FOUR YEAR UNDERGRADUATE (FYUG) PROGRAMME UNDER NATIONAL EDUCATIONPOLICY 2020

MICROBIOLOGY

NORTH EASTERN HILL UNIVERSITY, SHILLONG

Preface:

A Bachelor of Science (B.Sc.) program in Microbiology typically offers a comprehensive study of microorganisms, including bacteria, viruses, fungi, and protozoa, along with their interactions with humans, animals, plants, and the environment

Program Outcomes (POs):

Program outcomes in a Microbiology program typically encompass the knowledge, skills, and abilities that students are expected to acquire by the time they complete their studies. These outcomes reflect the core competencies necessary for success in the field of microbiology and related disciplines.

1. Understanding of Microbial Diversity: Students should demonstrate knowledge of the diversity of microorganisms, including bacteria, viruses, fungi, and protozoa, as well as their classification, structure, and function.
2. Proficiency in Laboratory Techniques: Students should be proficient in basic and advanced laboratory techniques used in microbiology, including aseptic techniques, microbial culturing, microscopy, molecular biology methods, and biochemical assays.
3. Knowledge of Microbial Physiology and Genetics: Students should have a deep understanding of microbial physiology, metabolism, and genetics, including microbial growth, reproduction, gene expression, and regulation.
4. Understanding of Microbial Ecology and Environmental Microbiology: Students should understand the roles of microorganisms in natural ecosystems, including their contributions to nutrient cycling, biogeochemical processes, and environmental sustainability.
5. Knowledge of Microbial Pathogenesis and Host-Pathogen Interactions: Students should understand the mechanisms by which microorganisms cause disease in humans, animals, and plants, including virulence factors, host immune responses, and strategies for microbial evasion.

1st Semester

Course Code	Course Title	Credits			Total Contact Hours
		Theory	Practical	Total	
MIC-100	Introductory Microbiology (Major)	3	1	4	75
MIC-100	Minor	3	1	4	75
MDC-110-119	Any of the available courses as notified by the University from time to time	3		3	45
AEC-120-129	Any of the available courses as notified by the University from time to time	3		3	45
SEC-130-139	Any of the available courses as notified by the University from time to time	3		3	45
VAC-140	Environmental Sciences	3		3	45
	TOTAL	18	2	20	330

2nd Semester

Course Code	Course Title	Credits			Total Contact Hours
		Theory	Practical	Total	
MIC-150	Bacteriology (Major)	3	1	4	75
MIC-150	Minor	3	1	4	75
MDC-160-169	Any of the available courses as notified by the University from time to time	3		3	45
AEC-170-179	Any of the available courses as notified by the University from time to time	3		3	45
SEC-180-189	Any of the available courses as notified by the University from time to time	3		3	45
VAC-190-199	Any of the available courses as notified	3		3	45

	by the University from time to time				
TOTAL		**18**	**2**	**20**	**330**

MIC – Microbiology; MDC – Multi Disciplinary Course; AEC – Ability Enhancement Course; SEC – Skill Enhancement Course; VAC – Value Added Course; VTC – Vocational Education and Training Course

3rd Semester

Course Code	Course Title	Credits Theory	Credits Practical	Total Credits	Total Contact Hours
MIC-200	**Virology (Major)**	**3**	**1**	**4**	**75**
MIC-201	**Mycology & Phycology (Major)**	**3**	**1**	**4**	**75**
MDC-210-219	**Any of the available courses as notified by the University from time to time**	**3**		**3**	**45**
AEC-220-229	**Any of the available courses as notified by the University from time to time**	**2**		**2**	**30**
SEC-230-239	**Any of the available courses as notified by the University from time to time**	**3**		**3**	**45**
VTC-240-249	**Any of the available courses as notified by the University from time to time**	**1**	**3**	**4**	**105**
Total		**15**	**5**	**20**	**375**

4th Semester

Course Code	Course Title	Credit			Total Contact Hours
		Theory	Practical	Total	
MIC-250	Basic Biochemistry (Major)	3	1	4	75
MIC-251	Microbial Physiology (Major)	3	1	4	75
MIC -252	Microbial Ecology & Environmental Microbiology (Major)	3	1	4	75
MIC- 253	Plant Pathology & Agricultural Microbiology (Major)	3	1	4	75
VTC-260-269	Any of the available courses as notified by the University from time to time	3	1	4	105
Total		15	5	20	405

5th Semester

Course Code	Course Title	Credit			Total Contact Hours
		Theory	Practical	Total	
MIC-300	Medical Bacteriology &Virology (Major)	3	1	4	75
MIC-301	Food & Dairy Microbiology (Major)	3	1	4	75
MIC-302	Microbial Genetics (Major)	3	1	4	75
MIC-303	Food Fermentation Technology (Minor)	3	1	4	75
MIC-304	Internship		4	4	120
Total		12	8	20	420

6th Semester

Course Code	Course Title	credit			Total Contact Hours
		Theory	Practical	Total	
MIC-350	Medical Mycology &Parasitology (Major)	3	1	4	75
MIC-351	Molecular Biology (Major)	3	1	4	75
MIC-352	Immunology (Major)	3	1	4	75
MIC 353	Industrial Microbiology (Major)	3	1	4	75
VTC-360-369	Any of the available courses as notified by the University from time to time	3	1	4	105
Total		15	5	20	435

3rdSemester

MIC-200 **Virology** **Total Credits: 4**

Total Contact Hours: 75

Total Marks: 100

Course Objectives:

This course is designed with an objective to provide the basic information about the history, discovery, and classification of Viruses. The course also provides information about different kind of viruses infecting eukaryotic and prokaryotic microorganisms, virus life cycle and methods of cultivation.

Learning Outcomes:

1. Thorough knowledge and understanding of the history, discovery and classification of viruses.
2. Understanding different types of viruses infecting other groups of living organisms.
3. Understanding the concept of virus life cycle, their multiplication and methods of cultivating them.

Total Credits: 3

(Theory)

Total Contact Hours: 45

Unit I:

History anddiscovery of viruses, nomenclature and ICTV classification of viruses, general properties, size and structure of viruses. Virus multiplication: interaction of viruses with cellular receptors, different modes of entry, assembly, maturation and release. Transcription of RNA and DNA viruses. Lytic and lysogenic cycle.

Unit II:

Isolation of viruses: plant (experimental and tissue cultured plants), animal (embryonated chicken eggs, cell cultures, and living animals), bacteriophage (lawn culture). Virus purification: ultra-centrifugation and filtration. Infectivity assay method- plaque, systemic assay of viruses and hemagglutinin assay.

Unit III:

Salient features: Bacteriophage (T4 phage and lambda phage), plant viruses (TMV and Caulimovirus), animal virus (HIV and Herpes), mycophage, cyanophage, satellite virus and oncoviruses. Ttransmission of plant and animal viruses.

(Practical)

Total Credits: 1

Total Contact Hours: 30

Unit IV:

1. Cultivation and enumeration of bacteriophages.
2. Isolation of coliphages from raw sewage.
3. Demonstration of cultivation of viruses in embryonated chicken eggs.
4. Study of symptoms: plant viruses (tomato leaf curl, maize mosaic virus and wheat streak mosaic virus).
5. Study of symptoms: animal viruses (Hepatitis B and Rhabdovirus).

Suggested readings

1. Powar CB and Bundale S. (2023).Virology: Fundamentals and Applications.Himalaya Publishing House.
2. Whelan S. (2023). Fields Virology. 7th edition. Wolters Kluwer
3. Mishra B (2021). Textbook of Medical Virology. 2nd edition. CBS Publishers and Distributors Pvt. Ltd
4. Reddy R and Reddy SM (2007). Essentials of Virology. 2nd edition. Scientific Publishers.
5. Flint J, Racaniello RR, Rall GF, Hatziioannou T and Skalka AM. (2020). Principles of Virology. 5th edition. ASM Press.
6. Wang A and Li Y (2021). Plant Virology: Methods and Protocols. 1st edition. Springer-Verlag, New York.
7. Burleson FG, Chambers TM and Wiedbrauk DL (204). Virology: A laboratory Manual. Academic Press.
8. Cappuccino JG and Sherman N (2020) Microbiology: A Laboratory Manual. 12th edition. Pearson publishing company

3rdSemester

MIC-201	**Mycology and Phycology**	**Total Credits: 4**
		Total Contact Hours: 75
		Total Marks: 100

Course Objectives:

The main objective of the course is to provide an in-depth knowledge on the morphology, reproduction, importance of fungi and algae and to perform appropriate laboratory experiments.

Learning Outcomes:

1. Understanding the general characteristics of fungi and algae
2. Appreciating the importance of fungi and algae.
3. Understanding the importance of fungi and algae in food, medicine and industry.

4.

(Theory) ***Total Credits: 3***

Total Contact Hours: 45

Unit I:

History and development of mycology.Classification of fungi by Alexopolous, Mims and Blackwell (1996). Salient features and significance of Phycomycetes (Chytridiomycetes, Oomycetes, Zygomycetes), Ascomycetes, Basidiomycetes and Deuteromycetes. Type study- *Rhizopus, Saccharomyces, Aspergillus, Agaricus.*

Unit II:

Classification of Algae:Fritsch (1935) classification, criteria for algal classification. General characteristics and salient features of algae:Chlorophyceae, Euglenophyceae, Chrysophyceae,Xanthophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonadineae, Phaeophyceae, Rhodophyceae, Myxophyceae.Type study: *Chlamydomonas, Euglena, Polysiphonia,Ectocarpus,Chara*

Unit III:

Importance of fungi in decomposition of organic matter and as plant pathogens, degradation of pesticides. Uses of fungi: as food, in medicine, in industries. Economic importance of algae: role of algae in soil fertility and in industry (bio-fuel, bio-pigments and food). Biological importance of phytoplankton's and water blooms, Diatomaceous earth.

(Practical) ***Total Credits: 1***

Total Contact Hours: 30

Unit IV:

1. Isolation and enumeration of fungi from soil.
2. Study of the morphological characteristics of molds through temporary and permanent slides- *Rhizopus, Mucor, Penicillium, Alternaria, Fusarium*
3. Study of yeast morphology, cultural characteristics and reproductive structures.
4. Study of the morphological characteristics of algae through temporary and permanent slides- *Chara, Polysiphonia, Ectocarpus, Chlamydomonas.*

Suggested Readings:

1. Aneja KR and Mehrotra RS (2023).An Introduction to Mycology. 3rd edition. New Age InternationalPublishers

2. Alexopoulos CJ, Mims CW and Blackwell M. (2007). Introductory Mycology. 4th edition. John Wiley and Sons, Inc.

3. Lee RE. (2018). Phycology. 5th Edition, Cambridge University Press

4. Vashishta BR and Sinha AK. (2020). Fungi. S. Chand and Company Ltd.

5. Moore D, Robson GD, Trinci APJ (2011). 21st Century Guidebook to Fungi. Cambridge University Press.

6. Bagyanarayana B, Bhadraiah B, and Kunwar IK.(2018) Mycology, Plant Pathology, & Microbial Biotechnology. BS Publications.

7. S. SundaraRajan (2023). Introduction to algae. V.M Pubkishers.

8. Van Dan Hoek C, Mann DG and Jahns HM. (2009). Algae: An Introduction to phycology. Cambridge University Press

9. Dubey RC and Maheshwari DK (2023). Practical Microbiology. 4th edition. S. Chand and Company Ltd, New Delhi.

10. Cappuccino JG and Sherman N (2020) Microbiology: A Laboratory Manual. 12th edition. Pearson publishing company

4thSemester

MIC-250	**Basic Biochemistry**	**Total Credits: 4**
		Total Contact Hours: 75
		Total Marks: 100

Course Objectives:

The objective of the course is to impart knowledge on properties, structures and importance of macromolecules.

Learning Outcomes:

1. Understanding of various biomolecules in-depth.
2. Understanding the laws of thermodynamics and use in biological systems.
3. Understanding importance of enzyme in biological systems.

(Theory) ***Total Credits: 3***

Total Contact Hours: 45

Unit I:

Thermodynamics and Bioenergetics: first and second law, concept of enthalpy, entropy, free energy change, equilibrium constant, spontaneous reactions, coupled reactions, oxidation reduction reaction. Biological solvents: structure and properties of water, ionic products of water, pH, buffers and Henderson-Hasselbalch equation.

Unit II:

Macromolecules: definition, types and properties: carbohydrates, amino acids, proteins, lipids, fats and nucleic acids. Vitamins: classification and characteristics with suitable examples, sources and importance. Porphyrins: Definition, structure, properties and importance of hemoglobin, chlorophyll and cytochrome.

Unit III:

Introduction to enzymes: definition, nomenclature, IUB classification, active sites, concept of ES complex and activation energy. Factors affecting enzyme activity- substrate, pH, temperature and inhibitors (competitive, noncompetitive and uncompetitive). Enzymes Kinetics- Michaelis-Menten equation- form and derivation, Significance of K_m and V_{max}. Regulation of enzyme activity-allosteric regulation, covalent modification and zymogenicity

(Practical) ***Total Credits: 1***

Total Contact Hours: 30

Unit IV:

1. Preparation of buffer Solutions (phosphate buffer and acetate buffer) using Henderson-Hasselbalch equation.
2. Estimation of amino acids by ninhydrin test method.
3. Estimation of carbohydrates by anthrone reagent.
4. Estimation of proteins by Lowry's method
5. Estimation of total reducing sugars (glucose) by DNSA method.

Suggested Readings

1. Campbell, MK (2012) Biochemistry, 7th ed., Published by Cengage Learning

2. Campbell, PN and Smith AD (2011) Biochemistry Illustrated, 4th ed., Published by Churchill Livingstone

3. Tymoczko JL, Berg JM and Stryer L (2012) Biochemistry: A short course, 2nd ed., W.H.Freeman

4. Berg JM, Tymoczko JL and Stryer L (2011) Biochemistry, W.H.Freeman and Company

5. Nelson DL and Cox MM (2021) Lehninger Principles of Biochemistry, 8thedition., W.H. Freeman and Company

6. Willey MJ, Sherwood, LM & Woolverton C J (2013) Prescott, Harley and Klein's Microbiology by. 9th Ed., McGrawHill

7. Voet,D. and Voet J.G (2011) Biochemistry 4th edition, John Wiley and Sons

8. Chawla R (2020). Practical Clinical Biochemistry: Methods and Interpretations..Jaypee Brothers Medical Publishers.

4thSemester

MIC-251	**Microbial Physiology**	**Total Credits: 4**
		Total Contact Hours: 75
		Total Marks: 100

Course Objectives:

This course is designed with an objective to provide the basic information on microbial growth and their nutritional requirements. Further this course is also designed to provide basic concept on microbial metabolism and cellular respiration.

Course Learning Outcome:

1. Understanding about microbial growth and nutrition.
2. Understanding of cellular respiration and fermentation pathways.

(Theory) ***Total Credits: 3***
Total Contact Hours: 45

Unit I:

Nutritional classification of microorganisms: photoautotrophs, photochemotrophs, chemoautotrophs and chemoheterotrophs. Microbial nutrients: macro and micronutrients. Nutrient uptake and transport: passive and facilitated diffusion. Microbial growth: primary and secondary metabolites,effect of nutrients concentration on bacterial growth.

Unit II:

Concept of anaerobic respiration, Embden-Meyerhof Parnas (EMP) pathway (glycolysis), fermentation, Krebs Cycle (TCA cycle). Physiology of fermentation- alcoholic, lactic acid (homo and heterofermentative), propionic acid, butyric and mixed acid fermentation pathway.

Unit III:

Basic concepts on: aerobic respiration, catabolism and anabolism, substrate level phosphorylation, oxidative phosphorylation, electron transport chain, proton motive force. Bacterial photosynthesis - oxygenic photosynthesis (cyanobacteria) and anoxygenic photosynthesis (purple and green bacteria).

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Effect of nutrients carbon on bacterial growth.
2. Effect of temperature on bacterial growth.
3. Effect of temperature on bacterial growth.
4. Extraction and estimation of photosynthetic pigment chlorophyll a.
5. Demonstration of anaerobic respiration in microbes.

Suggested readings

1. Reddy SR and Reddy SM (2023). Microbial Physiology. 2nd edition. Scientific Publishers, India
2. Moat A.G. and Foster S.W. John (2004). Microbial Physiology. 4th edition. Wiley and Sons, New York.
3. Caldwell, D. R. (1999). Microbial Physiology and Metabolism.2nd edition. Brown Publishers.
4. Stainer, RY, Adelberg EA and Ingraham JL (2000). General Microbiology. PR Macmillan.

5. White, D., Drummond, J. and Fuqua, C. (2011). The Physiology and Biochemistry of Prokaryotes. 4th edition. Oxford University Press, UK.
6. Willey, J. M., Sandman, K. and Wood, D. (2019). Prescott's Microbiology. 11th edition. McGraw Hill Higher Education, USA.
7. Dubey RC and Maheshwari DK (2023). Practical Microbiology. 4th edition. S. Chand and Company Ltd, New Delhi.
8. Cappuccino JG and Sherman N (2020) Microbiology: A Laboratory Manual. 12th edition. Pearson publishing company

4thSemester

MIC-252	**Microbial Ecology & Environmental Microbiology**	**Total Credits: 4**
		Total Contact Hours: 75
		Total Marks: 100

Course Objectives:

To provide a basic understanding of environmental microbiology and its applications.

Learning Outcomes:

1. Understand the occurrence, abundance and distribution of microorganisms in the environment and their role, and also the different methods for their detection and characterization.
2. Comprehensive understanding of environmental microbiology and microbial ecology.
3. Understand the basic principles of environmental microbiology and be able to apply these principles to understanding and solving environmental problems – waste water treatment and bioremediation

(Theory) ***Total Credits: 3***
Total Contact Hours: 45

Unit I:

Concept and scope of environmental microbiology. Distribution of microorganisms: terrestrial environment (soil profile and soil microflora), aquatic environment (microflora of fresh water and marine habitats), aeromicroflora and dispersion of microbes, extremophiles (high & low temperature, pH, high hydrostatic & osmotic pressures, salinity and low nutrient level).

Unit II:

Microbe-microbe interaction- positive interaction (commensalism, synergism, symbiosis), negative interaction (amensalism, parasitism, and predation). Plant- microbe interaction (phyllosphere, rhizosphere, mycorrhiza) and animal- microbe interaction. Microorganisms in - carbon cycle, nitrogen cycle, nitrogen fixation, symbiotic and non-symbiotic- process of nitrogen fixation. Microbial transformation of phosphorus, sulphur and micronutrients in soil and their importance.

Unit III:

Solid waste management: organic compost and biogas. Liquid waste management: sewage treatment and disposal- primary, secondary- aerobic (activated sludge, oxidation ponds, trickling filters), anaerobic (septic tanks and digester), tertiary treatment- chlorination, BOD. Biodegradation of common pesticides and crude spills. Biodeterioration of leather, monuments

(Practical) ***Total Credits: 1***

Total Contact Hours: 30

Unit IV:

1. Isolation of microorganisms (fungi and bacteria) from air by settle plate method
2. Isolation of microorganism (fungi and bacteria) from rhizosphere soil
3. Isolation of cellulose degrading microorganisms from soil
4. Microbial examination of water by MPN method (potable and sewage water).
5. Study of antagonism between soil microorganisms by plate method (Fungi vs fungi; bacteria vs fungi)

Suggested Readings:

1. Madigan MT, Martinko JM and Parker J. (2021). Brock Biology of Microorganisms. Global edition. Pearson/ Benjamin Cummings

2. Maier RM, Pepper IL and Gerba CP. (2009). Environmental Microbiology. 2nd edition, Academic Press

3. Sharma PD (2016). Environmental Microbiology. Rastogi Publications.

4. Laskin AI (2020). Microbial Ecology. 1st edition, CRC press.

5. Mohapatra, P.K (2013). Textbook on Environmental Microbiology. I.K International Publishing House Pvt Ltd, New Delhi

6. Varnam H and Evans MG (2000). Environmental Microbiology. Manson publishing ltd.
7. Willey J, Dorothy W, and Sandman K (2022). Prescott's Microbiology. 12th edition. McGraw Hill Higher Education.
8. Dubey RC and Maheshwari DK (2023). Practical Microbiology. S. Chand and Company Ltd, New Delhi.
9. Cappuccino JG and Sherman N (2020) Microbiology: A Laboratory Manual. 12th edition. Pearson publishing company

4thSemester

MIC-253 Plant Pathology and Agricultural Microbiology **Total Credits: 4**
Total Contact Hours: 75
Total Marks: 100

Course Objectives:

This course was designed with an objective to help students to know about plant diseases, types of pathogens in plant diseases and the complex interaction between agriculture system and micro-organisms.

Learning Outcomes:

1. Understand the importance of microorganisms in sustainable agriculture.
2. Understanding the different symptoms, epidemiology and management of plant pathogens.
3. Understand how nitrogen fixing organisms are used for biofertilizer and biopesticides production.

(Theory) ***Total Credits: 3***
Total Contact Hours: 45

Unit I:

History and development of plant pathology. Definition, concept, and importance of plant diseases. Role of environmental factors and host nutrition on disease development. Causes and factors affecting plant disease development (biotic and abiotic factors).

Unit II:

Plant diseases caused by fungi: downy mildew of grapes, blast disease of rice, tikka disease of groundnut, late blight of potato. Plant diseases caused by bacteria: bacterial blight of paddy, citrus

canker, common scab of potato. Plant diseases caused by viruses: tobacco mosaic, leaf curl of tomato, yellow vein mosaic of bhindi. Plant disease caused by mycoplasma and mycoplasma like organisms- sandal spike, grassy shoot disease of sugarcane.

Unit III:

Biofertilizers- Definition, Types and importance- steps in mass production of bacterial biofertilizers – quality guidelines for biofertilizers. Mass production of *Rhizobium*, *Azotobacter* and mycorrhiza. Plant response to biofertilizers application. Biopesticides -Introduction, types and importance (*Bacillus thuringiensis*, NPV, *Trichoderma*), mode of action, factors influencing and target pests. Integrated pest management (IPM).

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Isolation of symbiotic nitrogen fixer *Rhizobium* from root nodules
2. Isolation of non-symbiotic nitrogen fixer *Azotobacter* from soil
3. Study of Mycorrhiza from roots.
4. Preparation of slides from infected plant roots.
5. Study of plant pathogens- late blight, powdery mildew, citrus canker.
6. Report on Field Trip to a Biofertilizer and Biopesticide units

Suggested Readings

1. Agrios GN. (2006). Plant Pathology. 5th edition. Academic press, San Diego,
2. Mukherjee N. and Ghosh J. (2004) Agricultural Microbiology.Kalyani Publishers; 1st edition
3. Glick B.R. (2015) Beneficial Plant Bacterial Interactions, Springer.
4. Singh RS. (2017). Introduction to Principles of Plant Pathology. 5th edition. Medtech
5. Tronsmo AM, and Collinge DB. (2020). Plant Pathology and plant diseases. CABI publishing
6. Rangaswami G and BagyaraDJ (2023), Agricultural Microbiology -2nd edition. PHI learning Pvt limited.
7. Mohammed SK, Zaidi A , Musarrat J. (2009), Microbial strategies for crop improvement, Springer verlag Berlin Publisher.
8. Subha Rao NS (2020). Agricultural Microbiology. 3rd edition. Medtech

9. Dubey RC and Maheshwari DK (2023). Practical Microbiology. 4th edition. S. Chand and Company Ltd, New Delhi

10. Cappuccino JG and Sherman N (2020) Microbiology: A Laboratory Manual. 12th edition. Pearson publishing company

5thSemester

MIC-300	**Medical Bacteriology and Virology**	**Total Credits: 4**
		Total Contact Hours: 75
		Total Marks: 100

Course Objectives:

This course is designed with an objective to provide the basic understanding and fundamentals of medical microbiology and the different types of diseases caused by bacteria and viruses in human. This course is designed to inculcate the knowledge of anti-microbial agents and their role to combat diseases.

Course Learning Outcome:

1. Understanding of the medical aspects of microbiology.
2. Understand the role of microorganisms in causing diseases in human.
3. Understand how antimicrobial agents help to control and combat diseases.
4. Understand how to isolate and identify microorganisms from human body.

(Theory) ***Total Credits: 3***
Total Contact Hours: 45

Unit I:

Normal microflora of the human body: Skin, respiratory tract, gastrointestinal tract and urogenital tract. Definitions: pathogen, pathogenicity, virulence, invasion, endotoxins, exotoxins and disease carriers. Infection and types of infection. Mode of transmission of infection.

Unit II:

General account of microbial pathogenesis, clinical symptoms, laboratory diagnosis, prophylaxis and treatment. Bacterial diseases: typhoid, tuberculosis and syphilis. Virus diseases: HIV, Hepatitis, SARs and rabies.

Unit III:

Definition: antiseptic, microbicidal agents, microbiostatic agents and antimicrobial agent. Antibiotics and their mode of action (cell wall synthesis, cell membrane function, protein synthesis, nucleic acid synthesis). Bacterial drug resistance: genetic and non- genetic drug resistance. Antiviral drugs.

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Study of composition and use of important differential media for identification of clinically important bacteria: blood and Chocolate agar, CLED Agar, Mannitol salt agar, Deoxycholate citrate agar, TCBS, Venkatraman Ramakrishnan (VR) Medium.
2. Isolation and identificationof microorganisms from skin.
3. Isolation and identification of microbes from sputum/stool and urine.
4. Acid Fast staining of bacteria.
5. MIC and antimicrobial test by disk diffusion method against *E.coli* and *Staphylococcus*.

Suggested readings

1. Anathanarayana R, Paniker CK, Kanungo R and Saxena S (2022). Anathanarayana and Paniker's Text Book of Microbiology. 12th edition. University Press, India
2. Riedel S, Morse SA, Mietzner T and Miller S (2010). Jawetz, Melnick and Adelberg's Medical Microbiolog 28th edition. McGraw Hill Lange.
3. Pelczar MT, Chan ECS and Krieg NR (2015). Microbiology. Tata McGraw Hill Publication.
4. Stanier RY, Adelberg EA and Ingraham JL (2007) General microbiology. Macmillian Press London
5. Bareja R (2020). Practical Medical Microbiology. IP Innovative Publication Pvt. Ltd
6. Goering R, Dockrell HM, Zuckerman P and Chiodini PL (2024). Mims' Medical Microbiology and Immunology. 7th edition. Elsevier.
7. Murray PR, Rosenthal K and Pfaller MA (2020). Medical Microbiology 9th edition. Elsevier.
8. Apurba SS (2023). Essentials of medical Microbiology. 4th edition. Jaypee Brothers Medical Publishers.

5thSemester

MIC-301	**Food and Dairy Microbiology**	**Total Credits: 4**
		Total Contact Hours: 75
		Total Marks: 100

Course objective:

The objective of the course is to impart knowledge on the application of microbes in food and dairy industry, auditing of food safety and quality control/management system to obtain global food safety and quality requirement of public health and hygiene.

Learning outcome:

1. Understanding the significance and activities of microorganisms in food and dairy industries.
2. Acquire knowledge on the factors affecting growth and survival of microorganisms in food and dairy products.
3. Attained information on microbial food spoilage, food intoxications and food infections

(Theory) ***Total Credits: 3***
Total Contact Hours: 45

Unit I:

Natural flora of food, intrinsic and extrinsic factors affecting growth and survival of microbes in foods. Sources and factors affecting spoilage of vegetables, fruits, meat, eggs, bread, canned foods. Principles of food preservation: physical methods (temperature, irradiation, hydrostatic pressure, aseptic packaging), chemical methods (organic acids, SO_2, nitrite and nitrates, salt, sugar, ethylene oxide).

Unit II:

Microbiology of fermented milk: starter cultures, fermented dairy products (yogurt, kefir, koumiss, butter, butter milk and cheese). Fermented foods: idli, dosa, tempeh, soy sauce, poi, wines, sauerkraut. Local fermented food: tungtap, tungrymbai. Nutritional value of fermented foods. Probiotics: definition and uses.

Unit III:

Food poisoning, food infections and food intoxications. Bacterial and fungal food poisoning: botulism, Staphylococcal poisoning, aflatoxins, amatoxins and phallotoxins. Algal food

poisoning. Food borne disease outbreaks, laboratory testing, preventive measures, food sanitation, plant sanitation, employees' health standards, quality control.

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Isolation and identification of microbes from spoiled fruits and vegetables.

2. Preparation of curd and estimation of its acidity.

3. Isolation of lactic acid bacteria from fermented milk.

4. Determination of microbiological quality of milk sample by methylene blue reduction test

5. Study of food borne pathogens through permanent slides- *Clostridium botulinum, Staphylococcus aureus, Bacillus cereus, E. coli and Salmonella*

Suggested Reading:

1. Jay JM (2005). Modern Food Microbiology, CBS Publishers and Distributors, New York

2. Stantury PF, Whitekar A and Hall SJ (2016). Principles of Fermentation Technology.

3. Faridi AA (2014). Dairy Microbiology. Random Publications, New Delhi.

4. Parihar P and Parihar L (2011). Dairy Microbiology. Agrobios

5. Adams M.R. and Moss M.O. (2022). Food Microbiology. 4th edition. New Age International Publisher (P) Limited, Publishers

6. Frazier and Wasthoff, Food Microbiology (2017). Tata McGraw-Hill Publishing Company Ltd., New Delhi.

7. Aneja KR (2018). Modern food microbiology. Medtech

8. Dubey RC and Maheshwari DK (2023). Practical Microbiology. 4th edition. S. Chand and Company Ltd, New Delhi.

9. Garg N, Garg KL and Mukerji KG (2010). Laboratory Manual of Food Microbiology I K International Publishing House Pvt. Ltd.

10. Aneja KR (2022), Experiments in Microbiology, Plant pathology, tissue culture and microbial biotechnology. 6th edition. New age International Publishers.

5thSemester

MIC-302 **Microbial Genetics** **Total Credits: 4**

Total Contact Hours: 75

Course Objectives:

The objective of this course is to enable students to understand the concept of microbial genetics, microbial genome organization, and the significance of mutation in microbial evolution.

Learning Outcomes:

a. Understanding the fundamental concepts of microbial genetics

b. Understand about the different types of mutation and their role in evolution.

c. Understand the use of bacterial plasmids as research tools and application in microbial genetics.

(Theory) ***Total Credits: 3***

Total Contact Hours: 45

Unit I:

Genome organization- prokaryotic and eukaryotic microbes. Mutations- definition, types of mutations (induced and spontaneous), uses of mutants. Mutagens- physical and chemical mutagens. Detection and isolation of mutants (auxotrophic and resistant)

Unit II:

Plasmids: definition, types (episomes, cosmids), detection and purification. Replication of bacteriophage and plasmid DNA.Transposable elements- insertion sequences, transposons.

Unit III:

Recombination in bacteria: conjugation, transformation and transduction (generalized and specialized). Fungal genetics: Recombination in fungi – *Neurosporacrassa*. Life cycles and sexual process- Heterokaryosis, parasexual cycle and vegetative incompatibility.

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. UV induction of mutation in bacteria
2. Isolation of mutants using antibiotics
3. Preparation of survival curve
4. Replica plating technique for isolation of mutants.
5. Study of budding in yeast.

Suggested Readings:

1. Maloy SR, Cronan JE and FreifelderD(1994) Microbial Genetics ,2nd edition. Jones and Bartlett Publishers, Inc

2. Primrose SB (2014). Principles of gene manipulation and genomics. 7th edition. Wiley-Blackwell.

3. Gardner EJ, Simmons MJ and Snustad DP. (2006). Principles of genetics. 8th edition Wiley.

4. Stick Berger M.W. Genetics (2015).Pearson Education India.

5. Brown TA (2023). Genomes. 5th edition. CRC Press.

5th Semester

MIC-303	**Food Fermentation Technology**	**Total Credits: 4**
	(Minor)	**Total Contact Hours: 75**

Course Objectives:

The objective of the course is to make the student aware of the basic principles of food fermentation technologies and to also make the students ideally skilled for self-employment.

Learning Outcomes:

1. Understand the concept, principles and procedures involved in the area of fermented food production.
2. Understand and evaluate raw materials quality and their influence on the properties of final products.
3. Understand large scale productions of commercially significant fermentation.

(Theory) ***Total Credits: 3***
Total Contact Hours: 45

Unit I:

History and definition of fermented food, types of fermented food and substrates/raw materials used. Advantages and disadvantages of fermented foods, health benefits & hazards of using fermented food.

Unit II:

Microorganisms and production process of fermented - food (idli, dosa, bread, soy sauce, tampeh, sauerkraut), dairy products (yoghurt, buttermilk, kumiss, kefir and cheese), local fermented food (tungrymbai, tungtap), alcoholic beverages (beer, whisky and wine). Probiotics: Health benefits, types of microorganisms used.

Unit III:

Concept of packaging, important functions of package, packaging laws and regulations. Evaluation of quality, safety and interaction with foods of various types of packaging materials. HACCP for Food Safety- Principles, flow diagrams, limitations. Microbial standards for different Foods – BIS standards for common fermented foods. Quality control using Microbiological criteria- control at Source (training, facilities and operations, equipment, cleaning, and disinfection), FSSAI, BSI and their importance

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Estimation of lactic acid bacteria from fermented milk.
2. Microbiological analysis of fermented food products: Bacterial count.
3. Production of Sauerkraut
4. Isolation and enumeration of microorganisms from local fermented food
5. Production of wine from grapes.

Sugested Readings

1. Joshi VK. (2004) "Biotechnology Food Fermentation" Volume 1. Educational Publishers & Distributors.

2. Robert W. Hutkins.(2006) "Microbiology and Technology of Fermented Foods", 2nd Edition, Blackwell.
3. Stanbury PF, Whitaker A. and Hall SJ. (2016). Principles of Fermentation Technology. 3 rd Edition. Butterworth-Heinemann. ISBN: 9780080999531
4. McFadden B (2022) Food Fermentation Technologies. Kaufman Press.
5. Holzapfel W. (2014). Advances in Fermented Foods and Beverages, Woodhead Publishing.
6. Jay JM, Loessner MJ, Golden DA (2005) Modern Food Microbiology, 7th edition. Springer.
7. Gilmartin C (2020). Fermented food: A practical guide. The Crowood Press Ltd
8. Dubey RC and Maheshwari DK (2023). Practical Microbiology. 4th edition. S. Chand and Company Ltd, New Delhi
9. Aneja KR (2017). Experiments in Microbiology, Plant Pathology, Tissue culture and microbial Biotechnology. New age publishers.
10. Cappuccino JG and Sherman N (2020) Microbiology. 12th edition A Laboratory Manual, Pearson publishing company

5th Semester

MIC-304	**Internship**	**Total Credits: 4**
		Total Contact Hours: 75
		Total Marks: 100

Course Objective:

The objective of the course is to equip students with technical skills essential for microbiological research and application, analyzed experimental data using statistical methods and bioinformatics tools, interpreting results within the context of microbiological principles, enhanced written and oral communication skills by effectively documenting experimental procedures, presenting findings to peers and mentors, and preparing reports or presentations summarizing internship outcomes.

Learning Outcomes:

1. Develop practical laboratory skills essential for microbiological research.
2. Learn how to design and execute experiments independently or as part of a team, including planning, troubleshooting, and adapting protocols as necessary.
3. Gain proficiency in analyzing experimental data using statistical methods and bioinformatics tools, and interpreting results within the context of biochemical principles.

4. Foster critical thinking skills necessary for evaluating scientific literature, identifying research gaps, and proposing innovative solutions to biochemical problems.

Sl.No	Evaluation of Interns	Marks distribution	Credits
1	Experimental / Field work 12 days x 6 hours = at least for 72 hours	50	2
2	Internship Report 48 hours.	25	1
3	Presentation and Viva.voce	25	1
Total		**100**	**4**

Suggested Readings:

1. Aniket Singh. (2018). The complete book of internships in India: Intern abroad this summer. Notion Press, Incorporated.
2. Woodard, E. (2015). The ultimate guide to internships: 100 steps to get a great internship and thrive in it. Allworth Press.
3. McLachlan, J. E., & Hess, P. F. (2015). Get an internship and make the most of it: Practical information for high school and community college students. Rowman & Littlefield Publishers.
4. Green, M. E. (1997). Internship success: Real-world, step-by-step advice on getting the most out of internships. VGM Career Horizons.
5. Khoury, R. J., & Selby, J. (2021). How to intern successfully: Insights and actions to optimize your experience. Waterside Productions.
6. Shindell, R. (2019). Total internship management supervisor's handbook: A manager's guide to delivering an amazing internship experience. Intern Bridge, Incorporated.
7. Labor, S. L. (2020). Student internship success workbook (Supervisor's guide): 20+ Lessons and activities for student intern career readiness. Independently published.

6th Semester

MIC-350	**Medical Mycology and Parasitology**	**Total Credits: 4**
		Total Contact Hours: 75
		Total Marks: 100

Course Objectives:

This course is designed with an objective to provide the basic understanding and fundamentals of medical mycology and parasitology and the types of diseases caused by fungi and parasites with respect to human. This course is also designed to inculcate the knowledge of antifungal and anti-parasites agents and their role to combat diseases.

Learning Outcomes:

1. Understanding the mechanism by which pathogens cause disease.
2. Understand how to isolate, identify and perform lab diagnosis of pathogenic fungi and parasites from human body.
3. Understand how antifungal and anti-parasite agents help to control and combat diseases.

(Theory) ***Total Credits: 3***
Total Contact Hours: 45

Unit I:

Study of pathogenic fungi: pathogenicity, clinical features and laboratory diagnosis of superficial mycosis: dermatophytes, *Pityriasis versicolor*, *Tinea nigra*, black and white Piedra. Subcutaneous mycosis: Mycetoma, Chromomycosis and Sporotrichosis. Systemic mycosis: Coccidioidomycosis, Blastomycosis and Histoplasmosis. Opportunistic mycosis: Candidiasis, Cryptococcosis, Aspergillosis and Penicilliosis.

Unit II:

Antifungal agents and fungal toxins: inhibitors of fungal - cell wall synthesis, plasma membrane function, protein synthesis and mitosis. Mechanisms of anti-fungal drug resistance. Fungal toxins-General properties and types of mycotoxins.

Unit III:

Parasitology: General characteristics, pathogenesis, laboratory diagnosis, prevention and treatment of- intestinal parasites- *Giardia lamblia, Entamoeba histolytica, Trichuris trichiura* and *Ascaris lumbricoides.* Blood parasite- *Plasmodium vivax, Wucheria bancrofti* and *Leishmania donovani*.

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Isolation and identification of fungi from skin and nasal discharge.
2. Antagonistic effect of fungi against bacteria
3. Stool examination for detection of intestinal parasites: wet mount and iodine preparation.
4. Study of morphological characteristics of different parasites (*Giardia, Plasmodium, Ascaris*) from temporary or permanent slides.
5. Hospital Visit.

Suggested reading

1. Rajan S (2009). Medical Microbiology. First edition, MJP Publishers, Chennai.
2. Baveja V and Baveja CP (2019). Medical Parasitology. 4th edition. Arya Publishing House.
3. Ghosh S (2021). Paniker's Textbook of Medical Parasitology. 9th edition. Jaypee Brothers Medical Publishers.
4. Parija SC (2013). Text Book of Medical Parasitology – Protozoology and Helminthology,4th Edn. All India Publishers and Distributors, New Delhi.
5. Arora DR and Arora BB (2024) Medical Mycology. 3rd edition. CBS Pubkishers and Distributors Pvt Ltd.
6. Chatterjee KD (2009) Parasitology: Protozoology and Helminthology, 13thEdn. CBS Publishers & Distributors Pvt. Limited.
7. Paniker CKJ and Ghosh S (2021). Textbook of Medical Parasitology. 9th edition, Jaypee Brothers Medical Publishers
8. Godkar PB (2016).Textbook of medical microbiology and parasitology, microbiology. 1st edition Bhalani Publishing House
9. Westblade LF, Burd EM, Lockhart SR and Procop GW. (2023). Larones Medically Important Fungi: A Guide to Identification. 7th edition. ASM Press; CBS Publishers and Distributors Pvt Ltd.

6thSemester

MIC-351 **Molecular Biology** **Total Credits: 4**

Total Contact Hours: 75

Total Marks: 100

Course Objectives:

The objective of the course is to make the students understand molecular biology of microbes, gather sound knowledge about gene expression and to bring advancement in human life.

Learning Outcomes:

1. Understand the principle molecular events of cell incorporating DNA replication, transcription and translation in prokaryotic and eukaryotic organisms.
2. Understand post transcriptional modification and processing.
3. Understand translational regulation of lac and trp Operon.
4. Understand the genetic regulation at various levels.

(Theory) ***Total Credits: 3***

Total Contact Hours: 45

Unit I:

History and development of molecular biology. DNA topology, linking number, topoisomerases. DNA organization in prokaryotes and eukaryotes. DNA replication: mechanism of DNA replication (semi-conservative), enzymes and accessory proteins in prokaryotic and eukaryotic replication. Causes of DNA damage- spontaneous, chemical agent and radiation. DNA repair - direct repair, base excision repair, nucleotide excision repair, mismatch repair, recombination repair.

Unit II:

Transcription in Prokaryotes: prokaryotic RNA polymerase, transcription factors, promoter, enhancer, mechanism of transcription, initiation, promoter clearance and elongation. RNA splicing and processing (5'cap formation, polyadenylation, rRNA and tRNA splicing)

Unit III:

Concept of genetic code- triplet nature, degeneracy and universatility. Translational machinery in

prokaryotes, mechanism of initiation, elongation and termination. Regulation of gene expression – induction, activation and repression, attenuation and antisense control. Operon – lac aand trp.

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Estimation of DNA by using diphenylamine
2. Estimation of RNA by using orcinol
3. Isolation of bacterial plasmid DNA.
4. Isolation of chromosomal DNA.
5. Gel electrophoresis of plasmid DNA and examination of agarose gel.

Suggested reading:

1. Sathasivan K (2023). Introduction to Cell and Molecular Biology. LT Writing Publishers
2. Vologodskii A (2022). The Basics of Molecular biology. Springer.
3. Serrano R (2023). An Introductory Course on Molecular Biology. Canbridge Scholars Publishing.
4. Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts K and Walter P (2014). Molecular biology Of the Cell.6th edition. Garland Science
5. Clark DP, Pazdernik NJ and McGehee MR (2018). Molecular Biology. 3rd edition. Academic Cell Publishers.
6. Tropp BE (2012). Principles of Molecular Biology. Joones and Bartlett Publishers.
7. Cox MM, O'Donnell M and Doudna J (2015). Molecular Biology: Principles and Practice. 2nd edition. WH Freeman and Co Ltd.
8. Sivaranjani S, Ramadevi S, Ramabhai V, Everest P, Rani H and Gejalakshmi A (2023). Akinik Publications.

6thSemester

MIC-352 **Immunology** **Total Credits: 4**
Total Contact Hours: 75
Total Marks: 100

Course Objectives:

This course is designed with an objective to study the immune system and how it functions.

Learning Outcomes:

1. Understand the history and development of immunology.
2. Understand the principles governing vaccination and the mechanisms of protection against infectious diseases.
3. Understand and explain the basis of immunological tolerance and transplantation.
4. Understand and explain the basis of allergy and allergic diseases.
5. Understand and explain the immune system in tumor immunology and principles of immunotherapy.

(Theory) ***Total Credits: 3***
Total Contact Hours: 45

Unit I:

Overview of Immunology: History and scope of immunology. Physical and chemical barriers. Types of immunity- innate and acquired immunity. Organs, tissues and cells of immune system. Antigens: characteristics of an antigen (foreignness, molecular size and heterogeneity); Haptens; Epitopes (T & B cell epitopes); adjuvants. antibodies: structure, types, functions and properties of antibodies; antigenic determinants on antibodies (isotypic, allotypic, idiotypic); monoclonal antibody production (hybridoma technology). Antigen and antibody reactions – agglutination, precipitation, neutralization and opsonisation.

Unit II:

Generation of immune response: immunological memory and immunological tolerance, CMI, AMI. Major histocompatibility complex (structure and functions of MHC I & II molecules).Complement system- components of the complement system. Activation pathways (classical, alternative, and lectin pathways). Biological consequences of complement Activation. Immunohematology- ABO blood grouping, Rh and Rh incompatibilities.

Unit III:

Immunological disorders and transplantation immunology: Autoimmunity- definition and types (organ specific autoimmune disease and systematic autoimmune disease). Hypersensitivity- definition and types.Transplantation immunology- types of grafts, immunologic basis of graft

rejection, types of graft rejection and immunosuppressive therapy.Immunoprophylaxis– Vaccine (Killed, Live attenuated, recombinant DNA, synthetic and toxoid with an example each).

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Identification of human blood groups and Rh factor
2. Separation of serum from blood sample (demonstration).
3. To perform immunodiffusion by Ouchterlony method.
4. To perform WBC Count by slide staining method.
5. Perform Flocculation reaction- VDRL, Agglutination reaction- Widal test.

Suggested Readings:

1. Abbas AK, Lichtman AH, Pillai S. (2023). Functions and Disorders of the Immune System. 7th edition. Churchill Livingstone
2. Delves P, Martin S, Burton D, Roitt IM. (2016). Roitt's Essential Immunology. 13th edition Wiley Blackwell Scientific Publication, Oxford.
3. Murphy K, Travers P, Walport M. (2008). Janeway'sImmunobiology. 7th edition Garland Science Publishers, New York.
4. Peakman M, and Vergani D. (2009). Basic and Clinical Immunology. 2nd edition Churchill Livingstone Publishers, Edinberg.
5. Richard C and Geiffrey S. (2009). Immunology. 6th edition. Wiley Blackwell Publication
6. Punt J, Stranford JP, Jones S, and Owen JA (2018). Kuby Immunology. 8th edition. WH Freeman
7. Cappuccino JG and Sherman N (2020) Microbiology. 12th edition A Laboratory Manual, Pearson publishing company
8. Dubey RC and Maheshwari DK (2023). Practical Microbiology. 4th edition. S. Chand and Company Ltd, New Delhi

6thSemester

MIC-353 **Industrial Microbiology** **Total Credits: 4**

Total Contact Hours: 75

Total Marks: 100

Course Objectives:

This course is designed with an objective to provide a basic understanding of industrially important microorganisms and how to produce various industrially important products using fermentation

Learning Outcomes:

1. Understand the process of selection of the best microbial strains for the industry.
2. Understand the types of fermentation process, bioreactors and measurement of fermentation parameters.
3. Understanding the industrial production of important microbial metabolites and products.
4. Understand medium formulation and design for microbial fermentation and sterilization.

(Theory) ***Total Credits: 3***

Total Contact Hours: 45

Unit I:

Brief history, scope and developments in industrial microbiology. Isolation and screening of industrially important microorganisms and strain improvement methods. Fermentation Media- media components and formulation, crude media components, antifoam agents, precursors, inducers, inhibitors and buffering agents.Inoculum preparation

Unit II:

Fermentors- basic structure, construction and types- stirred tank fermentor, tower fermentor, airlift fermentor, and bubble cap fermentor. Types of industrial fermentation process- batch, continuous, surface, submerged and solid state fermentation. Process parameters- aeration, agitation, temperature regulation, foam regulation and pH regulation. Downstream processing steps- Separation of microbial cells, cell disruption, extraction, concentration, purification, drying.

Unit III:

Microbial production of industrial products- industrial alcohol, alcoholic beverages (beer, whiskey), wine, organic acid (citric acid), antibiotic (penicillin), amino acid (glutamic acid), enzymes (amylases), single cell protein (Quorn), vitamin (B_{12}& B_2), Biotransformation of steroids.

(Practical) ***Total Credits: 1***
Total Contact Hours: 30

Unit IV:

1. Demonstration of fermentation by using yeast
2. Penicillin production and testing of antimicrobial activity.
3. Ethanol production from cane sugar and jaggery
4. Preparation of wine from grapes
5. Citric acid production by *Aspergillus niger* and its estimation

Suggested Readings

1. Patel A.H. (2022). Industrial Microbiology. 2nd Edition, Laxmi Publications

2. Nduka Okafor, Benedict C. Okeke (2017). Modern Industrial Microbiology and Biotechnology2nd Edition CRC Press

3. Casida LE. (2019). Industrial Microbiology. 2nd edition. New Age International Private Limited

4. Crueger W and Crueger A. (2017). Biotechnology: A textbook of Industrial Microbiology. 3rd edition. Panima Publishing Co. New Delhi.

5. Prescott S.C. and Dunn CC. (2004) Industrial Microbiology. 4th Edition, Tata McGraw- Hill Publishing Company Limited, New Delhi.

6. McNeil. B, and Harvey L.M. (2007). Fermentation- A Practical Approach, IRL Press, New York

7. Agrawal, A.K. and Parihar,P 2008. Industrial Microbiology: Fundamentals and Applications. Agrobios, India

8. Dubey RC and Maheshwari DK (2023). Practical Microbiology. 4th edition. S. Chand and Company Ltd, New Delhi

9. Aneja KR (2017). Experiments in Microbiology, Plant Pathology, Tissue culture and microbial Biotechnology. New age publishers.

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