Learning Outcomes based Curriculum Framework (LOCF) for M.Sc. Microbiology

New Education Policy-2020

CHOICE BASED CREDIT SYSTEM COURSE
(CBCS- 2021 COURSE)

DEPARTMENT OF MICROBIOLOGY
SCHOOL OF INTERDISCIPLINARY AND APPLIED SCIENCES
CENTRAL UNIVERSITY OF HARYANA

Table of Contents

1. Background

1.1 Introduction to the Microbiology and the Department

The M.Sc. Microbiology programme provides a platform to inculcate the basic understanding of microbes and to develop skills related to different areas of Microbiology. Microbiology is a core subject of life sciences and is required as a platform course in all the areas of biological sciences. Public private sector entities look for skilled microbiology workforce preferably at post graduate level. Keeping that in mind this M.Sc. Microbiology scheme and syllabi is designed to provide thorough and updated knowledge of the subject, to enable easy entry for the students in public private sector workforce and to prepare researchers for carrying out research in cutting edge areas of Microbiology. In this course there are practicals in each semester to train the students with hands on laboratory skills. One core course on seminar presentation has been added which will help in developing public speaking skills and critical thinking in the students. For hands on training in different core areas of Microbiology, there is one full semester dissertation work in this programme. In the dissertation work student is given a research problem and experimental path seeking the solution to the selected problem. Student will be collecting data, analyse it and present it both orally and in writing. All these rigorous paths will produce a skilled human resource for the changing societal need.

The Department of Microbiology was established in June 2015 with the vision of bridging the gap between classical microbiology and applied aspects of microbiology with research on infectious diseases, Immunology, Food and agriculture, biofuels and bioenergy. The main objective of the Department is to impart quality education in the field of Microbiology and to create trained microbiologist to contribute to the fields of food production, pharmaceuticals, agrochemicals, environment, agriculture and public health research. The Department of Microbiology aims at using Microbial research as a tool for the benefit of mankind.

The Department offers M.Sc and Ph.D. program in Microbiology where the students are working in the areas of Immunology, Medical Microbiology, Molecular Biology, Food Microbiology Environmental Microbiology Soil & Agricultural Microbiology and Industrial Microbiology. The department also organizes various workshops, seminar, guest lectures in subject specific domains to enrich our students with recent developments in the field of Microbiology.

Research in the department seeks to meet challenges and provide information to us to eliminate pathogens, prevent newly emerging infectious diseases, and sustainable solutions of agricultural and environmental issues. The faculty members of the department are trained and have research expertise in different field of microbiology and are engaged in several research projects funded by various organizations such as UGC, DBT, DST, AISTDF and industry. The vision of our department is to become an internationally renowned and ideal department through highest teaching standards and performing quality research. The department houses several pieces of high end equipments. More than 100 papers have been published by the faculty of the Department in journals of National and International repute.

1.2 Introduction to the programme

The **M.Sc. Microbiology Programme** offered by Central University of Haryana is of two years duration and is divided into four semesters. The various courses of the programme are designed to include lectures, laboratory work, project training, viva, seminars, assignments and field trips. At the end of the programme, the student will be well-versed in basic as well as the advanced microbiology techniques and will gain hands-on experience in microbiology, including fermentation technology and molecular biology techniques.

Four categories of courses will be offered:

Core Courses: Include theoretical as well as practical courses

Elective courses: Include theoretical as well as practical Department specific courses, Student must opt for two out of four courses offered by the Department)

Open Elective: in 1st and 3rd semester student may opt for any one open elective offered by other departments of the university/ through swayam portal.

Skill Enhancement Elective Course: A separate project training-based course that leads to a dissertation worth twenty credits is also one of the Core Courses

The courses have also been designed in terms of skill enhancement in the students such as Industrial Microbiology, Biostatistics and Bioinformatics, Food and Dairy Microbiology, Advanced analytical techniques.

A student is required to accumulate a total of 100 credits to fulfill the requirements for a Master of Science degree in Microbiology.

1.3 Vision of the Department

The Department serves to be in the frontline of the field of Microbiology, aiming to be recognized as amongst the best for education and research in Microbiology.

1.4 Mission of the Department

- To equip the young minds with fundamental & applied knowledge in Microbiology
- To promoting all round personality development through multi-dimensional education
- To produce skilled human resource who can choose research areas or professional career as Microbiologists in industries and institutes.

2. PROGRAMME EDUCATIONAL OBJECTIVES (PEOS)

PEO-1 To inculcate scientific knowledge and professional ethics for the overall development of students

PEO-2 To equip the students with advanced microbiological analytical skills

PEO-3 To impart the students with entrepreneurial skills in microbiology to make them ready to contribute to society as responsible individuals

3. PROGRAMME OUTCOMES (PO):

- **Basic and applied knowledge:** Interdisciplinary knowledge to find solution for the complex biological problems
- **Problem analysis:** Ability to analyse society related/ applied research problem, design and execute experiments to find relevant solutions
- **Advanced Usage of Technology**: Apply advanced instrumentation tools, online resources with an understanding of the troubleshooting and limitations
- **Ethics:** Commitment towards professional ethics and responsibilities as a social endeavor to bring harmony with nature
- **Lifelong learning:** Scientific skills for industrial applications and entrepreneurship

4. PROGRAMME SPECIFIC OUTCOMES (PSOS)

PSO-1 Comprehensive theoretical and advanced knowledge on importance of microbes in diverse sphere of life

PSO-2: Familiarized with advanced tools and techniques of microbiological sciences.

PSO-3: Capacity to develop, employ and integrate technical and professional skills as a member of team withholding the essence of collaboration, cooperation and integrity

PSO-4 Entrepreneurial skill development through critical analysis of problems and hands on training for providing their sustainable solutions

PSO-5 Analysis of scientific or societal issues across the spectrum of related discipline.

PSO-6 Ability to upgrade knowledge independently and act upon means of improvement for life long learning.

PSO-7 Uphold the responsibility as a global citizen maintaining professional and ethical values

5. About Post Graduate attributes

The Masters course is designed to develop the current skills and abilities in the students in basic as well as advanced areas of Microbiology. A special emphasis is laid on the practical aspects of different areas of Microbiology as well as skill development. A course on Scientific communication skill development and seminar presentations will enhance of communication skills, socialistic approach and leadership qualities in the students. The course will provide highly skilled and knowledgeable manpower for different industrial sectors such as agriculture, food and dairy, medical and paramedical field as well as pursuing higher studies in reputed research institutes. A major component of the course is a skill enhancement elective course comprising complete semester for a research project. The student is guided throughout the semester for executing experiments related to a research problem and presenting the results in the form of an oral presentation as well as a thesis. The research work is evaluated through oral presentation alongwith a viva-voce. This activity will foster self-confidence and self-reliance in the student as he/she learns to work and think independently.

6. Structure of Master Course

6.1 Credit Summary Total Credits: 100

Semester	Credits				Total credits
	Core courses	Skill enhancement course	Elective courses		
			DCEC (Department specific elective)	GEC (Open Elective For other Department students)	
I	21	-	-	4	**25**
II	23	-	4	-	**27**
III	21	-	4	4	**29**
IV	3	16	-	-	**19**
Total	**68**	**16**	**8**	**8**	**100**

Credit distribution:

Core Theory courses: 68%
Core Practical/ Skill oriented courses: 30%
Multidisciplinary integrated courses: 17%

Semester wise Course Curriculum and Credit distribution Total credits: 100

Semester-I (Total credits - 25)

Course code	Course title	L	T	P	Type of course	Credit
SIAS MB 1 1 01 C 3003	Cell and Molecular Biology	3	0	0	Core	3
SIAS MB 1 1 02 C 3003	Principles of Biochemistry	3	0	0	Core	3
SIAS MB 1 1 03 C 3003	Essentials of Microbiology	3	0	0	Core	3
SIAS MB 1 1 04 C 4004	Microbial Diversity	4	0	0	Core	4
SIAS MB 1 1 05 C 3003	Virology	3	0	0	Core	3
SIAS MB 1 1 06 C 00105	**Practical-I**	0	0	10	Core	5
	Generic Elective Course (to be opted from other Department)	4	0	0	GEC	4

Semester-II (Total credits - 27)

Course code	Course title	L	T	P	Type of course	Credit
SIAS MB 1 2 01 C 4004	Advanced Analytical Techniques	4	0	0	Core	4
SIAS MB 1 2 02 C 4004	Microbial Genetics	4	0	0	Core	4
SIAS MB 1 2 03 C 2002	Biosafety, Bioethics and IPR	2	0	0	Core	2
SIAS MB 1 2 04 C 4004	Microbial Physiology and Metabolism	4	0	0	Core	4
SIAS MB 1 2 05 C 4004	Food and Dairy Microbiology	4	0	0	Core	4
SIAS MB 1 2 06 C 00105	Practical-II	0	0	10	Core	5

SIAS MB 1 2 01 DCEC 4004	Soil and Agriculture Microbiology[#]	4	0	0	DCEC	4
SIAS MB 1 2 02 DCEC 4004	Environmental Microbiology[#]	4	0	0	DCEC	4
SIAS MB 1 2 03 DCEC 4004	The Microbiome[#]	4	0	0	DCEC	4

*One of the courses will be opted by the student.

Semester-III (Total credits – 29)

Course Code	Course Title	L	T	P	Type of Course	Credit
SIAS MB 1 3 01 C 3003	Biostatistics and Bioinformatics	3	0	0	Core	3
SIAS MB 1 3 02 C 4004	Microbial Genomics, Proteomics and Metabolomics	4	0	0	Core	4
SIAS MB 1 3 03 C 4004	Industrial Microbiology	4	0	0	Core	4
SIAS MB 1 3 04 C 4004	Medical Microbiology and Immunology	4	0	0	Core	4
SIAS MB 1 3 05 C 0084	Practical-III	0	0	8	Core	4
SIAL MB 1 3 06 C 0202	Seminar	0	2	0	Core	2
SIAS MB 1 3 04 DCEC 4004	Biofertilizer and Compost Technology	4	0	0	DCEC	4
SIAS MB 1 3 05 DCEC 4004	Plant Pathology[#]	4	0	0	DCEC	4
SIAS MB 1 3 06 DCEC 4004	Biofuels and Bioenergy[#]	4	0	0	DCEC	4
	Generic Elective Course (to be opted from other Department)	4	0	0	GEC	4

[#]One of the course will be opted by the student**.**

Semester-IV (Total credits - 19)

Skill Enhancement Course

Course Code	Course Title	Type of Course	Credit
SIAS MB 1 4 01 C 3003	Research Methodology and Scientific Communication skills (online)	Core	3
SIAS MB 1 4 01 SEEC 0016	Dissertation	Core	16
	Total credits of the Program		**100**

Generic Elective Course (GEC): Offered by Department of Microbiology to students from other Departments of University.

Semester	Core/ Elective	Paper Code	Title of the Paper	Credit
I	GEC	SIAS MB 1 1 01 GEC 4004	Techniques in Microbiology	4
III	GEC	SIAS MB 1 3 03 GEC 4004	Applied Microbiology	4
	GEC	SIAS MB 1 3 04 GEC 4004	Microbes and Diseases	

SEMESTER-I

Course title: Cell and Molecular Biology **Credit: 3**
Course code: SIAS MB 1 1 01 C 3003 **Lectures: 45**

Course objectives:

- Detailed knowledge on fine structure and function of the cell.
- Familiarity with molecular biology pathways as cellular processes

Course Learning outcomes

- Understanding the organization of cell.
- Understanding the mechanisms of cell-to-cell communication.
- Knowledge on structure and function of DNA as genetic material.
- Molecular basis of genetic information and function

Unit-I

Archea, prokaryotic and eukaryotic cell (animal and plant cells); Theory of origin of eukaryotic cells; Structure and function of nucleus - nuclear envelope, nuclear pore complex; Nuclear protein-import and export, regulation of nuclear protein import and export; Organization of golgi, lysosome, structure and functions of ER, lysosome, mitochondria, chloroplasts and peroxisomes; Fluid mosaic model, membrane proteins, membrane lipids and membrane fluidity; Transport across cell membrane, passive transport, active transport-primary (P-type, F-type, V-type ATPases, ABC transporters), co-transport-symport and antiport; Ion channels, aquaporins, pinocytosis and phagocytosis; Cells as experimental models.

Unit-II

Introduction to cytoskeletal proteins; Organization of cytoskeletal protein and smooth muscle and skeletal muscles, movement of vesicles-role of actin and myosin; Structure of cilia and flagella; Prokaryotic and eukaryotic cell wall, cell matrix proteins; Cell-matrix interactions and cell-cell interactions; Adherence junctions, tight junctions, gap junctions, desmosomes, hemi-desmosomes, focal adhesions and plasmodesmata; Signalling molecules, receptors and their functions – G protein coupled receptors- Cyclic-AMP, Cyclic-GMP, IP3, Calcium, Receptor tyrosine kinases - EGF, insulin.

Unit-III

DNA as genetic material, forms of DNA; structure of various type of DNA; chromatin structure; super coiling; polytene and lamp brush chromosomes; properties of DNA in solution; denaturation and renaturation; reassociation reactions; COT curves; types of RNAs and their structures; role of RNA; Unusual bases in RNA; central dogma of molecular biology; DNA polymerases and other enzymes involved in replication; mutagenesis.

Unit-IV

Prokaryotic and eukaryotic gene structure: transcription-RNA polymerase, inhibitors of transcription; proof reading function and fidelity of DNA replication; possible modes of DNA

replication; theta model and rolling circle model of DNA replication; replication of DNA in eukaryotes; role of methylation; replication of viral RNA; reverse transcriptase, regulatory region and transcriptional unit of gene; post transcriptional processing of RNA: splicing, cap addition and polyadenylation, polynucleotide phosphorylase.

Suggested readings:

1. Cooper, GM, (2018) The Cell: A Molecular Approach 8th ed., Sinauer Associates is an imprint of Oxford University Press, ISBN: 1605357073.
2. Lodish H, Berk A, Zipursky SL, Matsudaira P, Baltimore D and Darnell J, WH (2016) Molecular Cell Biology 8th ed., Freeman & Company (New York), ISBN: 978-1-4641-0981-2 / ISBN:10: 1464183392.
3. Alberts B, Johnson A. Lewis J and Enlarge M (2008) Molecular Biology of the Cell 6th ed., Garland Science (Princeton), ISBN: 0-8153-1619-4 / ISBN:0-8153-1620-8.
4. Nelson DL, Cox MM, (2017) 7th ed., Lehninger Principles of Biochemistry. W.H. Freeman and Company, New York, USA. ISBN-10: 1-4641-2611-9.
5. Stryer L, Berg JM, Tymoczko JL, Gatto, Jr. GJ (2019) Biochemistry 9th ed., W.H. Freeman and Company, New York, USA. ISBN-10: 1-319-11467-9
6. Lewin B, Krebs J, Kilpatrick ST, Goldstein ES, (2017) Genes XII 12th Revised ed., Jones and Bartlett Publishers, Inc. Sudbury, Massachusetts, USA. ISBN No. 9781284104493.
7. Watson JD, Baker TA, Bell SP, Gann A, M, Levin RL and Cumming B (2013) Molecular Biology of the Gene 7th ed., San Francisco, ISBN: 0321905377.

SEMESTER-I

Course title: Principles of Biochemistry **Credit: 3**
Course code: SIAS MB 1 1 02 C 3003 **Lectures: 45**

Course Objectives

- To provide students with an understanding of biomolecules, the basic building blocks of living organisms
- To impart knowledge on metabolic and synthetic pathways of major biomolecules.

Course Learning Outcomes:

- Acquainted with chemical and molecular structures of biomolecules
- Able to determine the significance, role of biomolecules
- Able to determine the metabolic pathways in synthesis of biomolecules

Unit-I

Monosaccharides-structure of aldoses and ketoses, ring structure of sugars, conformations of sugars, mutarotation, anomers, epimers and enantiomers. Disaccharides: maltose, lactose and sucrose. Polysaccharides: homo and hetero-polysaccharides, structural and storage polysaccharides. Glycolysis - a universal pathway, reactions of glycolysis, production of acetyl CoA, reactions of citric acid cycle. Gluconeogenesis, glycogenesis and glycogenolysis.

Unit-II

Building blocks of lipids - fatty acids, glycerol, ceramide. Storage lipids - triacyl glycerol and waxes. Structural lipids in membranes-phospholipids, glycerophospholipids, galactolipids, sulpholipids, sphingolipids and sterols. β-oxidation of fatty acids. Fatty acid synthase complex. Synthesis of fatty acids.

Unit-III

Amino acids and peptides- classification (essential and non-essential amino acids), chemical reactions and physical properties. Introduction to protein structure and function. Enzymes: classification, kinetics (significance of k_m, k_{cat} and V_{max}), inhibition; amino acid metabolism-amino acid deamination and transamination, urea cycle. Synthesis and utilization of ketone bodies. Biosynthesis and breakdown of nutritionally non-essential amino acids. Synthesis of other amino acid derivatives such as neurotransmitters.

Unit-IV

Nucleotides - structure and properties. Nucleic acid structure-Watson - Crick Model of DNA. Structure of major species of RNA - mRNA, tRNA and rRNA. De novo synthesis of purine and pyrimidine nucleotides. Catabolism of purine and pyrimidine. Disorders of purine and pyrimidine metabolism.

Suggested readings:

1. Nelson, DL and Cox, MM (2017) Lehninger: Principles of Biochemistry 7th ed., WH Freeman and Company (New York), ISBN: 978-1319108243.
2. Garrett RH and Grisham CM (2017) Biochemistry 6th ed., , Brooks/Cole, ISBN: 9781305577206.
3. Rodwell VW, Bender DA, Botham KM, Kennelly, PJ and Weil PA (2018) Harper's Illustrated Biochemistry 7th ed., McGraw-Hill, ISBN: 9781259837937.
4. Ferrier, DR (2017) Lippincott's Illustrated Reviews Biochemistry 7th ed., Wolters Kluwer India Pvt. Ltd., ISBN: 978-9351297949.
5. Stryer L, Berg JM, Tymoczko JL, Gatto Jr. GJ (2019) Biochemistry 9th ed., W.H. Freeman and Company, New York, USA. ISBN-10: 1-319-11467-9.

SEMESTER-I

Course title: Essentials of Microbiology **Credit: 3**
Course code: SIAS MB 1 1 03 C 3003 **Lecture: 45**

Course objectives:

- To impart knowledge of historical discoveries in domain of Microbiology
- To make students familiar with organization of cellular components and their functions

Course Learning outcomes:

- Demonstrate the practical skills in basic microbiological techniques
- Designate the role of microorganisms in different ecosystems

- Retrieve and use contemporary information on different microbial groups

Unit-I

History and scope of Microbiology in 20th century; The spontaneous generation controversy; Germ theory of disease; Methods in microbiology: Preparation of microbiological media, Physical and chemical methods of sterilization; Pure culture techniques, maintenance and preservation of microbial cultures.

Unit-II

Bacterial Classification - Basis of bacterial classification and Archaea according to the Bergey's Manual of Systematic Bacteriology, Haeckel's three kingdom concept, Whittaker's five kingdom concept, three domain concept of Carl Woese, conventional, molecular and recent approaches to polyphasic bacterial taxonomy; evolutionary chronometers.

Unit-III

Organization of Bacterial Cell : Gram-positive and Gram-negative bacteria; Extracellular appendages: flagella- arrangement, basic structure and locomotive function; pili- different types, their distribution among bacteria & related functions; fimbriae- occurrence, function and features distinguishing pili and fimbriae; glycocalyx- composition and role in bacteria; and capsule-microcapsule and slime, General characteristics of archaea; differences between eubacteria and archaebacteria. key features of model archaeal organisms: Halobacterium; Pyrococcus; Sulfolobus; and Methanococcus.

Unit-IV

Bacterial Quorum sensing and role of biofilms and quorum sensing in microbial pathogenicity. Antimicrobial resistance, Methodologies for testing of antimicrobial activity (broth-dilution methods and agar diffusion methods), Introduction to two component system and its role in regulation of virulence determinants. horizontal gene transfer (HGT) and pathogenicity islands (PAI).

Suggested readings:

1. Tauro P, Kapoor KK, Yadav KS, and Sequeira MG (2019) An Introduction to Microbiology 3rded., New Age International Publishers. ISBN: 0852268785.
2. Madigan MT, Martinko JM, Bender KS, Buckley DH, Stahl DA (2018) Brock Biology of Microorganisms, 15thed., Pearson Education, ISBN 9781292235103.
3. Sherwood LM, Woolverton C.J (2017) Prescott's Microbiology, 10th ed., McGraw-Hill Education. ISBN 9781259281594.
4. Dubey, R.C. and Maheswari, D.K (2013) A text book of Microbiology 3rd ed.. Revised S. Chand and Company Ltd, New Delhi. ISBN: 9788121926201.
5. Pelczar Jr. M (2001) Microbiology 5th ed., McGraw Hill Education ISBN: 9780074623206.

SEMESTER-I

Course title: Microbial Diversity **Credit: 4**
Course code: SIAS MB 1 1 04 C 4004 **Lectures: 60**

Course objectives:

- To impart through knowledge on different groups of microorganisms
- To make students aware of significance of each group

Course Learning outcomes:

- Understanding the diversity of microbial world and their implications
- Understanding the basic structure, classification and importance of different microbial groups.
- Understanding of other microbial groups
- Understanding the characteristics and significances of different microbial groups

Unit-I

Morphology and fine structure of Bacteria: Morphological types – size, shape and arrangements; cell walls of archaea, Gram negative, Gram positive eubacteria. Structure and function of cell appendages and inclusions: capsule types, composition and function; flagella, fimbrae, pili, cilia, gas vesicles, chromosomes, carboxysomes, magnetosomes, phycobillisomes, nucleoid, plasmids (types of plasmids and function); Bacterial spores. Photosynthetic bacteria and cyanobacteria.

Unit-II

Introduction of algae: Occurrence and distribution, thallus structure, characteristics, nutrition, classification and reproduction. cell structure, pigmentation, thallus organization, nutrition, reproduction, alternation of generations. Algae as pollution indicators and eutrophication agent.

Unit-III

Introduction of fungi: Occurrence and distribution, somatic structure, hyphal growth, nutrition, heterothallism, fungi and ecosystem; saprophytic parasitic, mutualistic and symbiotic relationship with plants and animals. Classification of fungi. Reproduction in fungi: asexual, sexual and parasexual. Economic importance and applications of fungi. Symbiotic associations of algae with fungi.

Unit-IV

Introduction of protozoa: Protozoan general characteristics and classification based on flagellate or mastigophora, rhizopoda, ciliophora, and sporozoa; detailed study of euglena, monocystis, entameoba, paramecium and trypanosoma; role of protozoan in environment and health implication.

Suggested readings:

1. Tauro P, Kapoor KK, Yadav KS and Sequeira MG (2019) An Introduction to Microbiology 3rd ed., New Age International Publishers. ISBN: 0852268785.
2. Brown JW, (2015) Principles of Microbial Diversity ASM Press, Washington DC, ISBN-10: 9781555814427.

3. Das S and Dash H (2018) Microbial Diversity in the Genomic Era. 1st ed., , Academic Press, ISBN: 9780128148501.
4. Carter J and Saunders V, (2013) Virology: Principles and Applications. 2nd ed, John Wiley & Sons, ISBN: 9781119991434.
5. Willey J, Sherwood L, and Woolverton CJ (2017) Prescott's Microbiology 10th ed.,. McGraw-Hill Education, ISBN-1259281590.
6. Watkinson S, Boddy L and Nicholas M (2015) The Fungi 3rd ed., Academic Press. ISBN: 978012382035.
7. Barsanti L,Gualtieri P (2014). Algae: Anatomy, Biochemistry, and Biotechnology 2nd ed., CRC Press, ISBN: 1439867321.

SEMESTER-I

Course title: Virology **Credit: 3**
Course code: SIAS MB 1 1 05 C 3003 **Lectures: 45**

Course objectives:

- To impart an advanced understanding and applied knowledge on viruses
- To make the students familiar with pathogenesis of viruses

Course Learning outcomes:

- Description of physiology and types of viruses
- Knowledge on mechanisms of transmission and pathogenesis of viruses.
- Description of unusual viral outbreaks

Unit-I

Classification, Morphology and Chemistry of Viruses: Virus evolution and classification, properties of viruses, virus structure Working with viruses: Techniques for visualisation and enumeration of viral particles, measuring biological activity of animal viruses, assays for virus estimation and manipulation, characterization of viral products expressed in infected cells, Diagnostic virology, Physical and chemical manipulation of viruses.

Unit-II

History and development of plant virology, cryptograms, and classification of plant viruses and viroids: Brief history of virology highlighting the significant contributions of scientists to the development of plant virology; significance of plant virology and modern classification of plant viruses and viroids according to ICTV; and cryptograms of various plant viruses and virus groups

Unit-III

Concept of early and late proteins; regulation of transcription in lambda phage; 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 genomes (Influenza virus), non-segmented genomes (Picornavirus), capping and tailing (TMV); modes of transmission of plant and animal viruses; viral multiplication and replication strategies:

interaction of viruses with cellular receptors an entry of viruses; replication of viruses as per baltimore classification - assembly, maturation and release of virions.

Unit-IV

Causative agents, symptoms, mode of transmission and control of disease caused by human, animal and plant viruses – polio, influenza, rabies, common cold, aids, hepatitis, chikungunya, dengue, ebola, foot and mouth disease, blue tongue disease, mad cow disease, bud necrosis, tobacco mosaic disease and cauliflower mosaic disease; introduction to oncogenic viruses; types of oncogenic DNA and RNA viruses; mechanism of disease causation by plant viruses; antiviral compounds and their mode of action; interferon and their mode of action; use of viral vectors in cloning, expression, and gene therapy.

Suggested Reading:

- Patrick R, Murray, Ken S, Rosenthal P (2015) Medical Microbiology. 8th ed., Elsevier Press, ISBN: 9780323299565.
- Carrol KC, Morse SA, Mietzner T and Miller S. Jawetz, Melnick, & Adelberg's (2016) Medical Microbiology 27th ed.. McGraw-Hill Education, ISBN: 9780071824989
- Ryan K, Ahmad N, Alspaugh JA, Drew JL, Lagunoff M, Pottinger P, Reller LB, Reller M, Sterling and Weissman S. (2018) Sherris Medical Microbiology. 7th ed. McGraw-Hill Education, ISBN: 9781259859809.
- Carter J, Saunders V (2013) Virology: Principles and Applications. 2nd ed., Wiley & sons, ISBN: 9781119991427.
- Vegad J L Katiyar A K, (2015) A Textbook of Veterinary Special Pathology Infectious Diseases of Livestock and Poultry. 1st ed. CBS Publisher ISBN: 9788123927886.

SEMESTER – I

Course Title: Practical-I **Credit: 5**
Course Code: SIAS MB 1 1 06 C 00105

Course Learning outcome:

- Able to prepare biochemical solutions
- Skill development in pure culture techniques
- Able to demonstrate the quantification of different biomolecules
- Understanding the bacterial growth kinetics

List of practicals

1. Laboratory orientation, calibration, and demonstration of equipment.
2. Solutions, pH and buffers
3. Determination of pKa of acetic acid and glycine
4. Qualitative tests for carbohydrates, lipids, amino acids, and proteins in food samples
5. Metaphase chromosome preparation with G banding and C banding from blood sample

6. RNA *in-situ* hybridization to study gene expression in tissue section
7. Different staining methods and microscopic examination of bacteria, actinomycetes, algae, fungi and protozoa
8. Preparation of specific media for isolation of bacteria, and fungi from natural sources
9. Cell counting and cell viability assay
10. Determination of bacterial growth by turbidity measurements (Bacterial growth curve);
11. To study the types of growth (synchronous/ diauxic, batch);
12. To study the effect of incubation temperature, pH, salts on the growth of microorganisms
13. Production of microbial enzymes (amylase, phosphatase) and their separation using chromatographic techniques
14. Biochemical characterization of microbial enzymes.
15. Separation of carbohydrates, amino acids and plant pigments using paper/thin layer chromatography

Suggested readings:

1. Sheehan, D, Wiley Blackwell (West Sussex) (2010) Physical Biochemistry: Principles and Applications. 2nd ed., , ISBN: 978-0-470-85602-4 / ISBN: 978-0-470-85603-1.
2. Plummer, DT., (2017) An Introduction to Practical Biochemistry 3rd ed., McGraw Hill Education, ISBN: 978-0070994874.
3. Wilson K, and Walker J (2018) Principles and Techniques of Biochemistry and Molecular Biology 8th ed., Cambridge University Press. ISBN: 131661476X.
4. Harry W, Seeley, Paul JV, John J, (1990) Microbes in Action: A Laboratory Manual of Microbiology 4th Addition, W. H. Freeman ISBN: 978-0716721000.
5. American Society of Agronomy; Lab Manual edition (2009) Genetics: A Laboratory Manual 2nd ed., , ISBN: 978-0891185611.
6. Aneja KR (2014) Laboratory Manual of Microbiology and Biotechnology 1sted., Scientific International Pvt., Ltd. ISBN: 9789381714553.
7. Cappuccino, JH, Sherman, N., (2017) Microbiology: A Laboratory Manual. 11th ed., Pearson Education Inc, ISBN: 9780134298597

SEMESTER – I

Course title: Techniques in Microbiology **Credit: 4**

Course title: Techniques in Microbiology **Credit: 4**
Course code: SIAS MB 1 1 01 GEC 4004 **Lectures: 60**

Course objectives:

- To introduce the students to different methods of isolation, enumeration, maintenance and preservation of microorganisms

- To make students familiar with methods of identification of different groups of microorganisms

Course Learning outcomes:

- Know-how of the basic microbiological tools and techniques
- Understanding of applications of techniques for exploitation of microbes
- Ability to grow and identify specific microorganisms

Unit-I

Maintenance of asepsis - Autoclave, Hot air oven, Filtration, Laminar air flow; Isolation and cultivation of pure cultures- microbiological culture media; Isolation of bacteria (streak plate, spread plate, pour plate, serial dilution methods) screening and enrichment techniques; preservation and maintenance of microbial cultures, general setup of microbiological laboratory.

Unit-II

Simple staining, differential staining, acid fast staining, staining for visualization of specific microbial cell structures; Principle and applications of bright field and dark field microscopy; Phase contrast, Interference, Differential Interference Contrast Microscopy; Fluorescence, and Confocal Microscopy; SEM, TEM, and STEM; Specimen preparation in Light and Electron Microscopy

Unit-III

Factors affecting microbial growth, Estimation of microbial growth - direct and indirect methods for determination of numbers - viable (plate) count and total (Haemocytometer) count, Estimation of microbial biomass, determination of bacterial growth rate and generation time by turbidometry method, estimation of microbial protein and enzyme activities.

Unit-IV

Tools and techniques for microbial identification and characterization – morphological characterization of microbial cells and colonies, phenotypic methods (biochemical and physiological properties); molecular biology tools for identification and characterization of microbes, measurement of microbial metabolism; detection of non-culturable microbes and metagenomics.

Suggested readings:

1. Plummer, DT., (2017) An Introduction to Practical Biochemistry 3rd ed., McGraw Hill Education, ISBN: 978-0070994874.
2. Wilson K, and Walker J (2018) Principles and Techniques of Biochemistry and Molecular Biology 8th ed., Cambridge University Press. ISBN: 131661476X
3. Aneja KR (2014) Laboratory Manual of Microbiology and Biotechnology 1sted., Scientific International Pvt., Ltd. ISBN: 9789381714553.
4. Cappuccino, JH, Sherman, N., (2017) Microbiology: A Laboratory Manual. 11th ed., Pearson Education Inc, ISBN: 9780134298597

Semester-II

Course title: Advanced Analytical Techniques **Credit: 4**
Course code: SIAS MB 1 2 01 C 4004 **Lecture: 60**

Course objectives:

- To provide an advanced understanding of the core principles of various techniques used in biological experiments.
- To impart technical skills on use of advanced equipments

Course Learning outcomes:

- Demonstrate principles of various basic and advanced techniques used in biological experiments
- Critically analyze and interpret the results obtained from biological experiments
- Utilization of advanced techniques in determination of structures of biomolecules

Unit-I

Principle of microscopy: resolving powers of different microscopes, magnification; different types of microscopes, principle and applications of compound microscopy, dark microscopy, fluorescence microscopy, phase contrast microscopy, confocal microscopy, atomic force microscopy and electron microscopy (SEM, TEM, STEM); fixation and staining, freeze fracture/etch techniques.

Unit-II

Agarose gel electrophoresis, polyacrylamide gel electrophoresis (native PAGE and SDS-PAGE); Western transfer, iso-electric focusing (IEF), 2-Dimensional gel electrophoresis, pulse field electrophoresis; principle and applications of centrifugation, differential centrifugation, density gradient centrifugation and ultracentrifugation; cell separation by flow cytometry.

Unit-III

Paper chromatography (ascending and descending, 2-Dimensional); principle and applications of thin layer chromatography (TLC), column chromatography (gel filtration, ion exchange and affinity chromatography); methods of ligand immobilization, immuno-adsorption-hydrophobic interaction chromatography, metal chelate chromatography, covalent chromatography, high performance liquid chromatography (HPLC) and gas liquid chromatography (GLC).

Unit-IV

Principle and instrumentation of UV-visible, infrared spectroscopy, atomic absorption spectrophotometery, NMR spectroscopy, X-ray diffraction spectroscopy, N-terminal sequencing and peptide synthesis, introduction to proteomics, Yeast 2- hybrid and 3-hybrid systems, EMSA, foot printing, phage display, principle of mass spectrometry, electrospray ionization MS, MALDI, tandem MS for protein identification, ICAT-MS.

Suggested readings:

1. Sheehan, D, Wiley Blackwell (West Sussex) (2010) Physical Biochemistry: Principles and Applications. 2nd ed., , ISBN: 978-0-470-85602-4 / ISBN: 978-0-470-85603-1.
2. Plummer, DT., (2017) An Introduction to Practical Biochemistry 3rd ed., McGraw Hill Education, ISBN: 978-0070994874.
3. Wilson K, and Walker J (2018) Principles and Techniques of Biochemistry and Molecular Biology 8th ed., Cambridge University Press. ISBN: 131661476X
4. Freifelder D (1982) Physical Biochemistry: Applications to Biochemistry and Molecular Biology 2nd ed., , W.H. Freeman and Company (New York), ISBN:0-7167-1315-2 / ISBN:0-7167-1444-2.

Semester II

Course title: Microbial Genetics **Credit: 4**
Course code: SIAS MB 1 2 02 C 4004 **Lectures: 60**

Course objectives:

- To provide a comprehensive detail on microbial genomes
- To impart thorough knowledge on gene regulation and transfer mechanisms.

Learning outcomes:

- Understanding the structure and functions of genomes of different microbial groups
- Understanding the processes behind mutations and other genetic changes
- Identifying and distinguishing genetic regulatory mechanisms at different levels
- Basic understanding of bacterial genomics

Unit-I

Molecular basis of mutations - induced *versus* spontaneous mutations; gene mapping by recombination and complementation; fine gene structure analysis; cloning genes by complementation and marker rescue; DNA repair mechanisms; mutation and microbial evolution.

Unit-II

Gene transfer in bacteria - conjugation, transformation and transduction; Regulation of gene transfer by conjugation; Mapping the bacterial genomes using Hfr strains; transfer systems in gram positive bacteria; Ti plasmid and applications; transformation - molecular basis of natural transformation; transduction- generalized *versus* specialized transduction; mapping bacterial genes by transduction; tetrad analysis in fungi; positive and negative gene regulation and attenuation in different operons; riboswitches.

Unit-III

Genes involved in the lytic and lysogenic cycle of lambda phage; Replication and packaging of filamentous phages M13; Benzer's experiments to construct phage genetic linkage maps; Transposons and gene regulation; Yeast Ty -1 transposon; methods of gene cloning and sequencing; genome transplantation (Synthetic genome).

Unit-IV

Sequencing of microbial genomes; database of microbial genomes; understanding microbial genomes; house keeping genes, essential genes; cluster of orthologous genes; minimal genome; microbiome analysis through genetic tools; metagenome and advances of metagenomics; application of crispr-cas9 system based genome editing.

Suggested readings:

1. Krebs JE, Elliott S and Goldstein (2017) Lewin's GENES XII 12th ed.. Jones and Bartlett Publishers. ISBN: 9781284104493.
2. Klug, Cummings and Spencer (2016) Concepts of Genetics 10th ed.. Pearson Education India. ISBN: 9332577463.
3. Snyder L, Peters, Henkin and Champness (2013) Molecular Genetics of Bacteria 4th ed. ASM Press; ISBN: 9781555816278.
4. Gardner, Simmons and Snustad (2010) Principles of Genetics 8thed., Wiley India Pvt Ltd ISBN: 9788126510436.
5. Kalia VC, Shouche Y, Purohit HJ and Rahi P (2017) Mining of Microbial Wealth and MetaGenomics 1st ed.. Springer Nature Singapore Pte Ltd. ISBN: 9789811057076.
6. Das S and Dash HR (2018) Microbial Diversity in the Genomic Era 1st ed.. Academic Press, ISBN: 9780128148495.

SEMESTER-II

Course title: Biosafety, Bioethics and IPR **Credit: 2**
Course code: SIAL MB 1 2 03 C 2002 **Lecture: 30**

Course objectives:

- To impart knowledge of biosafety issues on microbes and genetically modified organisms
- To introduce the concept of intellectual property rights, patenting.

Course learning outcomes

- Learning of importance of Personnel Protective Equipment (PPE), general biosafety rules and different biosafety levels
- Understanding the role of regulatory agencies for working products derived from biotechnology
- Awareness on ethical issues involving biological material
- Knowledge on intellectual property rights and their implications in biological research and product development.

Unit-I

Biosafety: introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; PPE, GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants –Regulations: International regulations-Cartagena protocol, OECD consensus documents and Codex

Alimentarius; Indian regulations-EPA act and rules, guidance documents, regulatory framework-RCGM, GEAC, IBSC and other regulatory bodies.

Unit-II

Bioethics: Introduction, ethical conflicts in biological sciences-interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research - cloning and stem cell research, Human and animal experimentation, animal rights/welfare, Protection of environment and biodiversity - biopiracy.

Unit-III

Patenting: Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; patent application forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies.

Unit- IV

Patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing-outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad

Suggested readings:

1. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/
2. World Trade Organisation. http://www.wto.org
3. World Intellectual Property Organisation. http://www.wipo.int
4. International Union for the Protection of New Varieties of Plants. http://www.upov.int
5. National Portal of India. http://www.archive.india.gov.in
6. Parashar S, Goel D (2013) IPR, Biosafety and Bioethics Pearson Publishing India, ISBN: 9788131774700.
7. Nambisan P (2017) An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology. Academic Press, ISBN: 9780128092316.
8. http://dbtindia.gov.in/guidelines-biosafety

SEMESTER-II

Course title: Microbial Physiology and Metabolism **Credit: 4**
Course code: SIAL MB 1 2 04 C 4004 **Lectures: 60**

Course objectives:

- To describe metabolic and physiological diversity among prokaryotes.
- To impart knowledge on metabolic cycles of prokaryotic microorganisms

Course learning outcomes:

- Learning of principles of microbial catabolic and anabolic pathways
- Understanding the transport systems and the mechanisms of energy conservation in microbial metabolism
- Identifying various physiological groups of bacteria with their special features
- Understanding of biosynthesis of basic biomolecules.

Unit-I

Nutritional categories of microorganisms based on carbon and energy sources; Metabolite transport - passive and facilitated, primary and secondary active transport, group translocation (phosphotransferase system), symport, antiport and uniport, electrogenic and electroneutral transport, transport of iron; Microbial Growth - Definition balanced and unbalanced growth, growth curve, the mathematics of growth, generation time, specific growth rate, batch and continuous culture, synchronous growth, diauxic growth curve; Effect of physical and chemical factors on growth.

Unit-II

Brief account of photosynthetic and accessory pigments - chlorophyll, bacteriochlorophyll, rhodopsin, carotenoids, phycobiliproteins; Autotrophy - oxygenic, anoxygenic photosynthesis; Autotrophic generation of ATP; Fixation of CO_2; Calvin cycle pathway. Chemolithotrophy - Sulphur, iron, hydrogen, nitrogen oxidations, methanogenesis, Bioluminescence.

Unit-III

Respiratory metabolism - Embden-Mayer Hoff pathway, Entner Doudroff pathway, Pentose phosphate pathway, Krebs cycle, Branched TCA cycle, Reverse TCA cycle, glyoxalate pathway, oxidative and substrate level phosphorylation, gluconeogenesis, pasteur effect; fermentation of carbohydrates - homo and heterolactic fermentations; halophiles and ATP synthesis.

Unit-IV

Biosynthesis of peptidoglycan, polysaccharides, major amino acids, polyamines, lipids, nucleotides - purines and pyrimidines; assimilation of nitrogen; dormancy and germination; microbial differentiation, sporulation and morphogenesis, cell division cycle in *E. coli* and yeast.

Suggested readings:

1. Tauro P, Kapoor KK, Yadav KS, and Sequeira MG (2019), An Introduction to Microbiology 3rd ed., , New Age International Publishers. ISBN: 0852268785
2. Cohen GN (2014) Microbial Biochemistry. 3rd edition. Springer Netherlands. ISBN 978-90-481-9437-7
3. White D, Dummond J and Fuqua, C. (2011) The Physiology and Biochemistry of Prokaryotes. 4th edition. Oxford University Press. ISBN: 9780195393040
4. Willey J, Sherwood L and Woolverton CJ (2017) Prescott's Microbiology. 10th ed.. McGraw-Hill Education, ISBN: 1259281590
5. Dubey RC and Maheswari, DK (2013) A text book of Microbiology (Revised) S. Chand and Company Ltd, New Delhi. ISBN: 9788121926201

SEMESTER-II

Course title: Food and Dairy Microbiology **Credit: 4**
Course code: SIAS MB 1 2 05 C 4004 **Lecture: 60**

Course Objectives:

- To provide the knowledge about food associated microorganisms and microbial spoilage and preservation of foods
- To provide insights on producing dairy and non-dairy fermented foods, and role of probiotics and prebiotics in improving human health

Course Learning outcomes:

- Understanding about the interactions between microorganisms and the food environment
- Knowledge of the various food fermentations, and methods for preservation of foods
- Understanding about the detection, preventive measures and sources of food infections and intoxications caused by various microorganisms

Unit-I

Food associated microorganisms; Natural flora and sources of contamination of foods; intrinsic and extrinsic factors affecting growth and survival of microbes in foods; microbial spoilage of cereals, vegetables and fruits, meat products and sea foods, eggs, milk and milk products, and canned foods; microbial succession during food spoilage

Unit-II

Principles of food preservation; various methods of food preservation - physical, chemical and biological methods; hurdle technology; recent developments in food preservation methods including predictive microbiology, and modified atmospheric packaging; food sanitation - HACCP, indices and regulations of food quality and safety

Unit-III

Fermentation process for producing dairy foods - (yogurt, acidophilus milk, curd, kefir, kumiss, cheese) and non-dairy foods (plant based- sauerkraut, soy sauce and tempeh; and animal based, distilled and non-distilled alcoholic beverages); industrial considerations of dairy starter cultures; probiotics - health benefits, mechanisms of action, types and availability; prebiotics

Unit-IV

Gut microbiome and human health; food-borne infections of bacterial, fungal and viral origin (causative agents, foods involved, symptoms and preventive measures); Food intoxications of microbial origin; methods for detection of food-borne pathogens.

Suggested readings:

1. Ray, B, and Bhunia, A (2014) Fundamental Food Microbiology. 5th ed. CRC Press, Taylor and Francis Group. ISBN 9781466564435.

2. Erkman, O, and Bozoglu, TF (2016). Food Microbiology: Principles into Practice. Microorganisms related to foods, foodborne diseases and food spoilage, Volume 1 and 2, John Wiley & Sons, Inc. ISBN: 9781119237761.
3. Adams MR, Moss M, and McClure P (2016) Food Microbiology. 4th ed., Royal Society of Chemistry. ISBN: 978-1849739603.
4. Poltronieri P (2017) Microbiology in Dairy Processing: Challenges and Opportunities, John Wiley & Sons Ltd and the Institute of Food Technologists ISBN: 1119114802.
5. Frazier WC, and Westhoff DC (2013) Food Microbiology 5th ed., Tata McGraw-Hill Publishing Company Ltd, New Delhi, India.
6. Jay JM, Loessner MJ, and Golden, DA (2006) Modern Food Microbiology. 7th edition. Springer.
7. Rayand B, and Bhunia A (2013) Fundamental Food Microbiology. 5th edition. CRC press.
8. Doyle MP, and Beuchat LR (2007) Food Microbiology: Fundamentals and Frontiers. 3rd edition. ASM press.
9. Montville T, Matthews K, and Kniel K (2017) Food Microbiology: An Introduction. 4th edition. ASM press.

SEMESTER-II

Course title: Practical-II **Credit: 5**

Course code: SIAS MB 1 2 06 C 00105

Learning course outcomes:

- Able to analyze diversity of different microbes in different ecological niches
- Skill development in analysis of soil microorganisms
- Able to determine the microbial quality of food products
- Understanding the concepts of bacterial genetics

List of practivals

1. Morphological, physiological and biochemical characterization of bacterial cultures.
2. Isolation and identification of fungi and algae from different environmental samples;
3. Study of virus architecture using electron microphotographs of TMV, poliovirus and adenovirus;
4. Discussion on cultivation and cytopathic effects of animal viruses;
5. Bacteriophage assay using the plaque technique
6. Isolation of nucleic acid and characterization by gel Electrophoresis
7. Recombination in bacteria – Preparation of competent cells and transformation of plasmid DNA in E. coli.
8. Conjugation in bacteria.
9. Plasmid curing using different agents
10. Determination of mutation rate – natural and induced

11. Isolation of different bacterial and fungal organisms important in recycling of C, N, P in soil;
12. Measurement of CO_2 evolution rate to study decomposition in soil,
13. Estimation of different Soil enzymes- (dehydrogenase/ FDA hydrolase/ β-glucosidase)
14. Determination of Microbial biomass carbon
15. Determination of RS ratio of soil
16. Determination of quality of milk by methylene blue reductase test (MBRT) and SPC;
17. Microbiological examination of different food samples;
18. Determination of antibacterial activity of lactic acid bacteria
19. Screening of microorganisms from soils and industrial effluents for bioremediation applications
20. Microbiological quality control tests for water;

Suggested readings:

1. Aneja KR (2014) Laboratory Manual of Microbiology and Biotechnology 1st ed., Scientific International Pvt., Ltd. ISBN: 9789381714553.
2. Cappuccino, JH, Sherman, N., (2017) Microbiology: A Laboratory Manual. 11th ed., Pearson Education Inc, ISBN: 9780134298597

SEMESTER-II

Course title: Soil and Agriculture Microbiology **Credit: 4**
Course code: SIAL MB 1 2 01 DCEC 4004 **Lectures: 60**

Course objectives:

- To make understand the students about role of soil microbes in biogeochemical cycle of nutrients and organic matter degradation
- To make students familiar with PGPR and other microbial inoculants, and their role in maintaining soil fertility

Learning outcome:

- Understanding the role of microorganisms in the biogeochemical cycles of nutrients
- Understanding the role of microbes in degradation of solid organic waste and other organic pollutants.
- Understanding the different types of interactions between plants and microbes

Unit-I

History of development of soil microbiology; soil microorganisms: major groups, their diversity, abundance, characteristics; direct and indirect methods of studying soil microorganisms and their activities; influence of soil and environmental factors on microflora; soil health-major microbial indicators and their significance

Unit-II

Microorganisms in biogeochemical cycles of carbon, nitrogen, phosphorus, sulphur, iron and manganese; biodegradation of starch, cellulose, hemicellulose, pectin and lignin in soil; biodegradation of pesticides and other xenobiotics; production of biogas; composting-microbiology, types and factors affecting composting; vermicomposting, green manuring

Unit-III

Plant-microbe interactions, Concepts of Rhizosphere, R:S ratio, Rhizoplane, spermosphere, phyllosphere microorganisms; PGPR, Biological Nitrogen fixation - symbiotic, non-symbiotic, associative symbiotic and endophytic organisms, process of nitrogen fixation; Molecular biology of Nitrogen fixation

Unit-IV

Biofertilizers – Types (Bacterial, fungal and algal), mass production and quality assurance; Microbial Biocontrol agents for insects and diseases- development and their significance. Mycorrhizae, Types of mycorrhizae and their interactions with plants

Suggested readings:

- Mehnaz S, Springer (2017) Rhizotrophs: Plant Growth Promotion to Bioremediation vol 2., ISBN: 9789811048616.
- Hakeem KR, Akhtar MS and Abdullah SNA (2016) Plant, Soil and Microbes Vol-1 Implications in Crop Science 1st ed., Springer Cham, ISBN: 9783319274539.
- Lugtenberg B (2016) Principles of plant-microbe interactions. Springer Cham, ISBN 3319381857.
- Paul EA (2017) Soil Microbiology, Ecology and Biochemistry 4th ed., Academic Press, New York, USA. ISBN: 9780124159556.
- Sylvia D, Fuhrmann J, Hartel P and Zuberer D (2005) Principles and Applications of Soil Microbiology 2nd ed., Pearson Education, USA. ISBN: 9780130941176.
- Alexander M (1985) Introduction to Soil Microbiology 3rd ed., , Wiley Eastern, New Delhi. ISBN: 9780894645129.

SEMESTER-II

Course title: Environmental Microbiology **Credit: 4**
Course code: SIAS MB 1 2 02 DCEC 4004 **Lectures: 60**

Course objectives:

- To understand the role of microorganisms in environmental processes
- To learn principles and applications of microbiology in bioremediation of pollutants and wastewater treatment.

Learning outcomes:

- Know-how of the effect of environmental condition on microbes
- Understanding the interactions between microorganisms and their environment
- Understanding of applications of microorganisms in solving environmental problems

Unit-I

Historical developments and contributions of scientists in environmental microbiology; introduction and scope of environmental microbiology; environmental factors affecting microbial growth; impacts of GMOs on environment; role of microorganisms in mitigating global climate change; tools and techniques for studying microbial interactions with their environment.

Unit-II

Microbiology of natural environments: terrestrial environments; rhizosphere; aquatic environments (freshwater, marine and estuarine habitats); ground water; aeromicroflora and dispersal of microbes; human microbiomics; microbial interactions in rumen.

Unit-III

Microbiology of extreme environments: microbial growth and survival under hot environments, cold environments, alkaline environments, acidic environments, saline environments, environments rich in heavy metal, low nutrient environments, environments with high hydrostatic pressure, organic solvents and radiation; polyextremophiles. Space microbiology.

Unit-IV

Microbial indicators of environmental pollution; bioremediation of recalcitrant organic pollutants; microbial technology for waste management and treatment- solid waste management, landfills, utilization of solid wastes for production of food and feed, fuel and fertilizer; wastewater microbiology: microbiology of sewage and industrial effluents (paper and pulp, distillery etc.) - aerobic (trickling filters, activated sludge, oxidation ponds etc.) and anaerobic processes in wastewater treatment; enhanced recovery of metals, petroleum and bioenergy from natural resources. Biodegradation and biodeterioration.

Suggested readings:

1. Manual of Environmental Microbiology (2016), 4th ed., Yates, MV, Nakatsu CH, Miller RV and Pillai RV, ASM Press (USA), Print ISBN: 9781555816025, e-ISBN : 9781555818821.
2. Environmental Microbiology for Engineers (2016), 1st ed., Ivanov V, ISBN: 9780429109003.
3. Environmental Microbiology: From Genomes to Biogeochemistry (2015), 2nd ed., Madsen EL, John Wiley & Sons, Inc., ISBN: 978-1-118-43963-0.
4. Environmental Microbiology: Fundamentals and Applications (2015), 1st ed., Bertrand JC, Caumette P, Lebaron, P, Matheron R, Normand P and Sime-Ngando T, Springer Netherlands, eBook ISBN: 978-94-017-9118-2, Hardcover ISBN: 978-94-017-9117-5.
5. Environmental Microbiology (2016-17), 1st ed., Sharma, PD, Rastogi Publications (India), ISBN: 978-93-5078-140-1.

Semester-II

Course Title: The Microbiome **Credit: 4**
Course Code: SIAS MB 1 02 03 DCEC 4004 **Lectures: 60**

Course objectives:

- To define the microbiome of human, animal and plants
- To know the techniques used in studying the microbiomes

Course Learning outcomes

- Understanding the use of omics technologies in studying the microbiomes
- Understanding of changes of microbiome on health

Unit-I

History of the study of the microbiome; methods to study microbiome- DNA-based analysis of microbial communities, 16S rRNA gene amplicon sequencing and shotgun metagenomics sequencing methods; Functional analysis of the microbiome from DNA sequences.

Unit-II

Techniques used to analyse microbiome data- assignment of taxonomy; generating OTU tables, quality control: Describing the complexity of the microbiome eg. alpha and beta-diversity; comparing microbial communities, phylogenetic trees, UniFrac, principal coordinate analyses, Venn diagrams, heat maps; development of new bioinformatics methods for microbiome studies.

Unit-III

Functional studies of the Microbiome- Measurement of microbial products (the metabolome, proteome and glycome; role of microbiome and its products, nutrition, metabolism, the gut brain axis, and in immune- inflammatory processing. Introduction to the Human Microbiome; The Human Microbiome Project (HMP); Diversity of the Human Microbiome

Unit-IV

Gut microbiome changes in various diseases including liver diseases, obesity, diabetes, and other disorders; the mycome and virome in health and disease. Direct health effects of gut microbiome; Use of the microbiome in screening, diagnosis and monitoring diseases.

Suggested readings:

1. Unravelling the Soil Microbiome: Perspectives for Environmental Sustainability (2020) 1st edi., Dubey RK, Tripathi V, Prabha R, Chaurasia R, Singh DP, Rao CS, El-Keblawy A and Abhilash PC, Springer Cham, ISBN: 978330155155.
2. Microbiome and Metabolome in Diagnosis, Therapy and other strategic Applications (2019) 1st edi., Faintuch J and Faintuch S. Academic Press (New York) ISBN: 9780128152492.
3. Diet, Microbiome and Health (2018) 1st ed., Holban AM, Grumezescu AM. Academic Press (New York), ISBN: 9780128114407.
4. Functional importance of the plant microbiome: Implications for agriculture, forestry and bioenergy (2017) 1st ed., Doty SL. Springer Cham. ISBN: 978-3-319-65896-4.
5. Microbiome Analysis: Methods and Protocols. (2018) 1st ed., Beiko RG, Hsiao W and Parkinson J. Springer New York. ISBN: 9781493987269.
6. The Gut Microbiome in Health and Disease (2018). 1st ed., Haller D. Springer International Publishing. ISBN 978-3-319-90544-0.

SEMESTER-III

Course title: Biostatistics and Bioinformatics **Credit: 3**
Course code: SIAS MB 1 3 01 C 3003 **Lectures: 45**

Course objectives:

- To introduce the students in the field of bioinformatics

- To enables them to understand the concepts of statistics in biology.

Course Learning outcomes:

- Handling commonly used bioinformatics tools and understand their pros and cons
- Statistically analyse the data in a biologically relevant manner
- Understanding the role of computer science in predicting structure and function of biomolecules
- Understanding basic computer skills necessary for the conduct of research

Unit-I

Definition of selected terms scale of measurements related to statistics; Methods of collecting data, Presentation of data statistical Tables, Need for reduction of data measures of averages and location, Measures of dispersion: Range, quartile deviation, mean deviation and relative deviation. Probability: basic concepts; basic theorems of probability addition and multiplication theorems; conditional probability of Bayes Theorems. Probability mass function, probability density function, cumulative distribution function.

Unit-II

Probability distribution definition and applications; Binominal distribution, Poisson distribution, Normal distribution, logic of statistical standard error estimation testing of hypothesis.Tests of significance: Null hypothesis, alternative hypothesis, type I error, type II error, level of significance, and power of test. Tests for mean based on normal distribution, one sample t-test, two-sample t-test, paired-sample t-test, Chi-Squared test, and Tests for variance based on normal distribution – one sample and two-sample problem. One-way and Two-way analysis of variance (ANOVA) techniques. Correlation concept and applications, Spearman's rank correlation coefficient, regression concept and applications.

Unit-III

Historical background. Scope of bioinformatics - genomics, proteomics, computer aided drug design (structure based and ligand based approaches), Applications of bioinformatics. Introduction to biological databases - primary, secondary and composite databases, Different formats of molecular biology data. NCBI, nucleic acid databases (GenBank, EMBL, DDBJ, NDB), protein databases (PIR, Swiss-Prot, TrEMBL, PDB)

Unit-IV

Similarity, identity and homology. Alignment-local and global alignment, pairwise and multiple sequence alignments, alignment algorithms, amino acid substitution matrices (PAM and BLOSUM), BLAST and CLUSTAL omega. Identification of open reading frames (ORF), Concept of orthology, paralogy and homology in gene and protein sequences. Methods and tools for phylogenetic analysis, maximum parsimony, maximum likelihood and distance methods; creation, evaluation and interpretation of evolutionary trees phylogenetic tree.

Suggested Readings:

1. Fundamentals of Statistics (2016) Goon, AM, Gupta, MK and Dasgupta, B. Vol. I & II. World Press, ASIN: B01LB7MH74.
2. Statistical Methods (2012) 1st ed., Das, NG. Vol I & II. Tata McGraw Hill, ISBN: 9780070263512.

3. Probability and Statistics for Engineers and Scientists (2013) 9th ed., Walpole, RE, Myers, RH, Myers, SL and Ye, Pearson Education India KE ISBN: 978-9332519084.
4. Biostatistics: A Foundation. for Analysis in the Health Sciences (2012) 10th ed., Daniel, WW and Cross, CL. John Wiley & Sons, ISBN: 978-1118302798.
5. Essential Bioinformatics (2006) 1st ed., Xiong J, Cambridge University Press, ISBN: 978-0521600828.
6. Fundamental concepts of Bioinformatics (2003) Krane DE and Raymer ML Pearson, ISBN: 978-8177587579.
7. An Introduction to Bioinformatics (2017) 1st ed., Knight R, Larsen and Keller Education, ISBN: 978-1635490459.
8. Concepts of Bioinformatics and Genomics (2016) 1st ed., Momand J, McCardy A, Heubah, S and Warter-Perez N, Oxford University Press, ISBN: 978-0199936991.

SEMESTER - III

Course title: Microbial genomics, proteomics and metabolomics **Credit: 4**
Course code: SIAS MB 1 3 02 C 4004 **Lectures: 60**

Course objectives:

- To obtain a fundamental knowledge and insights on microbial genomics,
- To understand the comparative and functional genomics, proteomics and metabolomics

Learning Outcomes

- Understanding of high throughput techniques including genomics, proteomics and metabolomics for microbiological research
- Ability of data mining for genomics and proteomics from different databases and its interpretation
- Applications of different microbial omics techniques in different areas of life sciences

Unit-I

Introductions of omics technologies and their applications in microbiology. Principles of microbial genomics such as sequencing, assembly, annotation of microbial genomes and its application to study microbial community. Metagenomics, comparative and functional genomics

Unit II

Major bioinformatics tools and databases and their application in Microbial Genomics; Search and retrieval of biological information and databases sequence for Microbial Genomics; Microbial genome projects, Human Microbiome Project. Genome annotation, Genome editing, tools involved in genome editing such as CRISPR/Cas9.

Unit III

Introduction to Proteomics; Bridging Genomics and Proteomics; Analysis of proteomes – Extraction of microbial proteome and sample preparation. Two-dimensional polyacrylamide gel

electrophoresis; Mass spectrometry based methods for proteome analysis; Quantitative proteomics; Metaproteomics; Application of proteomics in microbiology

Unit-IV

Metabolomics-Targeted and untargeted approaches; Intracellular and exometabolomes-Polar metabolites and lipid profiling-Mass spectrometry based techniques-Processing and analysis of metabolome data sets-Metabolite identification; Topics of current interest in microbial metabolomics

Suggested Readings

1. Head, Steven R., Ordoukhanian, Phillip, Salomon, Daniel R (2018) Next Generation Sequencing Methods and Protocol. Springer
2. Izard, Jacques., Rivera, Maria. (2014) Metagenomics for Microbiology. Elsevier
3. Kaufmann, Michael., Klinger, Claudia., Savelsbergh, Andreas. (2017) Functional Genomics Methods and Protocols. Springer
4. Integrative Approaches For Understanding OMICS Data (2018) 1st ed., Springer Singapore ISBN:978-981-13-2924-1

SEMESTER-III

Course title: Industrial Microbiology **Credit: 4**
Course code: SIAS MB 1 3 03 C 4004 **Lecture: 60**

Course Objectives:

- To provide the knowledge of features of industrially important microorganisms, their screening and selection from natural resources
- To provide insights on design and types of fermenter, their modes of operations for achieving maximum product output and various strategies for product recovery after fermentation

Learning outcomes:

- Understand the role of microorganisms in industrial processes for the benefit humankind
- Be familiarized about principles of industrial fermentation process and equipment
- Learn microbial strain improvement strategies, large-scale applications of microbes for commercial production of valuable products

Unit I

Historical perspectives and recent developments in Industrial Microbiology; Scope of Industrial Microbiology; Fermentation processes and types of microbial products; Sources of Industrially important microorganisms and their screening (including high throughput techniques) and selection; Characteristics of industrially relevant microbes, their maintenance and preservation; Characteristics of solid substrate and submerged fermentations.

Unit II

Fermentation media- characteristics of substrates and nutrients (carbon and nitrogen) balance during fermentation, stoichiometric principles; formulation and optimization of media using one-factor and statistical approaches; methods and principles of media sterilization (batch and continuous methods); Inoculum development; Batch, continuous and fed-batch cultivation of microorganisms; Kinetics of microbial growth, substrate utilisation and product formation during fermentation bioprocess

Unit III

Basic components of fermenters (impellers, seal, baffles and spargers, sampler, foam control), construction material and designing; Fermenter types - Stirred tank, bubble column, airlift, packed and fluidized bed, photobioreactors, solid state reactors; Instrumentation and control of bioprocesses. Scale-up and scale-down principles. Downstream processes for product recovery - cell disruption, precipitation, filtration, centrifugation, extraction, chromatography, membrane process, drying, crystallization, packaging).

Unit IV

Concept of primary and secondary metabolites; microbial applications for production of alcohols, organic acids, industrial enzymes, antibiotics, health products (hormones and recombinant vaccines), bioenergy; Microbial transformations; Microbial Strain Improvement using recombinant DNA technology and metabolic engineering; Fermentation process economics.

Suggested Readings:

1. Glazer, A.N., and Nikaido, H. 2007. Microbial Biotechnology: Fundamentals of Applied Microbiology. 2nd edition. Cambridge University Press.
2. Casida, L.E.J.R. 2016. Industrial Microbiology. Second Edition. New Age International (P) Ltd., Publishers. New Delhi, India.
3. Crueger, W., and Crueger, A. 2000. Biotechnology: A Test Book of Industrial Microbiology, Second Edition, Panima Publishing corporation, New Delhi.
4. El-Mansi, E.M.T., Bryce, C.F., Demain, A.L., and Allman A.R. 2012. Fermentation Microbiology and Biotechnology edited. 3rd edition. CRC Press.
5. Flickinger, M.C., and Drew, S.W. 1999. Encyclopaedia of Bioprocess Technology Fermentation, Biocatalysis and Bioseperation Vil. V., John Wiley and Sons Publications.
6. Crommelin, J.A.D., Sindelar, R.D., and Meibohm, B. 2013. Pharmaceutical Biotechnology: Fundamentals and Applications. 4th Edition. Springer.
7. Joe, M.M., Sivakumar, P.K. and Sukesh, K. 2010. An Introduction to Industrial Microbiology. S. Chand Publishing, New Delhi.
8. Kalaichelvan, P.T., and Arul Pandi, I. 2007. Bioprocess Technology, MJP publishers, Chennai.
9. M. L. Shuler, and F. Kargi. 2015. Bioprocess Engineering: Basic Concepts by 2nd edition. Pearson Education India.
10. N. Okafor. 2020. Modern Industrial Microbiology & Biotechnology. 2nd edition. CRC Press, USA.

11. Patel A.H. 2016. Industrial Microbiology. 2nd Edition. Laxmi Publications (P) Ltd. New Delhi, India
12. Peppler, H., and Pearman, D. 1979. Microbial Technology, Vol. I, Academic Press, New York.
13. Prescott, L.M., Harley, J.P., and Helin, D.A. 2008. Microbiology, 5th Edition, McGraw Hill, New Delhi.
14. Stanbury, P.F, Whitaker, A., and Hall, S.J. 2016. Principles of Fermentation Technology, 3rd edition, Butterworth-Heinemann.
15. Waites, M.J., Morgan, N.L., Rockey, J.S., and Higton, G. 2001. Industrial Microbiology: An Introduction, Blackwell Science, London.

SEMESTER-III

Course title: Medical Microbiology and Immunology **Credit: 4**
Course code: SIAS MB 1 3 04 C 4004 **Lecture: 60**
Course Objectives:

- To understand the various components of the host immune system, their structure and organization, and functions to serve as the defense system of the body.
- To understand the operational mechanisms which underlie the host defense system, allergy and organ transplantation.

Course Learning Outcomes:

- Able to describe normal human microflora, and role of microbes in causing diseases
- Able to understand the fundamental bases of immune system and immune response
- Will gather information about the structure and organization of various components of the immune system
- Able to understand the genetic organization of the genes meant for expression of immune cell receptors and the bases of the generation of their diversity
- Able to understand the operation and the mechanisms which underlie the immune response
- CO5: Will be able to apply the knowledge gained to understand the phenomena like host defense, hypersensitivity (allergy), organ transplantation and certain immunological diseases

Unit-I

Normal microflora of the human body and its importance: normal microflora of skin, throat and gastrointestinal tract; Collection, transport and culturing of clinical samples (sputum, urine, blood, stools) for microbiological analysis; Human microbiome. Causative agents, symptoms, mode of transmission and control of diseases caused by staphylococcus aureus, streptococcus pyogenes, Haemophilus influenzae, Mycobacterium tuberculosis, Escherichia coli, Salmonella typhi, Vibrio cholerae, Helicobacter pylori, Bacillus anthracis, Clostridium tetani, Treponema pallidum and torch group of pathogens; causative agents, symptoms, mode of transmission and control of diseases dermatomycoses, histoplasmosis, candidiasis, malaria and kala-azar; mechanism of action of various antimicrobial agents - inhibitors of nucleic acid synthesis, cell wall synthesis, cell membrane function and protein synthesis.

Unit-II

Host-defenses, hematopoiesis, cells of the immune system, primary and secondary lymphoid organs and tissues (MALT).Anatomical barriers, cell types of innate immunity, soluble molecules and membrane associated receptors (PRR), connections between innate and adaptive immunity, chemokines. Antigens and haptens, factors that dictate immunogenicity, B and T cell epitopes. Structure and distribution of classes and subclasses of immunoglobulins (Ig), Ig fold, effector functions of antibody, antigenic determinants on Ig and Ig super family**.** Multigene organization of Ig locus, mechanism of V region DNA rearrangement, ways of antibody diversification. Antigen independent phase of B cell maturation and selection, humoral response – T-dependent and T-independent response.

Unit-III

Complement activation by classical, alternate and MB lectin pathway, biological consequences of complement activation, regulation and complement deficiencies. General organization and inheritance of MHC, structure, distribution and role of MHC class I and class II proteins, pathways of antigen processing and presentation. Structure and role of T cell receptor, and co-receptor, T cell development, generation of receptor diversity, selection and differentiation. General properties of effector T cells, cytotoxic T cells (Tc), natural killer cells; NKT cells and antibody dependent cellular cytotoxicity (ADCC).

Unit-IV

Mechanism of tolerance, Organ specific and systemic autoimmune diseases, possible mechanisms of induction of autoimmunity, IgE mediated (Type I) hypersensitivity, antibody mediated cytotoxic (Type II) hypersensitivity, immune complex mediated (type III) hypersensitivity and delayed type (Type IV) hypersensitivity. Immunological basis of graft rejection, clinical manifestations, immunosuppressive therapy, Immunohistochemistry, Immunocytochemistry and privileged sites. Vaccines - active and passive immunization, types of vaccines.

Suggested readings:

1. Kuby Immunology (2018) 8th ed., Punt J, Stranford S, Jones P and Owen JA, W.H Freeman and Company, ISBN: 978-1319114701.
2. Janeway's Immunobiology (2017) 9th ed., Murphy KM and Beaver C, WW Norton and Company, ISBN: 978-0815345510.
3. Roitt's Essential Immunology (2017) 13th ed., Delvis PJ, Martin SJ, Burton DR and Roitt, IM, Wiley-Blackwell, ISBN: 978-1118415771.
4. Lehninger: Principles of Biochemistry (2017) 7th ed., Nelson, DL and Cox, MM, WH Freeman and Company (New York), ISBN: 978-1319108243.
5. Lippincott's illustrated Reviews Immunology (2012) 2nd ed., Doan T, Melvold R, Viselli S and Waltenbaugh, C, Wolters Kluwer India Pvt, Ltd, ISBN: 978-8184737639.

SEMESTER-III

Course title: Practical-III **Credit: 4**
Course code: SIAS MB 1 3 05 C 0084

Course Learning outcomes

- Able to analyze diversity of different microbes in different ecological niches
- Skill development in analysis of microbial ecology
- Able to conduct the techniques related to microbial genomics and proteomics
- Understanding the concepts of immunological reactions

List of practicals

1. Study of resident microflora of the skin;
2. Identification of pathogens using biochemical assays
3. Identification of specific pathogens using kits (eg. Widal Test);
4. Antibiotic susceptibility testing using Kirby-Bauer method;
5. Determination of minimal inhibitory concentration (MIC) of an antibiotic using double dilution technique or E-test strips.
6. Isolation of industrially important microorganism from different sources
7. Determination of yield coefficient of *Saccharomyces cerevisiae* on various substrates
8. To study the design of fermenter and its working;
9. Production of ethanol using different substrates by yeast
10. Production of extracellular enzymes submerged and solid state conditions;
11. Isolation of genomic DNA and RNA from bacteria;
12. Isolation of plasmid DNA from bacterial culture;
13. Isolation of metagenome from different sample
14. Isolation of metaproteome from soil and its 2 D gel electrophoresis analysis
15. Data mining for whole genome analysis and its annotation
16. Metabolomic analysis of a representative bacteria
17. Transformation experiment in *E.coli* by chemical method and electroporation and determination of transformation efficiency;
18. Designing and amplification of gene of interest by Polymerase Chain Reaction
19. Isolation, characterization of bacteria fungi present in cultivated and diseased plants
20. To study occurrence of disease by inoculation with bacterial or fungal pathogens
21. Measuring plant disease intensity under controlled conditions;
22. Biochemical and physiological tests for detection of pathogens in fruits and vegetables;
23. Determination of microbial interactions such as antagonism and symbiosis
24. Calculations on the diversity indices to determine microbial diversity,
25. Demonstrations on phylogenetic analysis of microorganisms
21. Agglutination and Precipitation based assays
22. Immunodiffusion assays by Ouchterlony method;
23. Demonstration of Immunoelectrophoresis; Dot-ELISA and Western blotting

Suggested Readings:

1. Microbiology: A laboratory Manual. (2017) 11th ed. Cappuccino JG, Welsh C. Pearson Education, Inc. ISBN: 9780134098630.
2. Laboratory Manual of Microbiology and Biotechnology (2014) 1st ed. Aneja KR, Scientific International Pvt. Ltd., ISBN: 9789381714553.

3. Laboratory Manual and Workbook in Microbiology: Applications to Patient Care (2003) 7th ed. Morello JA, Helen PA and Mizer E, McGraw Hill Publications ISBN: 0072463546.

SEMESTER - III

Course title: Seminar **Credit: 2**

Course code: SIAL MB 1 3 06 C 0202

Seminar will be of 45-minute duration during which the presentation will be followed by questions session by the audience comprising of faculty and students. Every student shall be required to submit the topic of his/her seminar in consultation with the Head of the Department/Faculty members/student advisors well in advance so that the same may be displayed on the notice board. The presenter has to write an Abstract to be distributed during Seminar in addition to two copies of write-up giving relevant details of the background of the subject, methods used and references/List of sources from where the material for presentation has been collected.

SEMESTER - III

Course title: Biofertilizer and Compost Technology **Credit: 4**
Course code: SIAS MB 1 3 04 DCEC 4004 **Lectures: 60**

Course objective:

- To familiarize the students with the basic concepts regarding the use of microorganisms as biofertilizers and compost inoculants, their mass production
- To familiar students with the quality assurance of bioinoculants.

Learning outcomes:

- Understanding the use of microorganisms as biofertilizer and compost inoculant
- Understanding various applications of microbial inoculants in agriculture and solid waste management
- Skill development in biofertilizer and compost technology

Unit-I

Principles of crop inoculation with microbial agents, organic farming-role of biofertilizers and organic manures; overview of microbial inoculants-types and their mode of application, types of formulation- advantages and disadvantages.

Unit-II

Carriers for inoculants: types and their characteristics, strain selection of bacteria and cyanobacteria for biofertilizer production and quality control, mass multiplication: methodology and constraints/benefits, bulk production (small scale and commercial scale), setting up of pilot scale inoculant production plants.

Unit-III

Rhizobium: Isolation, characterization and formulation; *Azotobacter*: isolation, characterization and formulation; phosphate solubilizing microorganisms: isolation, characterization and formulation; am fungi- types, multiplication methods and formulations; ecology of inoculants/ microorganisms in soil, cyanobacteria as biofertilizer for paddy cultivation.

Unit-IV

Composting- microbiology, types and quality testing; vermi-compost: types of earthworms, production technology and its evaluation; biocontrol agents: evaluation and formulations; biogas production technology; silage production.

Suggested Readings:

1. Sustainable Green Technologies for Environmental Management (2019). 1st ed. Shachi SV and Venkatramanan, RP, Springer (Singapore) ISBN 9789811327711.
2. Solid Waste as a Renewable Resource: Methodologies (2015) 1st ed. Albanese, JAF and Ruiz, MP CRC Press. ISBN 9781771882439.
3. Biofertilizer Technology (2013) 1st ed., Kannaiyan, S, Kumar, K and Govindarajan K Scientific Publisher. ISBN 9789386102485.
4. Compost Science and Technology, Vol 8. (2011) 1st ed. Diaz LF, De Bertoldi M and Bidlingmaier W, Elsevier, ISBN 9780080439600
5. Microbes for Sustainable Agriculture (2010) Tilak, KVBR, Pal, KK and De, R. I.K. International Publishing House Private Ltd. (New Delhi) ISBN 9789380026886

SEMESTER - III

Course title: Plant Pathology **Credit: 4**
Course code: SIAS MB 1 3 05 DCEC 4004 **Lectures: 60**

Course objective:

- To appraise the students about principles plant pathology and diseases of agricultural crops.
- To upraise the students about disease resistance and various methods of controlling diseases

Learning Outcomes:

- Understanding of factors responsible for diseases in the crops
- Determining the mechanisms of pathogens for causing diseases in plants
- Demonstrating the techniques for management of crop diseases

Unit-I

Introduction and history of plant pathology; definitions and concepts of plant diseases; biotic and abiotic factors responsible for plant diseases; Interaction of microorganisms with plants and their effect on plant growth. Modern detection methods

Unit-II

Host-pathogen interactions - recognition and infection, symptomatology, disease development- role of enzymes, toxins, growth regulators; defense strategies,; hypersensitivity responses including oxidative burst, phenolics, phytoalexins, PR proteins, elicitors and their effects on host plants.

Unit-III

Growth, reproduction, survival and dispersal of important plant pathogens; Role of environment and host nutrition on disease development; diseases of some important cereals (Rice, wheat), vegetables (Tomato, Potato), commercial crops (Cotton, Sugarcane) and fruit crops (Mango, Citrus, Grapes).

Unit-IV

Plant disease resistance – pathogen associated molecular patterns, pattern recognition receptors, PTI, effectors, ETI, disease control in plants - physical, chemical methods; use of biocontrol agents - bacteria and fungi; Molecular approaches for plant protection - applications and constraints.

Suggested readings:

1. Introduction to Principles of Plant Pathology (2018) 5thed. Singh RS, Scientific International Pvt. Ltd. ISBN: 9739386479488.
2. Plant Pathology (2018) 1sted., Burchett, S and Burchett S CRC Press, ISBN: 9780815344834.
3. Principles of Plant Pathology (2014) Jagtap G, Dhutraj D and Dey U. Agrobios (India), ISBN-978-8177544916.
4. Plant Pathology, (2005) 5thed., Agrios GN, Academic Press (New York) ISBN: 9780120445653.
5. Molecular Plant Pathology (2003) 1st ed., Dickinson M, Sheffield Annual Plant Reviews, CRC Press. ISBN: 9781841271088.

SEMESTER-III

Course title: Biofuels and Bioenergy **Credit: 4**
Course code: SIAS MB 1 3 06 DCEC 4004 **Lectures: 60**

Course objectives:

- To provide a thorough understanding of various renewable feedstocks for production of biofuels
- To provide students with knowledge on different technologies used in biofuel facility operations.

Course Learning outcomes:

- Understand the situation of utilization of biomass for energy resources
- Learn the developments in different generations of biofuels
- Understand the technologies related to life cycle assessment

Unit I

Bioenergy/Biofuel concept, advantages and disadvantages, types and generations of biofuels, biomass resources/feedstocks for bioenergy production: types (agricultural residues, energy crops, foresrty waste and municipal wastes and others), production, availability, and characteristics. General principles of the carbon cycle, greenhouse effect and global climate change. Bioeconomy, circular bioeconomy, biorefinery concept.

Unit II

Structure and function of lignocellulosic biopolymers, various types of pretreatment technologies (Mechanical, Physical, chemical, physicochemical, biochemical, ionic liquids, etc.) general scheme for bioconversion of biomass to biofuel; biomass characterization techniques, concept of pseudo-lignin and inhibitors, biodiesel production; environmental impacts of biofuel production

Unit III:
Lignocellulolytic enzymes (LCEs) such as cellulase, hemicellulase, etc.; accessory enzymes (swolenin; LPMOs and AAs); submerged and solid-state fermentation technology for enzyme production, recent developments and commercialization aspects of LCE enzyme; enzymatic hydrolysis process; saccharification yield and efficiencies; enzyme cocktail preparations for achieving higher saccharification yield; factors affecting biomass hydrolysis

Unit IV
Recent trends and advancements in biofuels production (ethanol, biodiesel from oil crops, microbial fuel cells, biohydrogen, biogas and other value-added product generation in an integrated approach), role of microbes, types and characterization, Effect of pH, temperature, nutrients, etc.; Life cycle assessment of biofuels and biofuel technologies, India's energy demand and supply management,

Suggested Readings
1. Mahesh & Dayal (1992). Renewable Energy Environment and Development, Konark Publishers (P) Ltd.
2. Rao S & Parulakar BB (1994). Energy Technology, Khanna Publishers, New Delhi.
3. David N-S Hon DNS & Nobuo Shiraishi N (2000). Wood and Cellulosic Chemistry, CRC Press.
4. Sorensen B (2010) Renewable Energy, Academic Press.
5. Kasthurirangan G, van Leeuwen J, Robert C (2012). Sustainable Bioenergy and Bioproducts, Springer.

SEMESTER - III

Course title: Applied Microbiology **Credit: 4**
Course code: SIAS MB 1 3 03 GEC 4004 **Lectures: 60**

Course objective:

- To understand the role of microorganisms and microbial processes in welfare of humankind
- To correlate the traditional microbiological techniques to microbial applications and their control.

Learning outcomes:

- Understanding of basic applications of microorganisms
- Know-how of the beneficial and harmful roles played by microbes
- Understanding of the roles of microbes in medical, environmental, industrial and food processes

Unit-I

History, applications and scope of microbiology- introduction to microscopic and pure culture techniques, microbial cell structure and functions, Microbial Growth and Control, balanced and unbalanced growth, growth curve.

Unit-II

Microbial Interactions with humans –normal microflora of human body, nosocomial infections, some common examples of food, air, water borne diseases, and their causative agents, antibiotics and Vaccines; Introduction to immunodiagnostics – RIA, ELISA.

Unit-III

Role of microorganisms in environment and agriculture, biogeochemical cycles (N, C, P), plant growth promoting bacteria, beneficial associations and interactions of microbes with microbe themselves, plant and animals, biodegradation, biodeterioration, biomineralization, bioremediation.

Unit-IV

Industrial and food applications of microbes, food fermentations (sauerkraut, tofu, tempeh, cheese, fermented milk), starter cultures, probiotics and prebiotics, industrial production of microbial biomass (baker yeast and SCP), primary (alcohol, vitamins and enzymes) and secondary metabolites (antibiotics).

Suggested readings:

1. Kuby Immunology (2018) 8th ed., Punt J, Stranford S, Jones P and Owen JA, W.H Freeman and Company, ISBN: 978-1319114701.
2. Manual of Environmental Microbiology (2016), 4th ed., Yates MV, Nakatsu CH, Miller, RV and Pillai RV, ASM Press (USA), Print ISBN: 9781555816025, e-ISBN : 9781555818821
3. Environmental Microbiology: Fundamentals and Applications (2015), 1st ed., Bertrand, JC, Caumette P, Lebaron P, Matheron R, Normand P and Sime-Ngando T, Springer Netherlands, eBook ISBN: 978-94-017-9118-2, Hardcover ISBN: 978-94-017-9117-5.
4. Environmental Microbiology (2016-17), 1st ed., Sharma, PD, Rastogi Publications (India), ISBN: 978-93-5078-140-1
5. Industrial Microbiology (2016), 2nd ed., Casida LEJR, New Age International (P) Ltd., New Delhi, India., ISBN: 9788122438024
6. Modern Industrial Microbiology and Biotechnology (2017), 2nd ed., Okafor N and Okeke, BC, CRC Press, ISBN: 9781138550186
7. Biotechnology: A Test Book of Industrial Microbiology (2017) 2nd ed., Crueger W, Crueger A and Aneja KR., Panima Publishing corporation (New Delhi), ISBN: 9789385998638

SEMESTER - III

Course title: Microbes and Diseases **Credit: 4**
Course code: SIAS MB 1 3 04 GEC 4004 **Lectures: 60**

Course objectives:

- To provide a comprehensive detail on different infectious agents and their implications.
- To update the students with newer infectious microbes

Course Learning outcomes:

- Fundamental understanding of ecological factors that affect the transmission of infectious diseases
- Understanding the virulent determinants and social implications of infectious agents
- Understanding the concepts of emerging and re-emerging pathogens

Unit-I

Bacterial Pathogenesis: Types of Bacterial Pathogens (Primary Pathogens; Opportunistic Pathogens); Pathogen Classification (BSL-1-4); Pathogenicity; Virulence factor; Transmission of Pathogens (Aerosol, Oral, Direct contact, Fomite, Vector-borne, Zoonoses); Koch's Postulates (Modified).

Unit-II

Penetration of Host Defenses: Capsules; Cell Wall Components; Enzymes, (Exoenzymes, Coagulases, Kinases, Hyaluronidase, Collagenase, IgA proteases); Antigenic Variation. Penetration into Host Cytoskeleton: Invasins, Cadherin Damage to Host Cells: Using Hosts Nutrients, Direct Damage to Colonized Area, Production of Toxins (Exotoxins, Endotoxins) Bacterial Secretion System.

Unit-III

Regulation of Virulence Factors: Sigma Factors, Two Component System, Evolution of Bacterial Pathogens: Horizontal Gene Transfer, Pathogenicity Island, Antibiotic Resistance, Plasmids, Lysogeny and Pathogenicity, Pathogenic Properties of Virus, Eukaryotic Pathogens (Fungi; Protozoa; Algae).

Unit-IV

Microbes and Human Life: Medical and Pharmaceutical benefits of Microbes; Emerging and Reemerging Infectious Diseases; Bioterrorism.

Suggested readings:

1. Murray PR. (2017) Basic Medical Microbiology 1st ed. Elsevier. ISBN: 978032347676
2. Carrol KC, Morse SA, Mietzner T and Miller S. Jawetz, Melnick, & Adelberg's (2016) Medical Microbiology 27th ed... McGraw-Hill Education. ISBN: 9780071824989
3. Ryan K, Ahmad N, Alspaugh JA, Drew JL, Lagunoff M, Pottinger P, Reller LB, Reller M, Sterling C, Weissman S (2018) Sherris Medical Microbiology 7th ed.. McGraw-Hill Education. ISBN: 9781259859809
4. Punt J, Stranford S,Jones P, Owen J (2019) Kuby Immunology 6th ed.. W.H. Freeman and Co. Publishers.
5. Ananthanaryan and Paniker (2017) Textbook of Microbiology 10th ed., Universities Press, ISBN: 9789386235251

Semester-IV

Course title: Research Methodology and Scientific Communication Skills Credit: 3
Course code: SIAS MB 1 4 01 C 3003 Lectures: 45

Course objectives:

- To provide knowledge about tools and techniques related with scientific communication and research methodology.
- To impart knowledge on scientific writing skills

Learning outcomes:

- Understanding the existence of scientific knowledge in ancient times
- Acquiring the skills of scientific reading, writing and presentations
- Appreciating the scientific ethics through case studies

Unit-I

Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.

Unit-II

Choosing a mentor, lab and research question; maintaining a lab notebook. Concept of effective communication- setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences.

Unit-III

Presentation skills - formal presentation skills; preparing and presenting using over-head projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

Unit-IV

Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

Suggested readings:

1. Research Methodology: Methods And Techniques (2019) 4th ed., Kothari CR and Garg G, New Age International Publishers, ISBN: 978-9386649225.
2. Communicate Science Papers, Presentations, and Posters Effectively (2015) Patience GS, Boffito DC, Patience P, Academic Press, ISBN: 978-0128015001.
3. Successful Scientific Writing: A Step-by-Step Guide for the Biological and Medical Sciences (2014) 4th ed., Matthews JR and Matthews RW, Cambridge University Press ISBN: 978-1107691933.

4. Doing Science: Design, Analysis, and Communication of Scientific Research. (2001) Valiela I, Oxford: Oxford University Press, ISBN 10:019538573X.
5. On Being a Scientist: a Guide to Responsible Conduct in Research. (2009) 3rd ed., Washington DC, National Academies Press.

SEMESTER-IV

Course title: Dissertation **Credit: 16**
Course code: SIAS MB 1 4 01 SEEC 0016

Course Learning outcomes:

- Identifying appropriate research question and applying suitable research designs
- Execution of independent research experiments
- Application of knowledge and skills previously gained for selected research problem
- Establishing links between theory and methods in selected area of research
- Understand and apply ethical standards of conduct in the collection and evaluation of data and other resources

Guidelines for Project File

Research experience is as close to a professional problem-solving activity as anything in the curriculum. It provides exposure to research methodology and an opportunity to work closely with a faculty guide. It usually requires the use of advanced concepts, a variety of experimental techniques, and state-of-the-art instrumentation.

Research is genuine exploration of the unknown that leads to new knowledge which often warrants publication. But whether or not the results of a research project are publishable, the project should be communicated in the form of a research report written by the student.

Sufficient time should be allowed for satisfactory completion of reports, taking into account that initial drafts should be critiqued by the faculty guide and corrected by the student at each stage.

The file is the principal means by which the work carried out will be assessed and therefore great care should be taken in its preparation.

In general, the File should be comprehensive and include

- A short account of the activities that were undertaken as part of the project;
- A statement about the extent to which the project has achieved its stated goals.
- A statement about the outcomes of the evaluation and dissemination processes engaged in as part of the project;
- Any activities planned but not yet completed as part of the project, or as a future initiative directly resulting from the project;
- Any problems that have arisen that may be useful to document for future reference.
- The guidelines and format for dissertation is given below:

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Dissertation Guidelines

1. **GENERAL :**

The manual is intended to provide broad guidelines to the M.Sc. candidates in the preparation of the dissertation report. In general, the project report shall report, in an organised and scholarly fashion an account of original research work of the candidate leading to the discovery of new facts or techniques or correlation of facts already known.

2. NUMBER OF COPIES TO BE SUBMITTED:

Students should submit three copies to the Head of the Department concerned on or before the specified date.

3. ARRANGEMENT OF CONTENTS OF DISSERTATION:

Dissertation material should be arranged as follows:

1. Cover Page & Title page
2. Declaration
3. Certificate
4. Abstract (Hindi and English)
5. Acknowledgements
6. Table of Contents
7. List of Tables
8. List of Figures
9. List of Symbols, Abbreviations and Nomenclature (Optional)
10. Chapters
11. References
12. Appendices
13. One page CV

The Tables and Figures shall be introduced in the appropriate places.

4. PAGE DIMENSIONS AND MARGIN:

The dimensions of the dissertation should be standard A4 size paper may be used for preparing the copies, **standard margin** with 1.5 line spacing.

5. MANUSCRIPT PREPARATION:

The general text of thesis shall be typed in font style Times New Roman and font size 12. Same quality of paper should be used for the preparation of the entire report/thesis; except figure, photos are shown.

5.1 **Cover Page & Title Page** - A specimen copy of the Cover page & Title page for report/thesis are given in Annexure I.

5.2 **Certificate**-The Bonafide Certificate as per the format shown in Annexure II

5.3 **Abstract**: Abstract should be an essay type (HINDI and ENGLISH) of narration not exceeding 500 words outlining the research problem, the methodology used for tackling it and a summary of the findings, typed in 1.5line spacing.

5.4 **Acknowledgements:** The acknowledgements shall be brief and should not exceed onepage. The student's signature shall be made at the right bottom above his / her name typed in capitals.

5.5 **Table of contents** - The table of contents should list all material following it as wellas any material which precedes it. The title page, Bonafide Certificate and Acknowledgment will not find a place among the items listed in the Table of Contents but the page numbers in lower case Roman letters are to be accounted for them. One and a half spacing should be adopted for typing the matter under this head. A specimen copy of the Table of Contents for report / thesis is given in Annexure III.

5.6 **List of Table** - The list should use exactly the same captions as they appear above thetables in the text and the caption shall follow 'sentence case'. One and a half spacing should be adopted for typing the matter under this head.

5.7 **List of Figures** - The list should use exactly the same captions as they appear belowthe figures in the text and the caption shall follow 'sentence case'. One and a half spacing should be adopted for typing the matter under this head

5.8 **List of Symbols, Abbreviations and Nomenclature** - One and a half spacing shouldbe adopted for typing the matter under this head. Standard symbols, abbreviations etc. should be used.

5.9 **Chapters** - The chapters may include

Chapter I – Introduction

Chapter II - Literature Review

Chapter III –Materials and Methods

Chapter IV- Results and Discussion

1.10. Research output/outcome if any published or presented in conference/seminar/symposium may be included.

1.11. List of References - Any works of other researchers, if used either directly orindirectly, should be indicated at appropriate places in the report/thesis. The citation may assume any one of the following forms**. APA Style.**

APA in-text citation style uses the author's last name and the year of publication, for example: (Field, 2005).

Example:

Derwing, T. M., Rossiter, M. J., & Munro, M. J. (2002). Teaching native speakers to listen to foreign-accented speech. *Journal of Multilingual and Multicultural Development,* 23(4), 245-259.

Thomas, H. K. (2004). *Training strategies for improving listeners' comprehension of foreign-accented speech* (Doctoral dissertation). University of Colorado, Boulder.

6. TYPING INSTRUCTIONS

6.1 General

This section includes additional information for final typing of the thesis. Some information given earlier under 'Manuscript preparation' shall also be referred. The impressions on the typed/duplicated/printed copies should be black in colour. Corrections, interlineations and crossing out of letters or words will not be permitted in any of the copies of the report/thesis intended for submission. Erasures, if made, should be neatly carried out in all copies. A sub-heading at the bottom of a page must have at least two full lines below it or else it should be carried over to the next page. The last word of any page should not be split using a hyphen. One and a half spacing should be used for typing the general text. The general text shall be typed in Font Style Times New Roman and Font Size 12.

Single spacing should be used for typing:

(i) Long Tables

(ii) Long quotations
(iii) Foot notes

(iv) Multilane captions
(v) References

6.2 Chapters The format for typing chapter headings, division headings and sub division headings shall be same as given in Table of Contents.

7. BINDING SPECIFICATIONS

Thesis should be spiral or soft cover book bound, the cover of thesis should be of dark greencolor, printed with golden ink and the text for printing should be identical as prescribed for the title page.

APPENDIX I A:(A typical Specimen of Cover Page & Title Page–**DISSERTATION**)

<Font Style Times New Roman - Bold>

TITLE OF DISSERTATION

<Font Size 18><1.5 line spacing>

DISSERTATION

<Font Size 14>

Submitted by

<Font Size 14><Italic>

NAME OF THE CANDIDATE

<Font Size 16>

Under the Supervision of

NAME OF THE SUPERVISOR

in partial fulfillment for the award of the degree of

<Font Size 14><1.5 line spacing>

MASTER OF SCIENCE IN

NAME OF THE PROGRAMME

<Font Size 16>

DEPARTMENT OF

SCHOOL OF ……..

CENTRAL UNIVERSITY OF HARYANA

MAHENDERGARH-HARYANA

<Font Size 14><1.5 line spacing>

MONTH AND YEAR

DECLARATION

I ……, student of the School of Interdisciplinary and Life Sciences, Central University of Haryana, Mahendergarh hereby declare and certify with my signature that my thesis entitled

…… submitted to the Department of ……., Central University of Haryana, India in partial fulfillment of the requirements for the award of the Degree of Master of Science is a record of original research work done by me and the dissertation has not been the basis for the award of any degree/diploma/associateship/fellowship or similar title of any candidate of any University. I have faithfully and accurately cited all my sources, including books, journals, handouts and unpublished manuscripts, as well as any other media, such as the Internet, letters or significant personal communications.

I understand the concept of "plagiarism" and declare that while drafting this dissertation I have refrained from plagiarism. I know that plagiarism not only includes direct copying, but also the extensive use of other's ideas without proper referencing or acknowledgement (which includes the proper use of references and quotation marks).

If my dissertation found to be plagiarized at any point of time, I'll be solely responsible and will be ready to accept any decision taken by the competent authority including rejection of my dissertation.

(Supervisor) (Signature of student)

For example

(A typical Specimen of Table of Contents)

<Font Style Times New Roman, Font Size 14>

TABLE OF CONTENTS

ANNEXURE II

Curriculum vitae

<Font Style Times New Roman, Font Size 14>

Personal Details

Name :

Date of birth : DD Month, YYYY

Place of birth :

Nationality : Indian

Permanent Address :

Email Id :

Mobile No. :

Education

M.Sc. (Subject) : YYYY Central University of Haryana, India

B.Sc. (Subject). : YYYY (Name of the University) with …. % of marks

Higher Secondary : YYYY (Name of the board) with …. % of marks

Secondary : YYYY, (Name of the board) with …. % of marks

9. Teaching Learning Process

- Classroom Lectures
- Interactive sessions
- Animation and videos demonstration
- Quizzes
- Flipped classroom
- Group discussions
- Seminars
- Electronic learning
- Tutorials
- Laboratory demonstrations
- Collaborative Learning
- Self-assessed or peer-assessed assignments

10. Blended Learning

Blended learning mode will be adopted in teaching the courses. This mode of learning uses direct as well as indirect mode of instructions through application of ICT. Students gets individualized computer assisted learning. This will also include live discussion on the topic in the theory classroom. This provides more flexible teaching learning environment.

1. Assessment and Evaluation

- Continuous Comprehensive Evaluation at regular after achievement of each Course-level learning outcome
- Formative Assessment on the basis of activities of a learner throughout the programme instead of one-time assessment
- Oral Examinations to test presentation and communication skills
- Open Book Examination for better understanding and application of the knowledge acquired
- Group Examinations on Problem solving exercises
- Seminar Presentations
- Review of Literature
- Collaborative Assignments

2. Key words

- Microbiology
- LOCF
- NEP-2020
- Blended Learning
- Face to face (F to F) Learning
- Programme Outcomes
- Programme Specific Outcomes
- Course-level Learning Outcomes
- Postgraduate Attributes
- Learning Outcome Index
- Formative Assessment and Evaluation
- Comprehensive and Continuous Evaluation

3. References

- National Education Policy-2020. https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf
- The draft subject specific LOCF templates available on UGC website. https://www.ugc.ac.in/ugc_notices.aspx?id=MjY5OQ==
- Draft Blended Mode of Teaching and Learning: Concept Note available on UGC website. https://www.ugc.ac.in/pdfnews/6100340_Concept-Note-Blended-Mode-of-Teaching-and-Learning.pdf

4. Appendices

- Curricular Reforms— Extracts from National Education Policy-2020