge of how microbes are used in the fermentative production of organic acids, alcohols, enzymes, antibiotics and various foods in the industry.*
2. *Has acquired knowledge of various physical parameters which affect production of industrial products by the microorganisms and the safety aspects of the production and use of these products.*
3. *Has developed laboratory skills in producing alcohol and enzymes by fermentative process using bacteria/yeast; Laboratory skills of testing microbial load in milk.*

Course Content:

Theory

Unit-1: Brief history and developments in industrial microbiology. Types of fermentation processes – solid state, liquid state, batch, fed-batch and continuous Types of fermenters– laboratory, pilot- scale and production fermenters. Components of a typical continuously stirred tank bioreactor. Primary and secondary screening. Preservation and maintenance of industrial strains.

Unit-2: Downstream processing-filtration, centrifugation, cell disruption, solvent extraction. Microbial production of industrial products- citric acid, ethanol and penicillin. Industrial production and uses of the enzymes- amylases, proteases.

Unit-3: Ingredients used in fermentation medium-molasses, corn steep liquor, whey & Yeast extract. Food as a substrate for microbial growth; Intrinsic and extrinsic parameters that affect microbial growth in food Microbial spoilage of food - milk, egg, bread.

Unit-4: Food preservation techniques: Physical methods - high temperature, low temperature, irradiation, aseptic packaging. Chemical methods - salt, sugar, benzoates, citric acid, ethylene oxide, nitrate and nitrite Food sanitation and control – HACCP.

Unit-5: Fermented dairy products - yogurt, kefir, and cheese. Probiotics definition, examples and benefits. Food intoxication by *Clostridium botulinum* and *Staphylococcus aureus*. Food infection by *Salmonella* and *E.coli*

Practical

1. Study of different parts of fermenter (Diagrammatic)
2. Microbial fermentations for the production and estimation (qualitative and quantitative) of: Enzymes: Amylase and Protease; Amino acid: Glutamic acid; Organic acid: Citric acid; Alcohol: Ethanol
3. A visit to any educational institute/industry to see an industrial fermenter, and other downstream processing operations.
4. MBRT of milk samples and their standard plate count.
5. Alkaline phosphatase test to check the efficiency of pasteurization of milk.
6. Isolation of spoilage microorganisms from spoiled vegetables/ fruits.
7. Preparation of Dahi.

Reference books

1. Nduka Okafor. Modern Industrial Microbiology and Biotechnology. 1st Edition. Science Publishers. (2007).
2. Waites, M . J ., Morgan, N.L., Rockey, J.S. and Hinton, G. Industrial Microbiology: An introduction. Blackwell science Publishers. (2002).
3. Nduka Okafor, Benedict C. Okeke. Modern Industrial Microbiology and Biotechnology. CRC Press.(2017)
4. W Clarke. Biotechnology: Industrial Microbiology A Textbook. CBS Publishers and Distributors (2016)

Semester-IV

Course Name: Microbial Genetics
Course Code: BSCHMCBC401

Course Type: **C**	Course Details: **CC-8**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will -*

1. *Understood genome organization of model organisms namely E. coli and Saccharomyces, and the molecular mechanisms that underlie mutations.*

2. *Developed a fairly good knowledge about the three well known mechanisms by which genetic material is transferred among the microorganisms namely transformation, transduction and conjugation.*

3. *Be able to describe different types of the extra-chromosomal elements or the plasmids; the nature of the transposable elements in the prokaryotic and the eukaryotic cells.*

4. *Gain hands on skills of isolation of plasmid DNA from bacterial cells and its visualization by performing agarose gel electrophoresis.*

Course Content:

Theory

Unit – 1: Genome organization: *E. coli*, *Saccharomyces*. Mutations and mutagenesis: Definition and types of Mutations; Physical and chemical mutagens; Molecular basis of mutations; Functional mutants (loss and gain of function mutants); Uses of mutations. Reversion and suppression: True revertants; Intra- and inter-genic suppression; Ames test; Mutator genes.

Unit – 2: Microbial Genetics: Transformation- discovery, Griffith's experiment, mechanism of transformation; Factors affecting transformation process, Competence and development of competence in *S. Pneumonia*. Transduction – discovery, Lederberg and Tatum's experiment, mechanism and types of transduction- Generalized transduction, specialized transduction, Sexduction and abortive transduction.

Unit – 3: Conjugation- discovery, experimental evidence, *F*-factor, F^+ & *Hfr*, mechanism of conjugation, Cross between *Hfr*, F^+, F^- & F' Conjugant and its application. Mapping based on bacterial genetics.

Unit – 4: Types of plasmids – F plasmid, R Plasmids, colicinogenic plasmids, Ti plasmids, linear plasmids, yeast- 2µ plasmid, Plasmid replication and partitioning, Host range, plasmid-incompatibility, plasmid amplification, Regulation of copy number, curing of plasmids.

Unit – 5: Prokaryotic transposable elements – Insertion Sequences, composite and non-composite transposons, Replicative and Non replicative transposition, Mu transposon. Eukaryotic transposable elements - Maize (Ac/Ds). Uses of transposons and transposition.

Practical

1. Preparation of Master and Replica Plates.
2. Study the effect of UV mutagen on bacterial cells and Study survival curve of bacteria after exposure to ultraviolet (UV) light.
3. Isolation of genomic DNA from *E.coli* and visualization through agarose gel electrophoresis.
4. Demonstration of bacterial conjugation.
5. Demonstration of bacterial transformation and transduction.

Reference Books

1. Benjamin Lewin, Gene VII, Oxford University Press, (2000).
2. Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter, Molecular biology of the Cell, 4th Edition. Garland publishing Inc. (2002).
3. Darnell, Lodish and Baltimore, Molecular Cell Biology, Scientific American Publishing Inc. (2000).
4. Watson. J.D, Baker. T.A, Bell. S.P, Gann. A. Levine. M. Losick. R, Molecular Biology of Gene, 5th Edition. The Benjamin/Cummings Pub. Co. Inc. (2003).
5. Brown T.A., Gene Cloning and DNA analysis. 2nd Edition, ASM press. (2004).
6. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
7. Glick BR and Pasternak JJ, Molecular Biotechnology, 2nd Ed. ASM press. (2003).
8. Uldis N. Streips, Ronald E. Yasbin. Modern Microbial Genetics. 2nd Edition Wiley- Liss, Inc. (2002).
9. Gardner E J, Simmons M J and Snupstad DP, Principles of genetics, 8th edition John Wiley & Sons, (2006).
10. Harvey Lodish; Arnold Berk; Chris A. Kaiser; Monty Krieger; Anthony Bretscher;
11. Hidde Ploegh; Angelika Amon; Kelsey C. Martin, Stephen C. Harrison. Molecular Cell biology. Macmillan Higher Education
12. David Freifelder. Essentials of molecular biology. Jones and Bartlett Publishers, 1998.

Course Name: Environmental Microbiology and Microbial Ecology
Course Code: BSCHMCBC402

Course Type: **C**	Course Details: **CC-9**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the completion of this course, the students will -*

1. *Developed a fairly good knowledge and understanding of different types of environments and habitats where microorganisms grow including the microbiomes of the human gut and animal gut.*

2. *Be able to identify the important role microorganisms play in maintaining healthy environment by degradation of solid/liquid wastes; how these activities of microorganisms are used in sewage treatment plants, production of activated sludge and functioning of septic tanks*

3. *Understood the significance of BOD/ COD and various tests involving use of enumerating fecal E. coli for assessing quality of water.*

4. *Developed the practical skills for conducting experiments to assess the BOD/COD of waste waters and their interpretation; practically assess the portability of drinking water by the use of standard microbiological tests.*

Course Content:

Theory

Unit – 1: Terrestrial Environment: Soil profile and soil microflora. Aquatic Environment: Microflora of fresh water and marine habitats. Atmosphere: Aeromicroflora and dispersal of microbes. Air purification. Animal Environment: Microbes in/on human body (microbiomics) & animal (ruminants) body.

Unit-2: Solid Waste management: Sources and types of solid waste, Methods of solid waste disposal (composting and sanitary landfill). Liquid waste management: Composition and strength of sewage (BOD and COD), Primary, secondary (oxidation ponds, trickling filter, activated sludge process and septic tank) and tertiary sewage treatment.

Unit-3: Principles and degradation of common pesticides, organic (hydrocarbons, oil spills) and inorganic (metals) matter, biosurfactants. Treatment and safety of drinking (potable) water, methods to detect potability of water samples: (a) standard qualitative procedure: presumptive test/ MPN test, confirmed and completed tests for faecal coliforms (b) Membrane filter technique.

Unit-4: History, significance and developments in the field of microbial ecology. Contributions of Beijerinck, Winogradsky. Waksman Structure and function of ecosystems. Microbial succession in decomposition of plant organic matter. Biological Interaction: A. Microbe–Microbe Interactions - Mutualism, Synergism, Commensalism, Competition,

Amensalism, Parasitism, Predation, Biocontrol agents. B. Microbe–Plant Interactions Roots, Aerial Plant surfaces.

Unit-5: Carbon cycle: Microbial degradation of cellulose, hemicelluloses, lignin and chitin. Nitrogen cycle: Nitrogen fixation, ammonification, nitrification, denitrification and nitrate reduction. Phosphorus cycle: Phosphate immobilization and solubilisation. Sulphur cycle: Microbes involved in sulphur cycle.

Practical

1. Analysis of soil pH, moisture content, water holding capacity.
2. Isolation of microbes (bacteria & fungi) from soil with different moisture content.
3. Isolation of microbes (bacteria & fungi) from rhizosphere and rhizoplane.
4. Assessment of microbiological quality of water- MPN, IMViC.
5. Demonstration of BOD of waste water sample.
6. Study the presence of microbial activity by detecting (qualitatively)
7. Enzyme (amylase, protease) in soil.
8. Isolation of *Rhizobium* from root nodules.

Reference Books

1. Medigan, M.T., Martinko, J.M. and Parker, J. Brock Biology of Microorganisms. Pearson Education Inc., New York
2. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
3. Willey, Sherwood, Woolverton. Prescott, Harley, and Klein's Microbiology McGraw-Hill publication
4. Tortora, Funke, Case. Microbiology. Pearson Benjamin Cummings.
5. JACQUELYN G. BLACK. Microbiology Principles and explorations. JOHN WILEY & SONS, INC.

Course Name: Industrial Microbiology
Course Code: BSCHMCBC403

Course Type: **C**	Course Details: **CC-10**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will -*

1. *Be capable of describing a large number of substrate that are used for the industrial fermentation processes.*

2. *Developed an understanding of different types of reactors or fermenters which are used for laboratory, pilot and industrial scale fermentations and their processes parameters.*

3. *Acquired a detailed knowledge of number of products which are produced by industrial fermentation processes.*

Course Content:

Theory

Unit – 1: Sources of industrially important microbes and methods for their isolation, preservation and maintenance of industrial strains, strain improvement, Crude and synthetic media; molasses, corn- steep liquor, sulphite waste liquor, whey, yeast extract and protein hydrolysates.

Unit-2: Types of fermentation processes - Solid-state and liquid-state (stationary and submerged) fermentations; batch, fed-batch (e.g. baker's yeast) and continuous fermentations. Components of a typical bio-reactor, Types of bioreactors- Laboratory, pilot- scale and production fermenters, constantly stirred tank and air-lift fermenters, Measurement and control of fermentation parameters- pH, temperature, dissolved oxygen, foaming and aeration.

Unit-3: Down-stream processing; Cell disruption, filtration, centrifugation, solvent extraction, precipitation, lyophilization and spray drying. Microbial cells as food. SCP –mushroom cultivation.

Unit-4: Microbial production of industrial products (micro-organisms involved, media, fermentation conditions, downstream processing and uses) - Citric acid, ethanol, penicillin, glutamic acid, Vitamin B12. Enzymes (amylase) wine, beer.

Unit-5: Methods of immobilization, advantages and applications of immobilization, large scale applications of immobilized enzymes (glucose isomerase). Role of Microbes in Medicine and textile industry.

Practical

1. Demonstrate different parts of fermenter
2. Microbial fermentations for the production and estimation of alcohol: Ethanol
3. A visit to any industry or production center related to Microbiology.

Reference Books

1. Reed. G. Prescott and Dunn's Industrial Microbiology. CBS Publishers. (1999).
2. Demain, A. L. Industrial Microbiology and Biotechnology. 2nd Edition. (2001).
3. Waites, M.J., Morgan, N.L, Rockey, J.S. and Higton, G. Industrial Microbiology: An introduction. Blackwell Science Publishers (2002).
4. Casida LE, Industrial Microbiology, J. Wiley, (1968).
5. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
6. Willey, Sherwood, Woolverton. Prescott, Harley, and Klein's Microbiology McGraw-Hill publication
7. Tortora, Funke, Case. Microbiology. Pearson Benjamin Cummings.

Course Name: Food Fermentation Techniques
Course Code: BSCHMCBSE401

Course Type: **SE**	Course Details: **SEC-2**			L-T-P: **4 - 0 - 0**	
Credit: **4**	Full Marks: 50	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		0	10	0	40

Course Learning Outcomes: *By the conclusion of this course, the students will -*

1. *Develop a very good understanding of practical aspects commercially produced food and fermentative products.*

2. *Develop a very good understanding of practical use of microbiology for better production of home-based food and fermentation products for day-to-day use*

Course Content:

Theory

Unit – 1: Fermented Foods: Definition, types, advantages and health benefits, fermented foods used by common public, domestication.

Unit-2: Milk Based Fermented Foods: Dahi, Yogurt, Buttermilk (Chach) and cheese: Preparation of inoculums, types of microorganisms and production process.

Unit-3: Grain Based Fermented Foods: Soy sauce, Bread, Idli and Dosa: Microorganisms and production process, Preparation and preservation.

Unit-4: Vegetable Based Fermented Foods: Pickels, Saeurkraut: Microorganisms and production process. Preparation and preservation methods.

Unit-5: Fermented Meat and Fish: Types, microorganisms involved, fermentation process. Probiotic Foods: Definition, types, microorganisms and health benefits.

Reference books

1. Stanbury, PF., Principles of Fermentation Technology. Whittaker, A and Hall, S.J. 2nd Edition. Pergamon Press (1995).
2. Banwart, GJ. Basic Food Microbiology. CBS Publishers and Distributors, Delhi. (1989).
3. Hobbs BC and Roberts D. Food poisoning and Food Hygiene. Edward Arnold (A division of Hodder and Stoughton) London.
4. Dolle Michaell P. Food Microbiology: Fundamentals and Frontiers.
5. Joshi. Biotechnology: Food Fermentation Microbiology, Biochemistry and Technology. Volume 2.
6. John Garbult. Essentials of Food Microbiology. Arnold International.

7. John C. Ayres. J. Orwin Mundt. William E. Sandinee. Microbiology of Foods. W.H. Freeman and Co.
8. E. M. T. El-Mansi (Editor), C. F. A. Bryce (Editor), Arnold L. Demain (Editor), & 1 More Fermentation Microbiology and Biotechnology Hardcover CRC Press 2012.

Course Name: Microbial Products
Course Code: BSCHMCBSE402

Course Type: **SE**	Course Details: **SEC-2**			L-T-P: **4 - 0 - 0**	
Credit: **4**	Full Marks: 50	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		0	10	0	40

Course Learning Outcomes: *By the conclusion of this course, the students-*

1. *Have developed a very good understanding of practical aspects of production of bio fertilizers.*
2. *Have developed a very good understanding of practical aspects of the production of bio pesticides/ bio insecticides.*

Course Content:

Theory

Unit – 1: Bio fertilizers: General account of the microbes used as biofertilizers for various crop plants and their advantages over chemical fertilizers. Symbiotic N_2 fixers: *Rhizobium* - Isolation, characteristics, types, inoculum production and field application, legume/ pulses plants. *Frankia* - Isolation, characteristics. *Azolla* - Isolation, characterization, mass multiplication, Role in rice cultivation, Crop response, field application.

Unit-2: Cyanobacteria as bio-fertilizers- Isolation, characterization, mass multiplication, Role in rice cultivation, Crop response, field application. Non - Symbiotic Nitrogen Fixers. Free living *Azospirillum, Azotobacter*- isolation, characteristics, mass inoculums, production and field application.

Unit-3: Phosphate Solubilizes: Phosphate solubilizing microbes - Isolation, characterization, mass inoculum production, field application. PGPR – Isolation and Characterization; mass production and application.

Unit-4: Mycorrhizal Bio-fertilizers: Importance of *mycorrizal* inoculum, types of mycorrhizae and associated plants, Mass inoculum production of VAM, field applications of *Ectomycorrhizae* and VAM.

Unit-5: Bioinsecticides : General account of microbes used as bioinsecticides and their advantages over synthetic pesticides, *Bacillus thuringiensis*, production, Field applications, Viruses – cultivation and field applications.

Reference Books

1. Eldor A. Paul. Soil Microbiology. Ecology and Biochemistry. VI Edition: Academic Press, (2007).
2. Eugene L. Madsen. Environmental Microbiology: From Genomes to Biogeochemistry. I Edition, Wiley- Blackwell Publishing. (2008).
3. Agrios, G.N. Plant pathology. Harcourt Asia Pvt. Ltd. (2000).
4. Buchanan. B.B., Gruissem, W. and Jones, R.L Biochemistry and Molecular Biology of Plants. I.K. International Pvt. Ltd. (2000).
5. Mehrotra R S and Ashok Agrawal. Plant Pathology. Tata McGrawHill, 6th reprint (2006).
6. K. S. Bilgrami, H. C. Dube. A textbook of modern pathology. 6th Edition, Vani Educational Books, a division of Vikas, (1984).
7. Shalini Suri. Biofertilizer and Biopesticide Aph Publishing Corporation (2011)

Course Name: Genetic Engineering and Biotechnology

Course Code: BSCHMCBGE401

Course Type: **GE**	Course Details: **GEC8**		L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students-*

1. *Has acquired a fairly good knowledge of the tools and the methods for genetic engineering.*
2. *Has acquired a fairly good understanding of how these tools and methods are employed in the laboratory for manipulation of DNA so as to make it relevant for biotechnological uses.*
3. *Students can perform isolation of DNA, amplification of any gene by PCR and its analysis by gel electrophoresis.*

Course Content:

Theory

Unit –1 Introduction to genetic engineering: Milestones in genetic engineering and biotechnology Restriction modification systems: Mode of action, applications of Type II restriction enzymes in genetic engineering. DNA modifying enzymes and their applications: DNA polymerases. Terminal deoxynucleotidyl transferase, kinases and phosphatases, and DNA ligases

Unit– 2: Cloning: Use of linkers and adaptors: Transformation of DNA: Chemical method, Electroporation. Methods of DNA, RNA and Protein analysis: Agarose gel electrophoresis, Southern - and Northern - blotting techniques, dot blot, DNA microarray analysis, SDS-PAGE, and Western blotting

Unit– 3: Cloning Vectors: Definition and Properties Plasmid vectors: pBR and pUC series Bacteriophage lambda and M13 based vectors Cosmids, BACs, YACs Expression vectors: *E.coli* lac and T7 promoter-based vectors, yeast YIp, YEp and YCp vectors, Baculovirus based vectors, mammalian SV40-based expression vectors.

Unit– 4: DNA Amplification and DNA sequencing: PCR: Basics of PCR, RT-PCR, Real-Time PCR Genomic and cDNA libraries: Preparation and uses, Genome sequencing Sanger's.

Unit– 5: Application of Genetic Engineering and Biotechnology: Gene delivery: Microinjection, electroporation, biolistic method (gene gun), liposome and viral- mediated delivery, Agrobacterium - mediated delivery. Products of recombinant DNA technology: Products of human therapeutic interest - insulin, hGH, antisense molecules. Bt transgenic - cotton, brinjal, flavosavo tomato, Gene therapy, recombinant vaccine, protein engineering.

Practical

1. Isolation of Plasmid DNA from *E.coli.*
2. Digestion of DNA using restriction enzymes and analysis by agarose gel electrophoresis.
3. Interpretation of sequencing gel electropherograms (DIAGRAMATIC)
4. Designing of primers for DN Aamplification (SOFTWARE BASED)
5. Amplification of DNA by PCR (SCHEMATIC)
6. Demonstration of Southern blotting (SCHEMATIC)

Reference books

1. Benjamin Lewin, Gene VII, Oxford University Press, (2000).
2. Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter, Molecular biology of the Cell, 4th Edition. Garland publishing Inc. (2002).
3. Darnell, Lodish and Baltimore, Molecular Cell Biology, Scientific American Publishing Inc. (2000).
2. Watson. J.D, Baker. T.A, Bell. S.P, Gann. A. Levine. M. Losick. R, Molecular Biology of Gene, 5th Edition. The Benjamin/Cummings Pub. Co. Inc. (2003).
3. David Frifielder, Stanely R. Maloy, Molecular biology and Microbial genetics. 2nd Edition, Jones and Barlett Publishers. (1994).
4. Brown T.A., Gene Cloning and DNA analysis. 2nd Edition, ASM press. (2004).
5. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
6. Glick BR and Pasternak JJ, Molecular Biotechnology, 2nd Ed.ASM press. (2003).
7. Uldis N. Streips, Ronald E. Yasbin. Modern Microbial Genetics.2nd Edition Wiley-Liss, Inc.(2002).
8. Desmond S. T. Nicholl. An Introduction to Genetic Engineering

Semester-V

Course Name: Medical & Veterinary Microbiology and Immunology
Course Code: BSCHMCBC501

Course Type: **C**	Course Details: **CC-11**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will clearly -*

1. *Understood the basic and general concepts of causation of disease by the pathogenic microorganisms and the various parameters of assessment of their severity including the broad categorization of the methods of diagnosis.*

2. *Develop a thorough understanding of common bacterial, viral, fungal, parasitic diseases of human being including some very important diseases of the animals also.*

3. *Conceptualized the protective role of the immune system of the host and developed an understanding of the basic components as well as the mechanisms underlying the immune system and its response to pathogenic microorganisms.*

4. *Able to conduct experiments for growing common bacteria in different microbiological media, antibiotic sensitivity determination and antigen antibody reaction (precipitation test in the agarose)*

Course Content:

Theory

Unit – 1: Importance of normal microflora of skin, throat, gastrointestinal tract, urogenital tract. Host pathogen interaction: Definitions - Infection, Invasion, Pathogen, Pathogenicity, Virulence, Toxigenicity, Carriers and their types, Opportunistic infections, Nosocomial infections. Transmission of infection, Pathophysiologic effects of LPS. Collection, transport and culturing of clinical samples, principles of different diagnostic tests (ELISA, Immunofluorescence, Agglutination based tests).

List of diseases of various organ systems and their causative agents. Symptoms, mode of transmission, prophylaxis and control of the diseases: Tuberculosis, Botulism, Tetanus, Polio, Hepatitis, Dengue, AIDS, Ebola, Malaria, Candidiasis, Leishmaniasis.

Unit-2: Study of following animal diseases with respect to etiology, symptoms, mode of transmission, prophylaxis and control: Swine flu, bird flu, Rabies, Bovine tuberculosis.

Unit-3: Structure and function of the cells, tissues and organs of immune system. Types of immunity - Humoral and cell-mediated, innate, acquired immunity. Characteristics of an antigen (Foreignness, Molecular size and Heterogeneity); Haptens; Epitopes (T & B cell epitopes); T-dependent and T-independent antigens; Adjuvants. Structure, Types, Functions and Properties of antibodies; Antigenic determinants on antibodies (Isotypic, allotypic, idiotypic); Monoclonal and Polyclonal antibodies.

Unit-4: Organization of MHC locus (Mice & Human); Structure and Functions of MHC I & II molecules. Primary and Secondary Immune Response; Generation of Humoral Immune Response (Plasma and Memory cells); Generation of Cell Mediated Immune Response (Self MHC restriction, T cell activation, Co- stimulatory signals). Components of the Complement system; Activation pathways (Classical, Alternative and Lectin pathways).

Unit-5: Hypersensitivity reactions; IgE mediated Type I Hypersensitivity, Antibody-mediated cytotoxic (Type II) Hypersensitivity, Immune complex mediated (Type III) Hypersensitivity, DTH mediated (Type IV) Hypersensitivity. Autoimmune diseases. Principles of Precipitation, Agglutination, Immunodiffusion, Immunoelectrophoresis, ELISA, Western blotting.

Practical

1. Study of bacterial flora of skin by swab method.
2. Perform antibacterial sensitivity by agar cup method.
3. Determination of minimal inhibitory concentration (MIC) of an antibiotic.
4. Widal test
5. Blood grouping
6. Dot ELISA
7. Study symptoms of the diseases with the help of photographs: Polio, Candidiasis, Tetanus, Leishmaniasis.
8. Ouchterlony double diffusion technique.
9. Study of various stages of malarial parasite in RBC using photographs.

Reference Books

1. Ananthanarayan R and Paniker CKJ. Textbook of Microbiology. 7th Edition. University Press Publication. (2005).
2. Roitt I. Essential Immunology. 10th Ed. Blackwell Science.
3. Kuby. Immunology. 4th edition. W. H. Freeman & company.
4. Willey JM, Sherwood LM, and Woolverton CJ. (2013) Prescott, Harley and Klein's Microbiology. 9th edition. McGraw Hill Higher Education.

Course Name: Agriculture, Food and Dairy Microbiology
Course Code: BSCHMCBC502

Course Type: **C**	Course Details: **CC-12**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will clearly -*

1. *Develop a understanding of the multifarious roles of microorganisms in soil, in association with plants and thus in the field of agriculture.*
2. *Able to describe the role of microorganisms in the production of food, its spoilage, including their role in homemade fermented foods.*
3. *Able to identify the role of microorganisms in the causation of the diseases and how to protect against food-borne pathogens.*
4. *Develop experimental skills for testing the milk and different foods for the presence of microorganisms*

Course Content:

Theory

Unit – 1: Microbes and their importance in maintenance of soil fertility. Vermiform compost. Concept of Rhizosphere, Phyllosphere, Rhizoplane.

Unit-2: Intrinsic and extrinsic factors that affect growth and survival of microbes in foods, natural flora and source of contamination of foods in general. Spoilage of vegetables, fruits, meat, eggs, milk and butter, bread, canned Foods. Principles of food preservation: temperature, canning, drying, irradiation, microwave processing and aseptic packaging, chemical methods of food preservation: salt, sugar, organic acids, SO_2, citrates, benzoates, nitrite and nitrates etc.

Unit-3: Dairy starter cultures, fermented dairy products: yogurt, acidophilus milk, dahi and cheese, other fermented foods: dosa, sauerkraut, soy sauce and tampeh, Probiotics: Health benefits, types of microorganisms used, probiotic foods available in market. Utilization and disposal of dairy by-product – whey.

Unit-4: Food borne diseases (causative agents, foods involved, symptoms and preventive measures) - Food intoxications: *Clostridium botulinum*, *Vibrio cholerae* and mycotoxins; Food infections: *Escherichia coli*, Salmonellosis, Shigellosis and *Campylobacter jejuni*.

Unit-5: Food sanitation and control; HACCP, Indices of food sanitary quality and sanitizers. Cultural and rapid detection methods of food borne pathogens using predictive microbiology: SMAC, Rainbow Agar, CHROM agar, LAMP. Genetically modified foods, Nutraceuticals, Biosensors in food- ECL, FRET, Aptamer, Applications of microbial enzymes in dairy industry [Protease, Lipases].

Practical

1. MBRT of milk samples.
2. Alkalinephosphatase test to check the efficiency of pasteurization of milk.
3. Isolation of any food borne bacteria from food products and reporting of colony morphology and staining property.
5. Isolation of spoilage microorganisms from spoiled vegetables/ fruits and reporting of colony morphology and staining property.
6. Preparation of Yogurt/ Dahi.

Reference books

1. Fundamental Principles of Bacteriology (7th Edition). A. J. SALLE. McGraw-Hill Book Co. New York and London.
2. N S Subba Rao. Soil Microbiology. Oxford and IBH publishing Company 2009.
3. Prescott, M.J., Harley, J.P. and Klein, D.A. Microbiology. 5th Edition WCB McGrawHill, New York, (2002).
4. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
5. Medigan, M.T., Martinko, J. M. and Parker, J. Brock Biology of Microorganisms. Pearson Education Inc., New York.

Course Name: Biophysics, Biomathematics & Biostatistics
Course Code: BSCHMCBDSE501

Course Type: **DSE**	Course Details: **DSEC-1 or 2**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students clearly-*

1. *Understand the basic physical parameters of cells or biological processes and basic methods used to study these.*
2. *Have developed basic knowledge of mathematics as applied to biological phenomenon.*
3. *Have developed basic concepts of statistics and their importance*

Course Content:

Theory

Unit – 1: Diffusion and Brownian motion; Helix coil transition, Energetics and topology of Protein folding and DNA supercoiling, Principle of X-ray diffraction and its biological application.

Unit-2: Statistical methods: Applications and scope of statistics, Principles of statistical analysis of biological data. Sampling parameters. Difference between sample and population, Sampling errors, Censoring, difference between parametric and non-parametric statistics.

Unit-3: Measures of central tendency, Mean, Median and Mode; Measures of dispersion, standard deviation and variance; Skewness, kurtosis.

Unit-4: Probability; Discrete and continuous random variable, Concept of Normal Distribution and Curve fitting; Correlation and regression. Emphasis on examples from biological systems.

Unit-5: Concept of Sample size, Testing of hypothesis, Level of significance and degree of freedom; Large sample test based on normal distribution; Small sample test based on *t*-test, Z- test and F test; Confidence interval; Distribution-free test; Chi-square test; ANOVA.

Practical

1. Mean, Median, Mode from grouped and ungrouped Dataset
2. Standard Deviation and Coefficient of Variation
3. Correlation
4. Regression
5. Normal Distribution and finding area under the curve using normal probability
7. Testing of Hypothesis- *z*-test, *t*-test and *Chi*-Square-test

Reference Books

1. Wilson &Walker. Principles and Techniques in Practical Biochemistry. Cambridge University Press.
2. Chap T. Le and Lynn E. Eberly .Introductory Biostatistics 2nd Edition. Wiley
3. Introduction to Biostatistics by Pranab Kr Banerjee. S Chand Publication.
4. Statistical Methods (Vol 1 and 2) by N G Das. Tata McGraw-Hill Education India.

Course Name: Heredity and Evolution
Course Code: BSCHMCBDSE502

Course Type: **DSE**	Course Details: **DSEC-1 or 2**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students have -*

1. *Developed perception of evolution taking examples from well-studied models organisms of bacteria, fungi and other organisms.*
2. *Good understanding of concepts of Mendelian genetics and structural organizations of chromosomes.*
3. *Developed practical skills to do karyotyping and pedigree analysis*

Course Content:

Theory

Unit – 1: Historical developments; Model organisms in genetic analyses and experimentation: *Escherichia coli, Saccharomyces cerevisiae, Neurospora crassa, Drosophila melanogaster*. Mendel's Laws: Dominance, segregation, independent assortment, deviation from Mendelian inheritance, Chromosome theory of inheritance: Allele, multiple alleles, pseudoallele, complementation tests.

Unit-2: Extensions of Mendelian genetics: Allelic interactions, concept of dominance, recessiveness, Incomplete dominance and co-dominance, Multiple alleles, Epistasis, penetrance and expressivity. Linkage and recombination of genes, Cytological basis of crossing over, Crossing over at four-strand stage, Molecular mechanisms of crossing over, mapping.

Unit-3: Interaction of genes (Factor hypothesis) – Complementary gene, Inhibitory gene, Duplicate gene and lethal gene. Rules of extranuclear inheritance, Organelle heredity-Chloroplast mutations in *Chlamydomonas*, mitochondrial mutations in *Saccharomyces*, Maternal effects– Shell coiling in *Limnaea peregra*. Infectious heredity - Kappa particles in *Paramecium*.

Unit-4: Structural organization of chromosomes - centromeres, telomeres and repetitive DNA, Packaging DNA molecules into chromosomes, Concept of euchromatin and heterochromatin, Normal and abnormal karyotypes of human chromosomes, Chromosome banding, Giant chromosomes: Polytene and lampbrush chromosomes, Variations in chromosome structure: Deletion, duplication, inversion and translocation, Variation in chromosomal number and structural abnormalities- Klinefelter syndrome, Turner syndrome, Down syndrome.

Unit-5: Homologous and non-homologous recombination, including transposition, site-specific recombination. Basic definitions of Pedigree analysis, Polygenic inheritance.

Practical

1. Assessing Mendelian Principle using Chi square test
2. Demonstration of Barr Body
3. Demonstration of Karyotyping
4. Demonstration of Polytene chromosome

Reference Books

1. Gardner EJ, Simmons MJ, Snustad DP. Principles of Genetics. 8th Ed. Wiley-India
2. Snustad DP, Simmons MJ (2011). Principles of Genetics. 6th Ed. John Wiley and Sons Inc.
3. Weaver RF, Hedrick PW. Genetics. 3rd Ed. McGraw-Hill Education
5. Klug WS, Cummings MR, Spencer CA, Palladino M (2012). Concepts of Genetics. 10th Ed. Benjamin Cummings
6. Griffith AJF, Wessler SR, Lewontin RC, Carroll SB. (2007). Introduction to Genetic Analysis. 9th Ed. W.H. Freeman and Co., New York
7. Russell PJ. *i* Genetics - A Molecular Approach. Benjamin Cummings

Course Name: Microbial Biotechnology
Course Code: BSCHMCBDSE503

Course Type: **DSE**	Course Details: **DSEC-1 or 2**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students have -*

1. *Developed an understanding how microbiology is relevant to technological developments for agriculture and environment.*
2. *Developed an understanding how microbiology is relevant to technological developments for industries related to food and fermentations.*
3. *Developed an understanding how developments in recombinant DNA technology is juxtaposed with microbially-based technological developments for agriculture, industry and environment.*

Course Content:

Theory

Unit – 1: Microbial biotechnology: Scope and its applications in human therapeutics, agriculture (Biofertilizers, PGPR, *Mycorrhizae*), environmental and food technology. Genetically engineered microbes for industrial applications: Bacteria and yeast.

Unit – 2: Recombinant microbial production processes in pharmaceutical industries - Streptokinase, recombinant vaccines (Hepatitis B vaccine). Microbial polysaccharides and polyesters, Microbial production of bio-pesticides, bioplastics Microbial biosensors.

Unit-3: Microbial based transformation of steroids and sterols. Bio-catalytic processes and their industrial applications: Production of high fructose syrup and production of cocoa butter substitute.

Unit-4: Microbial product purification: filtration, ion exchange & affinity chromatography techniques. Immobilization methods and their application: Whole cell immobilization. RNAi and its applications in silencing genes, drug resistance, therapeutics, and host pathogen interactions.

Unit-5: Bio-ethanol and bio-diesel production: commercial production from lignocellulosic waste and algal biomass, Biogas production: Methane and hydrogen production using microbial culture. Microorganisms in bioremediation: Degradation of xenobiotics, mineral recovery, removal of heavy metals from aqueous effluents.

Practical

1. Study yeast cell immobilization in calcium alginate gels.
2. Study enzyme immobilization by sodium alginate method.

3. Production of curd and microbial examination of curd.
4. Alcohol production.

Reference Books

1. Richard H. Baltz. Julian E Davies and Arnold L. Demain Manual of Industrial Microbiology and Biotechnology. 3rd edition, ASM Press (2010).
2. Daniel Forciniti. Industrial Bioseperation: Principles andpractice. 1st edition, Wiley-Blackwell (2008).
3. Reed. G. Prescott and Dunn's Industrial Microbiology. CBS Publishers. (1999).
4. Demain, A. L. Industrial Microbiology and Biotechnology. 2nd Edition. (2001).
5. EL Mansi. E.M.T., Fermentation Microbiology and Biotechnology. 2nd Edition, CRC Taylor & Francis (2007).
6. Waites, M.J., Morgan, N.L., Rockey, J.S. and Higton, G. Industrial Microbiology: An introduction. Blackwell Science Publishers (2002).

Semester-VI

Course Name: Advanced Microbiology
Course Code: BSCHMCBC601

Course Type: **C**	Course Details: **CC-13**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will –*

1. *Explain salient characteristics of genomes of representative microorganisms.*
2. *Understood the concept and importance of metagenomics.*
3. *Develop an initial understanding of recent developments of host-microbe interactions, synthetic biology, viable but non-culturable forms of microorganism etc.*
4. *Able to extract DNA from bacteria / soil and perform PCR for 16s Ribosomal genes using universal primers and interpret the results.*

Course Content:

Theory

Unit – 1: Evolution of Microbial Genomes**:** Salient features of sequenced microbial genomes, core genome pool, flexible genome pool and concept of pan genome. Evolution of bacterial virulence - Genomic islands, Pathogenicity islands (PAI) and their characteristics.

Unit - 2: Metagenomics: Brief history and development of metagenomics, Understanding bacterial diversity using metagenomics approach. Basic knowledge of viral metagenome, metatranscriptomics, metaproteomics and metabolomics.

Unit - 3: Molecular Basis of Host-Microbe Interaction: Basic concept on Epiphytic fitness in plant pathogens, Hypersensitive response (HR) to plant pathogens, Type three secretion systems (TTSS) of plant and animal pathogens, Biofilms: types of microorganisms, molecular aspects and significance in environment, health care, virulence and antimicrobial resistance.

Unit - 4: Systems and Synthetic Biology: Networking in biological systems, Quorum sensing in bacteria, Basics of synthesis of poliovirus in laboratory, Future implications of synthetic biology with respect to bacteria and viruses.

Unit - 5: Microbiomes and its importance, VBNC (viable but not culturable bacteria). Genetically modified organisms and their uses. Modern methods of rapid identification of microbes (PCR, mass spectrometry, fluorescence based techniques). CRISPR-Cas system.

Practical

1. Extraction of metagenomics DNA from soil and its estimation.
2. Virtual demonstration of PCR amplification of metagenomics DNA using universal 16s ribosomal gene primers.

Reference Books

1. Benjamin Lewin, Gene VII, Oxford University Press.
2. Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter, Molecular biology of the Cell, 4th Edition. Garland publishing Inc, (2002).
3. Darnell, Lodish and Baltimore, Molecular Cell Biology, Scientific American Publishing Inc.
4. Watson. J.D, Baker. T.A, Bell. S.P, Gann. A. Levine .M. Losick. R, Molecular Biology of Gene, 5th Edition. The Benjamin/ Cummings Pub. Co. Inc (2003).
5. David Frifielder, Stanely R. Maloy, Molecular biology and Microbial genetics. 2nd Edition, Jones and Barlett Publishers.
6. Brown T.A., Gene Cloning and DNA analysis. 2nd Edition, ASM press. (2004).
7. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
8. Glick BR and Pasternak JJ, Molecular Biotechnology, 2nd Ed. ASM press. (2003).
9. Uldis N.Streips, Ronald E. Yasbin. Modern Microbial Genetics.2nd Edition Wiley-Liss, Inc. (2002).
10. Russel P J, Essential genetics, Blackwell Science Inc, 2 sub edition.

Course Name: Recombinant DNA Technology
Course Code: BSCHMCBC602

Course Type: **C**	Course Details: **CC-14**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students will -*

1. Acquire a fairly good knowledge of the tools and the methods for genetic engineering.
2. Acquire a fairly good understanding of how these tools and methods are employed in the laboratory for manipulation of DNA so as to make it relevant for biotechnological uses.
3. Be able to perform isolation of DNA, amplification of any gene by PCR and its analysis by gel electrophoresis.

Course Content:

Theory

Unit – 1: Introduction to genetic engineering: Milestones in genetic engineering and biotechnology. Restriction modification systems: Mode of action, applications of Type II restriction enzymes in genetic engineering. DNA modifying enzymes and their applications: DNA polymerases, Terminal deoxynucleotidyl transferase, kinases and phosphatases, and DNA ligases.

Unit-2: Cloning: Use of linkers and adaptors: Transformation of DNA: Chemical method, Electroporation. Methods of DNA, RNA and Protein analysis: Agarose gel electrophoresis, Southern - and Northern - blotting techniques, dot blot, DNA microarray analysis, SDS-PAGE, and Western blotting.

Unit-3: Cloning Vectors: Definition and Properties Plasmid vectors: pBR and pUC series, Bacteriophage lambda and M13 based vectors, Ti vector, Cosmids, BACs, YACs Expression vectors: *E.coli* lac and T7 promoter-based vectors, yeast YIp, YEp and YCp vectors, Baculovirus based vectors, mammalian SV40-based expression vectors.

Unit-4: DNA Amplification and DNA sequencing: PCR: Basics of PCR, RT-PCR, Real-Time PCR, Genomic and cDNA libraries: Preparation and uses, Genome sequencing Sanger's method of DNA sequencing: traditional and automated sequencing, NGS.

Unit-5: Application of Genetic Engineering and Biotechnology**:** Gene delivery: Microinjection, electroporation, biolistic method (gene gun), liposome and viral- mediated delivery, *Agrobacterium* - mediated delivery. Products of recombinant DNA technology: Products of human therapeutic interest - insulin, hGH, antisense molecules. *Bt* transgenic - cotton, brinjal, flavosavo tomato, Gene therapy, recombinant vaccine, protein engineering.

Practical

1. Isolation of plasmid DNA from *E. coli*.
2. Study different conformations of plasmid DNA through agarose gel electrophoresis.
3. Software based demonstration for Designing of primers.
4. Demonstration of Amplification of DNA by PCR.

Reference Books

1. Benjamin Lewin, Gene VII, Oxford University Press.
2. Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter, Molecular biology of the Cell, 4th Edition. Garland publishing Inc, (2002).
3. Darnell, Lodish and Baltimore, Molecular Cell Biology, Scientific American Publishing Inc.
4. Watson. J.D, Baker. T.A, Bell. S.P, Gann. A. Levine. M. Losick. R, Molecular Biology of Gene, 5th Edition. The Benjamin/ Cummings Pub. Co. Inc (2003).
5. David Frifielder, Stanely R. Maloy, Molecular biology and Microbial genetics. 2nd Edition, Jones and Barlett Publishers.
6. Brown T.A., Gene Cloning and DNA analysis. 2nd Edition, ASM press. (2004).

7. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
8. Glick BR and Pasternak JJ, Molecular Biotechnology, 2nd Ed. ASM press. (2003).
9. Uldis N. Streips, Ronald E. Yasbin. Modern Microbial Genetics.2nd Edition Wiley-Liss, Inc. (2002).
10. Russel P J, Essential genetics, Blackwell Science Inc, 2 sub edition.

Course Name: Project Work on Microbiology of Societal Importance
Course Code: BSCHMCBDSE601

Course Type: **DSE**	Course Details: **DSEC-3 or 4**			L-T-P: **0 - 0 - 12**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		60		40	

Course Learning Outcomes: *By the conclusion of this course, the students-*

1. Developed skills to design small project.

2.Should develop the habit of teamwork and perform experiments related to the project.

3. Developed basic skills for data retrieval, representation, analysis and interpretation.

Guidelines:

1. A short term project should be done guided by the dept. of microbiology of the college from where the student registered.
2. If required the faculty may collaborate with faculties of microbiology dept of colleges under Kazi Nazrul University through principals of the collaborating institutes.
3. Duration of lab work must be restricted within the time span of the corresponding semester.
4. Each project may be divided within groups of students
5. Project has to be planned depending on the available facility otherwise HOD may request Principals of the respective college for the procurement of chemicals, financial assistance and instruments if it is essential.
6. At the end of the seminar each student must submit project report along with other practical of the corresponding semester

Course Name: Basic Computer and Bioinformatics
Course Code: BSCHMCBDSE602

Course Type: **DSE**	Course Details: **DSEC-3 or 4**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the conclusion of this course, the students-*

1. Developed skills to use computers for analysis of biological data.

2. Skill to use important biological databases, use tools to retrieve data, and compare the data of the biological macromolecules

3. Developed basic skills for data retrieval, representation, analysis and interpretation

Course Content:

Theory

Unit – 1: Computer fundamentals: Basic concept of computer organization, generations of computer, hardware, software, basics of operating systems (windows), Classification of computers and computer languages. Internet & Web: MS office and internet introduction, importance, requirements of internet, search engines, webpages.

Unit-2: RDBMS - Definition of relational database; Biological databases - nucleic acid, genome, protein sequence and structure, gene expression databases, Database of metabolic pathways, Mode of data storage – File formats - FASTA, Genbank and Uniprot, Data submission & retrieval from NCBI, EMBL, DDBJ, Uniprot, PDB.

Unit-3: Local and global sequence alignment, pairwise and multiple sequence alignment. Scoring an alignment, scoring matrices, PAM & BLOSUM series of matrices. Types of phylogenetic trees, Different approaches of phylogenetic tree construction - UPGMA, Neighbor joining, Maximum Parsimony, Maximum likelihood.

Unit-4: Diversity of Genomes: Viral, prokaryotic & eukaryotic genomes; Genome, transcriptome, proteome; 2-D gel electrophoresis, MALDI TOF spectroscopy; Major features of completed genomes of *E. coli*, *S. cerevisiae*, and *Arabidopsis*.

Unit-5: Hierarchy of protein structures, modeling structural classes; Motifs, Folds and Domains. Protein structure prediction in presence and absence of structure template Energy minimizations and evaluation by Ramachandran plot. Protein structure and rational drug design.

Practical

1. Introduction to operating systems - Windows
2. Introduction to bioinformatics databases: NCBI/PDB/DDBJ, Uniprot, PDB.
3. Sequence retrieval using BLAST

4. Sequence alignment & phylogenetic analysis using clustal W & phylip
5. Picking out a given gene from genomes using Genscan (promoter region identification, repeat in genome, ORF prediction). Gene finding tools (Glimmer), Primer designing.
6. Protein structure prediction: primary structure analysis, secondary structure prediction using psi-pred, homology modeling using Swiss model. Molecular visualization using jmol, Protein structure model evaluation (PROCHECK).

Reference Books

1. Mount D., Bioinformatics: Sequence and Genome Analysis. Cold Spring Harbor Laboratory Press, New York. (2004).
2. Baxevanis, A.D. and Francis Ouellellette, B.F., Bioinformatics- A Practical Guide to the Analysis of Genes and Proteins. Wiley India Pvt Ltd. (2009).
3. Teresa K. Attwood, David J. Parry-Smith, Introduction to Bioinformatics. Pearson Education. (1999).
4. Jean-michel Claverie Cedric Notredame. Bioinformatics for Dummies. Publisher: Dummies (2007).
5. Arthur M. Lesk. Introduction to bioinformatics. Oxford University Press.(2004)
6. Dan E. Krane and Michael L. Raymer. Fundamental Concepts of Bioinformatics (2002).
7. KRANE. Fundamental Concepts of Bioinformatics, (2003).
8. Teresa Attwood. Introduction to Bioinformatics. (2007).

Course Name: Mycology and Phycology
Course Code: BSCHMCBDSE603

Course Type: **DSE**	Course Details: **DSEC-3 or 4**			L-T-P: **4 - 0 - 4**	
Credit: **6**	Full Marks: 100	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	10	20	40

Course Learning Outcomes: *By the completion of this course the students able to-*

1. Describe useful and harmful activities of fungi and algae.
2. Identify commonly available fungi and algae and their characteristics.
3. Discuss how fungi and algae are used as biofertilizers in agriculture and as biopesticides.
4. Grow mushroom in the laboratory.

Course Content:

Theory

Unit – 1: Characteristics, classification and cellular & thallus organization of fungi. General features, structure, nutrition, reproduction of different fungi group - *Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes*. Heterothallism and Para-sexuality.

Unit-2: General features, taxonomic status and evolutionary significance economic importance of important fungal genera - *Mucor, Saccharomyces, Penicillium, Neurospora, Agaricus, Alternaria*. General account and importance of lichen. Important plant diseases caused by fungi- symptoms, disease cycles and control (Late & Early blight, Black rust and Red rot).

Unit-3: Role of fungi in biotechnology, Application of fungi in food industry (Flavor & texture, Fermentation, Baking, Organic acids, Enzymes, Myco -proteins); Secondary metabolites (Pharmaceutical preparations); Agriculture (Biofertilizers); Mycotoxins; Biological control (*Mycofungicides, Mycoherbicides, Mycoinsecticides*). Mushroom and its cultivation.

Unit-4: General characteristics and evolution of algae. Occurrence, thallus organization, algae cell ultra-structure, pigments, flagella, eye- spot food reserves and vegetative, asexual and sexual reproduction. Classification of algae.

Unit-5: General features, structure and reproduction and economic importance of *Chlamydomonas, Chlorella, Diatoms, Oscillatoria, Spirulina, Anabaena, Nostoc*. Mass cultivation of algae as a source of protein.

Practical

1. Preparation of Potato Dextrose Medium.
2. Isolation of fungi from natural sources
3. Study of the vegetative and reproductive structures through temporary or permanent slides: *Mucor, Saccharomyces, Penicillium, Agaricus* and *Alternaria*.

Reference Books

1. Alexopoulus, C.J., Mims, C.W. and Blackwel, M, Introductory Mycology. John Wiley, New York.
2. Mehrotra, R.S. and K.R. Aneja, An Introduction to Mycology. New Age International Press, New Delhi.
3. Webster, J. Introduction to fungi. Cambridge University Press. Cambridge, U.K.
4. Jhon Webster and R W S Weber. Introduction to Fungi. Cambridge University Press 2007.
5. Pelczar Jr MJ, Chan ECS, and Krieg NR. (2004). Microbiology. 5th edition Tata McGraw Hill.