Approved by BoS (12 August, 2026)

COURSE CONTENTS & SYLLABUS

(Effective from the Academic Year 2026-2027)

UG (7-8 semesters) – MICROBIOLOGY
(Honours)

National Education Policy (NEP) - 2020

DEPARTMENT OF BOTANY AND MICROBIOLOGY
HEMVATI NANDAN BAHUGUNA GARHWAL UNIVERSITY
(A CENTRAL UNIVERSITY)
Srinagar, Garhwal – 246174, Uttarakhand, INDIA

SYLLABUS: UG – MICROBIOLOGY (7-8 semesters)

DEPARTMENT OF MICROBIOLOGY

Hemvati Nandan Bahuguna Garhwal University
(A Central University)
Srinagar, Garhwal – 246174, Uttarakhand, INDIA

U.G (7-8 semesters) – Microbiology (Honours)				
Sem.	**Codes**	**Credits**		**Paper name**
		T	P	
VII	Core Major-I	5	-	Fundamentals of Microbial Life
	Core Major-II	5	-	Biochemistry of Microbial Life
	Core Major-III	5	-	Microbial Cytology
	Core Major Elective-I	3	1	Molecules of Microbial Life
	Major Practical-1	-	5	Practical based on Core Majors I, II and III
	Minor-I	2	2	Basic Bioinformatics
	Total credits	**20+8=28**		
VIII	Core Major-IV	5	-	Laboratory Methods in Microbiology
	Core Major-V	5	-	Functional Microbial Physiology
	Core Major-VI	5	-	Genetic Engineering
	Core Major Elective-II	3	1	Introductory Immunology
	Major Practical-2	-	5	Practical based on Core majors IV, V and VI
	Minor-II	2	2	Fundamentals of Epidemiology
	Total credits	**20+8=28**		
NHEQF Level- 6		Student on exit after successfully completing four years (i.e., securing minimum required 176 credits along with securing additional 2 credits under SSD course work) will be awarded “Four years Bachelor’s Degree (Honours)”, in related field/discipline.		

U.G (VII semesters) – Microbiology (Honours)

Core Major – I: Fundamentals of Microbial Life

Credits: 5 **75 h**

Unit I: History and Classification (15 h)

History and development of microorganisms; Conflicts over spontaneous generation; Golden era of microbiology; Concepts of prokaryotes and eukaryotes; Classification of microorganisms: Haeckel's three kingdom concept, Whittaker's five kingdom concept, Eight kingdom classification, Techniques used in microbial classification (Morphological, chemotaxonomic and genetic methods); Future of microbiology.

Unit II: Microscopy (15 h)

Principle of bright field microscopy, dark field microscopy, fluorescence and electron (transmission and scanning) microscopy and their applications in microbiology, Staining of microorganisms, simple staining, negative staining, Gram staining and endospore staining.

Unit III: Basics of Microbiology (15 h)

Microbial nutrition; Culture media; Culture techniques for isolation of pure culture; Cultivation of aerobic and anaerobic bacteria; Preservation methods; Microbial growth; Generation time, Diauxic growth curve; Effect of environmental conditions (pH, temperature, aeration, etc.) on microbial growth.

Unit IV: General Bacteriology (15 h)

Ultrastructure of bacterial cell: Morphology of bacteria, Structure and properties of cell wall and cell membrane, Cell wall synthesis, Capsule (Types, composition and function), Ultrastructure and functions of flagella, cilia, pili, s-layer, ribosomes and nucleoid; Reserve food materials- PHB, phosphate granules, oil droplets, cyanophycean granules and sulphur inclusions Bacterial reproduction; Characteristic features of Archaea.

Unit V: General Virology (15 h)

Discovery of viruses; Characteristic feature of viruses, viroids, virusoids prions and Satellite viruses; Baltimore scheme of classification; Morphology and ultrastructure: Capsids and their arrangements, Types and composition of envelopes, Viral genome (Types and structures); Isolation and cultivation of viruses using embryonated eggs, Multiplication of viruses; Bacteriophage: Structural organization, Cultivation, Replication, One step growth curve, Eclipse phase, Phage production, Burst size; Application of bacteriophages.

Suggested Readings

1. Willey, J., Sandman, K., and Wood, D., (2023) Prescott's Microbiology (12th Edition), McGraw-Hill, New York.
2. Madigan, M.T., Bender, K.S., Buckley, D.S., Sattley, W.M., Stahl, D.A. (2020) Brock Biology

of Microorganisms, (16th Edition), Pearson Publisher, USA
3. Pommerville, J.C. Alcamo's fundamentals of microbiology. Jones and Bartlett Learning, Sudbury.
4. Wheelis, M. Principles of modern microbiology. Jones and Bartlett Learning, Sudbury.
5. Stanier, R.Y., Ingraham, J.L., Wheelis, M.L. and Painter, P.R. General microbiology. MacMillan Press, London.
6. Sclegel, H.G. General Microbiology. Cambridge University Press, Cambridge.
7. Pelczar, M.J., Chan, E.C.S. and Kreig, N.R. Microbiology. McGraw-Hill, New York.
8. Dubey, R.C. and Maheshwari, D K, A Textbook of Microbiology, S Chand, New Delhi
9. Hawkes, P.W., Spence, J.C.H. (2019) Springer Handbook of Microscopy, Springer Nature Switzerland
10. Dimmoc, N.J., Easton, A.J. and Leppard, K.N. Introduction to Modern Virology. Wiley-Blackwell, New Jersey.
11. Read related review articles and research papers published recently in reputed journals.

Core Major – II: Biochemistry of Microbial Life (Theory)

Credits: 5 **75 h**

Unit I – Acid–Base Chemistry (12 h)

Bronsted and Lewis concepts; conjugate acid–base pairs; ionization of solutions; pH and pKa; physiological relevance of pH. Biological buffers; Henderson–Hasselbalch equation, buffer capacity, polyprotic acids, amphoteric salts, ionic strength in biological systems, Lab buffers; Phosphate, bicarbonate, histidine-containing peptides, Good's buffers.

Unit II – Bioenergetics (12 h)

Energy generation in biological systems: substrate-level phosphorylation, oxidative phosphorylation, photophosphorylation. Electron transport chain: organization in bacteria and mitochondria; artificial electron donors; inhibitors and uncouplers. Chemiosmotic theory of ATP synthesis; experimental evidence and modern perspectives. High-energy phosphate compounds: ATP, GTP, PEP, creatine phosphate. Phosphate group transfer potential; free energy of ATP hydrolysis under physiological conditions.

Unit III – Carbohydrate Metabolism (12 h)

Glycolysis and its regulation. TCA cycle and amphibolic role. Glyoxylate shunt and its significance in microbes. Pentose phosphate pathway: oxidative and non-oxidative phases. Anaplerotic reactions and gluconeogenesis. Fermentation pathways: lactic acid, ethanol, mixed acid, butanediol, propionic acid.

Unit IV – Lipid Metabolism (10 h)

Biosynthesis of fatty acids, triacylglycerols, phospholipids, cholesterol, steroids, isoprenoids. Regulation of cholesterol biosynthesis (HMG-CoA reductase). B-oxidation, α-oxidation, ω-oxidation of fatty acids. Ketogenesis and ketolysis. Integration of lipid metabolism with carbohydrate metabolism.

Unit V – Amino Acids & Nucleotides (15 h)

Biosynthesis of Amino acids and its regulation. Deamination and transamination reactions. Biosynthesis of purines and pyrimidines (de novo and salvage pathways). Regulation of nucleotide biosynthesis. Degradation pathways of purines (uric acid) and pyrimidines. Role of nucleotides in cellular energy and signaling (ATP, GTP, cAMP, cGMP).

Unit VI – Enzymes: Structure, Function & Regulation (14 h)

Mechanisms of enzyme catalysis: acid–base catalysis, covalent catalysis, metal ion catalysis. Kinetics of single-substrate and multi-substrate reactions (sequential, ping–pong mechanisms). Reversible and irreversible inhibition (competitive, non-competitive, uncompetitive, mixed). Allosteric enzymes: sigmoidal kinetics, cooperative binding, models of allostery (MWC, KNF). Regulation of enzyme activity: covalent modification, feedback inhibition. Determination of active site structure and turnover number. Applications of enzymes in biotechnology and industry.

Suggested Readings

1. Nelson, D. L., Cox, M. M., & Hoskins, A. (2021). Lehninger Principles of Biochemistry. Macmillan. (8th edition)
2. Rodwell, V., Bender, D., Botham, K. M., Weil, P. A., & Kennelly, P. J. (2022). Harper's Illustrated Biochemistry. 28. Citeseer, New York, United States. (32nd edition)
3. Voet, D., Voet, J G., Pratt, C W. (2018). Voets Principles of Biochemistry, 235. John Wiley. (5th edition)
4. Berg, J., Stryer, L. (2023). Biochemistry. 1120. Springer Verlag. (10th edition)

Core Major - III: Microbial Cytology (Theory)

Credits: 5 **75 h**

UNIT I: Cellular Architecture and Membrane Organization (15 h)

Comparative cellular organization of Bacteria, Archaea and microbial Eukarya; cellular dimensions, morphology and principles governing cellular organization; prokaryotic and eukaryotic cellular compartmentalization; fungal cell wall; plasmids; Plasma membrane composition, structural organization and fluid mosaic model; membrane asymmetry and membrane microdomains; membrane fusion and fission; passive transport including simple and facilitated diffusion and osmosis; active transport including primary and secondary transport; ion channels, pumps and transporters; ABC transporters.

UNIT II: Intracellular Organization, Cytoskeleton and Cellular Dynamics (15 h)

Microbial cytoskeleton (FtsZ, MreB, crescentin/CreS, DivIVA, Par proteins and bactofilins) and its roles in cell shape, polarity, chromosome positioning and division. Eukaryotic cytoskeleton: actin filaments, microtubules and intermediate filaments; organization and dynamics. Cell polarity and spatial organization of proteins; molecular motors and cellular motility, including kinesins, dyneins and myosins. Organization and functions of major eukaryotic organelles. Vesicular trafficking, endocytosis and exocytosis; COPI/COPII and clathrin-mediated trafficking; Rab GTPases, SNARE proteins and endosomal trafficking.

UNIT III: Chromosome Organization, Cell Cycle and Cell Division (15 h)

Bacterial and archaeal chromosome organization; nucleoid-associated proteins; chromosome domains, condensation, partitioning and segregation; plasmid inheritance and Par systems. Eukaryotic chromosome organization: chromatin, nucleosomes, euchromatin and heterochromatin, centromeres and telomeres. Microbial cell cycle, chromosome replication and segregation; divisome assembly; FtsZ-ring/Z-ring formation and bacterial cytokinesis. Eukaryotic cell-cycle organization (G_1, S, G_2 and M); cyclins and cyclin-dependent kinases; cell-cycle checkpoints; DNA-damage response and spindle assembly checkpoint. Molecular mechanisms of mitosis and meiosis, chromosome segregation and cytokinesis.

UNIT IV: Protein Targeting, Secretion and Cellular Communication (15 h)

Protein folding and molecular chaperones; signal peptides and intracellular protein targeting. Bacterial Sec and Tat pathways; targeting to bacterial membranes. Eukaryotic protein targeting and sorting through the endoplasmic reticulum and secretory pathway; ER–Golgi trafficking and intracellular protein sorting. Bacterial secretion systems (Types I–VII), membrane vesicle biogenesis and extracellular vesicles. Microbial cellular communication: quorum sensing, two-component regulatory systems, chemotaxis-associated signaling, contact-dependent signaling and principles of microbial multicellularity. Basic eukaryotic cellular signaling through cell-surface receptors, GPCRs, receptor tyrosine kinases and second messengers, with emphasis on MAPK and PI3K-Akt pathways.

UNIT V: Cellular Stress, Survival and Cell Death (15 h)

Cellular stress and adaptation in microorganisms, including oxidative, osmotic, thermal, envelope and protein stress; stress-response systems, proteostasis and stringent response. Microbial survival strategies: dormancy, persistence, persister cells, viable but non-

culturable states and microbial aging. Microbial programmed cell death, toxin–antitoxin systems, abortive infection, autolysis and apoptosis-like cell death in bacteria and fungi. Eukaryotic cell-death pathways: apoptosis, caspases and Bcl-2 family proteins; autophagy and cellular homeostasis; and regulated cell death including pyroptosis, ferroptosis and necroptosis.

Suggested References and Readings

1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P. Molecular biology of the cell. Garland Science, New York.
2. Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Scott, M.P., Bretscher, A., Ploegh, H. and Matsudaira, P. Molecular cell biology. W.H. Freeman and Company, New York.
3. Madigan, M. T., Bender, K. S., Buckley, D. H., Sattley, W. M. & Stahl, D. A. Brock Biology of Microorganisms. 16th ed. Pearson.
4. Cooper, G.M. and Hausman, R.E. Cell: Molecular approach. ASM Press, Washington, D.C.
5. de Robertis, E. D. P. and de Robertis, E.M.F. Cellular and molecular biology. Saunders, Philadelphia.
6. Snyder, L., Peters, J. E., Henkin, T. M. & Champness, W. Molecular Genetics of Bacteria. ASM Press.
7. Pollard, T.D., Earnshaw, W.C. and Schwartz, J.L. Cell biology. Saunders, Philadelphia.
8. Karp, G. Cell and molecular biology- Concepts and experiments. John Wiley and Sons, New York.
9. Slonczewski, J. L., Foster, J. W. & Zinser, E. R. Microbiology: An Evolving Science. 5th ed. W. W. Norton, 2020.
10. Key Review Articles & Recent Literature
11. Read review articles published in reputed and Indexed Scientific journals.
12. Recommended online resources - NCBI, UniProt, PDB, InterPro, Pfam, STRING, KEGG, BRENDA, PubMed

Major Practical - 1
(Practical exercises based on Majors I, II, and III)

Credits: 5 **Hours: 150**

Introduction to Microbial World

1. Safety rules of working in microbiology lab, disposal of cultures, calibration, validation and maintenance of instruments.
2. Principles and working of instruments used in microbiology lab.
3. Media preparation and its sterilization.
4. Isolation and enumeration of bacteria and fungi from given sample.
5. Isolation and maintenance of pure culture of bacteria and fungi.
6. Staining of bacterial cell (Simple staining, gram staining and negative staining).
7. Measurement of bacterial cell size using micrometer.
8. Staining of endospore and capsule.
9. Staining of fungal cell.

Fundamentals of Microbial Biochemistry

1. Preparation of Molar, normal, and Buffer solutions; pH adjustment.
2. Reducing Sugars: DNS method using glucose standard curve.

Suggested Readings

1. Jayaraman J (2011). Laboratory manual in Biochemistry. New age international publishers, New Delhi.
2. Sadasivam S, Manickam A, (2008). Biochemical methods. New age international publishers, New Delhi.

Microbial Cytology

1. Study of different stages of mitosis.
2. Study of different stages of meiosis.
3. Study of mechanism of diffusion.
4. Study of mechanism of exosmosis and endosmosis.
5. Effect of isotonic, hypotonic and hypertonic solutions on cell.
6. Study of bacterial membrane permeability and the effect of selected environmental or chemical factors on membrane integrity using appropriate indicator-based assays.
7. Bioinformatics-based analysis of bacterial cytoskeletal proteins such as FtsZ, MreB and crescentin, including sequence retrieval, conserved-domain analysis and prediction of structural features.
8. Comparative sequence and structural analysis of representative prokaryotic and eukaryotic cytoskeletal proteins and interpretation of their functional similarities and differences.
9. Analysis of bacterial protein-targeting signals and prediction of cellular localization of selected proteins with reference to the Sec and Tat pathways using appropriate bioinformatics tools.
10. **Bioinformatics & Virtual Lab Modules** *(Essential where wet lab access is limited)* Virtual Microscopy & Live-Cell Imaging

Online platforms (e.g., https://www.swissbiopics.org/, https://www.swissbiopics.org/ and https://idr.openmicroscopy.org/) to study subcellular structures

Suggested Readings

1. Cappuccino J., and Welsh C., Microbiology: A Laboratory Manual, 11th Edition, Pearson, USA
2. Dubey, R.C. and Maheshwari, D K, Practical Microbiology, S Chand, New Delhi
3. Practical Biochemistry by Pamela Jha
4. Practical Manual of Biochemistry by G. Sattanathan, S.S. Padmapriya, B. Balamuralikrishnan,
5. Sambrook, J. and Russell, D.W. Molecular cloning: A laboratory manual. Cold Spring Harbor Lab Press, New York.
6. Miller, J.H. Experiments in molecular genetics. Cold Spring Harbor Lab Press, New York.
7. Murray, R.G.F., Wood, W.A. and Krieg, N.B. Methods for general and molecular bacteriology. ASM Press, Washington, D.C.
8. Chaitanya, K.V. Cell and molecular biology: A lab manual. PHI Learning, New Delhi.
9. Celis, J.E. Cell biology: A laboratory handbook. Elsevier, Amsterdam.

Core Major: Elective – I: Molecules of Microbial Life (Theory)

Credits: 3 **45 h**

Unit I: Microbial Genome (10 h)

Structure and chemical properties of DNA and RNA; Types of DNA (A-, B-, and Z-DNA) and DNA topology DNA denaturation and renaturation; Special DNA structures (G-quadruplexes); Telomeres and their biological importance

Unit II: DNA Replication and Transcription (10 h)

DNA replication mechanisms in prokaryotes and eukaryotes. Steps of transcription: initiation, elongation, and termination; Role of transcription factors and regulatory proteins; RNA processing: capping, polyadenylation, and splicing; Types and functions of RNA (mRNA, tRNA, rRNA, and non-coding RNAs)

Unit III: Translation and Gene Expression (10 h)

Genetic code: features and exceptions; Protein synthesis (translation) in prokaryotes and eukaryotes; Structure and function of ribosomes; Post-translational modifications of proteins; Regulation of gene expression: lac, trp, and arabinose (ara) operons; Regulatory RNAs: miRNA, siRNA, piRNA, and lncRNA.

Unit IV: Genome Recombination, Mobile Elements, and Mutation (15 h)

DNA recombination: homologous and non-homologous recombination; Major proteins involved in DNA repair and recombination; Transposons and retrotransposons; Types and causes of mutations; Chemical and physical mutagens and their effects on microbial genomes.

Suggested Readings

1. Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Scott, M.P., Bretscher, A., Ploegh, H. and Matsudaira, P. Molecular cell biology. W.H. Freeman and Company, New York.
2. Krebs, J.E., Goldstein, E.S. and Kilpatrick, S.T. Lewin's genes. Jones and Bartlett Learning Publishers, Sudbury.
3. Nelson D. L. and Cox, M.M. Lehninger principles of biochemistry. W.H. Freeman and Company, New York.
4. Snustad, D.P. and Simmons, M.J. Principles of genetics. John Wiley and Sons, New York.
5. Malacinski, G.M. and Friefelder, D. Essentials of molecular biology. Jones and Bartlett Learning, Sudbury.
6. Synder, L.J., Peters, E., Henkins, T.M. and Champness, W. Molecular genetics of bacteria. ASM Press, Washington, D.C.
7. Maloy, S.R., Cronan, J.E. and Freifelder, D.M. Microbial genetics. Jones and Bartlett Learning, Sudbury.
8. Hartwell, L. Genetics: From genes to genome. McGraw-Hill, New York.
9. Weaver, R. Molecular biology. McGraw-Hill, New York.
10. Watson, J.D., Baker, T., Bell, S.P., Gann, A., Levine, M. and Lodwick, R. Molecular biology of the gene. Pearson Education, New Jersey.

Practical based on Core Major Elective – I

Molecules of Microbial Life (Practical)

Hours: 30 **Credits: 1**

1. Quantitative estimation of DNA by diphenyl amine (DPA) and spectrophotometric method.
2. Determination of quality of DNA by spectrophotometric method.
3. Determination of Tm of given DNA sample.
4. Study of the effect of temperature and pH on the denaturation of DNA.

Suggested Readings

1. Sambrook, J. and Russell, D.W. Molecular cloning: A laboratory manual. Cold Spring Harbor Lab Press, New York.
2. Murray, R.G.F., Wood, W.A. and Krieg, N.B. Methods for general and molecular bacteriology. ASM Press, Washington, D.C.
3. Chaitanya, K.V. Cell and molecular biology: A lab manual. PHI Learning, New Delhi.
4. Celis, J.E. Cell biology: A laboratory handbook. Elsevier, Amsterdam.

Minor – I: Basic Bioinformatics (Theory)

Credits: 02 **30 h**

Unit I – Bioinformatics and Biological Databases (6 h)

Concept, scope and applications of bioinformatics; bioinformatics in microbiology; types of biological data; primary and secondary databases; major resources: NCBI, GenBank/RefSeq, EMBL-EBI/ENA, UniProt and PDB; accession numbers and identifiers; FASTA format; retrieval and interpretation of nucleotide and protein sequences.

Unit II – Sequence Analysis and BLAST (7 h)

Sequence identity, similarity and homology; homologues, orthologues and paralogues; basic concept of pairwise alignment; global and local alignment; scoring and gap penalties; BLAST and FASTA; BLASTn and BLASTp; interpretation of E-value, bit score, percentage identity and query coverage; identification of homologous sequences and basic functional inference.

Unit III – Multiple Sequence Alignment and Phylogenetics (6 h)

Purpose of multiple sequence alignment; conserved and variable regions; introduction to Clustal Omega/MUSCLE; basic concepts of molecular phylogenetics; phylogenetic trees; UPGMA and Neighbor-Joining; bootstrap support; interpretation and applications in microbial identification, taxonomy and evolutionary studies.

Unit IV – Microbial Genomics and Functional Annotation (6 h)

Basic organization of microbial genomes; genome sequencing and assembly concepts; structural and functional annotation; homology-based functional prediction; introduction to UniProt, KEGG, COG and InterPro/Pfam; comparative genomics; orthologs and gene families; introduction to antimicrobial-resistance and virulence-gene analysis; basic concept of metagenomics.

Unit V – Structural Bioinformatics and Emerging Applications (5 h)

Protein structural levels; PDB; basic molecular visualization; introduction to homology modelling and structure prediction; conceptual introduction to AI-based protein structure prediction such as AlphaFold; introduction to protein–ligand interaction and molecular docking; PubChem; applications of bioinformatics in antimicrobial research and drug discovery.

Recommended Books and Current Online Resources

1. Lesk, A.M. Introduction to Bioinformatics. Oxford University Press.
2. Raghava, G.P.S., & Raghava, S. (2010). Bioinformatics for Beginners. Alpha Science International.
2. Pevsner, J. Bioinformatics and Functional Genomics. Wiley-Blackwell.
3. Zvelebil, M. & Baum, J.O. Understanding Bioinformatics. Garland Science.
4. Mount, D.W. Bioinformatics: Sequence and Genome Analysis. Cold Spring Harbor Laboratory Press.
5. NCBI/BLAST official documentation and NCBI Handbook.
6. UniProt Knowledgebase and current analysis tools.
7. EMBL-EBI/ENA resources; PDB; KEGG.
8. QIIME 2 current amplicon/microbiome documentation.
9. Current official database/software documentation should supersede older interface-specific instructions.

Minor – I: Basic Bioinformatics (Practicals)

Credits: 02 **60 h**

1. **Introduction to Biological Databases & Data Retrieval**
   - Navigating NCBI, EMBL, DDBJ, and UniProt databases.
   - Downloading nucleotide and protein sequences in FASTA and GenBank formats.
   - Searching microbial-specific databases (MG-RAST, IMG, KEGG).

2. **Sequence Alignment**
   - Pairwise sequence alignment using BLAST (nucleotide and protein).
   - Interpreting BLAST results (E-value, score, identity).
   - Performing Multiple Sequence Alignment (MSA) using Clustal Omega/MUSCLE.

3. **Phylogenetic Analysis**
   - Construction of phylogenetic trees using MEGA or PhyML.
   - Bootstrap analysis for tree reliability.
   - Application of phylogenetics in microbial taxonomy case study.

4. **Microbial Genome and Metagenome Analysis**
   - Genome annotation using NCBI Genome Browser.
   - Comparative genomics using online tools (IMG, PATRIC).
   - Metagenomic data analysis using MG-RAST or QIIME (sample dataset).

5. **Project-based Mini Assignment**
   - Retrieve sequences of a microbial gene/protein of interest.
   - Perform alignment, build a phylogenetic tree, and interpret evolutionary relationships.
   - Prepare a short report with data visualization.

U.G (VIII semesters) – Microbiology (Honours)

Core Major-IV: Laboratory Methods in Microbiology - (Theory)

Credits: 5 **75 h**

Unit I: Advanced Microscopy and Biosensors (15 h)

Microscopy: *Light microscopy*: Phase contrast microscopy, Fluorescence microscopy, Total Internal Reflection Fluorescence (TIRF) microscopy, and confocal microscopy; Scanning and transmission electron microscopy; Atomic Force Microscopy (AFM). Biosensors: Introduction to Biosensors and their evolution; Cell-based biosensors; DNA biosensors.

Unit II: Centrifugation Technologies (15 h)

Basic Principles: Centrifugal force, sedimentation rate, sedimentation coefficient. Types and Applications: Clinical, micro, high-speed, ultracentrifuges, industrial centrifuges; Fixed-angle, swinging bucket, zonal, and continuous flow rotors. Density gradient ultracentrifugation.

Unit III: Modern Chromatography Techniques (15 h)

Basic Principles: Adsorption, partitioning, and separation efficiency. Techniques: Adsorption, ion-exchange, affinity, size exclusion, thin-layer, gas chromatography (GC), High-performance liquid chromatography (HPLC) and Ultra High Performance Liquid Chromatography (UHPLC).

Unit IV: Electrophoretic Techniques (15 h)

Core Concepts: Charge-based separation and gel systems. Types: Paper, moving boundary, isoelectric focusing, SDS-PAGE, native PAGE, reducing PAGE, Disc electrophoresis, Pulse Field Gel Electrophoresis (PFGE).

Unit V: Spectroscopy, Mass Spectrometry, and Radiotracer Technology (15 h)

Core Techniques: UV-Vis, IR, Fluorescence spectroscopy. Principle and applications of NMR; Mass Spectrometry; Radiotracers and radioactivity detection: GM counter & scintillation counters.

Suggested Readings

1. Wilson, K. and Walker, J. Principles and techniques of biochemistry and molecular biology. Cambridge University Press, Cambridge.
2. Robyt, J.F. and White, B.J. Biochemical techniques: Theory and practice. Waveland Press, Long Grove.
3. Chatwal, G. and Anand, S. Instrumental methods of chemical analysis. Himalaya Publishing House, Mumbai.
4. Hamilton, R.J. and Sewell, P.A. Introduction to high performance liquid chromatography. Chapman and Hall Limited, London.
5. Sharma, V.K. Techniques in microscopy and cell biology. Tata McGraw-Hill, New Delhi.
6. Hames, B.D. Gel electrophoresis of proteins: A practical approach. Oxford University Press, Oxford.
7. Wilson, Keith, Andreas Hofmann, John M. Walker, and Samuel Clokie, eds. *Wilson and Walker's principles and techniques of biochemistry and molecular biology*. Cambridge university press, 2018.Keeler, J. Understanding NMR spectroscopy. John Wiley and Sons, New York.
8. Davies, A.M.C. and Creaser, C.S. Analytical applications of spectroscopy. Royal Society of Chemistry, California.
9. Wang, C.H. and Willis, D.L. Radiotracer methodology in biological science. Prentice Hall, New Jersey.
10. Sambrook, J. and Russell, D.W. Molecular cloning: A laboratory manual. Cold Spring Harbor Lab Press, New York.

Core Major – V: Functional Microbial Physiology (Theory)

Credits: 5 **75 h**

Unit I – Phototrophy and Chemotrophy (15 h)

Cyclic and non-cyclic photophosphorylation, proton motive force generation, CO_2 fixation pathways. Chemolithotrophy: ecological role and energy yield, Sulphur, iron, hydrogen, and nitrogen oxidation pathways, Methylotrophy: C1 metabolism, methanotrophy, energetics, Methanogenesis in archaea: biochemistry, coenzymes (F_{420}, coenzyme M), and regulation.

Unit II – Nitrogen and Sulphur metabolism (15 h)

Genetics of nitrogen fixation: nif and fix gene clusters, regulation (NifA, NifL, and environmental control), Symbiotic nitrogen fixation: Rhizobium–legume interaction, nodule formation, leghaemoglobin function. Nitrate/nitrite assimilation and dissimilation, ammonium assimilation (GS-GOGAT pathway, GDH pathway), Regulation of nitrogen metabolism (ntr system, PII proteins). Assimilatory and dissimilatory sulphate reduction pathways, Biosynthesis of cysteine and methionine, Glutathione biosynthesis and function in oxidative stress and sulphur homeostasis.

Unit III: Respiration and Fermentation (15 h)

Anaerobic respiration: alternative electron acceptors (nitrate, fumarate, sulphate, CO_2, metals), ecological significance. Mechanism of oxygen toxicity and microbial defences (superoxide dismutase, catalase, peroxidases). Biochemistry of lactic acid, alcoholic, mixed acid, butanediol, propionic acid, butyric acid fermentations, Fermentation of amino acids (Stickland reactions), Industrial relevance of fermentative pathways.

Unit IV – Microbial Transport Systems (15 h)

Principles of membrane transport, Donnan equilibrium, thermodynamics of transport. Passive and facilitated diffusion, primary and secondary active transport. Group translocation: phosphoenolpyruvate-dependent phosphotransferase system (PEP–PTS) and its role in catabolite repression. ABC transporters: structure, function, and regulation. Protein secretion pathways in bacteria (Sec, Tat, Type I–VI secretion systems).

Unit V: Communication in prokaryotes (15 h)

Intercellular signaling: pheromone-mediated communication, quorum sensing (AHLs, oligopeptides, AI-2 signaling), biofilm formation. Intracellular signaling: two-component regulatory systems, phosphorelays, secondary messengers (c-di-GMP, ppGpp, cAMP). Cross- kingdom signaling between microbes and hosts/plants.

Suggested Readings

1. Madigan, M.T., Bender K.S., Buckley D.H, Sattley W.M, Stahl D.A (2021) Brock biology of microorganisms. Pearson, London, United Kingdom.
2. Moat, A. G., Foster, J. W., & Spector, M. P. (Eds.). (2002). *Microbial physiology*. John Wiley & Sons.
3. Poole, R. K. (2019). *Advances in microbial physiology* (Vol. 74). Academic Press.
4. White, D., Drummond, J. T., Fuqua, C., White, D., & Drummond, J. T. (2007). *The physiology*

and biochemistry of prokaryotes (Vol. 4). New York: Oxford University Press.

5. Bruggeman, F. J., Planqué, R., Molenaar, D., & Teusink, B. (2020). Searching for principles of microbial physiology. *FEMS microbiology reviews*, *44*(6), 821-844.

Core Major-VI (Theory): Genetic Engineering

Credits: 5 **75 h**

Unit I: Principles, Nucleic Acids and Tools of Gene Cloning (15 h)

- Isolation and purification of DNA and RNA: genomic, plasmid, bacteriophage DNA and total RNA; conventional and column-based methods; assessment of purity and integrity.
- Restriction endonucleases: recognition sequences, sticky and blunt ends, isoschizomers and applications in cloning and mapping.
- DNA-modifying enzymes: DNA ligases, polymerases, kinases, phosphatases, terminal deoxynucleotidyl transferase and recombinases.
- Cloning vectors: essential features; plasmid vectors, λ and M13 phage vectors, cosmids, phagemids, BACs, YACs and shuttle vectors.
- Specialized vectors: Ti plasmid-based plant vectors and commonly used viral vectors for animal cells; basic principles and applications.
- Contemporary cloning: Gateway cloning, Gibson assembly, Golden Gate cloning, synthetic biology vectors and CRISPR-associated nucleases.

Unit II: Gene Cloning Strategies, Libraries and Screening (15 h)

- General workflow of recombinant DNA cloning: target identification, vector selection, insert preparation, assembly, host introduction, selection, screening, validation and preservation.
- DNA fragment generation and modification: restriction digestion, PCR, adaptors, linkers and homopolymer tailing.
- DNA delivery: bacterial transformation by chemical and electroporation methods; eukaryotic transfection; microinjection, biolistics and viral delivery.
- Construction of genomic and cDNA libraries: principles, representation, screening and applications.
- Selection and screening: antibiotic selection, blue-white screening, reporter-based screening, colony PCR, restriction analysis, hybridization-based screening, immunoscreening and functional complementation.
- Validation of recombinant clones: insert size/orientation, restriction analysis and sequencing-based confirmation; troubleshooting of cloning experiments.
- Concepts of high-throughput cloning and NGS-compatible library preparation.

Unit III: Recombinant Gene Expression and Protein Production (15 h)

- Expression-vector architecture: promoters, enhancers/operators, terminators, translation-initiation elements, selectable markers, reporter genes, signal peptides and affinity tags.
- Prokaryotic expression systems: inducible pET/T7 and pBAD systems; promoter strength, induction, basal expression and host-vector compatibility.
- Eukaryotic expression systems: yeast, fungi, insect cells and mammalian cells; CMV/pcDNA and baculovirus-based systems.
- Selection of expression hosts according to protein complexity, localization, folding and post-translational modification requirements.
- Fusion proteins, affinity tags, codon optimization, rare codons, inclusion bodies, protein solubility and strategies to improve recombinant protein yield.
- Post-translational modification and protein targeting in heterologous systems; limitations of bacterial expression of eukaryotic proteins.

- Characterization of recombinant products: SDS-PAGE, activity assays, ELISA, immunoblotting, affinity purification and principles of mass-spectrometric protein identification.
- Emerging platforms: cell-free protein synthesis, synthetic-biology chassis and CRISPR-mediated transcriptional activation.

Unit IV: DNA/RNA Analysis, Amplification, Sequencing and Mutagenesis (15 h)

- Hybridization-based analysis: Southern, Northern and Western blotting; Dot/Slot blot; probe design, labeling, hybridization stringency and signal detection.
- DNA sequencing: Sanger sequencing; overview of NGS and sequencing-by-synthesis; third-generation sequencing including SMRT and nanopore methods; comparative advantages and limitations.
- PCR: principle, components, primer design, fidelity, specificity, optimization and troubleshooting.
- PCR variants: multiplex, nested, touchdown, hot-start, degenerate PCR, RT-PCR, qPCR and RACE; interpretation of amplification and controls.
- Isothermal amplification: LAMP and RPA; principles, applications and comparison with PCR.
- Digital PCR: partitioning, absolute quantification and applications.
- Site-directed mutagenesis: oligonucleotide-directed and PCR-based approaches; insertion/deletion strategies and mutant screening.
- CRISPR-Cas genome editing: guide RNA, Cas9/Cas12, knockout, knock-in and targeted replacement; base editing and prime editing.

Unit V: Genome Analysis, Functional Genomics and Applications (15 h)

- Genome-analysis methods: chromosome walking, DNA fingerprinting and molecular markers; principles and applications of DNA profiling and STR analysis.
- Gene-expression/regulatory analysis: ribonuclease protection assay, DNA footprinting, EMSA/gel-shift, reporter assays and ChIP-based analysis.
- Functional genomics: antisense technology, ribozymes, RNA interference, CRISPR/Cas9 gene disruption and dCas9-based transcriptional repression/activation.
- Gene knockout and targeted modification in bacterial and eukaryotic systems; homologous recombination, selection and validation.
- Strategies for genome sequencing and gene-expression analysis; comparative and functional interpretation of sequence and expression data.
- Applications in medicine: recombinant vaccines, recombinant therapeutic proteins, monoclonal antibodies, antibody engineering, gene therapy and CRISPR-based therapeutics.
- Applications in agriculture: transgenic plants, molecular markers, genome-edited crops and resistance to biotic and abiotic stresses.
- Industrial and synthetic biotechnology: enzyme engineering, metabolic engineering, pathway optimization, recombinant biomanufacturing and synthetic biology.
- Forensics and diagnostics: DNA profiling, STR analysis, molecular diagnosis and strain identification; ethical, biosafety and regulatory considerations.

Suggested Reading

1. Brown, T.A. Gene cloning and DNA analysis: An introduction. Wiley-Blackwell, New Jersey.
2. Primrose, S.B. and Twyman, R. Principles of gene manipulation and genomics. Wiley- Blackwell, New Jersey.
3. Nicholl, D.S.T. An introduction to genetic engineering. Cambridge University Press, Cambridge.
4. Glick, B.R., Pasternak, J.J. and Patten, C.L. Molecular biotechnology: Principles and applications of recombinant DNA. ASM Press, Washington, D.C.
5. Hartwell, L. Genetics: From genes to genome. McGraw-Hill, New York.
6. Clark, D.P., & Pazdernik, N.J. (2021). *Molecular Biology: Understanding the Genetic Revolution* (4th ed.). Academic Press.
7. Old, R.W. and Primrose, S.B. Principles of gene manipulations. Blackwell Science, Oxford.
8. Winnacker, E.L. From genes to clones: Introduction to gene technology. Wiley-VCH, Germany.
9. Kingsman, S.M. and Kingsman, A.J. Genetic engineering: An introduction to gene analysis and exploitation in eukaryotes. Blackwell Science, Oxford.
10. Greene, J.J. and Rao, V.B. Recombinant DNA principles and methodologies. Marcel Dekker, New York.
11. Brown, T.A. Genomes. Wiley-Liss, Oxford.
12. Pevsner, J. Bioinformatics and functional genomics. Wiley-Blackwell, New Jersey.
13. Sambrook, J. and Russell, D.W. Molecular Cloning: A laboratory manual. Cold Spring Harbor Lab Press, New York.
14. Reece R.J. Analysis of genes and genomes. John Wiley and Sons, New York.
15. Recombinant DNA Safety Guidelines, Department of Biotechnology, Government of India.
16. Recent reviews from high-quality indexed journals.

Core Major Elective - II (Theory)
Introductory Immunology

Credits: 3 **45 h**

Unit I: Immune System and Immunity (15 h)

History of immunology; Innate and acquired immunity; Determinants of innate immunity; Hematopoiesis; Cells and organs of immune system: B lymphocyte, T lymphocyte, NK cells, Monocyte/Macrophages, Dendritic cells, Eosinophils, Basophils, Neutrophils, Mast cells, Organization and structure of lymphoid organs and their role in immunity; Humoral and cell-mediated immunity.

Unit II: Antigens and Antibodies (10 h)

Antigens: Structure and properties; Haptens; Adjuvants; Immunogenicity; Immunoglobulin: Structures, Heterogeneity, Types and subtypes, Properties (Physiochemical and biological), Antibody effector mechanism, Antibody receptors, Antibody diversity, Theories of antibody production, Effect of somatic mutations on the antibody diversity, Recombinant antibodies, Hybridoma technology.

Unit III: Complement system and Cytokines (10 h)

Complement System: Structure, properties and functions of different components, Complement activation pathways (Classical, alternate and lectin pathways), Biological consequences of complement activation, Complement assay; Structure and function of various cytokines; Cytokine receptors.

Unit IV: Immunopathology and Transplantations (10 h)

Immunopathology: Rh- blood groupings, Hypersensitivity reactions (Antibody mediated type I, anaphylaxis, type II- antibody dependent cell cytotoxicity, type III-immune complex mediated reactions and type IV-delayed hypersensitivity reactions); Transplantation: Graft vs. host reaction and rejection.

Core Major Elective - II (Practicals)
Introductory Immunology

Credits: 1 **30 h**

1. Separation and preservation of serum and plasma.
2. Determination of blood group and Rh factor.
3. Quantitative estimation of antigen by radial immunodiffusion.
4. Determination of concentration of antigen by sandwich ELISA/Dot-ELISA method.

Suggested Readings (Theory and Practical)

1. Punt, P., Stranford, S., Jones, P., Owen, J.A. Kuby Immunology. W.H. Freeman and Company, New York.
2. Male, D.K. Immunology: An illustrated outline. Elsevier Health Sciences, Philadelphia.
3. Spec, A., Escota, G., Davies, B, O'Halloran, J., (2025), Comprehensive Review of Infectious Diseases, 2nd Edition. Elsevier
4. Abbas, A.K., Lichtman, A.H.H. and Pillai, S. Cellular and molecular immunology. Saunders, Philadelphia.
5. Delves, P.J., Martin, S.J., Burton, D.R. and Roitt, I.M. Roitt's essential immunology. Wiley-Blackwell, New Jersey.
6. Tizard, I.R. Immunology: An introduction. Saunders, Philadelphia.
7. Playfair, J.H.L. Immunology at a glance. Blackwell Scientific Publications, Oxford.
8. Abbas, A.K. and Lichtman, A.H.H. Basic immunology: Functions and disorders of the immune system. Saunders, Philadelphia.
9. Chapel, H., Haeney, M., Misbah, S. and Snowden, N. Essentials of clinical immunology. Wiley, New Jersey.
10. Coico, R. and Sunshine, G. Immunology: A short course. Wiley- Blackwell, New Jersey.
11. Gerald B. Pier, Jeffrey B. Lyczak, Lee M. Wetzler, Immunology, Infection, and Immunity, ASM Press
12. Frank C. Hay, Olwyn M. R. Westwood, Practical Immunology, Wiley-Blackwell
13. Miller, L. E., Christine, D. S. (2021) Clinical Immunology and Serology: A Laboratory, F A Davis Co
14. Read review articles and research papers related to this syllabus published recently in reputed journals.

Major Practical - 2

(Practical based on Core Majors IV, V and VI)

Credits: 5 **150 h**

Practical based on Core major IV
Laboratory Methods in Microbiology - (Practical)

1. Separation and identification of amino acids by ascending and descending paper chromatography.
2. Separation and identification of sugars by paper chromatography.
3. Separation and identification of sugars by thin-layer chromatography.
4. Verification of Lambert-Beer's law.
5. Determination of molecular weight of DNA by agarose gel electrophoresis.

Suggested Readings

1. Wilson, K. and Walker, J. Principles and techniques of biochemistry and molecular biology. Cambridge University Press, Cambridge.
2. Robyt, J.F. and White, B.J. Biochemical techniques: Theory and practice. Waveland Press, Long Grove.
3. Chatwal, G. and Anand, S. Instrumental methods of chemical analysis. Himalaya Publishing House, Mumbai.
4. Hamilton, R.J. and Sewell, P.A. Introduction to high performance liquid chromatography. Chapman and Hall Limited, London.
5. Sharma, V.K. Techniques in microscopy and cell biology. Tata McGraw-Hill, New Delhi.
6. Hames, B.D. Gel electrophoresis of proteins: A practical approach. Oxford University Press, Oxford.
7. Wilson, Keith, Andreas Hofmann, John M. Walker, and Samuel Clokie, eds. *Wilson and Walker's principles and techniques of biochemistry and molecular biology*. Cambridge university press, 2018.Keeler, J. Understanding NMR spectroscopy. John Wiley and Sons, New York.

Practical based on Core major V

<u>Functional Microbial Physiology – (Practicals)</u>

1. Gas production in fermentation (Durham tube method).
2. Detection of nitrate reduction.

Suggested Readings

- Aneja K. R. (2005). Experiments In Microbiology, Plant Pathology And Biotechnology. New age international publishers, New Delhi.

Practical based on Core major VI

Genetic Engineering – (Practicals)

Wet Lab Experiments

1. Isolation of genomic and plasmid DNA from bacteria.
2. Restriction digestion and analysis by agarose gel electrophoresis.
3. Ligation of DNA fragments and preparation of recombinant plasmid.
4. Transformation of competent *E. coli* cells and selection of transformants.
5. PCR amplification of target gene and analysis.
6. Expression of recombinant protein in *E. coli* and SDS-PAGE analysis.
7. Western blotting for detection of recombinant protein.

Bioinformatics-Based Practicals

1. Retrieval of gene sequences from NCBI and sequence analysis.
2. Designing primers for PCR and mutagenesis using online tools.
3. Predicting expression and solubility of recombinant proteins using bioinformatics tools.
4. Phylogenetic analysis of gene sequences.

Suggested Readings

1. Sawhney, S.K. and Singh, R. Introductory practical biochemistry. Narosa Publishing House, New Delhi.
2. Boyer, R.F. Modern experimental biochemistry. Prentice Hall, New Jersey.
3. Wilson, K. and Walker, J.M. Principles and techniques of practical biochemistry. Cambridge University Press, Cambridge.
4. Sambrook, J. and Russell, D.W. Molecular cloning: A laboratory manual. Cold Spring Harbor Lab Press, New York.
5. Rhodes, P.M. and Stanbury, P.F. Applied microbial physiology: A practical approach. IRL Press, Oxford.
6. Microbiology: a laboratory manual by Cappuccino, James G
7. Practical Microbiology by RC Dubey, Maheshwari DK
8. Sambrook, J. and Russell, D.W. Molecular cloning: A laboratory manual. Cold Spring Harbor Lab Press, New York.
9. Miller, J.H. Experiments in molecular genetics. Cold Spring Harbor Lab Press, New York.
10. Wilson, K. and Walker, J.M. Principles and techniques of practical biochemistry. Cambridge University Press, Cambridge.
11. Chaitanya, K.V. Cell and molecular biology: A lab manual. PHI Learning, New Delhi.
12. Celis, J.E. Cell biology: A laboratory handbook. Elsevier, Amsterdam.

Minor-II-Fundamentals of Epidemiology (Theory)

Hours: 30 **Credits: 2**

Unit I – Introduction to Epidemiology (15 h)

- Definition, scope, and history of epidemiology.
- Basic concepts: incidence, prevalence, morbidity, mortality, case fatality rate.
- Types of epidemiological studies: descriptive, analytical, and experimental.
- Epidemiological triad (agent–host–environment).
- Emerging and re-emerging infectious diseases – global perspective.

Unit II – Disease Transmission & Dynamics (15 h)

- Modes of transmission: direct, indirect, airborne, vector-borne, zoonotic.
- Chain of infection and breaking the chain.
- Reservoirs of infection in humans, animals, and the environment.
- Dynamics of disease occurrence: endemic, epidemic, pandemic, sporadic.
- Mathematical models in epidemiology (basic reproduction number R_0, herd immunity concept).

Suggested Readings

1. Nelson, K.E., & Williams, C.M. (2014). *Infectious Disease Epidemiology: Theory and Practice*. Jones & Bartlett Learning.
2. Ryan, K., & Ahmad, N. (2018). *Sherris Medical Microbiology*. McGraw-Hill.
3. Park, K. (2021). *Preventive and Social Medicine*. Banarsidas Bhanot Publishers.
4. Jawetz, E., Melnick, J.L., & Adelberg, E.A. (2022). *Medical Microbiology*. McGraw-Hill.

Minor-II-Fundamentals of Epidemiology - (Practicals)

Credits: 2 **60 h**

1. ***Epidemiological Data Analysis***
   - Calculation of incidence, prevalence, morbidity, and mortality rates using sample datasets.
   - Epidemic curve plotting and interpretation.
2. ***Food Microbiology for Public Health***
   - Isolation of foodborne pathogens (e.g., *E. coli*, *Salmonella*) from food samples.
   - Detection of contamination by standard microbiological methods.
3. ***Bioinformatics in Epidemiology***
   - Using online databases for disease tracking (e.g., WHO, CDC).
   - Data visualization using spreadsheet tools.

Suggested Readings

1. Alan J. Silman, Gary J. Macfarlane (2002). *Epidemiological Studies: A Practical Guide: A Practical Guide* . Cambridge University Press.