SIKKIM UNIVERSITY

(A Central University Established by an Act of Parliament of India, 2007)

LEARNING OUTCOME - BASED CURRICULUM

M.Sc (MICROBIOLOGY) PROGRAMME

(With effect from Academic Session 2023-24)

DEPARTMENT OF MICROBIOLOGY

SIKKIM UNIVERISTY

6th MILE, TADONG - 737102

GANGTOK, SIKKIM, INDIA

VICE-CHANCELLOR'S MESSAGE

Sikkim University stands at the forefront of embracing the transformative National Education Policy (NEP) 2020. In alignment with NEP 2020's vision and the guidelines of the Learning Outcomes-based Curriculum Framework (LOCF) mandated by the UGC, we have undertaken a comprehensive revision of our curriculum across all departments. This initiative ensures a holistic educational experience that transcends traditional knowledge delivery, emphasizing the practical application of knowledge in real-world scenarios.The shift towards LOCF marks a pivotal change from teacher-centric to learner-centric education, fostering a more active and participatory approach to learning. Our updated curriculum clearly defines Graduate Attributes, Programme Learning Outcomes (PLOs), and Course Learning Outcomes (CLOs), setting clear objectives for our students to achieve. This revision is designed to enable a teaching-learning environment that supports the attainment of these outcomes, with integrated assessment methods to monitor and encourage student progress comprehensively.

A key innovation in our curriculum is the mandatory integration of Massive Open Online Courses (MOOCs) through the SWAYAM platform, enhancing accessibility and the breadth of learning opportunities for students. Our approach encourages multidisciplinary studies through the curriculum while allowing for specialization. The curriculum embodies the policy's core principle of flexibility by enabling mobility for students, thereby allowing the exit and entry of students in the program.

I extend my heartfelt gratitude to our faculty, the Head of the Department, the Curriculum Development Committee members, the NEP coordinators, and the dedicated NEP Committee of Sikkim University for their relentless dedication to updating our curriculum. I appreciate Prof. Yodida Bhutia, the Chairperson, and all dedicated NEP Committee members for their thorough review and integration of LOCF and NEP components into our curriculum.

To our students, I convey my best wishes as we embark on this journey with our updated and inclusive curriculum, aiming not only to enrich their academic knowledge but also to nurture their personal growth, critical thinking, and ability to adapt and innovate in an ever-changing world.

Best wishes,

Prof. Avinash Khare
Vice Chancellor
Sikkim University

TABLE OF CONTENTS

PREAMBLE

The Two-Year Master of Science programme in Microbiology aims to impart conceptual clarity on both the fundamental and applied areas of the subject namely Environmental, Food and Industrial Microbiology. The Programme offers specialization papers as Elective Courses to impart advanced knowledge and experimental skills to the students.

POST GRADUATE ATTRIBUTES

Post Graduate attribute (PGA) includes disciplinary knowledge and understanding in both theory and experimental skills in Microbiology which the students should acquire and demonstrate. The graduates should demonstrate the following attributes:

PGA1: Disciplinary Knowledge and Understanding: Comprehensive knowledge and coherent understanding of Microbiology as a discipline and its inter-relationship with other allied disciplines. Understand the current and emerging developments in the field of Microbiology. Experimental skills and knowledge required for conducting research in Microbiology and other allied fields.

PGA2: Critical Thinking and Problem-Solving Aptitude: Capability to critically analyze and evaluate theories and concepts in Microbiology. Capacity for problem solving of critical issues related to the subject in real time scenario.

PGA3: Research Related Skills: Scientific aptitude to formulate and test hypothesis, analyze, interpret and draw conclusions to problems. Ability to plan, implement and report the results of research study abiding by the principles of research ethics.

PGA4: Communication Skills: Listen vigilantly, read texts and research papers analytically and express thoughts and ideas effectively in written and oral form.

PGA5: Digital Literacy and Skills: Competence to use ICT in a variety of learning and experimental assignments/situations and to use appropriate software for creating content and research work. Develop, design and deliver courses using appropriate digital resources.

PGA6: Teamwork and leadership quality: Ability to work effectively and courteously as an individual within a team and as a leader in diverse groups.

PGA7: Multicultural competence: Ability to demonstrate the knowledge, values and beliefs of multiple cultures and effectively engage in a multicultural society by respecting diversity.

PGA8: Value inculcation: Ability to imbibe and practice constitutional, humanistic, ethical, and moral values, practice responsible global citizenship. Adopt appropriate behaviour and participate in actions for environmental conservation, protection and sustainable development.

PROGRAM LEARNING OUTCOMES

PLO1: Acquire considerable knowledge of various domains of microbiology and fundamental concepts in specialised areas of food, environmental and industrial microbiology.

PLO2: Develop analytical and problem-solving skills by applying the concepts learned from different courses in microbiology.

PLO3: Acquaint students with contemporary research in various basic and applied fields of microbiology.

PLO4: Practice ethical and moral values in one's life.

PLO5: Participate in actions to address environmental protection and sustainable development.

PLO6: Acquisition of knowledge and essential employability skills for the societal development.

COURSE STRUCTURE OF MASTER DEGREE PROGRAMME IN MICROBIOLOGY

FIRST SEMESTER					
Course Code	**Title of the Course**	**Credits**	**Total Marks**	**Internal*Marks**	**External Marks**
MIC-C-501	Microbial Domains	4Credits	100	50	50
MIC-C-502	Microbial Metabolisms	4 Credits	100	50	50
MIC-C-503	Indian Contribution (Ancient and Modern) to Microbiology	4 Credits	100	50	50
MIC-V-504	Cyber Security	4 Credits	100	50	50
MIC-P-505	Laboratory Course- I	4 Credits	100	50	50
MIC-S-506	Biosafety and Biohazard Control Procedures	2 Credits	50	25	25
	Total	**22**	**550**	**275**	**275**
SECOND SEMESTER					
MIC-O-551	Instrumentation and Modern Analytical Techniques	4 Credits	100	50	50
MIC-C-552	Microbial Genomics and Metagenomics	4 Credits	100	50	50
MIC-C-553	Bioinformatics	4 Credits	100	50	50
MIC-P-554	Laboratory Course -II	4 Credits	100	50	50
MIC-C-555	Research Methodology	4 Credits	100	50	50
MIC-S-556	Diagnostic Techniques in Clinical	2 Credits	50	25	25

	Microbiology				
	Total	**22**	**550**	**275**	**275**
THIRD SEMESTER					
MIC-O-601	Immunology	4 Credits	100	50	50
MIC-C-602	Medical Microbiology	4 Credits	100	50	50
MIC-P-603	Laboratory Course III	2 Credits	50	25	25
Electives (Choose one theory course from E-604 to E-606 and one Practicum course from P-607 to P-609 from the selected course discipline/specialization #)					
MIC-E-604	Food Microbiology - I	4 Credits	100	50	50
MIC-E-605	Environmental Microbiology -I				
MIC-E-606	Industrial Microbiology-I				
MIC-P-607	Food Microbiology -I	4 Credits	100	50	50
MIC-P-608	Environmental Microbiology -I				
MIC-P-609	Industrial Microbiology -I				
MIC-S-610	Microbiological Quality Control in Food and Beverages	2 Credits	50	25	25
	TOTAL	**20**	**500**	**250**	**250**
FOURTH SEMESTER					
Electives (Choose any three theory courses from E-651 to E-656 and one Practicum course from P-657 to P-659 from the selected course discipline/specialization #)					
MIC-E-651	Food Microbiology - II	4 Credits	100	50	50
MIC-E-652	Food Microbiology - III				
MIC-E-653	Environmental Microbiology –II	4 Credits	100	50	50
MIC-E-654	Environmental Microbiology - III				
MIC-E-655	Industrial Microbiology - II				
MIC-E-656	Industrial Microbiology -III				
MIC-P-657	Food Microbiology –II & III	4 Credits	100	50	50
MIC-P-658	Environmental Microbiology - II & III				
MIC-P-659	Industrial Microbiology - II & III				
MIC-R-660	Dissertation	8 Credits	200	100	100
MIC-S-661	Microbiological Quality Control in Pharmaceutical Industry	2 Credits	50	25	25
	TOTAL	**22**	**550**	**275**	**275**
	TOTAL CREDITS	**86**	**2150**	**1075**	**1075**

C – Core; **V**- Value added Courses **E** – Elective; **O** – Open; **P** – Practicum Courses ; **S** – Skill Enhancement Courses; # Discipline/Specialization- Environmental/Food/Industrial Microbiology

Remarks:

• * to be evaluated internally through formative assessment

• The courses MIC-O-551, MIC-O-601 from First Semester and Second Semester respectively are offered as open courses which can be opted by students from any departments/disciplines from the University.

SWAYAM

Students may earn up to 40 percent of the total credits of the programme from SWAYAM (Study Webs of Active–Learning for Young Aspiring Minds). The selection of the course(s) from SWAYAM is subject to the availability and the 75 percent content similarity with the existing courses in the department. The credits and the grade earned by the students in the particular course will be transferred and added in their mark statement.

FIRST SEMESTER

MIC-C-501
MICROBIAL DOMAINS

Semester: First Semester | **Course Level: 500** | **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits | **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

COURSES LEARNING OUTCOMES:
Upon completion of the course students will be able to:

CLO1: Understand different domains of microorganisms and their current classification systems
CLO2: Understand the basic concept of fungi and unicellular fungi and its diversity
CLO3: Understand the basic concepts of Virology, classification of viruses, its structure and sub-viral agents
CLO4: Understand the diversity, ecology and evolution of Archaea

---

UnitI: About domains; Bacteria
Cultural and unculturable microorganisms. Domains of life; the tree of life; last universal common ancestor (LUCA); different types of domains; horizontal gene transfer. Bacterial domain; diversification through geological time; Biogeography of prokaryotic genes; Phylogenetic inferences of bacterial diversity from microbiome data; Gram-positive and Gram-negative bacteria; Bacterial phyla; Primitive thermophilic bacteria; Green phototrophic bacteria; un-cultivable bacteria. Newly discovered bacteria in the last five years.

Unit II: Eukaryotes (Fungi and yeasts)
Eukaryogenesis; Endosymbiosis and Eukaryotic cell evolution; Plastids; Fungi and unicellular fungi (yeast); Modern classification of fungi (molds) and yeasts. Dimorphic fungi; Ecology and diversity of microbial eukaryotes in different environments - Human microbiome, Food-associated matrices, geothermal, marine, and freshwater environments.

Unit III: Virus
History of viruses. Nature, origin and evolution of viruses. Classification of viruses. Principles of virus (Animal viruses, plant viruses and bacteriophages) structure, transcription, translation and replications. New emerging viruses. Characteristics of sub-viral agents – Viroids, Satellite viruses, Satellite nucleic acids and Prions. Bacteriophages and its role in food matrix and medical applications.

Unit IV: Archaea and other unclassified
General properties of the Archaea; Diversity, ecology and evolution of Archaea; Archaea and the origin of eukaryotes; Crenarchaeota, Euryarchaeota, Korarchaeota, Nanoarchaeota, and newly identified Phyla Brockarchaeota and Lokiarchaeota; Diversity of uncultivated Archaea; Diversity and phenotypes of human-associated Archaea. Role of archaea in food matrix and medical microbiology.

Suggested teaching learning strategies:

1. Lecture-cum discussion: On the basic taxonomic principles on which microbial classification is carried out and diversity of microbial world

2. Problem-Based Learning: Assignment will be provided to enhance problem solving skill of the students which will enhance the knowledge on Microbial diversity.
3. Journal Club: Assign scientific papers related to molecular biology techniques for students to read and discuss, encouraging critical analysis and understanding of the methods.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings :

1. Baker, B. J., De Anda, V., Seitz, K. W., Dombrowski, N., Santoro, A. E., and Lloyd, K. G. (2020). Diversity, ecology and evolution of Archaea. *Nature Microbiology*, 5(7): 887-900.
2. Brown, J. W. (2014). Principles of Microbial Diversity. John Wiley & Sons.
3. Cann, A.J. (2005). Principles of Molecular Virology. 4th edition. Academic Press.
4. De Anda, V., Chen, L. X., Dombrowski, N., Hua, Z. S., Jiang, H. C., Banfield, J. F., and Baker, B. J. (2021). Brockarchaeota, a novel archaeal phylum with unique and versatile carbon cycling pathways. *Nature Communications* 12(1), 2404.
5. Eme, L., Spang, A., Lombard, J., Stairs, C. W., and Ettema, T. J. (2017). Archaea and the origin of eukaryotes. *Nature Reviews Microbiology* 15(12): 711-723.
6. Imachi, H., Nobu, M. K., Nakahara, N., Morono, Y., Ogawara, M., Takaki, Y., and Takai, K. (2020). Isolation of an archaeon at the prokaryote–eukaryote interface. *Nature* 577(7791), 519-525.

MIC-C-502
MICROBIAL METABOLISMS

Semester: First Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be aware of biomolecules and mechanisms of catalysis.
CLO2: Students will learn about the mechanisms of molecular transport useful in the cellular systems.
CLO3: Learners will gain an insight on metabolomics and its use in the study of microbial metabolism.
CLO4: Students will learn about the strategies used by microbes to generate energy

---

Unit I: Biomolecules and Enzymes
Glycoconjugates in microbial systems: Structure and synthesis of glycoconjugates in microbial cells. Application of glycoconjugates. Proteins: amphoteric properties of amino acids and isoelectric points of amino acids and peptides; Ramachandran plot; Protein structure; Protein characterization and functional analysis. Lipids in the plasma membranes; Brief account of application of membrane lipids in classification of bacteria. Enzyme kinetics, enzyme inhibition and inhibitors. Allosteric enzymes and their regulation; Specific mechanisms of enzyme catalysis – serine proteases.

Unit II: Plasma Membranes and Secretory Systems
Plasma Membrane: Lipids in the plasma membranes; Brief account of application of membrane lipids in classification of bacteria. Transport across the membranes: Diffusion, osmosis, ion channels, active and passive transport, membrane pumps, mechanism of sorting and regulation of intracellular transport, electrical properties of membranes. Secretory systems in Gram-positive and negative bacteria.

Unit III: Fermentations and Phosphorylations
Energy yielding approaches in microbial groups: Fermentations; Phosphorylations in microorganisms: oxidative phosphorylations, photophosphorylations; Chemosynthesis; anaerobic respiration; aerobic chemoorganotrophic processes.

Unit IV: Introduction to Microbial Metabolomics
Metabolomics as a tool to study microbial metabolites: Definitions – Metabolites, approaches of metabolomics; Sample preparation for metabolomic; Brief introduction to the data acquisitions for metabolomic study – mass spectrometry and NMR; Metabolome database and metabolome data analysis. Targeted and untargeted metabolites, and their biological functions.

Suggested teaching learning strategies:

1. Lecture-cum discussion: On the biomolecules and molecular transport across the membranes.
2. Problem-Based Learning: Students will be provided with problems applicable in the field of the study and show them how these problems can be solved.

3. Journal Club: Assign scientific papers related to molecular biochemistry for students to read and discuss, encouraging critical analysis and understanding of the methods.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Oral Test, Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Nelson, D. L. and Cox, M.M. 2021. *Lenhinger's Principles of Biochemistry International Edition (Paperback)*. 8th edition. W.H. Freeman
2. J. Berg and L. Stryer, 1988.*Biochemistry*. 9th edition, W. H. Freeman & Co.
3. Madigan, T. M., Martinko, J.M. and Parker, J. 2021. *Brock's Biology of Microorganisms*. 16th edition, Prentice Hall College Div.
4. McKitrick, T. R., Ackerman, M. E., Anthony, R. M., Bennett, C. S., Demetriou, M., Hudalla, G. A., Ribbeck, K., Ruhl, S., Woo, C. M., Yang, L., Zost, S. J., Schnaar, R. L., & Doering, T. L. (2021). The Crossroads of Glycoscience, Infection, and Immunology. *Frontiers in Microbiology*, *12*. https://doi.org/10.3389/fmicb.2021.731008
5. Baidoo EEK. Microbial Metabolomics: A General Overview. Methods Mol Biol. 2019;1859:1-8. doi: 10.1007/978-1-4939-8757-3_1. PMID: 30421221.
6. Nicholson KR, Champion PA (2022) Bacterial secretion systems: Networks of pathogenic regulation and adaptation in mycobacteria and beyond. PLoS Pathog 18(7): e1010610. https://doi.org/10.1371/journal.ppat.1010610

MIC-C-503
INDIAN CONTRIBUTION (ANCIENT AND MODERN) TO MICROBIOLOGY

Semester: First Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Inculcate scientific development for nation-building.
CLO2: Respect the ancient Indian bacteriology-*Sukshmjeevanu*
CLO3: Understand the current status of microbiology in teaching and research
CLO4: Know about the scope and challenges in microbiology

Unit I:: Ancient Microbiology
Sukshmjeevanu in Vedas; Ancient Bacteriology. History of development of microbiological science in ancient India to modern India.

Unit II: Indian Microbiologists: Pre- and Post Independence
Contributions of Indian microbiologists in pre-Independence; Contributions of Indian microbiologists in post-Independence.

Unit III: Microbiology in India: Teaching and Research
The first Colleges and Universities in India which started teaching of microbiology as a separate subject; Microbiological societies and associations. Indian Journals in Microbiology (*Indian Journal of Microbiology; The Indian Journal of Pathology and Microbiology; Indian Journal of Medical Microbiology, Indian Journal of Microbiology Research, Indian Journal of Applied Microbiology*). Indian patents in microbiology.

Unit IV: Microbiology in India: status, challenges and scope
Main areas of microbiological research in India: Foods, Soil, Agriculture, Forestry, Marine, High Altitudes, Medical, Vaccine, Drugs, Antibiotics, Industrial applications, Dairy, Meat and Fishery, Biofuels, Computational Biology, Gut microbiota. Microbial products of India-biofertilizers, biofuels, probiotics, starter cultures, bakers and brewing yeasts, vaccines, enzymes, antibiotics, bio-preservative products; Challenges and scopes of Indian microbiological companies.

Suggested teaching learning strategies:

1. Lecture-cum discussion on history and development of microbiology in India since *Vedic* period to modern times.
2. Case Based Learning on teaching and research on microbiology in India.
3. Journal Club -Presentation assignments on main areas of microbiological research in India.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per the nature of the CLO.

Suggested Readings:

1. Lal, R., Singh, B., Sar, P. and Phale, P. (2022). Microbiology in India: status, challenges and scope. *Environmental Microbiology* 24: 2607-2611. https://doi.org/10.1111/1462-2920.16005
2. Sircar, N.N. (1919). Ancient Indian bacteriology. *Ancient Science of Life*, X (3): 180 – 184.
3. Tamang, J.P. (2022). "Ethno-Microbiology" of ethnic Indian fermented foods and alcoholic beverages. *Journal of Applied Microbiology* 133: 145-161.doi:10.1111/jam.15382.
4. Vijnana Bharati (2019). Indian contribution to Science. Vijnana Bharati publication, New Delhi

MIC- V-504

CYBER SECURITY

Semester: First Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 2+1+1 = 4 Credits **Lecture: 30 Hrs + Tutorial: 15 Hrs + Practical: 15 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be aware as well as develop a deeper understanding with various types of cyber attacks, cyber crimes, vulnerabilities and their remedies.
CLO2: Learners will be aware of existing legal framework and laws on cyber security.
CLO3: Students will be aware of the security aspects of social media platforms and ethical aspects associated with use of social media.
CLO4: Students will be able to take measures on cyber-protection.

Unit I: Overview of Cyber security and Cyber crimes
Cyber security increasing threat landscape, Cyber security terminologies- Cyberspace, attack, attack vector, attack surface, threat, risk, vulnerability, exploit, exploitation, hacker., Non-state actors, Cyber terrorism, Protection of end user machine, Critical IT and National Critical Infrastructure, Cyberwarfare, Case Studies.
Cyber crimes targeting Computer systems and Mobiles- data diddling attacks, spyware, logic bombs, DoS, DDoS, APTs, virus, Trojans, ransomware, data breach., Online scams and frauds- email scams, Phishing, Vishing, Smishing, Online job fraud, Online sextortion, Debit/ credit card fraud, Online payment fraud, Cyberbullying, website defacement, Cyber-squatting, Pharming, Cyber espionage, Cryptojacking, Darknet- illegal trades, drug trafficking, human trafficking., Social Media Scams & Frauds- impersonation, identity theft, job scams, misinformation, fake newscyber crime against persons - cyber grooming, child pornography, cyber stalking., Social Engineering attacks, Cyber Police stations, Crime reporting procedure, Case studies.
PRACTICAL-

1. Platforms for reporting cyber-crimes.
2. Checklist for reporting cyber-crimes online.

Unit II: Cyber Law; Data Privacy and Data Security
Cyber-crime and legal landscape around the world, IT Act,2000 and its amendments. Limitations of IT Act, 2000. Cyber crime and punishments, Cyber Laws and Legal and ethical aspects related to new technologies- AI/ML, IoT, Blockchain, Darknet and social media, Cyber Laws of other countries, Case Studies.
Defining data, meta-data, big data, non-personal data. Data protection, Data privacy and data security, Personal Data Protection Bill and its compliance, Data protection principles, Big data security issues and challenges, Data protection regulations of other countries- General Data Protection Regulations (GDPR),2016 Personal Information Protection and Electronic Documents Act (PIPEDA)., Social media- data privacy and security issues.

PRACTICAL

1. Setting privacy settings on social media platforms.

2. Do's and Don'ts for posting content on social media platforms.
3. Registering complaints on a Social media platform.

Unit III: - Cyber security management, Compliance and Governance

Cyber security Plan- cyber security policy, cyber crises management plan., Business continuity, Risk assessment, Types of security controls and their goals, Cyber security audit and compliance, National cyber security policy and strategy.

Unit IV: PRACTICAL

1. Prepare password policy for computer and mobile device.
2. List out security controls for computer and implement technical security controls in the personal computer.
3. List out security controls for mobile phone and implement technical security controls in the personal mobile phone.
4. Log into computer system as an administrator and check the security policies in the system.

Suggested teaching learning strategies:

1. Lecture and interactive discussion on Cyber security and Cyber crimes.
2. Problem-Based Learning on Cyber security management, compliance and governance.
3. Journal Club: Presentation on current issues of cyber-crime, cyber security and existing laws for the same.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Cyber Security Understanding Cyber Crimes, Computer Forensics and Legal Perspectives by SumitBelapure and Nina Godbole, Wiley India Pvt. Ltd.
2. Information Warfare and Security by Dorothy F. Denning, Addison Wesley.
3. Security in the Digital Age: Social Media Security Threats and Vulnerabilities by Henry A. Oliver, Create Space Independent Publishing Platform.
4. Data Privacy Principles and Practice by Natraj Venkataramanan and Ashwin Shriram, CRC Press.
5. Information Security Governance, Guidance for Information Security Managers by W. KragBrothy, 1st Edition, Wiley Publication.
6. Auditing IT Infrastructures for Compliance By Martin Weiss, Michael G. Solomon, 2nd Edition, Jones Bartlett Learning.

MIC-P-505
LABORATORY COURSE -I

Semester: First Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 0+0+4= 4 Credits **Lecture: 0 Hrs + Tutorial: 0 Hrs + Practical: 60 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be acquainted with laboratory practices and modern methodologies in microbiology.
CLO2: Students will be able to perform basic microbiology techniques related to isolation and study of microorganisms.
CLO3: Learners will be acquainted with biochemical and microscopic methods to characterise microorganisms.
CLO4: Students will be able to perform quantification of some biomolecules and hands on training on agarose gel electrophoresis and SDS-PAGE.

Experiments

1. Good Microbiology Laboratory Practices and Laboratory discipline.
2. Demonstration of different instruments commonly used in microbiology laboratory.
3. Handling and care of microscopes.
4. Calibration of microscope and measurement of microscopic objects (Bacteria, yeast and fungal filaments/spores).
5. Staining: Preparation of stains, simple staining techniques, Differential staining techniques, Special staining techniques [smear preparation, Gram's staining, Acid fast staining (Demonstration), staining for metachromatic granules, Negative staining and spore staining].
6. Motility test by wet mount (hanging drop) and in solid media.
7. Sterilization and disinfection methods with special reference to hot air oven, autoclave, ultrafiltration.
8. Preparation of culture media and biochemical reagents.
9. Isolation of pure culture of bacteria by streak plate method.
10. Serial dilution and enumeration of bacteria by pour plate and spread plate methods.
11. Isolation of pure culture of fungi from the given sample by pour plate.
12. Identification of bacteria using standard biochemical tests– Carbohydrate fermentation tests (Glucose, lactose, fructose, sucrose, mannitol, arabinose) for detection of acid and gas production.
13. Identification of bacteria using standard biochemical tests– SIM, IMViC, and TSI.
14. Estimation of Carbohydrate.
15. Isolation and estimation of Protein.
16. Assay of enzymes: Amylase.
17. Enzyme activity -Factor influencing enzyme activity: pH, Temperature.
18. Separation of lipids and amino acids by Paper chromatography and Thin layer Chromatography.
19. Electrophoresis (Agarose and SDS-PAGE).
20. Demonstration of gas chromatography.
21. Demonstration HPTLC, Biolog, PCR.

Suggested teaching learning strategies:

1. Discussion on the aim and objective of the practical.
2. Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.
3. Knowing and adapting good laboratory practices.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50 (25+25 internal and final practical exam)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Baxevanis, A. D. & Ouellette, B. F. F. (2004). *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins*, 3rd edition, USA: Wiley-Inter Science. 1-560. ISBN-13: 978-0471478782.
2. Goldman, E. & Green, L. H. (2008). *Practical Handbook of Microbiology*, 2nd edition. USA:CRC Press. 1-874. ISBN-13: 978-0849393655.
3. Krane, D. E. &Raymer, M. L. (2002). *Fundamental Concepts of Bioinformatics*. USA:Benjamin Cummings (Pearson). 1-320. ISBN-13: 978-0805346336.
4. Plummer, D. (2017). *Introduction to Practical Biochemistry*, 3rd edition. New York: McGraw Hill Education. 1-332. ISBN-13: 978-0070994874.
5. White, D. &Hegeman G. D. (1998). *Microbial Physiology and Biochemistry Laboratory: A Quantitative Approach*. New York, USA: Oxford University Press. 1-176. ISBN-13: 978-0195113136.
6. Wilson, K. & Walker, J. (2000). *Principles and Techniques of Practical Biochemistry*, 5th edition. UK: Cambridge University Press. 1-802. ISBN-13: 978-0521651042.
7. Womble D. D. &Krawetz S. A. (2003) *Introduction to Bioinformatics: A Theoretical and Practical Approach*. India, New Delhi: Springer. 1-746. ISBN-13: 978-1588290649.

MIC- S-506
BIOSAFETY AND BIOHAZARD CONTROL PROCEDURES

Semester: First Semester **Course Level: 500** **Total Marks: 50**
L+T+P: 1+1+0 = 2 Credits **Lecture: 15 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be aware of critical analysis on concepts of "Biosafety Levels and Guidelines" while working in laboratory.

Unit I: Biosafety
Good Microbiological Practices and Procedures. International and National Biosafety Guidelines. Classification of Biosafety Levels.

Unit II: Biohazard Control Procedures
Biohazard- Definition, introduction, classification. Biohazard Control Procedures.

Suggested teaching learning strategies:

1. Lecture and interactive discussion on Good microbiological practices and procedures; International and National Biosafety Guidelines and Classification of Biosafety Levels.
2. Problem-Based Learning on handling biosafety issues in the working laboratory.
3. Journal Club: Presentation of case studies of relevant and current biosafety issues and revised guidelines.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 25	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 25	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Byrd J. J., Emmert E., Maxwell R., Townsend H., (2019). ASM Task Committee on the Revision of the 2012 Laboratory Biosafety Guidelines. Guidelines for Biosafety in Teaching Laboratories Version 2.0: A Revised and Updated Manual for 2019. *Journal of Microbiology and Biology Education.* 20 (3):20.3.57. doi: 10.1128/jmbe.v20i3.1975.
2. Laboratory Biosafety Manual. (2020). World Health Organization; Geneva: (Laboratory biosafety manual, fourth edition and associated monographs). Licence: CC BY-NC-SA 3.0 IGO. ISBN 978-92-4-001131-1 (electronic version) ISBN 978-92-4-001132-8 (print version).
3. Ta L., Gosa L., Nathanson D.A. (2019). Biosafety and Biohazards: Understanding Biosafety Levels and Meeting Safety Requirements of a Biobank. *Methods in Molecular Biology*. 1897:213-225. doi: 10.1007/978-1-4939-8935-5_19.

SECOND SEMESTER

MIC-O-551
INSTRUMENTATION AND MODERN ANALYTICAL TECHNIQUES

Semester: Second Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 2+1+1 = 4 Credits **Lecture: 30 Hrs + Tutorial: 15 Hrs + Practical: 15**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Design and execute analytical experiments using various modern instruments.
CLO2: Understand the principles and applications of various analytical techniques used in modern research in microbiology.
CLO3: Analyze and interpret the data obtained from various analytical techniques and instrumentation.
CLO4: Apply the knowledge gained to design and execute analytical experiments to solve real-world problems.

Unit I: Microscopy
Principle and application: Light microscopy (Bright field, Dark field, Phase contrast, fluorescence microscopy and confocal microscopy), electron microscopy (Scanning and transmission microscopy), Atomic force Microscopy.

Unit II: Spectroscopy and Centrifugation
Spectrometric techniques: Principles of spectrophotometry (Lambert-Beers law, scatterings), Ultraviolet and visible light spectroscopy, Fluorescence spectroscopy, Atomic spectroscopy, Infrared and Raman spectroscopy. Mass spectroscopy and MALDI – TOF, ICP-MS, NMR, XRD. Centrifugation techniques: Preparative centrifugation and Analytical centrifugation, Care and safety aspects of centrifuges.

Unit III: Chromatography and Electrophoresis
Principles and application of Chromatography. Types: Paper and thin layer chromatography, Column chromatography, gel filtration, ion exchange, affinity, high-pressure liquid, Gas liquid chromatography, HPTLC. Electrophoresis of proteins and nucleic acids.

Unit IV Molecular Biology Techniques
Radio-isotopic and Fluorescence techniques. PCR, Real Time PCR, Blotting techniques. Molecular Markers (RAPD, RFLP, AFLP & Microsatellite); DNA Barcoding. Sequencing techniques: Sanger sequencing, Pyrosequencing, 16S rRNA amplicon sequencing and shotgun sequencing.

Suggested teaching learning strategies:

1. Lecture-cum discussion: On the basic principles on which modern analytical techniques works
2. Hands-on Microscopy: Provide students with access to microscopes and specimens, allowing them to explore and observe various samples first-hand.
3. Demonstration Experiments: Conduct live demonstrations of spectroscopic techniques, such as UV-Vis spectroscopy or nuclear magnetic resonance (NMR), to illustrate the principles and applications of these methods.

4. Problem-Based Learning: Present students with complex scenarios that require the selection and optimization of chromatographic or electrophoretic methods to solve analytical problems.
5. Journal Club: Assign scientific papers related to molecular biology techniques for students to read and discuss, encouraging critical analysis and understanding of the methods.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested readings:

1. Allison L.A. (2021). Fundamental Molecular Biology, 3rd Edition. Wiley.
2. Jain A., Jain R., & Jain S. (2020). Basic Techniques in Biochemistry, Microbiology and Molecular Biology. Springer. doi: 10.1007/978-1-4939-9861-6.
3. Kimura A. (2022). Quantitative Biology: A Practical Introduction. Springer. doi:10.1007/978-981-16-5018-5.
4. Pandey S., Goswami S.K., & Jain B.P. (2020). Protocols in Biochemistry and Clinical Biochemistry. Elsevier.
5. Patil N., & Sivaram A. (2022). A Complete Guide to Gene Cloning: From Basic to Advanced. Springer. doi: 10.1007/978-3-030-96851-9.
6. Seidman L.A., Moore C.J. & Mowery J. (2021). Basic Laboratory Methods for Biotechnology: Textbook and Laboratory Reference. CRC Press. doi: 10.1201/9780429282799.

MIC- C-552

MICROBIAL GENOMICS AND METAGENOMICS

Semester: Second Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be familiar with the microbial genomics and the role and characteristics of plasmids.
CLO2: Learners will acquire knowledge on gene expressions strategies used by the micoroganisms
CLO3: Students will be acquainted with the role of mobile genetic elements, RNA molecules, mutations and repair mechanisms of genetic materials.
CLO4: Students will be familiar with current development in proteomics and genomics microbiology.

Unit I: Microbial Genetics
Introduction to the Gene transfer mechanisms: transformation, transduction, conjugation. Genetic mapping with the help of conjugation and transduction;
Phage genetics: Benzer's studies on r-II region of T4 and complementation, recombination in bacteriophages (T2), use of phages in microbial genetics
Plasmid: Introduction of bacterial and yeast plasmids, classification, incompatibility, copy number control, purification, properties, detection, transfer, replication and curing

Unit II: Transcription, translation and gene regulation
RNA polymerase structure and function, prokaryotic promoter sequence; transcription initiation, elongation and termination; anti-termination. Major differences between prokaryotic and eukaryotic transcription. Concept of genetic code, translation process in prokaryotes, translational proof-reading, translational inhibitors. Major differences between prokaryotic and eukaryotic translation. Operon – Positive and Negative regulation of lac operon; attenuation of trp operon, inhibitors of protein biosynthesis

Unit III: Transposons, RNA Molecules, Mutation
Transposable elements (DNA transposons, viral like retrotransposons, polyA retrotransposons), mechanism of transposition; RNA interference; Mutation – mutagens, types, causes and detection of mutation. In vitro mutagenesis and deletion techniques. DNA damage and repair: types of DNA damage-deamination, oxidative damage, alkylation and pyrimidine dimers; repair pathways – mismatch, short patch repair, nucleotide/base, excision repair, recombination repair and SOS system.

Unit IV: Recombinant DNA technology, Genomics and Proteomics
Phenomenon of Restriction Modification systems; molecular cloning, expression of recombinant proteins in prokaryotic and eukaryotic vectors; Preparation of cDNA libraries in plasmid. Phagemid, cosmid, BAC and YAC vectors. Gene knockout in bacteria, Fluorescence in situ hybridization, sequence tagged site mapping; genome – structure and function, annotation, transcriptome – microarray or chip analysis; Introductory Proteomics. Introduction to unculturable microorganisms – metagenomics and microbiome.

Suggested teaching learning strategies:

1. Lecture-cum discussion: Lectures on the recent advancements in the microbial genomics and metagenomics will be held followed by discussions.
2. Problem-Based Learning: Assignment on genomics and recombinant DNA technologies will be provided to enhance problem solving skill of the students.
3. Journal Club: Students will present latest research developments in the field of genomics and metagenomics in journal club to enhance students' knowledge, analytical skill in the field of microbial genomics.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Birge, E.A. (2000). *Bacterial and Bacteriophage Genetics*. 4th ed. New York Inc.: Springer-Verlag. 1-576. ISBN-13: 978-0387987309.
2. Fraser, C. M., Read, T., Nelson, K. E. & Venter, J. C. (2004). *Microbial Genomes*. New Jersey: Humana Press. 1-536. ISBN-13: 978-1588291899.
3. Glick, B. R. & Pasternak, J. J. (2002). *Molecular Biotechnology: Principles and Applications of Recombinant DNA*, 3rd edition. Washington, DC: American Society for Microbiology (ASM). 1-860. ISBN-13: 978-1555812249.
4. Lodish, H. F., Berk, A., Kaiser, C., Krieger, M., Bretscher, A., Ploegh, H. L., & Amon, A. (2021). *Molecular cell biology*. New York: Macmillan learning.
5. Panda, A. K., Jin, F., Kumar, N. S., Bisht, S. S., & Mandal, S. D. (2021). *Metagenomics and Microbial Ecology: Techniques and Applications*, 1st edition. United States: CRC Press. 1-200. ISBN-13: 978-0367487348.
6. Primrose, S. B., Twyman, R., & Old, B. (2001). *Principles of Gene Manipulation: An Introduction to Genetic Engineering*, 6th Edition. New Jersey, United States: Wiley–Blackwell. 1-400. ISBN-13: 978-0632059546.
7. Snyder, L. (2020). *Bacterial Genetics and Genomics*, 1st Edition. New York City: Garland Science. 1-389. ISBN-13: 978-0815345695

MIC-C-553
BIOINFORMATICS

Semester: Second Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes
Upon completion of the course students will be able to:

CLO1: Students will understand the importance of the application of bioinformatics in Microbiology.
CLO2: Student will develop basic concepts in the field of bioinformatic analysis
CLO3: Students will acquire knowledge in analysing Sanger sequencing, next generation sequencing, metagenomics as well as whole-genome analysis.

Unit I:-: Introduction to Bioinformatics
History of bioinformatics; Machine Learning;Integration of bioinformatics in many scientific fields; Homology;Computers and operating systems required for bioinformatics- Linux, Python, Biopython; Command line user interface (CLI);Different files and formats commonly used in bioinformatics like fasta, fastq, bam, sam, Genbank flat file (gbk), general feature format (gff/gff3).

Unit II: Sanger sequencing and whole-genome analysis tools
LPSN (List of Prokaryotic names with Standing in Nomenclature); SequenceScanner, Chromas, BioEdit, FinchTV, ClustalW, Mallard, Phylogenetics, MEGA (Molecular Evolutionary Genetics Analysis); (MLST) Multilocus sequence typing;BLAST (Basic Local Alignment Search Tool), EzTaxon, NCBI, GenBank;Whole-genome analysis - QUAST, Unicycler,SPAdes, BRIG (BLAST Ring Image Generator; Pangenomics (roary, PGAP).

Unit III: High-throughput sequencing analysis tools
Quality checking tools - FastQC, MultiQC; Mothur, QIIME1/QIIME2 (Quantitative Insights Into Microbial Ecology), USEARCH, UCHIME, UPARSE, OTU (operational taxonomic unit), sOTUs (sub-OTUs), mOTUs (molecular OTUs), ASVs (Amplicon sequence variants);Databases (Greengenes, SILVA, UNITE, RDP);Gene prediction from 16S rRNA gene using PICRUSt/PICRUSt2 (Phylogenetic Investigation of Communities by Reconstruction of Unobserved States), Piphillin,PanFP, CopyRighter, Tax4Fun.

Unit IV: Shotgun metagenomics and metagenome-assembled genome analysis tools
Metagenomics assemblersfor shot reads – MEGAHIT, MetaSPAdes; Metagenomics assemblers for long reads – Canu, NECAT, metaFlye; Metataxonomic analysis tools - kaiju, kraken, metaphlan; Gene prediction tools - MetaGeneMark, FragGeneScan, Prodigal; Predictive functional tools - BlastKOALA, GhostKOALA, EggNOG-mapper, SqueezeMeta, KEGG (Kyoto Encyclopedia of Genes and Genomes), COG (Clusters of Orthologous Genes), BioCyc;Metagenome-assembled genome analysis tools - MaxBin2, CONCOCT, MetaBAT2, DAS Tool, CheckM, Genome Taxonomy Database (GTDB-Tk); Secondary metabolites prediction tools – BAGEL4, antiSMASH. CRISPR/Cas elements prediction tools – CRISPRCasFinder, CRISPRedict, CRISPRDetect.

Suggested teaching learning strategies:

1. Lecture-cum discussion: Lesson on how computer setup works and various operating systems.
2. Hands-on practice: Provide students access to various computer system with different operating system.
3. Demonstration experiments: Conduct case studies sequencing analysis of various pipelines for Sanger, High-throughput amplicon sequencing. Shotgun metagenomics and whole-genome analysis.
4. Problem-based learning: Present students with different datasets so that a useful insight can be drawn with statistics.
5. Journal Club: Assign student with papers related to various sequencing platform-based analyses.

Assessment framework

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Suggested Readings:

1. Beiko, R. G., Hsiao, W., and Parkinson, J. (Eds.). (2018). Microbiome analysis: methods and protocols. Humana New York, United States, ISBN: 978-1-4939-8726-9.
2. Christensen, H. (Ed.). (2018). Introduction to Bioinformatics in Microbiology. Cham, Switzerland: Springer International Publishing, Switzerland, ISBN: 978-3-319-99279-2.
3. Izard, J., and Rivera, M. (Eds.). (2014). Metagenomics for Microbiology. Academic Press, London, United Kingdom, ISBN: 978-0-12-410472-3.
4. Ranganathan, S., Nakai, K., and Schonbach, C. (2018). Encyclopedia of bioinformatics and computational biology: ABC of bioinformatics. Elsevier. Cambridge, United States, ISBN: 978-0-12-811432-2.
5. Mengoni, A., Galardini, M., and Fondi, M. (2016). Bacterial Pangenomics. Humana. New York, United States, ISBN: 978-1-0716-1101-2.
6. Singh, M. (Ed.). (2016). Research in Computational Molecular Biology: 20th Annual Conference, Santa Monica, CA, United States, Springer, ISBN: 978-3-319-31956-8.
7. Aoki, K. F., and Kanehisa, M. (2005). Using the KEGG database resource. *Current Protocols in Bioinformatics*, 11(1), 1-12.doi: https://doi.org/10.1002/0471250953.bi0112s11.
8. Estaki, M., Jiang, L., Bokulich, N. A., McDonald, D., González, A., Kosciolek, T., and Knight, R. (2020). QIIME 2 enables comprehensive end-to-end analysis of diverse microbiome data and comparative studies with publicly available data. *Current Protocols in Bioinformatics*, 70(1), e100.doi: https://doi.org/10.1002/cpbi.100.

9. Sun, S., Jones, R. B., and Fodor, A. A. (2020). Inference-based accuracy of metagenome prediction tools varies across sample types and functional categories. *Microbiome*, 8(1), 1-9.doi: https://doi.org/10.1186/s40168-020-00815-y.

10. Wemheuer, F., Taylor, J. A., Daniel, R., Johnston, E., Meinicke, P., Thomas, T., and Wemheuer, B. (2020). Tax4Fun2: prediction of habitat-specific functional profiles and functional redundancy based on 16S rRNA gene sequences. *Environmental Microbiome*, 15(1), 1-12.doi: https://doi.org/10.1186/s40793-020-00358-7.

11. Yang, C., Chowdhury, D., Zhang, Z., Cheung, W. K., Lu, A., Bian, Z., and Zhang, L. (2021). A review of computational tools for generating metagenome-assembled genomes from metagenomic sequencing data. *Computational and Structural Biotechnology Journal*, 19, 6301-6314.doi: https://doi.org/10.1016/j.csbj.2021.11.028.

12. Xiao, J., Zhang, Z., Wu, J., and Yu, J. (2015). A brief review of software tools for pangenomics. *Genomics, Proteomics&Bioinformatics*, 13(1), 73-76.doi: https://doi.org/10.1016/j.gpb.2015.01.007.

MIC-P-554
LABORATORY COURSE –II

Semester: Second Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 0+0+4 = 4 Credits **Lecture: 0Hrs + Tutorial: 0 Hrs + Practical: 60 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1. Students will be able to perform isolation of genomic and plasmid DNA from microorganisms.
CLO2. Students can also perform various other techniques of molecular biology.
CLO3. Students will be able to understand and use some of the bioinformatics tools.
CLO4. Students will also be able to identify microorganisms by BIOLOG

Experiments

1. Demonstration of primer designing used for polymerase chain reaction.
2. Identification of bacterial and fungal species using phylogenetic analysis.
3. Introduction to a command-line user interface and commonly used web servers.
4. Demonstration of different database commonly used in bioinformatics.
5. Nucleotide sequence searches and alignments.
6. Gene prediction and functional annotation from DNA sequences.
7. Isolation of genomic DNA from bacteria.
8. Isolation of plasmid DNA from bacteria.
9. Agarose gel electrophoresis of the isolated genomic and plasmid DNA.
10. PCR Amplification of target DNA.
11. Purification of PCR amplified DNA from agarose gel.
12. Quantification of DNA by UV-Visual spectroscopy.
13. Bacterial transformation.
14. Bacterial conjugation.
15. Electrophoresis SDS-PAGE and native page.
16. Demonstration of Real-Time PCR.
17. Demonstration of DNA sequencing techniques.
18. Isolation and identification of medically important bacteria from human skin and some clinical samples like pus, urine & stool.
19. Demonstration of BIOLOG for phenotypic identification of bacteria.

Suggested teaching learning strategies:

1. Discussion on the aim and objective of the practical.
2. Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.
3. Knowing and adapting good laboratory practices.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50 (25+25 internal and final practical exam)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Arora, D. K., Das, S., & Sukumar, M. (Eds.). (2013). *Analyzing Microbes: Manual Of Molecular Biology Techniques*. Heidelberg, USA: Springer. 1-290. ISBN: 978-3-642-34410-7.
2. Cappuccino, J. G. & Sherman, N. (2008). *Microbiology Lab Manual E*dition. USA: Benjamin-Cummings. 1-569. ISBN-13: 978-0805325782.
3. Carson, S., Miller, H. B., Srougi, M. C., &Witherow, D. S. (2019). *Molecular Biology Techniques: A Classroom Laboratory Manual*, 4th Edition. USA: Academic Press. 1-294. ISBN: 9780128180242.
4. Christensen, H. (2018). *Introduction to Bioinformatics in Microbiology*, 1st edition. Switzerland: Springer. 1-213. ISBN-13: 978-3319992792.
5. Collee, J. G., Fraser, A. G., Marmion, B. P. & Simmons, A. (1996). *Mackie &Mccartney Practical Medical Microbiology*, 14th edition. Netherlands: Elsevier. 1-992. ISBN-13: 978-8131203934.
6. Sambrook, J. (2001). *Molecular Cloning: A Laboratory Manual*, 3rd Edition. U.S.: Cold Spring Harbor Laboratory (CSHL) Press. 1-2344. ISBN-13: 978-0879695774.
7. Wilson, K., & Walker, J. (2010). *Principles and techniques of biochemistry and molecular biology*. Cambridge, United Kingdom: Cambridge University Press. 1-744. ISBN-13: 978-0521178747.

MIC-C-555
RESEARCH METHODOLOGY

Semester: Second Semester **Course Level: 500** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes

CLO1: Upon completion of the course Students will be familiar with research problems, research designs and data collection methods.
CLO2: Learners will be able to understand the basic concepts of statistics and statistical methods.
CLO3: Students will be acquainted with some of the methods and tools of data analysis.
CLO4: Students will be able to carry out research problems individually in a perfect scientific method.

Unit I: Research Design and Data Collection
Research methodology: different types of research design, Sampling design- procedures of sampling, criteria of selecting a sampling procedure and different types of sample designs. Primary and secondary data.

Unit II: Processing and Analysis of Data
Processing operations: Elements/types of analysis, usefulness of statistics in research, dispersion, Correlation and regression analysis: Bivariate and multivariate correlation, concepts of linear and higher order regression, multivariate regression, regression models. Types of data, Introduction to computer based programming in data analysis such as R.

Unit III: Testing of Hypotheses and Bio-statistics
Basic concepts of testing of hypothesis: Types of Hypotheses. Statistical test for the Hypotheses (Univariate and Multivariate). - F and t- tests , Parametric and Non-parametric tests, Chi square test, Normality tests, ANOVA, One Way ANOVA (Mann- Whitney, Kruskal-Wallis), Two Way ANOVA, ANCOVA. Multivariate analysis techniques (PCA, PCoA, CCA, NMDS).

Unit IV: Scientific Writing
Types of scientific documents, guidelines for preparation of scientific articles, documents, identification of journals, referencing and reference management tools, Review articles, Types of review (narrative, systematic and meta analysis)

Suggested teaching learning strategies:

1. Lecture-cum discussion: Lectures on the recent advancements in the research methodology in the field of biological sciences will be held followed by discussions.
2. Problem-Based Learning: Assignment will be provided to enhance problem solving skill of the students which will enhance the knowledge on research methodology.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Oral Test, Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. CSIR (2019). *CSIR Guidelines for Ethics in Research and in Governance*. Council of Scientific and Industrial Research, New Delhi.
2. Kothari, C.R. and Garg, G. (2019). *Research Methodology*. New Delhi: New Age International Publishers. 1-480. ISBN-13: 978-9386649225
3. Lortie, C.J. and Filazzola, A. (2020). A contrast of meta and metafor packages for meta-analyses in R. *Ecology and Evolution* 10(20):10916-10921. doi: 10.1002/ece3.6747
4. Norman, G. R. and Streiner, D. L. (2014). *Biostatistics: The Bare Essentials*. 4th edition. USA: People's Medical Publishing House Co., Ltd. 1-438. ISBN-13: 978-1607951780.
5. Pruzan, P (2018). *Research Methodology: The Aims, Practices and Ethics of Science,* Springer. 1-326. ISBN-13: 3319800844-978
6. UGC Notification (2018). University Grants Commission (Promotion Of Academic Integrity And Prevention Of Plagiarism In Higher Educational Institutions) Regulations, 2018, UGC, New Delhi.

MIC-S-556
DIAGNOSTIC TECHNIQUES IN CLINICAL MICROBIOLOGY

Semester: Second Semester **Course Level: 500** **Total Marks: 50**
L+T+P: 1+1+0 = 2 Credits **Lecture: 15 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be aware of various methods of sample collections and transportation techniques applied in the clinical microbiology
CLO2: Students will be aware of various diagnostic techniques in clinical microbiology.

Unit I: Specimen Collection and Transportation of Microbiological Specimens
Specimen Safety considerations, General guidelines for proper specimen collection and transportation. Collection of Anaerobic Specimens, Blood, Ear, and Eye specimens, Genital Sample, Sputum Sample, Spinal Fluid Specimens, Sterile Body Fluid Specimens, Stool Specimens, Urine cultures, Wound cultures, Nasopharyngeal Specimen Collection.
Isolation, Characterization and identification of pathogens from various clinical Specimens. Rapid tests commonly used to detect microorganisms in specimens. Study of antibiotic sensitivity of common pathogens, Concentration techniques of stool for ova and cyst, Wet preparation of fecal sample for ova and cyst, Identification of ova and cyst in stool sample.

Unit II: Biochemical, Serological and Molecular Tests
API 20E system, BACTEC system, BIOLOG, VITEK, Germ tube test, Hair perforation test, Chlamydospore production test, Phenol oxidase test. WIDAL, Rapid Cholera Dipstick, VDRL, TPHA, Mantoux test, T-SPOT. TB test, Rapid Urease Test, Rapid tests for HIV, RPHA for HbsAg, Haemagglutination inhibition for influenza, AGD and counter immune electrophoresis for detection of viral antigens or antiviral antibodies, Real Time Detection for Corona and other RNA viruses, NASBA: nucleic acid sequence-based amplification, MALDI: matrix-assisted laser desorption/ionization, Microarrays. SDS-PAGE:(sodium dodecyl sulfate–polyacrylamide gel electrophoresis).

Suggested teaching learning strategies:

Lecture-cum discussion: Lectures on the process of specimen collection and transportation of microbiological specimens.

Problem-Based Learning: Assignment will be provided on diagnostic techniques in clinical microbiology.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 25	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 25	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Madigan, M. T., Bender, K. S., Buckley, D. H., Sattley, W. M. and Stahl, D. A. (2019). Brock Biology of Microorganisms. 15th edition. Pearson. ISBN 9781292235103.
2. Pepper, I.L., Gerba, C.P. and Gentry, T.J. (2014). Environmental Microbiology. Third edition. Academic Press. ISBN: 9780123946263.
3. Salwan, R. and Sharma, V. (2022). Physiological and Biotechnological Aspects of Extremophiles. Academic Press. ISBN 978-0-12-818322-9.
4. Zhu D., Adebisi W.A., Ahmad F., Sethupathy S., Danso B. and Sun J. (2020). Recent Development of Extremophilic Bacteria and Their Application in Biorefinery. *Frontiers in Bioengineering and Biotechnology*. 8:483. doi: 10.3389/fbioe.2020.00483.

THIRD SEMESTER

MIC-O-601
IMMUNOLOGY

Semester: Third Semester | **Course Level: 600** | **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits | **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be aware of the concepts of immune systems and their roles.
CLO2: Students will be able to understand the principles of polyclonal antibodies, monoclonal antibodies, recombinant antibodies.
CLO3: Students will be able to understand role of MHC and complement system in immunology.
CLO4: Students will acquire knowledge on the techniques and applications of immunology.

Unit I: Historical perspective of Immunology, Cells and Organs
Historical perspective of Immunology, milestones in immunology. Cells and Organs of the Immune system: Hematopoiesis, Lymphoid cells, stem cells, Mononuclear cells, Granulocytes, Mast cells, and Dendritic cells. Lymphoid organs – Primary and Secondary lymphoid organs.

Unit II: Types of Immunity, Antigens, Humoral and Cell mediated immune response
Types of immunity: Innate immunity and adaptive immunity, comparative immunity, Immune dysfunction and its consequences. Antigens: types, properties, the study of antigenicity, immunogenicity versus antigenicity, and factors influencing immunogenicity. Epitopes, haptens, mitogens, superantigens. Viral and bacterial antigens. Antibodies: Basic and fine structure of Immunoglobulins, classes and biological activities of Immunoglobulins, Antigenic determinants – Iso, allo, and idiotypes. Immunoglobulin superfamily, antibody diversity, organization and expression of immunoglobulin genes.
Humoral immune response: Primary and secondary immune responses, induction, regulation of the immune effector response. Cell-mediated immune response: Induction and mechanism, antibody-dependent cell mediates cytotoxicity (ADCC). Immune effector mechanisms: Cytokines, Lymphokines, Chemokines and their classification, properties and functions.

Unit III: MHC, Complement system and autoimmune diseases
Major histocompatibility complex (MHC): Organization and Inheritance of HMC, cellular distribution of HMC molecules, regulations of HMC expression, MHC-immune responsiveness, disease susceptibility, MHC restriction, HLA antigens-Class I, II, III and their functions, Murine antigens and its functions. Complement cascade system: Complements nomenclature, classification, complement components, functions, activation, regulation, biological consequences, complement deficiencies. Hypersensitive and Allergic reactions: Classification, types I, II, III and IV. Immunopathology: Immunodeficiencies – Primary immunodeficiency (genetic) diseases due to B cell, T-cell and combined defects (Hypogammaglobulinemia, SCID, ADA) phagocytosis and complement defects. Autoimmune diseases–Autoimmunity, induction, mechanism of tissue damage in autoimmunity. Autoimmune diseases–Organ specific (Autoimmune anemias, Autoimmune thyroid diseases, Diabetes mellitus, Multiple sclerosis), Systemic autoimmune diseases (Rheumatoid arthritis, Systemic lupuserythematousus) and their therapy.

Unit IV: Techniques and applications of Immunology

Vaccinology: Types of immunization procedures, active and passive immunization, designing of vaccines, classical and novel/modern approaches for the production of vaccines, purified macromolecules as vaccines, Recombinant–vector vaccines, DNA vaccines, Synthetic peptide vaccines, Multivalent sub-unit vaccines, uses of vaccines, benefits of vaccination, mass immunization programs.

Polyclonal antibodies: Production of polyclonal antibodies-animals, additives, adjuvants, routes, dose, collection and preservation of antisera, purification of immunoglobulin's, quantitative and qualitative analysis of immunoglobulins. Monoclonal antibodies: Hybridomatechnology–principle and production of monoclonal antibodies, advantages and disadvantages over polyclonal antibodies, application of monoclonal antibodies. Recombinantantibodies: Production and their advantages over conventional antibodies.

Antigen and Antibody interactions: Affinity, Avidity, Crossreactivity. *Invivo* serological reactions: Phagocytosis, Opsonisation, Neutralization, Protectiontests. *In vitro* serological tests: Precipitation tests in liquid and semisolid media, single and double immuno diffusion tests. Immuno electrophoresis tests (Rocket, counter current). Agglutinations tests-HA and HI, latex agglutination. Complement fixation tests, Labeled antibody based tests – Enzyme linked immunosorbent assays (ELISA), Western blotting, Radioimmunoassay (RIA), Immunofluorescent and Immuno specific electron microscopy. Infectivity neutralization test.

Suggested teaching learning strategies:

1. Lecture-cum discussion: Lectures on the basic concepts of immunology and its techniques will be held followed by discussions.
2. Problem-Based Learning: Assignment will be provided to enhance problem solving skill of the students.
3. Journal Club: Students will read research articles and prepare presentations which will be examined by course teacher to check students' knowledge, analytical skill in the field of immunology.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Coleman, R. M. & Lombard, M. F. (1992). *Fundamental Immunology*, 2nd edition. United States: Brown (William C.) Co. 1-624. ISBN-13: 978-0697113108.
2. Goldsby, R. A., Kindt, T. J., Osborne, B. A., & Kuby, J. (2000). *Kuby Immunology*. 4th edition. New York: W.H. Freeman & Company.1-554. ISBN-13: 978-0716733317.
3. Hyde, R. M. (1995). *Immunology*, 3rd edition. Philadelphia: Williams & Wilkins. 1-316. ISBN-13: 9780683062311.
4. Janeway, C. A. & Travers P. (1994). *Immunobiology: The immune system in health and disease*. United States: Wiley–Blackwell. 1-500. ISBN-13: 978-0865428119
5. Roitt, I. M., Male, D. and Brostoff, J. (1995). *Immunology*, 4th edition. United States:Mosby. 1-416. ISBN-13: 978-0723421788.
6. Tizard, I. R. (1995). *Immunology: An Introduction*, Fourth Edition. Philadelphia: Saunders/Harcourt Brace College. 1-568. ISBN- 13: 9780030041983.

MIC-C-602
MEDICAL MICROBIOLOGY

Semester: Third Semester **Course Level: 600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Understand the basic concepts in medical microbiology and types of bacterial, fungal and parasitic pathogens
CLO2: Understand the working principle of the diagnostic methods.
CLO3: Understand the various diseases caused by fungal and parasitic pathogens and its culture characteristics
CLO4: Understand the various diseases caused by viruses

Unit I: Introduction to Medical Microbiology
Principles of Clinical Microbiology Koch's Postulates. Classification of medically important microorganisms. Normal microbial flora of human body and their role. Host-pathogen interaction. Infection: Sources and vehicles of infection: water-borne, air-borne, STDs, insect-borne, nosocomial. Establishment of infection: Mechanism of infection. Antimicrobials and their mode of action.

Unit II: Bacterial pathogens
Bacterial pathogens: Brief account of morphology, cultural characteristics, pathogenesis, clinical features, laboratory diagnosis, prevention and control of following: *Staphylococcus, Streptococcus, Pneumococcus, Neisseria, Corynebacterium,E. coli* O157:H7; *Clostridium*, organisms belonging to Enterobacteriaceae, *Vibrio, Haemophilus, Brucella, Mycobacterium*, Spirochaetes, *Actinomycetes, Acinetobacter, Helicobacter, Campylobacter, Borrelia;* antimicrobial resistance.

Unit III: Fungal and parasitic pathogens
Fungal and parasitic pathogens: Brief account of morphology, cultural characteristics, pathogenesis, clinical features, laboratory diagnosis, prevention and control of human fungal diseases. Dermatophytes, Dimorphic fungi, opportunistic fungal pathogens. Brief account of morphology, life cycle, pathogenesis, clinical features, laboratory diagnosis, prevention and control of important human parasitic diseases.

Unit IV: Viral diseases
Viral diseases: Virus-host interactions at cellular and organism levels. Common diseases caused by Coronavirus; Poxviruses; Herpes viruses; Adenoviruses; Picorna viruses; Orthomyxo; Paramyxo viruses; Arboviruses, Rhabdoviruses, Ebola, Marburg virus, Hepatitisviruses; Oncogenicviruses; Human Immunodeficiency viruses (HIV/AIDS). Prion diseases –Kuru, CJD disease, and GSS syndrome.

Suggested teaching learning strategies:

1. Lectures on the basic concepts of medical microbiology and various types of pathogens, i.e., bacterial, fungal, parasitic and viral will be held followed by discussions.
2. Library readings, Critical Discussion, Reflective Writing Comparative Analysis
3. Problem-Based Learning: Assignment will be provided to enhance problem solving skill of the students.
4. Individual and group presentations by students on selected themes.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Cann, A. J. (2012). *Principles of molecular virology* (standard edition). USA: Academic press. 1-300. ISBN 978-0-12-384939-7.
2. Dimmock, N. J., Easton, A. J., & Leppard, K. N. (2015). *Introduction to modern virology*. Hoboken, New Jersey: Wiley- Blackwell. 1-526.
3. Fields, B. N., Knipe, D. M., Howley, P. M., Everiss, K. D., & Kung, H. J. (1996). *Fundamental virology*. Philadelphia: Lippincott-Raven. 1-1340. ISBN 0781702844, 9780781702843.
4. Flint, S. J., Enquist, L. W., Krug, R. M., Skalka, A. M., & Racaniello, V. R. (2000). *Principles of Virology: Molecular Biology, Pathogenesis and Control*. Washington, DC: American Society for Microbiology. 1-820. ISBN-13: 978-1555811273.
5. Levy J. A., Fraenkel-Conrat H., & Owens O. S. (1994). *Virology*, 3rd Edition. San Francisco: Benjamin Cummings (Pearson). 1- 480. ISBN-13: 978-0139537530.

MIC-P-603
LABORATORY COURSE -III

Semester: Third Semester **Course Level: 600** **Total Marks: 50**
L+T+P: 0+0+2= 2 Credits **Lecture: 0 Hrs + Tutorial: 0 Hrs + Practical: 30 Hrs**

Course Learning Outcomes
Upon completion of the course

CLO1: Students will be acquainted with laboratory practices and methodologies in medical microbiology and immunology.
CLO2: Students will be able to perform characterisation and identification of medically important microorganisms.
CLO3: Students will be able to perform microbiology practicals like staining, antibiotic susceptibility test, MIC and some immunology techniques like ELISA and Immunoprecipitation

---

Experiments:
1. Antibiotic susceptibility testing by disc diffusion method and MIC
2. Demonstration of Acid Fast Bacilli (AFB) by ZN staining
3. Demonstration of BIOLOG for phenotypic identification of bacteria
4. Demonstration of Immuno-techniques like Agglutination
5. Precipitation Immuno-precipitation
6. Demonstration of western blot and ELISA

Suggested teaching learning strategies:

1. Class based discussion on the principle, aim and objective of the practical.
2. Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.
3. Group Discussion/ interactive session - Analysis and interpretation of experimental results.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 25 (Internal assessment)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 25	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:
1. Hay, F.C. and Westwood, O.M.R. 2002. Practical Immunology. Fourth Edition, Blackwell Science.
2. Cappuccino, J. G. and Sherman, N. 2007. Microbiology- A Laboratory Manual, Seventh Edition, Pearson Education, Inc. and Dorling Kindersley (Indi) Pvt Ltd, Delhi, India.

MIC-E-604
FOOD MICROBIOLOGY-I

Semester: Third Semester **Course Level: 600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be acquainted with different methods to achieve food preservation.
CLO2: Learners will be aware of different food-borne pathogens and toxications .
CLO3: Students will acquire knowledge on the use of the natural antimicrobial systems for increasing the shelf life and preservation of foods.
CLO4: Students will be aware of guidelines of Food Safety and Standards of some countries.

Unit I: Food Preservation Techniques
Principles of food preservation. Asepsis-removal of microorganisms (anaerobic conditions, high temperatures, low temperatures, drying). Factors influencing microbial growth in food-extrinsic and intrinsic factors; Chemical preservatives, Biological preservative and food additives. Canning, processing for heat treatment-D, Z, and F values and working out treatment parameters.

Unit II: Food-Borne Infections and Intoxications
Food-borne pathogens: Bacteria, fungi, yeasts, nematodes, protozoa, archaea, viruses, prions. Rapid detection methods of food contaminants – molecular, immunological, electrochemical biosensors. Food sanitation in the manufacture and retail trade. Effects of microbial intoxications.

Unit III: Natural Antimicrobial Systems
Antimicrobial agents: Few bacteria; their mechanism and types, antimicrobial peptides. Microbiological criteria - use of natural systems for food preservation – antimicrobial agents, antioxidants and enzymes and multiple hurdle technologies. Mechanism of antimicrobial resistance.

Unit IV: Food Safety Management Practices
Food control agencies and its regulations; Codex Alimentarius Commission and General Principles of food hygiene, Hazard analysis and critical control points (HACCP) and ISO22000:2018; Microbiological criteria in food safety. Guidelines of some Food Standards Authorities: Food Safety and Standards Authority of India (FSSAI), The European Food Safety Authorly (EFSA) and Food Safety and Inspection Service (FSIS) and Food and Drug Administration (FDA) of USA.

Suggested teaching learning strategies:

1. Lecture-based Approach: Start with lectures to introduce students to the basic concepts, principles of food safety and food safety management guidelines. Use presentation slides, case studies, and examples to enhance understanding.
2. Laboratory Exercises: Include hands-on laboratory exercises to give students practical experience in basic food microbiology techniques to achieve food safety.

3. Assignments and presentations: Assign problems related to the food microbiology or assign research papers or presentations on topics related to food microbiology to encourage students to explore specific applications and deepen their understanding.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Oral Test, Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Kalmia E. Kniel. Thomas J. Montville, Karl R. Matthews, 2017. Food Microbiology an introduction. 4th Editiion, ASM Press.
2. FJ Barba, AS Sant'Ana, Mohamed Koubaa (2018). Innovative Techonologies for Food Preservation:Inactivation of spoilage and pathogenic microorganisms.
3. Putnik P, Pavlić B, Šojić B, Zavadlav S, Žuntar I, Kao L, Kitonić D, Kovačević DB. Innovative Hurdle Technologies for the Preservation of Functional Fruit Juices. Foods. 2020 Jun 1;9(6):699. doi: 10.3390/foods9060699. PMID: 32492780; PMCID: PMC7353510.
4. Awuchi CG, Ondari EN, Nwozo S, Odongo GA, Eseoghene IJ, Twinomuhwezi H, Ogbonna CU, Upadhyay AK, Adeleye AO, Okpala COR. Mycotoxins' Toxicological Mechanisms Involving Humans, Livestock and Their Associated Health Concerns: A Review. Toxins (Basel). 2022 Feb 24;14(3):167. doi: 10.3390/toxins14030167. PMID: 35324664; PMCID: PMC8949390.
5. Henríquez L, Brenes-Acuña M, Castro-Rojas A, Cordero-Salmerón R, Lopretti-Correa M, Vega-Baudrit JR. Biosensors for the Detection of Bacterial and Viral Clinical Pathogens. Sensors (Basel). 2020 Dec 4;20(23):6926. doi: 10.3390/s20236926. PMID: 33291722; PMCID: PMC7730340.

MIC-E-605
ENVIRONMENTAL MICROBIOLOGY -I

Semester: Third Semester **Course Level: 600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Understand fundamental concepts of different domains of environmental microbiology.
CLO2: Understand the diversity, habitat and physiology of extremophiles
CLO3: Evaluate the importance of microbial biodegradation, bioremediation and bioleaching
CLO4: Analyse the importance of aeromicrobiological pathway and bioaerosol control

Unit I: Aquatic and Atmospheric Environments
Microbial habitats in the aquatic environment- Planktonic, benthic, microbial mats and biofilms. General characteristics of freshwater and marine habitats. Eutrophication and algal blooms. Nature of bioaerosols. Aeromicrobiological pathway (Launching, Transport and Deposition), Microbial survival in air. Extramural and Intramural aeromicrobiology. Bioaerosol control.

Unit II: Extreme Environments
Diversity, habitat and physiology of the extremophiles (Acidophiles, Alkaliphiles, Thermophiles, Psychrophiles, Barophiles, Halophiles and microorganisms resistant to radiations) - Mechanisms of adaptation and applications of extremophiles.

Unit III- Microbial Communication
Quorum sensing in Gram-negative bacteria- *Agrobacterium tumefaciens* Tra I/Tra R virulence system and *Vibrio fischeri*Lux I/Lux R bioluminescence system. Peptide mediated quorum sensing in Gram-positive bacteria. *Staphylococcus aureus* Agr C/ Agr A virulence system.

Unit IV: Microbial Biodegradation, Bioremediation and Bioleaching
Biodegradation of organic pollutants (Aliphatic, alicyclic, aromatic) and factors affecting biodegradation. Biodegradation of xenobiotics. Bioremediation – natural attenuation, biostimulation and bioaugmentation, *ex situ* and *in situ* bioremediation. Bioleaching.

Suggested teaching learning strategies:

1. Lecture-based approach: Lecture on fundamental concepts of different domains of environmental microbiology. Usage of ICT tools, presentation slides, case studies, and real time examples to enhance understanding of concepts.
2. Group Discussions: Group discussions and interaction among students to analyse and discuss solutions to problems in the field of environmental microbiology based on real time environmental issues.
3. Assignments: Assign research papers to students for reviewing and presentations on topics related to environmental microbiology.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Durvasula, R. V. and Subba Rao, D. V. (Eds.) (2020). Extremophiles from Biology to Biotechnology. First edition. CRC Press. ISBN 9780367572327.
2. Madigan, M. T., Bender, K. S., Buckley, D. H., Sattley, W. M. and Stahl, D. A. (2019). Brock Biology of Microorganisms. 15th edition. Pearson. ISBN 9781292235103.
3. Pepper, I.L., Gerba, C.P. and Gentry, T.J. (2014). Environmental Microbiology. Third edition. Academic Press. ISBN: 9780123946263.
4. Salwan, R. and Sharma, V. (2022). Physiological and Biotechnological Aspects of Extremophiles. Academic Press. ISBN 978-0-12-818322-9.
5. Zhu D., Adebisi W.A., Ahmad F., Sethupathy S., Danso B. and Sun J. (2020). Recent Development of Extremophilic Bacteria and Their Application in Biorefinery. *Frontiers in Bioengineering and Biotechnology*. 8:483. doi: 10.3389/fbioe.2020.00483.

MIC-E-606
INDUSTRIAL MICROBIOLOGY-I

Semester: Third Semester **Course Level: 600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:

Upon completion of the course students will be able to:

CLO1: Demonstrate a comprehensive understanding of the principles and practices of industrial microbiology, including the different types of industrial microorganisms and their applications.
CLO2: Understand the basic principles of genetic engineering in industrial microbiology, including the techniques used for gene cloning, expression, and modification.
CLO3: Apply basic techniques and tools used in industrial microbiology, such as microbial isolation, culture, and enumeration.
CLO4: Analyze the strategies for improving microbial strains for industrial applications, including mutation, selection, and recombinant DNA technology.

Unit I: Fundamentals of Industrial Microbiology
Definition, historical development, and scope of industrial microbiology.
Introduction to industrially important microorganisms–Bacteria, fungi, actinomycetes, microalgae, viruses, culture collection centres. Concept of generally regarded as safe (GRAS) microorganisms.

Unit II: Industrial strain and improvement techniques
Approaches to cultivation of industrially important strains: Screening criteria, enrichment, selection of nutrient media; specific screening for the desired product.
Techniques adapted for selection and improvement of industrial organisms for biotechnological applications.

Unit III: Agricultural Industrial Microbiology
Soil as a large reservoir of industrially important microorganism, rhizospheres and Phylloplane. Endophytic microorganisms and Mycorrhiza: PGPR. Biological Nitrogen Fixation in Symbiotic and Free-living microorganisms. Phosphate solubilizing bacteria. Biofertilizers-Types and Application. Biological control. Biopesticides. Humus Formation.

Unit IV: Genetic Engineering in Industrial Microbiology
Genetic tools for industrial microbiology, Plant genetic engineering, Significance of *Agrobacterium tumefaciens*. Brief discussion on Bt cotton, Beta-Carotene Maize, Golden Rice, Antisense RNA technology, Production of recombinant proteins, Genome editing and CRISPR technology for enhance production. Ethical and safety issues in using genetically modified organisms.

Suggested teaching learning strategies:

1. Lecture-based Approach: Start with lectures to introduce students to the basic concepts and principles of industrial microbiology. Use presentation slides, case studies, and examples to enhance understanding.

2. Laboratory Exercises: Include hands-on laboratory exercises to give students practical experience in basic microbiology techniques such as microbial culture, aseptic techniques, and media preparation.
3. Group Discussions: Organize group discussions where students can discuss and analyze real-world examples of industrial applications of microbiology, such as the production of antibiotics or fermentation processes.
4. Guest Speakers: Invite guest speakers from industry or academia who have expertise in industrial microbiology to share their experiences and provide insights into the field.
5. Assignments and Assessments: Assign research papers or presentations on topics related to industrial microbiology to encourage students to explore specific applications and deepen their understanding.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Boro, M., Sannyasi S., Chettri D., & Verma A.K. (2022). Microorganisms in biological control strategies to manage microbial plant pathogens: a review. Archives of Microbiology 204, (11): 666. https://doi.org/10.1007/s00203-022-03279-w.
2. Chettri, D., Sharma B., Verma A.K., & Verma A.K. (2021).Significance of Microbial Enzyme Activities in Agriculture. In Microbiological Activity for Soil and Plant Health Management, pp. 351-373. Springer, Singapore, 2021.https://doi.org/10.1007/978-981-16-2922-8_15.
3. Chettri, D., Verma A.K., & Verma A.K. (2022).Microbes and Their Application in the Food and Agriculture Industry. In Industrial Microbiology and Biotechnology, pp. 625-642. Springer, Singapore, 2022. 10.1007/978-981-16-5214-1_21.
4. Leung W.W-F. (2020). Centrifugal Separations in Biotechnology. Elsevier. doi: 10.1016/C2017-0-03265-2.
5. Murooka Y., &Imanaka T. (2020). Recombinant Microbes for Industrial and Agricultural Applications. Taylor & Francis. doi: 10.1201/9781003067191.
6. Verma A.K., Chettri D., & Verma A.K. (2022). Potential of CRISPR/Cas9-Based Genome Editing in the Fields of Industrial Biotechnology: Strategies, Challenges, and Applications. In Industrial Microbiology and Biotechnology, pp. 667-690. Springer, Singapore, 2022. 10.1007/978-981-16-5214-1_23.

MIC-P-607
FOOD MICROBIOLOGY – I

Semester: Third Semester **Course Level: 600** **Total Marks: 100**
L+T+P: 0+0+4 = 4 Credits **Lecture: 0 Hrs + Tutorial: 0 Hrs + Practical: 60 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be able to isolate and prepare pure cultures of pathogenic and non-pathogenic microbes in food samples.
CLO2: Students will be able to perform some of the techniques of characterisation of microorganisms found in food.
CLO3: Inculcation of scientific temperament among the students to do research in Food Microbiology for PhD programme.

Experiments:

1. Detection of pathogenic and spoilage microorganisms in foods
2. Isolation of pathogenic and spoilage microorganisms from various food items.
3. Performing Microscopic examination of microorganisms, staining of microbes obtained from food samples
4. Obtaining pure culture of pathogenic microorganisms from different foods and biochemical characterisation.
5. Identification of pathogenic microorganisms by molecular methods
6. Serological detection of pathogenic microbes and toxins in foods
7. Death/inactivation of microbes in food system by various antimicrobial agents – physical/chemical/biological
8. Antimicrobial activity of bacterial isolates.

Suggested teaching learning strategies:

1. Discussion on the aim and objective of the practical.
2. Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.
3. Demonstration: Demonstration of some of the practical for better understanding and reproducibility.

Assessment framework:

Assessment	**Written Modes**	**Oral Modes**	**Integrated Modes**
Formative Marks: 50 (25+25 internal and final practical exam)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Reading:

Harrigan, W.F. 1998. *Laboratory Methods in Food Microbiology.* 3rd edition. Academic Press, London.

MIC-P-608
ENVIRONMENTAL MICROBIOLOGY – I

Semester: Third Semester **Course Level: 600** **Total Marks: 100**
L+T+P: 0+0+4 = 4 Credits **Lecture: 0 Hrs + Tutorial: 0 Hrs + Practical: 60 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Develop conceptual clarity and practical skills for different techniques in environmental microbiology.
CLO2: Isolate and identify bacteria from environmental sample
CLO3: Isolate and characterize extremophiles
CLO4: Determine the antibacterial activity of plant extracts

Experiments
1. Isolation, enumeration and identification of bacteria from soil sample
2. Assessment of air microbial quality by using air sampler
3. Isolation, characterization and identification of thermophilic / psychrophilic bacteria
4. Preparation of plant extracts by solvent (methanol/ethanol) extraction
5. Determination of antibacterial activity of plant extracts by agar well diffusion method

Suggested teaching learning strategies:
1. Class based discussion on the principle, aim and objective of the practical.
2. Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.
3. Group Discussion/ interactive session - Analysis and interpretation of experimental results.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50 (25+25 internal and final practical exam)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Balouiri M, Sadiki M, Ibnsouda SK. (2016). Methods for in vitro evaluating antimicrobial activity: A review. *Journal of Pharmaceutical Analysis.* (2):71-79. doi: 10.1016/j.jpha.2015.11.005.
2. Cappuccino, J. G. and Sherman, N. (2014). Microbiology- A Laboratory Manual, Pearson Education, India. ISBN: 9789332535190.
3. Green, L. H. and Goldman, E. (2021). Practical handbook of Microbiology. 4th Edition. CRC Press. ISBN 9780367567637.

MIC-P-609
INDUSTRIAL MICROBIOLOGY -I

Semester: Third Semester **Course Level: 600** **Total Marks: 100**
L+T+P: 0+0+4 = 4 Credits **Lecture: 0 Hrs + Tutorial: 0 Hrs + Practical: 60 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Identify and culture industrially important microbes from different natural sources.
CLO2: Enumerate bacterial, fungal, and Actinomycetes counts from different natural sources using pour and spread plate methods.
CLO3: Evaluate the biocontrol activity of endophytic bacteria and their potential applications in industry.
CLO4: Develop critical thinking and problem-solving skills to design and execute experiments related to industrial microbiology.

Experiments

1. Culturing of industrially important microbes from different natural sources. Bacteria actinomycetes, yeast, fungi.
2. Enumeration of total bacterial, fungal and Actinomycetes counts from rhizospheric soil by pour & spread plate method
3. Isolation of endophytic bacteria
4. Isolation of symbiotic nitrogen fixers from leguminous/non-leguminous root nodules
5. Determination of biocontrol activity of endophytic bacteria.
6. Techniques of maintenance of stock cultures.

Suggested teaching learning strategies:

- Discussion on the aim and objective of the practical.
- Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.
- Knowing and adapting good laboratory practises.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50 (25+25 internal and final practical exam)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Amaresan N., Patel P., & Amin D. (2021). Practical Handbook on Agricultural Microbiology. Springer. doi:10.1007/978-1-0716-1724-3
2. Köhl, J., & Ravensberg, W. (2021). Microbial Bioprotectants for Plant Disease Management. Taylor & Francis. Burleigh Dodds Science Publishing Limited
3. Kumar A., & Radhakrishnan E.K. (2020). Microbial Endophytes: Functional Biology and Applications. Elsevier Science.
4. Mishra B.B., Nayak S.K., Mohapatra S. & Samantaray D. (2021). Environmental and Agricultural Microbiology: Applications for Sustainability. John Wiley & Sons. doi:10.1002/9781119525899
5. Mukerji K. G., & Garg K.L. (2020). Biocontrol of Plant Diseases. CRC Press. doi: 10.1201/9780429292347
6. Singh J., Vyas A., Wang S.,&Prasad, R. (2020). Microbial Biotechnology: Basic Research and Applications. Springer. doi: 10.1007/978-981-15-2817-0

MIC-S-610
MICROBIOLOGICAL QUALITY CONTROL IN FOOD AND BEVERAGES

Semester: Third Semester **Course Level: 600** **Total Marks: 50**
L+T+P: 1+1+0 = 2 Credits **Lecture: 15 Hrs + Tutorial: 15Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will be aware of basic concepts of methods used in food and beverage quality control and microbiological examinations
CLO2: They will be aware of rules and standards of food regulatory authorities.

Unit I. Basic practices in Food Microbiology Quality Control Laboratory
Basic concepts and applications of analytical instruments used in microbiological analysis. Calibration and validation of analytical instruments as per SOP and manual. Sampling and procedure for conducting microbial test according to SOP.
Monitoring, evaluation, and validation of samples from various sources. Sterility test/Bacterial Endotoxin Test (BET). Finding the causes of unwanted microbial contamination. Set alert and action thresholds and keep positive and negative controls in place while testing.

Unit II. Quality systems and its regulatory bodies
Basics of Food Quality Assurance and Quality Control, Quality Assurance in Food Industry, Validation and Verification, Quality Control and testing procedures; Documentation, Good Documentation Practices, SOPs & Protocols; Establishing Quality Control Checks: Inspection & Audits. Emerging trends in quality related aspects of food industry; Quality Systems in major segments of food industries; Food Quality Regulations and guidelines in India

Suggested teaching learning strategies:

1. Lecture-based Approach: Start with lectures to introduce students to the basic concepts of food and beverage quality control and microbiological examinations. Use presentation slides, case studies, and examples to enhance understanding.
2. Demonstration Experiments: Maintenance of SOP and maintenance of instruments in Food and Beverage industries. Demonstration of microbiological examination and quality control management in any food industry/ laboratory.
3. Guest Speakers: Invite industry experts/experts of food safety to talk on quality and safety management practices applicable in the field. They can discuss current trends, challenges, and advancements in the field.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 25	Class Test, Class Assignment, Self-Test, Online Test	Oral Test, Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 25	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. K P Sudheer and Bindu Lakshmanan. 2021. Safety and Quality Assurance in Food Supply Chain Emerging Technologies and Challenges. CRC Press. ISBN 9781032007281
2. Alexandru Mihai Grumezescu and Alina Maria Holban. 2019. Quality Control in the Beverage Industry, *Volume 17: the Science of Beverages. Elsevier.* https://doi.org/10.1016/C2017-0-02391-1
3. Inteaz Alli, 2003. Food Quality Assurance-Principles and Practices, CRC Press. ISBN *9781138034532*

FOURTH SEMESTER

MIC-E-651
FOOD MICROBIOLOGY-II

Semester: Fourth Semester **Course Level:600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students will understand the importance of 'ethno-microbiological' knowledge of the ancient people on production of fermented foods with modern interpretation of functional microbiota and several health promoting benefits to the consumers.
CLO2: Students will be aware of techniques to study microorganisms of fermented foods.
CLO3: Learners will understand the role of fermented foods in health of the consumers.
CLO4: Students will be aware of importance of fermented foods in shaping the beneficial communities of gut microbiota and the role of gut microbiota in the health of the host.

Unit I: Traditional Food Fermentation
Global dietary culture and history of traditional fermented foods and alcoholic beverages; Classification of global fermented foods and beverages. Types of fermentation: spontaneous/natural, back-slopping and starter culture. 'Ethno-microbiology' concept of fermented foods. Organoleptic properties of fermented foods: types of flavour, assessment for of sensory characters.

Unit II:: Microbiology of Fermented Foods
Culture dependent and culture independent methods. Application of multi-omics in fermented foods. Fermentation dynamics; Safety of fermented foods: biogenic amines. Cite any examples of four fermented foods/alcoholic beverages of India, and one each of South East Asia, Africa and Europe: traditional methods of preparations, culinary and microbial community structures.

Unit III: Health Benefits of Fermented Foods
Nutritional value of fermented foods. Health promoting benefits of fermented foods: metabolites; bio-active compounds, vitamins, bio-peptides, poly-glutamic acids and bio-enzymes and therapeutic properties-anticancer, anti-obesity, anti-thrombolysis and anti-diabetic. Cite any examples of two fermented foods of India/South East Asia/Africa/Europe: nutritional value and therapeutic properties.

Unit IV: Gut Microbiota
Anatomy and physiology of Gastrointestinal tract. Sampling methods for gut microbiota. Distributions and metataxonomics of gut microbiota in the GI tracts. Modulation of gut microbiota. Role of gut microbiota in nutrition and health. Correlation between consumption of fermented food and gut microbiota-illustrate an example of any clinically tested fermented food.

Suggested teaching learning strategies:

1. Case Studies: Present case studies of fermented foods, interaction of fermented foods with the gut microbiota. Discuss the strategies employed, challenges faced, and outcomes achieved.

2. Laboratory Exercises: Include hands-on laboratory exercises to give students practical approaches to study the fermented foods using the modern analytical techniques.
3. Journal articles/reviews: Ask students to research and present on the various types of fermented foods/interaction of fermented foods with the gut microbiota/approaches to study the fermented foods.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self Test, Online Test	Oral Test, Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Adams, M. R. and Nout, M. J. R. 2001. *Fermentation and Food Safety.* Aspen Publishers Inc., Maryland.
2. Tamang, J.P. 2009. *Himalayan Fermented Foods: Microbiology, Nutrition and Ethnic Values*. Taylor and Francis Group, USA.
3. Leeuwendaal NK, Stanton C, O'Toole PW, Beresford TP. Fermented Foods, Health and the Gut Microbiome. Nutrients. 2022 Apr 6;14(7):1527. doi: 10.3390/nu14071527. PMID: 35406140; PMCID: PMC9003261.
4. Min Yap, Danilo Ercolini, Avelino Álvarez-Ordóñez, Paul W. O'Toole, Orla O'Sullivan, Paul D. Cotter. 2022 Next-Generation Food Research: Use of Meta-Omic Approaches for Characterizing Microbial Communities Along the Food Chain
5. Annual Review of Food Science and Technology 2022 13:1, 361-384
6. Krzysztof Skowron[1] et al. 2022. Two Faces of Fermented Foods—The Benefits and Threats of Its Consumption. Frontiers in Microbiology. Volume 13 – 2022, https://doi.org/10.3389/fmicb.2022.845166

MIC-E-652
FOOD MICROBIOLOGY-III

Semester: Fourth Semester **Course Level:600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: This course will allow students to learn about functional foods, its production and importance.
CLO2: Students will also learn about characteristics and applications of prebiotics, probiotics and other biotics.
CLO3: Learners will also be aware of various health promoting bioactive molecules relevant to food system.
CLO4: Students will also learn about the application of metabolomics, genomics, and proteomics to study fermented foods.

Unit I: Functional and Nutraceutical Foods
Concepts of functional and nutraceutical foods. Molecular mechanisms of functional foods and nutraceutical foods. Role of functional microorganisms in production of functional fermented foods. Production protocol, composition of functional starter cultures, therapeutic uses, markets of two well known functional foods/functional fermented foods used as food supplements.

Unit II: Prebiotics and Probiotics & allied biotics
Concepts and definitions of prebiotics, probiotics, synbiotics, psychobiotics,paraprobiotics and postbiotics. Technological properties of probiotics; application of probiotics in metabolic diseases – obesity, cardiovascular, etc and infectious diseases - diarrhoea; *Helicobacter pylori*, psychobiotics in modulation of human behaviour. Dietary fibres and prebiotics substances; their role in modulation of host health. Paraprobiotics and postbiotic molecules – classification, characterisation and applications.

Unit III: Bioactive Compounds and Untargeted Metabolites in Fermented Foods
Structure of bioactive compounds. Types of bioactive compounds present in fermented foods- polyphenols, flavonoids, bio-peptides, exopolysaccharides, linoleic acid and vitamins; modulation of health by the bioactive compounds present in fermented foods. Structure and types of untargeted metabolites in fermented foods. Functional properties of untargeted metabolites in fermented foods-immunomodulators.

Unit IV: Foodomics
Concept and application of foodomics in fermented foods- metabolomics, transcriptomics, and proteomics. Methodologies for metabolomics, transcriptomics and proteomics. Cite an example of any fermented food with integrated omics approaches of metabolomics, transcriptomics and proteomics.

Suggested teaching learning strategies:

- Case Studies: Present case studies of functional foods, probiotics and prebiotics, their development and applications
- Research Presentations: Ask students to research and present on the latest research on probiotics and prebiotics. Encourage them to discuss the approaches and challenges in the development of functional foods, probiotics and prebiotics.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self Test, Online Test	Oral Test, Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Robert E.C. Wildman, Richard S. Bruno. 2019. Handbook of Nutraceuticals and Functional Foods. Routledge; Third edition, CRC Press.
2. Adriano Gomes da Cruz, C. Senaka Ranadheera, Filomena Nazzaro, Amir Mortazavian 2021. Probiotics and Prebiotics in Foods - Challenges, Innovations, and Advances. Academic Press. Paperback ISBN: 9780128196625
3. Gibson, G., Hutkins, R., Sanders, M. et al. 2017. Expert consensus document: The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. Nat Rev Gastroenterol Hepatol 14, 491–502. https://doi.org/10.1038/nrgastro.2017.75
4. Qingyan Guo, Pengfei Chen, Xianggui Chen. 2023, Bioactive peptides derived from fermented foods: Preparation and biological activities. Journal of Functional Foods. 101, 105422. https://doi.org/10.1016/j.jff.2023.105422
5. Caitríona Long-Smith, Kenneth J. O'Riordan, Gerard Clarke, Catherine Stanton, Timothy G. Dinan, and John F. Cryan 2020. Microbiota-Gut-Brain Axis: New Therapeutic Opportunities. Annual Review of Pharmacology and Toxicology. 60:477-502. https://doi.org/10.1146/annurev-pharmtox-010919-023628
6. Wu W, Zhang L, Zheng X, Huang Q, Farag MA, Zhu R, Zhao C. Emerging applications of metabolomics in food science and future trends. 2022. Food Chem X. doi: 10.1016/j.fochx.2022.100500. PMID: 36519105; PMCID: PMC9743159.

MIC-E-653
ENVIRONMENTAL MICROBIOLOGY -II

Semester: Fourth Semester **Course Level: 600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Understand the importance of environmentally transmitted pathogens and its influence on human health.
CLO2: Understand methods of solid and liquid waste management
CLO3: Assess the water quality
CLO4: Analyse the importance of microbial biosensors and its applications

Unit I- Solid and liquid waste management
Types and sources of solid wastes. Methods of treatment of solid wastes-landfill, composting, vermicomposting, anaerobic digestion, incineration, pyrolysis, management of hazardous wastes. Wastewater treatment- Primary, secondary and tertiary treatment processes. Disinfection.

Unit II- Drinking water treatment and indicator microorganisms
Coagulation–Flocculation–Sedimentation, filtration. Water softening process, disinfection. Indicator microorganisms for fecal contamination.

Unit III- Microbial biosensors
Introduction, Sensing techniques –electrochemical techniques and optical techniques. Types of microbial sensors.

Unit IV: Environmentally transmitted pathogens
Environmentally transmitted pathogens-Types of environmentally transmitted bacteria, opportunistic bacterial pathogens, Blue Green Algae, parasites, enteric viruses, respiratory viruses.

Suggested teaching learning strategies:

1. Lecture-based approach and interactive discussion: Discussion on the fundamental concepts of methods of solid and liquid waste management; drinking water treatment and indicator microorganisms in assessing water quality. Usage of ICT tools, presentation slides, case studies, and real time examples to enhance understanding of concepts.
2. Case Studies: Discussion of case studies to understand methods of solid and liquid waste management. Discuss the strategies employed, challenges faced and outcomes achieved.
3. Journal articles/reviews: Interactive sessions for students to review and present research articles/reviews on the importance of microbial biosensors and its applications.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

7. Bitton, G. (2011). Wastewater Microbiology. Fourth Edition, Wiley –Blackwell. ISBN-10 : 9780470630334

8. Madigan, M. T., Bender, K. S., Buckley, D. H., Sattley, W. M. and Stahl, D. A. (2019). Brock Biology of Microorganisms. 15th edition. Pearson. ISBN 9781292235103.

9. Nag, A. and Vizayakumar, K. (2005). Environmental Education and Solid Waste Management. New Age International (P) Ltd. Publishers, New Delhi. ISBN 13: 9788122416909.

10. Pepper, I.L., Gerba, C.P. and Gentry, T.J. (2014). Environmental Microbiology. Third edition. Academic Press, ISBN: 9780123946263.

11. Singh J. and Ramanathan, A. L. (2019). Solid Waste Management: Present and Future Challenges. Wiley India. *ISBN: 9789389447927.*

12. Su L., Jia W., Hou C., Lei Y. (2011). Microbial biosensors: a review. *Biosensors and Bioelectronics*. 26(5):1788-99. doi: 10.1016/j.bios.2010.09.005.

MIC-E-654
ENVIRONMENTAL MICROBIOLOGY -III

Semester: Fourth Semester **Course Level:600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Develop concepts of sampling methods of air, soil and water samples.
CLO2: Know applications of "omics" approaches in environmental microorganisms.
CLO3: Evaluate the importance of methods for detection of water-borne pathogens

---

Unit I-Environmental sample collection and processing
Sample collection and processing of soil and water samples. Sampling devices for the collection of air samples- Basic air sampling methods- impingement, impaction, centrifugation, filtration and deposition.

Unit II- Fundamental concepts of environmental metagenomics
Concepts- Fundamental Steps in Metagenomics: Extraction of metagenomic DNA. Construction of metagenomic library. Screening of metagenomic library. Metagenomic sequencing and analytical techniques. Classification of metagenomics.

Unit III- Characterization of environmental microorganisms through the "omics" approach
Fundamental concepts of transcriptomics, metabolomics, proteomics and bioinformatics in characterization of environmental microorganisms.

Unit IV- Methods for detection of water -borne pathogens
Emerging water- borne pathogens and related diseases.
Methods for detection of water -borne pathogens.

Suggested teaching learning strategies:

1. Lecture-based approach and interactive discussion: Discussion on the fundamental principles of sampling methods of air, soil and water samples; environmental metagenomics. Lectures through usage of ICT tools, case studies and current research reports.
2. Case Studies: Interactive session to evaluate the importance of methods for detection of water-borne pathogens which are of human and animal health concern with evidence based case studies.
3. Journal articles/reviews: Interactive sessions for students to review and present research articles/reviews on application of "omics" for characterizing environmental microorganisms.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Bridle, H. (Ed.) (2020). Waterborne Pathogens: Detection Methods and Applications. Second edition. Academic Press Inc.(London) Ltd. ISBN-10:0444643192
2. Kumar S., Nehra M., Mehta J., Dilbaghi N., Marrazza G., Kaushik A. Point-of-Care Strategies for Detection of Waterborne Pathogens. (2019). *Sensors (*Basel). 19(20):4476. doi: 10.3390/s19204476.
3. Pepper, I.L, Gerba, C.P. and Gentry, T J. (Eds.) (2015). Environmental Microbiology, 3rd edition, Academic Press.ISBN: 9780123946263.
4. Prayogo F.A., Budiharjo A., Kusumaningrum H.P., Wijanarka W., Suprihadi A., Nurhayati N. (2020). Metagenomic applications in exploration and development of novel enzymes from nature: a review. *Journal of Genetic Engineering and Biotechnology* Aug 4;18(1):39. doi: 10.1186/s43141-020-00043-9.
5. Ramírez-Castillo FY, Loera-Muro A, Jacques M, Garneau P, Avelar-González FJ, Harel J, Guerrero-Barrera AL. (2015). Waterborne pathogens: detection methods and challenges. Pathogens. 4(2):307-34. doi: 10.3390/pathogens4020307.
6. Streit, W. R. and Daniel R. (2023). Metagenomics. Methods and Protocols. Methods in Molecular Biology. Humana New York, NY. https://doi.org/10.1007/978-1-0716-2795-2.
7. Zhang L, Chen F, Zeng Z, Xu M, Sun F, Yang L, Bi X, Lin Y, Gao Y, Hao H, Yi W, Li M, Xie Y. (2021). Advances in Metagenomics and Its Application in Environmental Microorganisms. *Frontiers in Microbiology*. 12:766364. doi: 10.3389/fmicb.2021.766364. PMID: 34975791; PMCID: PMC8719654.

MIC-E-655
INDUSTRIAL MICROBIOLOGY-II

Semester: Fourth Semester **Course Level:600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Understand the concept of Fermentation process and their application in the production of various industrial products.
CLO2: Apply the principles of downstream processing to isolate, purify, and characterize the desired product.
CLO3: Analyse and interpret experimental data to optimize the bioprocess.
CLO4: Evaluate and compare different immobilization techniques for the production of enzymes and cells.

Unit I: Fermentation technology
Bioprocess Technology. Types of Fermenters. Fermentation in batch culture: Media formulation, Microbial growth kinetics (Batch and Continuous kinetics), Effect of growth and nutrient conditions on product formation. Solid-Sate and submerged fermentation

Unit II: Bioreactors design and process
Basic Bioreactor Configurations, Feature and function of individual parts, baffles, impellers, foam separators, sparger, culture vessel, cooling and heating devices, probes for online monitoring, measurement and control of fermentation process. Mechanically & non-mechanically agitated bioreactors. Mass transfer process in reactors.

Unit III: Downstream processing
Extraction of fermentation products, types of products obtained; microbial cell as the product, extracellular and intracellular products. Process and techniques adapted for product recovery; removal of insoluble, isolation and extraction of products, concentration of products, packing of products. factors affecting downstream processing and recovery.

Unit IV: Enzyme and cell Immobilization techniques
Concept of Enzyme and Whole Cell Immobilization: different Support/Matrix used in immobilization technique. Types/Methods of Immobilization: Adsorption, Covalent Bonding Entrapment Co-polymerization and Cross-linking, Encapsulation. Application of enzyme immobilization, Advantages and Disadvantages. Immobilization of whole cell: Methods, applications, Advantages and Disadvantages

Suggested teaching learning strategies:

1. Lecture-based Approach: Start with lectures to introduce students to the basic concepts and principles of fermentation technology. Use presentation slides, case studies, and examples to enhance understanding.
2. Demonstration Experiments: Conduct live demonstrations of small-scale fermentations and its different parts

3. Guest Speakers: Invite industry experts to share their experiences and insights into fermentation technology. They can discuss current trends, challenges, and advancements in the field.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self-Test, Online Test	Oral Test, Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Chettri D, Boro M., **&** Verma A.K. (2022). Enzyme Purification Strategies. In Enzymes in the Valorization of Waste (pp. 81-95). CRC Press. doi:10.1201/9781003187721-5
2. Kalaichelvan P.T. (2021). Microbiology and Biotechnology A Laboratory Manual. MJP Publishers.
3. Lang J. (2022). Principles of fermentation technology. Larsen & Keller Education.
4. Martínez-Espinosa R.M. (2020). New Advances on Fermentation Processes. Intech Open. doi: 10.5772/intechopen.78200
5. Shuler M.L. & Kargi F. (2022). Bioprocess Engineering: Basic Concepts, Global Edition. Pearson Education, India.
6. Wilson D. B., Sahm H., Stahmann K.P., & Koffas M. (2020). Industrial microbiology. John Wiley & Sons.

MIC-E-656
INDUSTRIAL MICROBIOLOGY-III

Semester: Fourth Semester **Course Level:600** **Total Marks: 100**
L+T+P: 3+1+0 = 4 Credits **Lecture: 45 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:

Upon completion of the course students will be able to:

CLO1: Demonstrate an understanding of the principles of industrial microbiology and its role in the production of therapeutic compounds, pharmaceutical drugs, organic acids, biopolymers, and industrially important enzymes.
CLO2: Explain the various microbial processes and fermentation techniques used in the production of these compounds.
CLO3: Analyze the regulatory requirements and quality control measures in the production of industrially important enzymes/compounds.
CLO4: Evaluate the principles of strain improvement and genetic engineering techniques used for enhancing microbial production.

Unit I: Microbial production of therapeutic compounds and pharmaceutical drugs
Industrial strain used, improvements, fermentation process, downstream process, and application: Penicillin, Cephalosporin, Streptomycin, vitamins B12 and riboflavin fermentation. Recombinant therapeutic proteins, hormones, bacterial Insulin through recombinant DNA technology.

Unit II: Microbial production of organic acids and amino acid
Industrial strain used, improvements, fermentation process, downstream process and application: Lactic acid, Citric acid, Fumaric acid, Itaconic acid, Kojicacid. Production of L-Lysine and Glutamic acid.

Unit III: Microbial production of biopolymers and bioplastic
Industrial strain used, improvements, fermentation process, downstream process and application: dextran, alginate, xanthan andpullulan, industrial production of bioplastics (PHB and PHA).

Unit IV: Microbial production of industrially important enzymes
Industrial strain used, improvements, fermentation process, downstream process, and application: Proteases, Amylases, Lipases, Carbohydrate Active Enzymes (cellulases & xylanases), Production of biofuels.

Suggested teaching learning strategies:

1. Case Studies: Present case studies of successful microbial production of therapeutic compounds and pharmaceutical drugs. Discuss the strategies employed, challenges faced, and outcomes achieved.
2. Research Presentations: Ask students to research and present on the various types of biopolymers and their industrial applications. Encourage them to discuss the microbial production processes and potential challenges.
3. Laboratory Exercises: Include hands-on laboratory exercises to give students practical aspects of microbial production of therapeutic compounds. This can include fermentation processes, downstream processing, and quality control techniques

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50	Class Test, Class Assignment, Self Test, Online Test	Oral Test, Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Bhadra S., Chettri D., & Verma A.K. (2022). Microbes in fructooligosaccharides production. Bioresource Technology Reports. doi: 10.1016/j.biteb.2022.101159.
2. Boro M., Verma A.K., Chettri D., Yata V.K., & Verma A.K. (2022). Strategies involved in biofuel production from agro-based lignocellulose biomass. Environmental Technology & Innovation. doi: 10.1016/j.eti.2022.102679.
3. Dudley, E. G. (2022). Food Microbiology: Fundamentals and Frontiers.Wiley.
4. Goyal A., & Sharma K. (2023). Glycoside Hydrolases: Biochemistry, Biophysics, and Biotechnology, 1st Edition. Elsevier.
5. Najafpour G. (2015) Biochemical Engineering and Biotechnology. Elsevier.doi: 10.1016/B978-0-444-63357-6.
6. Verma P. (2022). Industrial Microbiology and Biotechnology. Springer Singapore. doi: 10.1007/978-981-16-5214-1.

MIC-P-657
FOOD MICROBIOLOGY – II & III

Semester: Fourth Semester **Course Level:600** **Total Marks: 100**
L+T+P: 0+0+4 = 4 Credits **Lecture: 0 Hrs + Tutorial: 0 Hrs + Practical: 60 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Develop the practical skills and knowledge required by students to assess the microbiological quality and safety of fermented foods.
CLO2: Students will gain hands on experiences on taxonomy of microorganisms and isolation of prebiotics and probiotics from fermented foods.

Experiments:

1. Isolation and preparing pure culture of microbial groups – lactic acid bacteria and yeasts/moulds from fermented foods.
2. Molecular methods of identification of probiotic microorganisms from fermented foods.
3. Characterisation of bacteria and yeasts/moulds for probiotic characteristics-Acid tolerance, bile tolerance, hydrophobicity, antibiotic resistance.
4. Extraction and estimation of prebiotics from fermented foods.
5. Extraction and estimation of postbiotics from microbes.

Suggested teaching learning strategies:

- Discussion on the aim and objective of the practical.
- Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50 (25+25 internal and final practical exam)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Roberts, D. and Greenwood, M. 2002. *Practical Food Microbiology.* 3rd edition, Wiley-Blackwell.

MIC-P-658
ENVIRONMENTAL MICROBIOLOGY -II & III

Semester: Fourth Semester **Course Level:600** **Total Marks: 100**
L+T+P: 0+0+4 = 4 Credits **Lecture: 0 Hrs + Tutorial: 0 Hrs + Practical: 60 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Isolate and characterize the microorganism from water samples.
CLO2: Perform water quality assessment by Most Probable Number method and determination of Biological Oxygen Demand
CLO3: Detect fecal coliforms in water samples

Experiments
1. Isolation and characterisation of microorganisms from water samples
2. Water quality analysis by Most Probable Number (MPN) method
3. Detection of fecal coliforms in water samples
4. Estimation of Biochemical Oxygen Demand (BOD) from water/sewage samples

Suggested teaching learning strategies:

1. Class discussion on the principle, aim and objective of the practical.
2. Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.
3. Interactive session on analysis and interpretation of experimental results

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50 (25+25 internal and final practical exam)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 50	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Cappuccino, J. G. and Sherman, N. (2007). Microbiology- A Laboratory Manual, 7th Edition, Pearson Education, Inc. and Dorling Kindersley Pvt. Ltd, Delhi, India. ISBN: 9789332535190.
2. Motlagh A.M. and Yang Z. (2019). Detection and occurrence of indicator organisms and pathogens. *Water Environment and Research*. (10):1402-1408. doi: 10.1002/wer.1238.
3. Water and wastewater analysis – A guide manual by Central Pollution Control Board (2011). https://www.indiawaterportal.org/articles/water-and-wastewater-analysis-guide-manual-central-pollution-control-board

MIC-P-659
INDUSTRIAL MICROBIOLOGY - II & III

Semester: Fourth Semester **Course Level:600** **Total Marks: 100**
L+T+P: 0+0+4 = 4 Credits **Lecture: 0 Hrs + Tutorial: 0 Hrs + Practical: 60 Hrs**

Course Learning Outcomes:

Upon completion of the course students will be able to:

CLO1: Isolate and identify microbes producing industrially important enzymes, including cellulase, xylanase, amylase, lipase and proteases.
CLO2: Operate and troubleshoot a simple laboratory fermenter.
CLO3: Conduct bioethanol production using starchy materials and measure the quantitative estimation of bioethanol produced.
CLO4: Analyze and interpret experimental data and report findings in a scientific manner.

Experiments

1. Demonstration of a simple laboratory fermenter
2. Entrapment of yeast whole cell using calcium alginate beads
3. Analysis of glucose releasing efficiency of the immobilized yeast cells
4. Isolation of microbes producing industrially important enzymes: Cellulase, Xylanase, Amylase, Lipase and Proteases
5. Bioethanol production using starchy materials
6. Quantitative estimation of bioethanol produced using starchy materials

Suggested teaching learning strategies:

1. Discussion on the aim and objective of the practical.
2. Laboratory Exercises: Understanding each step given in the protocol, preparation of all required reagents and media.
3. Knowing and adapting good laboratory practices.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 50 (25+25 internal and final practical exam)	Aim and objective of the practical, Principle and procedure, documentation of observation, preparation of lab record file	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 50	Semester-end examinations conducted by the university will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Drapcho C.M., Nghiem J., & Walker T.A. (2020). Biofuels Engineering Process Technology. McGraw Hill.
2. Feldmann H. (2020). Yeast: Molecular and Cell Biology. Wiley VCH.

3. Liu S. (2020). Bioprocess Engineering: Kinetics, Sustainability, and Reactor Design. Elsevier. doi:10.1016/C2019-0-02589-7

4. Pandey A., Sirohi R., Larroche C., & Taherzadeh, M. (2022). Advances in Bioprocess Engineering: Current Developments in Biotechnology and Bioengineering. Elsevier. doi: 10.1016/C2020-0-04191-5.

5. Thatoi H., Mohapatra P.K.D., Mohapatra S. & Mondal, K.C. (2020). Microbial Fermentation and Enzyme Technology. CRC Press

6. Yadav A.N., Rastegari A.A., Yadav N., & Gaur R. (2020). Biofuels Production – Sustainability and Advances in Microbial Bioresources. Springer. doi: 10.1007/978-3-030-53933-7

MIC-R-660
DISSERTATION

Semester: Fourth Semester **Course Level: 600** **Total Marks: 200**
L+T+P: 0+2+6 = 8 Credits **Lecture: 0 Hrs + Tutorial: 30 Hrs + Practical: 90 Hrs**

Course Learning Outcomes:
Upon completion of the course

CLO1: Students can apply theoretical concepts and experimental skills to design research protocol/projects.
CLO2: Develop scientific aptitude and professional skills for designing, implementing and presenting the MSc Dissertation project.

Assessment framework for Dissertation

1. Students will choose the topics and Supervisors for Dissertation.
2. The students will submit their dissertation and defend their methodologies and findings before all Faculty members of the Department and one External Examiner at the end of the Fourth Semester.

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 100	Aim and objective of the dissertation topic, Principle and procedure, documentation of observation, preparation of Dissertation	Viva-Voce, Group Discussion	Protocols discussion and analysis of the results
Summative Marks: 100	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

MIC-S-661
MICROBIOLOGICAL QUALITY CONTROL IN PHARMACEUTICAL INDUSTRY

Semester: Fourth Semester **Course Level:600** **Total Marks: 50**
L+T+P: 1+1+0 = 2 Credits **Lecture: 15 Hrs + Tutorial: 15 Hrs + Practical: 0 Hrs**

Course Learning Outcomes:
Upon completion of the course students will be able to:

CLO1: Understand concepts of current good manufacturing practices (cGMP) in the pharmaceutical industry.
CLO2: Analyse the importance of quality certifications in pharmaceutical industry

Unit I: Quality control in pharmaceutical industry
Concept of quality control in pharmaceutical industry. Good Laboratory Practices.Overview of ICH guidelines. Quality control parameters for instruments, clothing, packing, processing line. Quality control of processes and products.

Unit II: Quality assurance and management in pharmaceutical industry
Introduction of quality assurance, ISO 9000 standard series. Good manufacturing practices (GMP). Overview of documentation in pharmaceutical industry. WHO GMP requirements, quality risk management.

Suggested teaching learning strategies:

1. Lecture Presentations: Start each unit with a comprehensive lecture presentation to introduce the key concepts, principles, and theories related to microbiological quality control in the pharmaceutical industry. Use visual aids, case studies, and real-world examples to engage students and promote understanding.
2. Guest Lectures and Industry Visits: Invite guest speakers from the pharmaceutical industry to share their experiences, insights, and best practices in microbiological quality control. Arrange field trips to pharmaceutical manufacturing facilities or quality control laboratories to give students a first-hand understanding of the industry's practices and standards.

Assessment framework:

Assessment	Written Modes	Oral Modes	Integrated Modes
Formative Marks: 25	Class Test, Class Assignment, Self-Test, Online Test	Viva-Voce, Group Discussion	Presentation, Seminars, Journal Club
Summative Marks: 25	Semester-end examinations conducted by the University will be considered the mode of summative assessment.		

Note: Teachers can choose any mode of formative assessment as per nature of the CLO.

Suggested Readings:

1. Quality Assurance of Pharmaceuticals: A Compendium of Guidelines and Related Materials. (2011). World Health Organization, Geneva, Switzerland.

2. Sardella M, Belcher G, Lungu C, Ignoni T, Camisa M, Stenver DI, Porcelli P, D'Antuono M, Castiglione NG, Adams A, Furlan G, Grisoni I, Hall S, Boga L, Mancini V, Ciuca M, Chonzi D, Edwards B, Mangoni AA, Tuccori M, Prokofyeva E, De Gregorio F, BertazzoliGrabinskiBroglio M, van Leeuwen B, Kruger P, Rausch C, Le Louet H. (2021). Monitoring the manufacturing and quality of medicines: a fundamental task of pharmacovigilance. *Therapeutic Advances in Drug Safety.* 12:20420986211038436. doi: 10.1177/20420986211038436.

3. Weinberg S. (2007). Good Laboratory Practice Regulations, 4th Edition, Vol. 69. CRC Press, Switzerland. https://doi.org/10.3109/9780849375842.

SYLLABUS REVIEW COMMITTEE

Sl. No.	Name & Designation	
1	**Professor Dr. Jyoti Prakash Tamang** Senior Professor & Head Department of Microbiology Sikkim University	Chairman
2	**Dr. Nagendra Thakur** Associate Professor Department of Microbiology Sikkim University	Member
3	**Dr. Buddhiman Tamang** Assistant Professor Department of Microbiology Sikkim University	Member
4	**Dr. Bimala Singh** Assistant Professor Department of Microbiology Sikkim University	Member
5	**Dr. Anil Kumar Verma** Assistant Professor Department of Microbiology Sikkim University	Member
6	**Dr. Meera Ongmu Bhutia** Guest Faculty Department of Microbiology Sikkim University	Member
7	**Dr. H. Nakibapher Jones Shangpliang** Guest Faculty Department of Microbiology Sikkim University	Member

The revised MSc syllabus of Microbiology has been reviewed by eminent Experts - Prof. Dr. Rup Lal, *FNA* Retired Professor, University of Delhi and Prof. Dr. D. J. Bagyaraj, *FNA*, NASI Hon. Scientist & Chairman, CNBRCD.