

**RADHA GOVIND UNIVERSITY
RAMGARH, JHARKHAND
DEPARTMENT OF MICROBIOLOGY**



**COURSE CURRICULUM FOR UNDERGRADUATE COURSES UNDER CHOICE BASED
CREDIT SYSTEM**

B.Sc. (Honours in Microbiology)

With effect from 2019-2022

**RADHA GOVIND UNIVERSITY
RAMGARH**

RADHA GOVIND UNIVERSITY, RAMGARH, JHARKHAND
DEPARTMENT OF MICROBIOLOGY

Vision & Mission

Vision

To contribute to nation building by transforming people through quality education, creating knowledge, to make invisible world more visible and inculcate scientific temper and provide platform research.

Mission

To create an ideal department keeping students at the centre of its aspirations and endeavours while manifesting wholehearted commitment.

To encourage research by providing state of the art facility and with committed standards.

To cultivate healthy and hygienic environment, to be good citizen of future India and no to extinction of Mankind.

Competence, discipline, dedication and contribution to society.

RADHA GOVIND UNIVERSITY, RAMGARH, JHARKHAND
DEPARTMENT OF MICROBIOLOGY

PROGRAM EDUCATION OBJECTIVE (PEO)

PEO 1: Have a successful career in Microbiology and related disciplines.

PEO 2: Excel in research career in microbiology and inter-disciplinary fields and actively contribute to science and society.

PEO 3: Possess technical and professional competency to address growing demands of society and industrial needs ethically.

PEO 4: Demonstrate life-long independent and reflective skills in their career.

PEO 5: Apply research and entrepreneurial skills augmented with a rich set of communication, teamwork and leadership skills to excel in their profession.

PEO 6: Enhance analytical and quantitative skills and demonstrate an understanding of basic computational and statistical techniques in the field of microbiology.

PROGRAMME SPECIFIC OUTCOME (PSO)

- ✚ The students of B.Sc. Microbiology should be able to:
- ✚ **PSO1:** To emphasize the distribution, morphology and physiology of microorganisms and demonstrate the skills in aseptic handling of microbes including isolation, identification and maintenance.
- ✚ **PSO2:** Demonstrate the ability to identify significant microbiological research questions, develop research protocols, and analyse research outcomes as per the scientific methods to improve the employment skills.
- ✚ **PSO3:** Enhance analytical and quantitative skills and demonstrate an understanding of basic computational and statistical techniques in the field of microbiology.

RADHA GOVIND UNIVERSITY, RAMGARH, JHARKHAND
DEPARTMENT OF MICROBIOLOGY

PROGRAMME OUTCOME (PO)

- ✚ **PO 1: Basic and applied knowledge:** Gathers in-depth knowledge of basic and applied areas of microbiology.
- ✚ **PO 2: Core microbiology laboratory skills:** Understands various methods of safe handling, culturing and storage of microorganisms in the laboratory.
- ✚ **PO 3: Critical Thinking:** Develops scientific logic and approaches a problem with critical reasoning.
- ✚ **PO 4: Effective Communication:** Develops effective communication skills through oral presentations of ongoing developments in the field and the compiling of information in the form of reports.
- ✚ **PO 5: Social Interaction:** Elicit views of others, mediate disagreements and help reach conclusions in group settings.
- ✚ **PO 6: Advanced Usage of Technology:** Apply advanced instrumentation tools, online resources with an understanding of the troubleshooting and limitations
- ✚ **PO 7: Modern Microbiology usage:** Develop new technologies, protocols, resources, using modern microbiological techniques and therapeutics and apply it to solve complex human health problems and conserve biodiversity.
- ✚ **PO 8: Global perspective:** Becomes acquainted with standard international practices and emerging technologies used to study microbes.
- ✚ **PO 9: Ethics:** Acquires an awareness of work ethics and ethical issues in scientific research as well as plagiarism policies.
- ✚ **PO 10: Research related skills:** Will develop ability to identify problems, give justifications for solutions by lab investigations & critical analysis by using appropriate research related biological skills.
- ✚ **PO 11: Environment and Sustainability:** Develops a basic understanding of the microbiological principles that have environmental implications, and gains an awareness of regulatory requirements and their compliance in biotechnology and microbiological research.
- ✚ **PO 12: Self-directed and Life-long Learning:** Develops self-discipline, planning and organization skills, and time management skills.

COURSE STRUCTURE

Details of Courses under B.Sc. (Honours)

Course	Credits
I. Core Course	
Core Course Theory (14 Papers)	$14 \times 04 = 56$
Core Course Practical (07 Papers)	$07 \times 04 = 28$
II. Elective Course (8 Papers)	
A.1. Discipline Specific Elective (04 Papers)	$04 \times 04 = 16$
A.2. Discipline Specific Elective Practical/ Tutorial (04 Papers)	$04 \times 02 = 08$
B.1. Generic Elective/ Interdisciplinary (4 Papers)	$04 \times 04 = 16$
B.2. Generic Elective Practical/ Tutorial (04 Papers)	$04 \times 02 = 08$
III. Ability Enhancement Courses	
1. Ability Enhancement Compulsory (2 Papers) English Communication Environmental Science	$02 \times 02 = 04$
2. Ability Enhancement Elective (Skill Based) (2 Papers) Constitution and Human Rights Life and Science	$02 \times 02 = 04$
<hr/> Total Credits	140

**PROPOSED SCHEME FOR CHOICE BASED CREDIT SYSTEM IN B.Sc. HONOURS
(MICROBIOLOGY)**

SEMESTER	CORE COURSE (14)	AECC (2)	SEC (2)	DSE (4)	GENERIC (4)
I	CC-1 CC-2 CC Practical	English Communication	-	-	GE-1
II	CC-3 CC-4 CC Practical	Environmental Science	-	-	GE-2
III	CC-5 CC-6 CC-7 CC Practical	-	SEC-1	-	GE-3
IV	CC-8 CC-9 CC-10 CC Practical	-	SEC-2	-	GE-4
V	CC-11 CC-12 CC Practical	-	-	DSE-1 DSE-2	-
VI	CC-13 CC-14 CC Practical	-	-	DSE-3 DSE-4	-

SEMESTER	COURSE OPTED	COURSE NAME	CREDITS
I	Ability Enhancement Compulsory Course-I	English Communication	2
	Core Course- I	Introduction to Microbiology and Microbial Diversity	4
	Core Course- II	Bacteriology	4
	Core Course Practical- I	-	4
	Generic Elective- 1	Introduction and Scope of Microbiology	2
	Generic Elective Practical-1	-	2
II	Ability Enhancement Compulsory Course-II	Environmental Science	2
	Core Course- III	Biochemistry	4
	Core Course- IV	Virology	4
	Core Course Practical- II	-	4
	Generic Elective- 2	Bacteriology	2
	Generic Elective Practical-2	-	2
III	Core Course- V	Microbial Physiology and Metabolism	4
	Core Course- VI	Cell Biology	4
	Core Course- VII	Molecular Biology	4
	Core Course Practical- III	-	6
	Skill Enhancement Course- 1	Constitution of India and Human Rights	2
	Generic Elective- 3	Microbial Metabolism	4
	Generic Elective Practical-3	-	2

IV	Core Course-VIII	Microbial Genetics	4
	Core Course- IX	Environmental Microbiology	4
	Core Course- X	Food and Dairy Microbiology	4
	Core Course Practical- IV	-	6
	Skill Enhancement Course- 2	Science and Life	4
	Generic Elective- 4	Microbes in Environment	4
	Generic Elective Practical-4	-	2
V	Core Course-XI	Industrial Microbiology	4
	Core Course- XII	Immunology	4
	Core Course Practical- V	-	4
	Discipline Specific Elective – 1	Bioinformatics	4
	Discipline Specific Elective – 2	Microbial Biotechnology	4
	Discipline Specific Elective Practical- 1	-	4
VI	Core Course-XIII	Medical Microbiology	4
	Core Course- XIV	Recombinant DNA Technology	4
	Core Course Practical- VI	-	4
	Discipline Specific Elective – 3	Plant Pathology	4
	Discipline Specific Elective – 4	Instrumentation and Biotechniques	4
	Discipline Specific Elective Practical- 2	-	4
TOTAL CREDITS			140

Structure of B. Sc. Honours Microbiology under CBCS

Core Course

- CC-1: Introduction to Microbiology and Microbial Diversity
- CC-2: Bacteriology
- CC-3: Biochemistry
- CC-4: Virology
- CC-5: Microbial Physiology and Metabolism
- CC-6: Cell Biology
- CC-7: Molecular Biology
- CC-8: Microbial Genetics
- CC-9: Environmental Microbiology
- CC-10: Food and Dairy Microbiology
- CC-11: Industrial Microbiology
- CC-12: Immunology
- CC-13: Medical Microbiology
- CC-14: Recombinant DNA Technology

Discipline Specific Elective

- DSE-1: Bioinformatics
- DSE-2: Microbial Biotechnology
- DSE-3: Plant Pathology
- DSE-4: Instrumentation and Biotechniques

Generic Electives

- GE-1: Introduction and Scope of Microbiology
- GE-2: Bacteriology and Virology
- GE-3: Microbial Metabolism
- GE-4: Microbes in Environment

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)
CC-1: INTRODUCTION TO MICROBIOLOGY AND MICROBIAL
DIVERSITY(THEORY)
SEMESTER –I

TOTAL HOURS: 60

CREDITS: 4

Unit 1 History of Development of Microbiology

No. of Hours: 15

Development of microbiology as a discipline, Spontaneous generation vs. biogenesis. Contributions of Anton von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming

Role of microorganisms in fermentation, Germ theory of disease, Development of various microbiological techniques and golden era of microbiology, Development of the field of soil microbiology: Contributions of Martinus W. Beijerinck, Sergei N. Winogradsky, Selman A. Waksman Establishment of fields of medical microbiology and immunology through the work of Paul Ehrlich, Elie Metchnikoff, Edward Jenner

Unit 2 Diversity of Microbial World

No. of Hours: 40

A. Systems of classification

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

B. General characteristics of different groups: **Acellular** microorganisms (Viruses, Viroids, Prions) and **Cellular** microorganisms (Bacteria, Algae, Fungi and Protozoa) with emphasis on distribution and occurrence, morphology, mode of reproduction and economic importance.

• **Algae**

History of phycology with emphasis on contributions of Indian scientists; General characteristics of algae including occurrence, thallus organization, algae cell ultra-structure, pigments, flagella, eyespot food reserves and vegetative, asexual and sexual reproduction. Different types of life cycles in algae with suitable examples: Haplobiontic, Haplontic, Diplontic, Diplobiontic and Diplohaplontic life cycles. Applications of algae in agriculture, industry, environment and food.

• **Fungi**

Historical developments in the field of Mycology including significant contributions of eminent mycologists. General characteristics of fungi including habitat, distribution, nutritional requirements, fungal cell ultra-structure, thallus organization and aggregation, fungal wall structure and synthesis, asexual reproduction, sexual reproduction, heterokaryosis, heterothallism

and parasexual mechanism. Economic importance of fungi with examples in agriculture, environment, Industry, medicine, food, biodeterioration and mycotoxins.

- **Protozoa**

General characteristics with special reference to *Amoeba*, *Paramecium*, *Plasmodium*, *Leishmania* and *Giardia*

Unit 3 An overview of Scope of Microbiology

No. of Hours: 5

**CC-1: INTRODUCTION TO MICROBIOLOGY AND MICROBIAL DIVERSITY
(PRACTICALS)
SEMESTER –I**

TOTAL HOURS: 60

CREDITS: 2

1. Microbiology Good Laboratory Practices and Biosafety.
2. To study the principle and applications of important instruments (biological safety cabinets, autoclave, incubator, BOD incubator, hot air oven, light microscope, pH meter) used in the microbiology laboratory.
3. Preparation of culture media for bacterial cultivation.
4. Sterilization of medium using Autoclave and assessment for sterility
5. Sterilization of glassware using Hot Air Oven and assessment for sterility
6. Sterilization of heat sensitive material by membrane filtration and assessment for sterility
7. Demonstration of the presence of microflora in the environment by exposing nutrient agar plates to air.
8. Study of *Rhizopus*, *Penicillium*, *Aspergillus* using temporary mounts
9. Study of *Spirogyra* and *Chlamydomonas*, *Volvox* using temporary Mounts
10. Study of the following protozoans using permanent mounts/photographs: *Amoeba*, *Entamoeba*, *Paramecium* and *Plasmodium*.

SUGGESTED READING

1. Tortora GJ, Funke BR and Case CL. (2008). Microbiology: An Introduction. 9th edition. Pearson Education
2. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms. 14th edition. Pearson International Edition
3. Cappucino J and Sherman N. (2010). Microbiology: A Laboratory Manual. 9th edition. Pearson Education Limited
4. Wiley JM, Sherwood LM and Woolverton CJ. (2013) Prescott's Microbiology. 9th Edition. McGrawHill International.
5. Atlas RM. (1997). Principles of Microbiology. 2nd edition. W.M.T. Brown Publishers.
6. Pelczar MJ, Chan ECS and Krieg NR. (1993). Microbiology. 5th edition. McGrawHill Book Company.
7. Stanier RY, Ingraham JL, Wheelis ML, and Painter PR. (2005). General Microbiology. 5th edition. McMillan.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-2: BACTERIOLOGY (THEORY)

SEMESTER –I

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Cell organization

No. of Hours: 14

Cell size, shape and arrangement, glycocalyx, capsule, flagella, endoflagella, fimbriae and pili.

Cell-wall: Composition and detailed structure of Gram-positive and Gram-negative cell walls, Archaeobacterial cell wall, Gram and acid fast staining mechanisms, lipopolysaccharide (LPS), sphaeroplasts, protoplasts, and L-forms. Effect of antibiotics and enzymes on the cell wall.

Cell Membrane: Structure, function and chemical composition of bacterial and archaeal cell membranes.

Cytoplasm: Ribosomes, mesosomes, inclusion bodies, nucleoid, chromosome and plasmids

Endospore: Structure, formation, stages of sporulation.

Unit 2 Bacteriological techniques

No. of Hours: 5 Pure

culture isolation: Streaking, serial dilution and plating methods; cultivation, maintenance and preservation/stocking of pure cultures; cultivation of anaerobic bacteria, and accessing non-culturable bacteria.

Unit 3 Microscopy

No. of Hours: 6

Bright Field Microscope, Dark Field Microscope, Phase Contrast Microscope, Fluorescence Microscope, Confocal microscopy, Scanning and Transmission Electron Microscope

Unit 4 Growth and nutrition

No. of Hours: 8

Nutritional requirements in bacteria and nutritional categories;

Culture media: components of media, natural and synthetic media, chemically defined media, complex media, selective, differential, indicator, enriched and enrichment media

Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation

Chemical methods of microbial control: disinfectants, types and mode of action

Unit 5 Reproduction in Bacteria

No. of Hours: 3 Asexual

methods of reproduction, logarithmic representation of bacterial populations, phases of growth, calculation of generation time and specific growth rate

Unit 6 Bacterial Systematics

No. of Hours: 8

Aim and principles of classification, systematics and taxonomy, concept of species, taxa, strain; conventional, molecular and recent approaches to polyphasic bacterial taxonomy, evolutionary

chronometers, rRNA oligonucleotide sequencing, signature sequences, and protein sequences.

Differences between eubacteria and archaeobacteria

Unit 7 Important archaeal and eubacterial groups

No. of Hours: 16

Archaeobacteria: General characteristics, phylogenetic overview, genera belonging to Nanoarchaeota (*Nanoarchaeum*), Crenarchaeota (*Sulfolobus*, *Thermoproteus*) and Euryarchaeota [Methanogens (*Methanobacterium*, *Methanocaldococcus*), thermophiles (*Thermococcus*, *Pyrococcus*, *Thermoplasma*), and Halophiles (*Halobacterium*, *Halococcus*)]

Eubacteria: Morphology, metabolism, ecological significance and economic importance of following groups:

Gram Negative:

Non proteobacteria: General characteristics with suitable examples Alpha proteobacteria:

General characteristics with suitable examples Beta proteobacteria: General characteristics with

suitable examples Gamma proteobacteria: General characteristics with suitable example.

Delta proteobacteria: General characteristics with suitable examples Epsilon proteobacteria:

General characteristics with suitable examples Zeta proteobacteria: General characteristics with

suitable examples

Gram Positive:

Low G+ C (Firmicutes): General characteristics with suitable examples High G+C

(Actinobacteria): General characteristics with suitable examples

Cyanobacteria: An Introduction

CC-2: BACTERIOLOGY (PRACTICAL)

SEMESTER –I

TOTAL HOURS: 60

CREDITS: 2

1. Preparation of different media: synthetic media BG-11, Complex media-Nutrientagar, McConkey agar, EMB agar.
2. Simple staining
3. Negative staining
4. Gram's staining
5. Acid fast staining-permanent slide only.
6. Capsule staining
7. Endospore staining.
8. Isolation of pure cultures of bacteria by streaking method.
9. Preservation of bacterial cultures by various techniques.
10. Estimation of CFU count by spread plate method/pour plate method.
11. Motility by hanging drop method.

SUGGESTED READINGS

1. Atlas RM. (1997). Principles of Microbiology. 2nd edition. WM.T.Brown Publishers.
2. Black JG. (2008). Microbiology: Principles and Explorations. 7th edition. Prentice Hall
3. Madigan MT, and Martinko JM. (2014). Brock Biology of Micro-organisms. 14th edition. Parker J. Prentice Hall International, Inc.
4. Pelczar Jr MJ, Chan ECS, and Krieg NR. (2004). Microbiology. 5th edition Tata McGraw Hill.
5. Srivastava S and Srivastava PS. (2003). Understanding Bacteria. Kluwer Academic Publishers, Dordrecht
6. Stanier RY, Ingraham JL, Wheelis ML and Painter PR. (2005). General Microbiology. 5th edition McMillan.
7. Tortora GJ, Funke BR, and Case CL. (2008). Microbiology: An Introduction. 9th edition Pearson Education.
8. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology. 9th edition. McGraw Hill Higher Education.
9. Cappuccino J and Sherman N. (2010). Microbiology: A Laboratory Manual. 9th edition. Pearson Education Limited.

GE-1: INTRODUCTION AND SCOPE OF MICROBIOLOGY (THEORY)

SEMESTER –I

TOTAL HOURS: 60

CREDITS: 4

Unit 1 History of Development of Microbiology

No. of Hours: 12

Development of microbiology as a discipline, Spontaneous generation vs. biogenesis. Contributions of Anton von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming

Role of microorganisms in fermentation, Germ theory of disease, Development of various microbiological techniques and golden era of microbiology, Development of the field of soil microbiology: Contributions of Martinus W. Beijerinck, Sergei N. Winogradsky, Selman A. Waksman Establishment of fields of medical microbiology and immunology through the work of Paul Ehrlich, Elie Metchnikoff, Edward Jenner

Unit 2 Diversity of Microorganisms

No. of Hours: 10

Systems of classification : Binomial nomenclature, Whittaker's five kingdom and Carl Woese's threekingdom classification systems and their utility

General characteristics of different groups: Acellular microorganisms (Viruses, Viroids, Prions) and Cellular microorganisms (Prokarya: Archaea and Bacteria, Eukarya : Algae, Fungi and Protozoa) giving definitions and citing examples

Protozoa : Methods of nutrition, locomotion & reproduction - Amoeba, *Paramecium* and *Plasmodium*

Unit 3 Microscopy

No. of Hours: 7

Bright Field Microscope, Dark Field Microscope, Phase Contrast Microscope, Fluorescence Microscope, Transmission Electron Microscope, Scanning Electron Microscope

Unit 4 Sterilization

No. of Hours: 5

Moist Heat, Autoclave, Dry Heat, Hot Air Oven, Tyndallization, Filtration.

Unit 5 Microbes in Human Health & Environment

No. of Hours: 10

Medical microbiology and immunology: List of important human diseases and their causative agents of various human systems. Definitions of immunity (active/passive), primary and secondary immune response, antigen, antibody and their types

Environmental microbiology: Definitions and examples of important microbial interactions – mutualism, commensalism, parasitism, Definitions and microorganisms used as biopesticides, biofertilizers, in biodegradation, biodeterioration and bioremediation (e.g. hydrocarbons in oil spills)

Unit 6 Industrial Microbiology

No. of Hours: 8

Definition of fermentation, primary and secondary metabolites, types of fermentations and fermenters and microbes producing important industrial products through fermentation.

Unit 7 Food and Dairy Microbiology

No. of Hours: 8

Microorganisms as food (SCP), microorganisms in food fermentations (dairy and non dairy based fermented food products) and probiotics. Microorganisms in food spoilage and food borne infections.

GE-1: INTRODUCTION AND SCOPE OF MICROBIOLOGY (PRACTICALS)

SEMESTER –I

TOTAL HOURS: 60

CREDITS: 2

1. Microbiology Laboratory Management and Biosafety.
2. To study the principle and applications of important instruments (biological safety cabinets, autoclave, incubator, BOD incubator, hot air oven, light microscope, pH meter) used in the microbiology laboratory
3. Preparation of culture media for bacterial cultivation
4. Sterilization of medium using Autoclave and assessment for sterility
5. Sterilization of glassware using Hot Air Oven and assessment for sterility
6. Sterilization of heat sensitive material by filtration and assessment for sterility
7. Demonstration of presence of microflora in the environment by exposing nutrient agar plate to air.
8. Study of different shapes of bacteria using permanent slides
9. Study of Rhizopus and Penicillium using permanent mounts
10. Study of Spirogyra and Chlamydomonas using permanent Mounts
11. Study of the following protozoans using permanent mounts/photographs: Amoeba, Entamoeba, Paramecium and Plasmodium

SUGGESTED READING

1. Tortora GJ, Funke BR and Case CL. (2008). Microbiology: An Introduction. 9th edition. Pearson Education
2. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms. 14th edition. Pearson International Edition
3. Cappucino J and Sherman N. (2010). Microbiology: A Laboratory Manual. 9th edition. Pearson Education Limited
4. Wiley JM, Sherwood LM and Woolverton CJ. (2013) Prescott's Microbiology. 9th Edition. McGrawHill International.
5. Atlas RM. (1997). Principles of Microbiology. 2nd edition. W.M.T. Brown Publishers.
6. Pelczar MJ, Chan ECS and Krieg NR. (1993). Microbiology. 5th edition. McGrawHill Book Company.
7. Stanier RY, Ingraham JL, Wheelis ML, and Painter PR. (2005). General Microbiology. 5th edition. McMillan.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-3: BIOCHEMISTRY (THEORY)

SEMESTER –II

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Bioenergetics

No. of Hours: 8

First and second laws of Thermodynamics. Definitions of Gibb's Free Energy, enthalpy, and Entropy and mathematical relationship among them, Standard free energy change and equilibrium constant Coupled reactions and additive nature of standard free energy change, Energy rich compounds: Phosphoenolpyruvate, 1,3- Bisphosphoglycerate, Thioesters, ATP

Unit 2 Carbohydrates

No. of Hours: 12

Families of monosaccharides: aldoses and ketoses, trioses, tetroses, pentoses, and hexoses. Stereo isomerism of monosaccharides, epimers, Mutarotation and anomers of glucose. Furanose and pyranose forms of glucose and fructose, Haworth projection formulae for glucose; chair and boat forms of glucose, Sugar derivatives, glucosamine, galactosamine, muramic acid, N- acetyl neuraminic acid, Disaccharides; concept of reducing and non-reducing sugars, occurrence and Haworth projections of maltose, lactose, and sucrose, Polysaccharides, storage polysaccharides, starch and glycogen. Structural Polysaccharides, cellulose, peptidoglycan and chitin

Unit 3 Lipids

No. of Hours: 12

Definition and major classes of storage and structural lipids. Storage lipids. Fatty acids structure and functions. Essential fatty acids. Triacyl glycerols structure, functions and properties. Saponification Structural lipids. Phosphoglycerides: Building blocks, General structure, functions and properties. Structure of phosphatidylethanolamine and phosphatidylcholine, Sphingolipids: building blocks, structure of sphingosine, ceramide. Special mention of sphingomyelins, cerebroside and gangliosides Lipid functions: cell signals, cofactors, prostaglandins, Introduction of lipid micelles, monolayers, bilayers

Unit 4 Proteins

No. of Hours: 12

Functions of proteins, Primary structures of proteins: Amino acids, the building blocks of proteins. General formula of amino acid and concept of zwitterion. Titration curve of amino acid and its Significance, Classification, biochemical structure and notation of standard protein amino acids Ninhydrin reaction. Natural modifications of amino acids in proteins hydrolysine, cystine and

hydroxyproline, Non protein amino acids: Gramicidin, beta-alanine, D-alanine and D- glutamic acid Oligopeptides: Structure and functions of naturally occurring glutathione and insulin and synthetic aspartame, Secondary structure of proteins: Peptide unit and its salient features. The alpha helix, the beta pleated sheet and their occurrence in proteins, Tertiary and quaternary structures of proteins.

Forces holding the polypeptide together. Human haemoglobin structure, Quaternary structures of proteins

Unit 5. Enzymes

No. of Hours: 12

Structure of enzyme: Apoenzyme and cofactors, prosthetic group-TPP, coenzyme NAD, metal cofactors, Classification of enzymes, Mechanism of action of enzymes: active site, transition state complex and activation energy. Lock and key hypothesis, and Induced Fit hypothesis. Significance of hyperbolic, double reciprocal plots of enzyme activity, K_m , and allosteric mechanism Definitions of terms – enzyme unit, specific activity and turnover number, Multienzyme complex : pyruvate dehydrogenase; isozyme: lactate dehydrogenase, Effect of pH and temperature on enzyme activity. Enzyme inhibition: competitive- sulfa drugs; non-competitive-heavy metal salts

Unit 6. Vitamins

No. of Hours: 4

Classification and characteristics with suitable examples, sources and importance

CC-3: BIOCHEMISTRY (PRACTICALS)

SEMESTER –II

TOTAL HOURS: 60

CREDITS: 2

1. Properties of water, Concept of pH and buffers, preparation of buffers and Numerical problems to explain the concepts
2. Numerical problems on calculations of Standard Free Energy Change and Equilibrium constant
3. Standard Free Energy Change of coupled reactions
4. Qualitative/Quantitative tests for carbohydrates, reducing sugars, non-reducing sugars
5. Qualitative/Quantitative tests for lipids and proteins
6. Study of protein secondary and tertiary structures with the help of models
7. Study of enzyme kinetics – calculation of V_{max} , K_m , K_{cat} values
8. Study effect of temperature, pH and Heavy metals on enzyme activity
9. Estimation of any one vitamin

SUGGESTED READING

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 (2008) Lehninger Principles of Biochemistry, 5th Edition., W.H. Freeman and Company,
6. Willey MJ, Sherwood, LM & Woolverton C J (2013) Prescott, Harley and Klein's Microbiology. 9th Ed., McGrawHill
7. Voet, D. and Voet J.G (2004) Biochemistry 3rd edition, John Wiley and Sons.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-4: VIROLOGY (THEORY)

SEMESTER –II

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Nature and Properties of Viruses

No. of Hours: 12

Introduction: Discovery of viruses, nature and definition of viruses, general properties, concept of viroids, virusoids, satellite viruses and Prions. Theories of viral origin

Structure of Viruses: Capsid symmetry, enveloped and non-enveloped viruses Isolation, purification and cultivation of viruses

Viral taxonomy: Classification and nomenclature of different groups of viruses

Unit 2 Bacteriophages

No. of Hours: 10

Diversity, classification, one step multiplication curve, lytic and lysogenic phages (lambda phage) concept of early and late proteins, regulation of transcription in lambda phage

Unit 3 Viral Transmission, Salient features of viral nucleic acids and Replication

No. of Hours: 20

Modes of viral transmission: Persistent, non-persistent, vertical and horizontal

Salient features of viral Nucleic acid : Unusual bases (TMV, T4 phage), overlapping genes (ϕ X174, Hepatitis B virus), alternate splicing (HIV), terminal redundancy (T4 phage), terminal cohesive ends (lambda phage), partial double stranded genomes (Hepatitis B), long terminal repeats (retrovirus), segmented (Influenza virus), and non-segmented genomes (picornavirus), capping and tailing (TMV) Viral multiplication and replication strategies: Interaction of viruses with cellular receptors and entry of viruses. Replication strategies of viruses as per Baltimore classification (phi X 174, Retroviridae, Vaccinia, Picorna) , Assembly, maturation and release of virions

Unit 4 Viruses and Cancer

No. of Hours: 6

Introduction to oncogenic viruses

Types of oncogenic DNA and RNA viruses: Concepts of oncogenes and proto-oncogenes

Unit 5 Prevention & control of viral diseases

No. of Hours: 8

Antiviral compounds and their mode of action Interferon and their mode of action

General principles of viral vaccination

Unit 6 Applications of Virology

No. of Hours: 4

Use of viral vectors in cloning and expression, Gene therapy and Phage display.

CC-4: VIROLOGY (PRACTICAL)

SEMESTER –II

TOTAL HOURS: 60

CREDITS: 2

1. Study of the structure of important animal viruses (rhabdo, influenza, paramyxo hepatitis B and retroviruses) using electron micrographs
2. Study of the structure of important plant viruses (caulimo, Gemini, tobacco ring spot, cucumber mosaic and alpha-alpha mosaic viruses) using electron micrographs
3. Study of the structure of important bacterial viruses (ϕ X 174, T4, λ) using electron micrograph.
4. Isolation and enumeration of bacteriophages (PFU) from water/sewage sample using double agarlayer technique
5. Studying isolation and propagation of animal viruses by chick embryo technique
6. Study of cytopathic effects of viruses using photographs
7. Perform local lesion technique for assaying plant viruses.

SUGGESTED READING

1. Dimmock, NJ, Easton, AL, Leppard, KN (2007). Introduction to Modern Virology. 6th edition, Blackwell Publishing Ltd.
2. Carter J and Saunders V (2007). Virology: Principles and Applications. John Wiley and Sons.
3. Flint SJ, Enquist, LW, Krug, RM, Racaniello, VR, Skalka, AM (2004). Principles of Virology, Molecular biology, Pathogenesis and Control. 2nd edition. ASM press Washington DC.
4. Levy JA, Conrat HF, Owens RA. (2000). Virology. 3rd edition. Prentice Hall publication, New Jersey.
5. Wagner EK, Hewlett MJ. (2004). Basic Virology. 2nd edition. Blackwell Publishing.
6. Mathews. (2004). Plant Virology. Hull R. Academic Press, New York.
7. Nayudu MV. (2008). Plant Viruses. Tata McGraw Hill, India.
8. Bos L. (1999) Plant viruses-A text book of plant virology by. Backhuys Publishers.
9. Versteeg J. (1985). A Color Atlas of Virology. Wolfe Medical Publication.

GE-2: BACTERIOLOGY AND VIROLOGY (THEORY)

SEMESTER – II

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Cell organization

No. of Hours: 10

Cell size, shape and arrangements, capsule, flagella and pili, Composition and detailed structure of gram- positive and gram- negative cell wall and archaeal cell wall, Structure, chemical composition and functions of bacterial and archaeal cell membranes, Ribosomes, inclusions, nucleoid, plasmids, structure, formation and stages of sporulation

Unit 2 Bacterial growth and control

No. of Hours: 8

Culture media: Components of media, Synthetic or defined media, Complex media, enriched media, selective media, differential media, enrichment culture media

Pure culture isolation: Streaking, serial dilution and plating methods, cultivation, maintenance and stocking of pure cultures, cultivation of anaerobic bacteria

Growth: Binary fission, phases of growth

Unit 3 Bacterial Systematics and Taxonomy

No. of Hours: 12

Taxonomy, nomenclature, systematics, types of classifications

Morphology, ecological significance and economic importance of the following groups: Archaea: methanogens, thermophiles and halophiles

Eubacteria: Gram negative and Gram positive

Gram negative: Non-proteobacteria– *Deinococcus*, *Chlamydiae*, Spirochetes Alpha proteobacteria- *Rickettsia*, *Rhizobium*, *Agrobacterium* Gamma proteobacteria –*Escherichia*,*Shigella*,*Pseudomonas*

Gram positive: Low G+C: *Mycoplasma*, *Bacillus*, *Clostridium*, *Staphylococcus* High G+C:

Streptomyces, *Frankia*

Unit 4 Introduction to Viruses

No. of Hours: 8

Properties of viruses; general nature and important features Subviral particles; viroids, prions and their importance Isolation and cultivation of viruses

Unit 5 Structure, and multiplication of viruses

No. of Hours: 12

Morphological characters: Capsid symmetry and different shapes of viruses with examples Viral multiplication in the Cell: Lytic and lysogenic cycle

Description of important viruses: salient features of the viruses infecting different hosts - Bacteriophages (T4 & Lambda); Plant (TMV & Cauliflower Mosaic Virus), Human (HIV & Hepatitis viruses)

Unit 6 Role of Viruses in Disease and its prevention

No. of Hours: 10

Viruses as pathogens: Role of viruses in causing diseases

Prevention and control of viruses: Viral vaccines, interferons and antiviral compounds

GE-2: BACTERIOLOGY AND VIROLOGY (PRACTICAL)
SEMESTER – I

TOTAL HOURS: 60

CREDITS: 2

1. Preparation of different media: Nutrient agar, Nutrient broth
2. To perform simple staining and Gram's staining of the bacterial smear
3. To perform spore staining
4. Isolation of pure cultures of bacteria by streaking method
5. Enumeration of colony forming units (CFU) count by spread plate method/pour plate
6. Study the morphological structures of viruses (DNA and RNA) and their important characters using electron micrographs
7. Study of the methods of isolation and propagation of plant viruses
8. Study of cytopathic effects of viruses using photographs

SUGGESTED READING

1. Atlas RM. (1997). Principles of Microbiology. 2nd edition. W.M.T. Brown Publishers
2. Madigan MT, Martinko JM, Dunlap PV and Clark DP (2014). Brock Biology of Microorganisms. 14th edition. Pearson Education, Inc.
3. Stanier RY, Ingraham JL, Wheelis ML and Painter PR. (2005). General Microbiology. 5th edition. McMillan
4. Carter J and Saunders V (2007). Virology; principles and Applications. John Wiley and Sons
5. Flint SJ, Enquist, LW, Krug, RM, Racaniello, VR Skalka, AM (2004) Principles of Virology, Molecular Biology, Pathogenesis and Control. 2nd edition. ASM Press
6. Shors Teri (2013) Understanding Viruses 2nd edition Jones and Bartlett Learning Burlington USA
7. Pelczar Jr MJ, Chan ECS, and Krieg NR. (2004). Microbiology. 5th edition Tata McGraw Hill.
8. Tortora GJ, Funke BR, and Case CL. (2008). Microbiology: An Introduction. 9th edition Pearson Education.
9. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology. 9th edition. McGraw Hill Higher Education.
10. Dimmock, NJ, Easton, AL, Leppard, KN (2007). Introduction to Modern Virology. 6th edition, Blackwell Publishing Ltd.
11. Cann AJ (2012) Principles of Molecular Virology, Academic Press Oxford UK.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)
CC-5: MICROBIAL PHYSIOLOGY AND METABOLISM (THEORY)
SEMESTER –III

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Microbial Growth and Effect of Environment on Microbial Growth

No. of Hours: 12

Definitions of growth, measurement of microbial growth, Batch culture, Continuous culture, generation time and specific growth rate, synchronous growth, diauxic growth curve

Microbial growth in response to environment -Temperature (psychrophiles, mesophiles, thermophiles, extremophiles, thermodurics, psychrotrophs), pH (acidophiles, alkaliphiles), solute and water activity (halophiles, xerophiles, osmophilic), Oxygen (aerobic, anaerobic, microaerophilic, facultative aerobe, facultative anaerobe), barophilic.

Microbial growth in response to nutrition and energy – Autotroph/Phototroph, heterotrophy, Chemolithoautotroph, Chemolithoheterotroph, Chemoheterotroph, Chemolithotroph, photolithoautotroph, Photoorganoheterotroph.

Unit 2 Nutrient uptake and Transport

No. of Hours: 10

Passive and facilitated diffusion

Primary and secondary active transport, concept of uniport, symport and antiport Group translocation

Iron uptake

Unit 3 Chemoheterotrophic Metabolism - Aerobic Respiration **No. of Hours: 16**

Concept of aerobic respiration, anaerobic respiration and fermentation Sugar degradation pathways i.e. EMP, ED, Pentose phosphate pathway TCA cycle

Electron transport chain: components of respiratory chain, comparison of mitochondrial and bacterial ETC, electron transport phosphorylation, uncouplers and inhibitors

Unit 4 Chemoheterotrophic Metabolism- Anaerobic respiration and fermentation

No. of Hours: 6

Anaerobic respiration with special reference to dissimilatory nitrate reduction (Denitrification; nitrate

/nitrite and nitrate/ammonia respiration; fermentative nitrate reduction)

Fermentation - Alcohol fermentation and Pasteur effect ; Lactate fermentation (homofermentative and heterofermentative pathways), concept of linear and branched fermentation pathways

Unit 5 Chemolithotrophic and Phototrophic Metabolism

No. of Hours: 10

Introduction to aerobic and anaerobic chemolithotrophy with an example each. Hydrogen oxidation (definition and reaction) and methanogenesis (definition and reaction)

Introduction to phototrophic metabolism - groups of phototrophic microorganisms, anoxygenic vs. oxygenic photosynthesis with reference to photosynthesis in green bacteria, purple bacteria and cyanobacteria

Unit 6 Nitrogen Metabolism - an overview

No. of Hours: 6

Introduction to biological nitrogen fixation Ammonia assimilation

Assimilatory nitrate reduction, dissimilatory nitrate reduction, denitrification

CC-5: MICROBIAL PHYSIOLOGY AND METABOLISM (PRACTICAL)

SEMESTER –III

TOTAL HOURS: 60

CREDITS: 2

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

SUGGESTED READINGS

1. Madigan MT, and Martinko JM (2014). Brock Biology of Microorganisms. 14th edition. PrenticeHall International Inc.
2. Moat AG and Foster JW. (2002). Microbial Physiology. 4th edition. John Wiley & Sons
3. Reddy SR and Reddy SM. (2005). Microbial Physiology. Scientific Publishers India
4. Gottschalk G. (1986). Bacterial Metabolism. 2nd edition. Springer Verlag
5. Stanier RY, Ingrahm JI, Wheelis ML and Painter PR. (1987). General Microbiology. 5th edition,McMillan Press.
6. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology. 9th edition. McGraw Hill Higher Education.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-6: CELL BIOLOGY (THEORY)

SEMESTER –III

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Structure and organization of Cell

No. of Hours: 12

Cell Organization – Eukaryotic (Plant and animal cells) and prokaryotic Plasma membrane:

Structure and transport of small molecules

Cell Wall: Eukaryotic cell wall, Extra cellular matrix and cell matrix interactions, Cell-Cell Interactions - adhesion junctions, tight junctions, gap junctions, and plasmodesmata (only structural aspects)

Mitochondria, chloroplasts and peroxisomes

Cytoskeleton: Structure and organization of actin filaments, association of actin filaments with plasmamembrane, cell surface protrusions, intermediate filaments, microtubules

Unit 2 Nucleus

No. of Hours: 4

Nuclear envelope, nuclear pore complex and nuclear lamina Chromatin – Molecular organization

Nucleolus

Unit 3 Protein Sorting and Transport

No. of Hours: 12

Ribosomes, Endoplasmic Reticulum – Structure, targeting and insertion of proteins in the ER, protein folding, processing and quality control in ER, smooth ER and lipid synthesis, export of proteins and lipids

Golgi apparatus – Organization, protein glycosylation, protein sorting and export from Golgi apparatus

Lysosomes

Unit 4 Cell Signalling

No. of Hours: 8

Signalling molecules and their receptors Function of cell surface receptors

Pathways of intra-cellular receptors – Cyclic AMP pathway, cyclic GMP and MAP kinase pathway

Unit 5 Cell Cycle, Cell Death and Cell Renewal

No. of Hours: 12

Eukaryotic cell cycle and its regulation, Mitosis and Meiosis Development of cancer, causes and types

Programmed cell death Stem cells

Embryonic stem cell, induced pluripotent stem cells

CC-6: CELL BIOLOGY (PRACTICAL)

SEMESTER –III

TOTAL HOURS: 60

CREDITS: 2

1. Study a representative plant and animal cell by microscopy.
2. Study of the structure of cell organelles through electron micrographs
3. Cytochemical staining of DNA – Feulgen
4. Demonstration of the presence of mitochondria in striated muscle cells/ cheek epithelial cell using vital stain Janus Green B
5. Study of polyploidy in Onion root tip by colchicine treatment.
6. Identification and study of cancer cells by photomicrographs.
7. Study of different stages of Mitosis.
8. Study of different stages of Meiosis.

SUGGESTED READING

1. Hardin J, Bertoni G and Kleinsmith LJ. (2010). Becker's World of the Cell. 8th edition. Pearson.
2. Karp G. (2010) Cell and Molecular Biology: Concepts and Experiments. 6th edition. John Wiley & Sons. Inc.
3. De Robertis, EDP and De Robertis EMF. (2006). Cell and Molecular Biology. 8th edition. Lipincott Williams and Wilkins, Philadelphia.
4. Cooper, G.M. and Hausman, R.E. (2009). The Cell: A Molecular Approach. 5th Edition. ASM Press & Sunderland, Washington, D.C.; Sinauer Associates, MA.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-7: MOLECULAR BIOLOGY (THEORY)

SEMESTER –III

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Structures of DNA and RNA / Genetic Material No. of Hours: 12

DNA Structure: Miescher to Watson and Crick- historic perspective, DNA structure, Salient features of double helix, Types of DNA, Types of genetic material, denaturation and renaturation, cot curves. DNA topology - linking number, topoisomerases; Organization of DNA Prokaryotes, Viruses, Eukaryotes. RNA Structure, Organelle DNA -- mitochondria and chloroplast DNA.

Unit 2 Replication of DNA (Prokaryotes and Eukaryotes) No. of Hours: 10

Bidirectional and unidirectional replication, semi- conservative, semi- discontinuous replication Mechanism of DNA replication: Enzymes and proteins involved in DNA replication –DNA polymerases, DNA ligase, primase, telomerase – for replication of linear ends

Various models of DNA replication including rolling circle, D- loop (mitochondrial), Θ (theta) mode of replication and other accessory protein, Mismatch and excision repair

Unit 3 Transcription in Prokaryotes and Eukaryotes No. of Hours: 8

Transcription: Definition, difference from replication, promoter - concept and strength of promoter RNA Polymerase and the transcription unit

Transcription in Eukaryotes: RNA polymerases, general Transcription factors

Unit 4 Post-Transcriptional Processing No. of Hours: 8

Split genes, concept of introns and exons, RNA splicing, spliceosome machinery, concept of alternative splicing, Polyadenylation and capping, Processing of rRNA, RNA interference: si RNA, miRNA and its significance

Unit 5 Translation (Prokaryotes and Eukaryotes) No. of Hours: 10

Translational machinery, Charging of tRNA, aminoacyl tRNA synthetases, Mechanisms of initiation, elongation and termination of polypeptides in both prokaryotes and eukaryotes, Fidelity of translation, Inhibitors of protein synthesis in prokaryotes and eukaryote

Unit 6 Regulation of gene Expression in Prokaryotes and Eukaryotes No. of Hours: 12

Principles of transcriptional regulation, regulation at initiation with examples from *lac* and *trp* operons, Sporulation in *Bacillus*, Yeast mating type switching , Changes in Chromatin

Structure - DNA methylation and Histone Acetylation mechanisms.

CC-7: MOLECULAR BIOLOGY (PRACTICAL)

SEMESTER –III

TOTAL HOURS: 60

CREDITS: 2

1. Study of different types of DNA and RNA using micrographs and model / schematic representations
2. Study of semi-conservative replication of DNA through micrographs / schematic representations
3. Isolation of genomic DNA from E. coli
4. Estimation of salmon sperm / calf thymus DNA using colorimeter (diphenylamine reagent) or UV spectrophotometer (A260 measurement)
5. Estimation of RNA using colorimeter (orcinol reagent) or UV spectrophotometer(A260 measurement)
6. Resolution and visualization of DNA by Agarose Gel Electrophoresis.
7. Resolution and visualization of proteins by Polyacrylamide Gel Electrophoresis (SDS-PAGE).

SUGGESTED READINGS

1. Watson JD, Baker TA, Bell SP, Gann A, Levine M and Losick R (2008) Molecular Biology of the Gene, 6th edition, Cold Spring Harbour Lab. Press, Pearson Publication
2. Becker WM, Kleinsmith LJ, Hardin J and Bertoni GP (2009) The World of the Cell, 7th edition, Pearson Benjamin Cummings Publishing, San Francisco
3. De Robertis EDP and De Robertis EMF (2006) Cell and Molecular Biology, 8th edition. Lippincott Williams and Wilkins, Philadelphia
4. Karp G (2010) Cell and Molecular Biology: Concepts and Experiments, 6th edition, John Wiley & Sons. Inc.
5. Sambrook J and Russell DW. (2001). Molecular Cloning: A Laboratory Manual. 4th Edition, ColdSpring Harbour Laboratory press.
6. Krebs J, Goldstein E, Kilpatrick S (2013). Lewin's Essential Genes, 3rd Ed., Jones and Bartlett Learning
7. Gardner EJ, Simmons MJ, Snustad DP (2008). Principles of Genetics. 8th Ed. Wiley-India

GE-3: MICROBIAL METABOLISM (THEORY)

SEMESTER – III

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Microbial Growth and Effect of Environment on Microbial Growth

No. of Hours: 12

Definitions of growth, Batch culture, Continuous culture, generation time and specific growth rate
Temperature and temperature ranges of growth

pH and pH ranges of growth

Effect of solute and water activity on growth
Effect of oxygen concentration on growth

Nutritional categories of microorganisms

Unit 2 Nutrient uptake and Transport

No. of Hours: 10

Passive and facilitated diffusion

Primary and secondary active transport, concept of uniport, symport and antiport
Group translocation

Iron uptake

Unit 3 Chemoheterotrophic Metabolism - Aerobic Respiration

No. of Hours: 16

Concept of aerobic respiration, anaerobic respiration and fermentation
Sugar degradation pathways i.e. EMP, ED, Pentose phosphate pathway
TCA cycle

Electron transport chain: components of respiratory chain, comparison of mitochondrial and bacterial
ETC, electron transport phosphorylation, uncouplers and inhibitors

Unit 4 Chemoheterotrophic Metabolism- Anaerobic respiration and fermentation

No. of Hours: 6

Anaerobic respiration with special reference to dissimilatory nitrate reduction
(Denitrification; nitrate

/nitrite and nitrate/ammonia respiration; fermentative nitrate reduction)

Fermentation - Alcohol fermentation and Pasteur effect; Lactate fermentation
(homofermentative and heterofermentative pathways), concept of linear and branched
fermentation pathways

Unit 5 Chemolithotrophic and Phototrophic Metabolism

No. of Hours: 10

Introduction to aerobic and anaerobic chemolithotrophy with an example each. Hydrogen
oxidation(definition and reaction) and methanogenesis (definition and reaction)

Introduction to phototrophic metabolism - groups of phototrophic microorganisms,
anoxygenic vs. oxygenic photosynthesis with reference to photosynthesis in green bacteria

and cyanobacteria

Unit 6 Nitrogen Metabolism - an overview

No. of Hours: 6

Introduction to biological nitrogen fixation Ammonia assimilation

Assimilatory nitrate reduction

GE-3: MICROBIAL METABOLISM (PRACTICAL)

SEMESTER –III

TOTAL HOURS: 60

CREDITS: 2

1. Study and plot the growth curve of *E. coli* by turbidimetric and standard plate count methods.
2. Calculations of generation time and specific growth rate of bacteria from the graph plotted with the given data
3. Effect of temperature on growth of *E. coli*
4. Effect of pH on growth of *E. coli*
5. Effect of Nitrogen and Carbon sources on *E. Coli*
6. Effect of salt on growth of *E. coli*
7. Demonstration of alcoholic fermentation
8. Demonstration of the thermal death time and decimal reduction time of *E. coli*.

SUGGESTED READINGS

1. Madigan MT, and Martinko JM (2014). Brock Biology of Microorganisms. 14th edition. Prentice Hall International Inc.
2. Moat AG and Foster JW. (2002). Microbial Physiology. 4th edition. John Wiley & Sons
3. Reddy SR and Reddy SM. (2005). Microbial Physiology. Scientific Publishers India
4. Gottschalk G. (1986). Bacterial Metabolism. 2nd edition. Springer Verlag
5. Stanier RY, Ingrahm JI, Wheelis ML and Painter PR. (1987). General Microbiology. 5th edition, McMillan Press.
6. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology. 9th edition. McGraw Hill Higher Education.

B.Sc. (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-8: MICROBIAL GENETICS (THEORY)

SEMESTER –IV

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Genome Organization and Mutations

No. of Hours: 18

Genome organization: *E. coli*, *Saccharomyces*, *Tetrahymena*

Mutations and mutagenesis: Definition and types of Mutations; Physical and chemical mutagens; Molecular basis of mutations; Functional mutants (loss and gain of function mutants); Uses of mutations

Reversion and suppression: True revertants; Intra- and inter-genic suppression; Ames test; Mutator genes

Unit 2 Plasmids

No. of Hours: 10

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

Unit 3 Mechanisms of Genetic Exchange

No. of Hours: 12

Transformation - Discovery, mechanism of natural competence

Conjugation - Discovery, mechanism, Hfr and F' strains, Interrupted mating technique and time of entry mapping

Transduction - Generalized transduction, specialized transduction, LFT & HFT lysates, Mapping by recombination and co-transduction of markers

Unit 4 Phage Genetics

No. of Hours: 8

Features of T4 genetics, Genetic basis of lytic *versus* lysogenic switch of phage lambda

Unit 5 Transposable elements

No. of Hours: 12

Prokaryotic transposable elements – Insertion Sequences, composite and non-composite transposons, Replicative and Non replicative transposition, Mu transposon

Eukaryotic transposable elements - Yeast (Ty retrotransposon), Drosophila (P elements), Maize (Ac/Ds)

Uses of transposons and transposition

CC-8: MICROBIAL GENETICS (PRACTICAL)

SEMESTER –IV

TOTAL HOURS: 60

CREDITS: 2

1. Preparation of Master and Replica Plates
2. Study the effect of chemical (HNO₂) and physical (UV) mutagens on bacterial cells
3. Study survival curve of bacteria after exposure to ultraviolet (UV) light
4. Isolation of Plasmid DNA from E.coli
5. Study different conformations of plasmid DNA through Agarose gel electrophoresis.
6. Demonstration of Bacterial Conjugation
7. Demonstration of bacterial transformation and transduction
8. Demonstration of AMES test.

SUGGESTED READING

1. Klug WS, Cummings MR, Spencer, C, Palladino, M (2011). Concepts of Genetics, 10th Ed., Benjamin Cummings
2. Krebs J, Goldstein E, Kilpatrick S (2013). Lewin's Essential Genes, 3rd Ed., Jones and Bartlett Learning
3. Pierce BA (2011) Genetics: A Conceptual Approach, 4th Ed., Macmillan Higher Education Learning
4. Watson JD, Baker TA, Bell SP et al. (2008) Molecular Biology of the Gene, 6th Ed., Benjamin Cummings
5. Gardner EJ, Simmons MJ, Snustad DP (2008). Principles of Genetics. 8th Ed. Wiley-India
6. Russell PJ. (2009). *i* Genetics- A Molecular Approach. 3rd Ed, Benjamin Cummings
7. Sambrook J and Russell DW. (2001). Molecular Cloning: A Laboratory Manual. 4th Edition, Cold Spring Harbour Laboratory press.
8. Maloy SR, Cronan JE and Friefelder D(2004) Microbial Genetics 2nd EDITION., Jones and BarlettPublishers

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-9: ENVIRONMENTAL MICROBIOLOGY (THEORY)

SEMESTER –IV

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Microorganisms and their Habitats

No. of Hours: 14

Structure and function of ecosystems

Terrestrial Environment: Soil profile and soil microflora

Aquatic Environment: Microflora of fresh water and marine habitats
Atmosphere: Aeromicroflora and dispersal of microbes

Animal Environment: Microbes in/on human body (Microbiomics) & animal (ruminants) body.

Extreme Habitats: Extremophiles: Microbes thriving at high & low temperatures, pH, high hydrostatic & osmotic pressures, salinity, & low nutrient levels.

Microbial succession in decomposition of plant organic matter

Unit 2 Microbial Interactions

No. of Hours: 12

Microbe interactions: Mutualism, synergism, commensalism, competition, amensalism, parasitism, predation

Microbe-Plant interaction: Symbiotic and non symbiotic interactions

Microbe-animal interaction: Microbes in ruminants, nematophagus fungi and symbiotic luminescent bacteria

Unit 3 Biogeochemical Cycling

No. of Hours: 12

Carbon cycle: Microbial degradation of cellulose, hemicelluloses, lignin and chitin

Nitrogen cycle: Nitrogen fixation, ammonification, nitrification, denitrification and nitrate reduction
Phosphorus cycle: Phosphate immobilization and solubilisation

Sulphur cycle: Microbes involved in sulphur cycle
Other elemental cycles: Iron and manganese

Unit 4 Waste Management

No. of Hours: 12

Solid Waste management: Sources and types of solid waste, Methods of solid waste disposal (composting and sanitary landfill)

Liquid waste management: Composition and strength of sewage (BOD and COD), Primary, secondary (oxidation ponds, trickling filter, activated sludge process and septic tank) and tertiary sewage treatment

Unit 5 Microbial Bioremediation

No. of Hours: 5

Principles and degradation of common pesticides, organic (hydrocarbons, oil spills) and inorganic (metals) matter, biosurfactants

Unit 6 Water Potability**No. of Hours: 5**

Treatment and safety of drinking (potable) water, methods to detect potability of water samples: (a) standard qualitative procedure: presumptive test/MPN test, confirmed and completed tests for faecalcoliforms (b) Membrane filter technique and (c) Presence/absence tests

CC-9: ENVIRONMENTAL MICROBIOLOGY (PRACTICAL)

SEMESTER –IV

TOTAL HOURS: 60

CREDITS: 2

1. Analysis of soil - pH, moisture content, water holding capacity, percolation, capillary action.
2. Isolation of microbes (bacteria & fungi) from soil (28°C & 45°C).
3. Isolation of microbes (bacteria & fungi) from rhizosphere and rhizoplane.
4. Assessment of microbiological quality of water.
5. Determination of BOD of waste water sample.
6. Study the presence of microbial activity by detecting (qualitatively) enzymes (dehydrogenase, amylase, urease) in soil.
7. Isolation of *Rhizobium* from root nodules.

SUGGESTED READINGS

1. Atlas RM and Bartha R. (2000). Microbial Ecology: Fundamentals & Applications. 4th edition. Benjamin/Cummings Science Publishing, USA
2. Madigan MT, Martinko JM and Parker J. (2014). Brock Biology of Microorganisms. 14th edition. Pearson/ Benjamin Cummings
3. Maier RM, Pepper IL and Gerba CP. (2009). Environmental Microbiology. 2nd edition, Academic Press
4. Okafor, N (2011). Environmental Microbiology of Aquatic & Waste systems. 1st edition, Springer, New York
5. Singh A, Kuhad, RC & Ward OP (2009). Advances in Applied Bioremediation. Volume 17, Springer-Verlag, Berlin Heidelberg
6. Barton LL & Northup DE (2011). Microbial Ecology. 1st edition, Wiley Blackwell, USA
7. Campbell RE. (1983). Microbial Ecology. Blackwell Scientific Publication, Oxford, England.
8. Coyne MS. (2001). Soil Microbiology: An Exploratory Approach. Delmar Thomson Learning.
9. Lynch JM & Hobbie JE. (1988). Microorganisms in Action: Concepts & Application in Microbial Ecology. Blackwell Scientific Publication, U.K.
10. Martin A. (1977). An Introduction to Soil Microbiology. 2nd edition. John Wiley & Sons Inc. New York & London.
11. Stolp H. (1988). Microbial Ecology: Organisms Habitats Activities. Cambridge University Press, Cambridge, England.
12. Subba Rao NS. (1999). Soil Microbiology. 4th edition. Oxford & IBH Publishing Co. New

Delhi.

12. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology. 9th edition. McGraw Hill Higher Education.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)
CC-10: FOOD AND DAIRY MICROBIOLOGY (THEORY)
SEMESTER –IV

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Foods as a substrate for microorganisms **No. of Hours: 8** Intrinsic and extrinsic factors that affect growth and survival of microbes in foods, natural flora and source of contamination of foods in general.

Unit 2 Microbial spoilage of various foods **No. of Hours: 10**
Principles, Spoilage of vegetables, fruits, meat, eggs, milk and butter, bread, canned Foods

Unit 3 Principles and methods of food preservation **No. of Hours: 12** Principles, physical methods of food preservation: temperature (low, high, canning, drying), irradiation, hydrostatic pressure, high voltage pulse, microwave processing and aseptic packaging, chemical methods of food preservation: salt, sugar, organic acids, SO₂, nitrite and nitrates, ethylene oxide, antibiotics and bacteriocins

Unit 4 Fermented foods **No. of Hours: 10**
Dairy starter cultures, fermented dairy products: yogurt, acidophilus milk, kumiss, kefir, dahi and cheese, other fermented foods: dosa, sauerkraut, soy sauce and tampeh, Probiotics: Health benefits, types of microorganisms used, probiotic foods available in market.

Unit 5 Food borne diseases (causative agents, foods involved, symptoms and preventive measures) **No. of Hours: 10**
Food intoxications: *Staphylococcus aureus*, *Clostridium botulinum* and mycotoxins;
Food infections: *Bacillus cereus*, *Vibrio parahaemolyticus*, *Escherichia coli*, Salmonellosis, Shigellosis, *Yersinia enterocolitica*, *Listeria monocytogenes* and *Campylobacter jejuni*

Unit 6 Food sanitation and control **No. of Hours: 5**
HACCP, Indices of food sanitary quality and sanitizers

Unit 7 Cultural and rapid detection methods of food borne pathogens in foods and introduction to predictive microbiology. **No. of Hours: 5**

CC-10: FOOD AND DAIRY MICROBIOLOGY (PRACTICAL)

SEMESTER –IV

TOTAL HOURS: 60

CREDITS: 2

1. MBRT of milk samples and their standard plate count.
2. Alkaline phosphatase test to check the efficiency of pasteurization of milk.
3. Isolation of any food borne bacteria from food products.
4. Isolation of spoilage microorganisms from spoiled vegetables/fruits.
5. Isolation of spoilage microorganisms from bread.
6. Preparation of Yogurt/Dahi.

SUGGESTED READINGS

1. Adams MR and Moss MO. (1995). Food Microbiology. 4th edition, New Age International (P) Limited Publishers, New Delhi, India.
2. Banwart JM. (1987). Basic Food Microbiology. 1st edition. CBS Publishers and Distributors, Delhi, India.
3. Davidson PM and Brannen AL. (1993). Antimicrobials in Foods. Marcel Dekker, New York.
4. Dillion VM and Board RG. (1996). Natural Antimicrobial Systems and Food Preservation. CAB International, Wallingford, Oxon.
5. Frazier WC and Westhoff DC. (1992). Food Microbiology. 3rd edition. Tata McGraw-Hill Publishing Company Ltd, New Delhi, India.
6. Gould GW. (1995). New Methods of Food Preservation. Blackie Academic and Professional, London.
7. Jay JM, Loessner MJ and Golden DA. (2005). Modern Food Microbiology. 7th edition, CBS Publishers and Distributors, Delhi, India.
8. Lund BM, Baird Parker AC, and Gould GW. (2000). The Microbiological Safety and Quality of Foods. Vol. 1-2, ASPEN Publication, Gaithersberg, MD.
9. Tortora GJ, Funke BR, and Case CL. (2008). Microbiology: An Introduction. 9th edition. Pearson Education.

GE-4: MICROBES IN ENVIRONMENT (THEORY)

SEMESTER – IV

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Microorganisms and their Habitats

No. of Hours: 14

Structure and function of ecosystems Terrestrial Environment: Soil profile and soil micro flora Aquatic Environment: Microflora of fresh water and marine habitats Atmosphere: Aero micro flora and dispersal of microbes Animal Environment: Microbes in/on human body (Microbiomics) & animal (ruminants) body. Extreme Habitats: Extremophiles: Microbes thriving at high & low temperatures, pH, high hydrostatic & osmotic pressures, salinity, & low nutrient levels.

Unit 2 Microbial Interactions

No. of Hours: 12

Microbe interactions: Mutualism, synergism, commensalism, competition, amensalism, parasitism, predation Microbe-Plant interaction: Symbiotic and non symbiotic interactions Microbe-animal interaction: Microbes in ruminants, nematophagus fungi and symbiotic luminescent bacteria

Unit 3 Biogeochemical Cycling

No. of Hours: 12

Carbon cycle: Microbial degradation of cellulose, hemicelluloses, lignin and chitin Nitrogen cycle: Nitrogen fixation, ammonification, nitrification, denitrification and nitrate reduction Phosphorus cycle: Phosphate immobilization and solubilisation Sulphur cycle: Microbes involved in sulphur cycle Other elemental cycles: Iron and manganese

Unit 4 Waste Management

No. of Hours: 12

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

Unit 5 Microbial Bioremediation

No. of Hours: 5

Principles and degradation of common pesticides, hydrocarbons (oil spills).

Unit 6 Water Potability

No. of Hours: 5

Treatment and safety of drinking (potable) water, methods to detect potability of water samples: (a) standard qualitative procedure: presumptive test/MPN test, confirmed and completed tests for faecal coliforms (b) Membrane filter technique and (c) Presence/absence tests.

GE-4: MICROBES IN ENVIRONMENT (PRACTICAL)

SEMESTER –IV

TOTAL HOURS: 60

CREDITS: 2

1. Analysis of soil - pH, moisture content, water holding capacity, percolation, capillary action.
2. Isolation of microbes (bacteria & fungi) from soil (28°C & 45°C).
3. Isolation of microbes (bacteria & fungi) from rhizosphere and rhizoplane.
4. Assessment of microbiological quality of water.
5. Determination of BOD of waste water sample.
6. Study the presence of microbial activity by detecting (qualitatively) enzymes (dehydrogenase, amylase, urease) in soil.
7. Isolation of Rhizobium from root nodules.

SUGGESTED READINGS

1. Atlas RM and Bartha R. (2000). Microbial Ecology: Fundamentals & Applications. 4th edition. Benjamin/Cummings Science Publishing, USA
2. Madigan MT, Martinko JM and Parker J. (2014). Brock Biology of Microorganisms. 14th edition. Pearson/ Benjamin Cummings
3. Maier RM, Pepper IL and Gerba CP. (2009). Environmental Microbiology. 2nd edition, Academic Press
4. Okafor, N (2011). Environmental Microbiology of Aquatic & Waste systems. 1st edition, Springer, New York
5. Singh A, Kuhad, RC & Ward OP (2009). Advances in Applied Bioremediation. Volume 17, Springer-Verlag, Berlin Heidelberg
6. Barton LL & Northup DE (2011). Microbial Ecology. 1st edition, Wiley Blackwell, USA
Campbell RE. (1983). Microbial Ecology. Blackwell Scientific Publication, Oxford, England.
7. Coyne MS. (2001). Soil Microbiology: An Exploratory Approach. Delmar Thomson Learning.
8. Lynch JM & Hobbie JE. (1988). Microorganisms in Action: Concepts & Application in Microbial Ecology. Blackwell Scientific Publication, U.K.
9. Martin A. (1977). An Introduction to Soil Microbiology. 2nd edition. John Wiley & Sons Inc. New York & London.
10. Stolp H. (1988). Microbial Ecology: Organisms Habitats Activities. Cambridge University Press, Cambridge, England.
11. Subba Rao NS. (1999). Soil Microbiology. 4th edition. Oxford & IBH Publishing Co. New Delhi.
12. Willey JM, Sherwood LM, and Woolverton CJ. (2013). Prescott's Microbiology. 9th

edition.McGraw Hill Higher Education.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-11: INDUSTRIAL MICROBIOLOGY (THEORY)

SEMESTER –V

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Introduction to industrial microbiology

No. of Hours: 2

Brief history and developments in industrial microbiology

Unit 2 Isolation of industrially important microbial strains and fermentation media

No. of Hours: 10

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

Unit 3 Types of fermentation processes, bio-reactors and measurement of fermentation parameters

No. of Hours: 12

Types of fermentation processes - Solid-state and liquid-state (stationary and submerged) fermentations; batch, fed-batch (eg. baker's yeast) and continuous fermentations

Components of a typical bio-reactor, Types of bioreactors-Laboratory, pilot- scale and production fermenters, constantly stirred tank and air-lift fermenters, Measurement and control of fermentation parameters - pH, temperature, dissolved oxygen, foaming and aeration

Unit 4 Down-stream processing

No. of Hours: 6

Cell disruption, filtration, centrifugation, solvent extraction, precipitation, lyophilization and spray drying

Unit 5 Microbial production of industrial products (micro-organisms involved, media, fermentation conditions, downstream processing and uses)

No. of Hours: 18

Citric acid, ethanol, penicillin, glutamic acid, Vitamin B12

Enzymes (amylase, protease, lipase) Wine, beer

Unit 6 Enzyme immobilization

No. of Hours: 4

Methods of immobilization, advantages and applications of immobilization, large scale applications of immobilized enzymes (glucose isomerase and penicillin acylase)

CC-11: INDUSTRIAL MICROBIOLOGY (PRACTICAL)

SEMESTER –V

TOTAL HOURS: 60

CREDITS: 2

1. Study different parts of fermenter
2. Microbial fermentations for the production and estimation (qualitative and quantitative) of:
 - a. Enzymes: Amylase and Protease
 - b. Amino acid: Glutamic acid
 - c. Organic acid: Citric acid
 - d. Alcohol: Ethanol
3. A visit to any educational institute/industry to see an industrial fermenter, and other downstream processing operations.

SUGGESTED READINGS

1. Patel A.H. (1996). Industrial Microbiology. 1st edition, Macmillan India Limited
2. Okafor N. (2007). Modern Industrial Microbiology and Biotechnology. 1st edition. Bios Scientific Publishers Limited. USA
3. Waites M.J., Morgan N.L., Rockey J.S. and Higton G. (2001). Industrial Microbiology: An Introduction. 1st edition. Wiley – Blackwell
4. Glaze A.N. and Nikaido H. (1995). Microbial Biotechnology: Fundamentals of Applied Microbiology. 1st edition. W.H. Freeman and Company
5. Casida LE. (1991). Industrial Microbiology. 1st edition. Wiley Eastern Limited.
6. Crueger W and Crueger A. (2000). Biotechnology: A textbook of Industrial Microbiology. 2nd edition. Panima Publishing Co. New Delhi.
7. Stanbury PF, Whitaker A and Hall SJ. (2006). Principles of Fermentation Technology. 2nd edition, Elsevier Science Ltd.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-12: IMMUNOLOGY (THEORY)

SEMESTER –V

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Introduction

No. of Hours: 4

Concept of Innate and Adaptive immunity; Contributions of following scientists to the development of field of immunology - Edward Jenner, Karl Landsteiner, Robert Koch, Paul Ehrlich, Elie Metchnikoff, Peter Medawar, MacFarlane Burnet, Neils K Jerne, Rodney Porter and Susumu Tonegawa

Unit 2 Immune Cells and Organs

No. of Hours: 7

Structure, Functions and Properties of: Immune Cells – Stem cell, T cell, B cell, NK cell, Macrophage, Neutrophil, Eosinophil, Basophil, Mast cell, Dendritic cell; and Immune Organs – BoneMarrow, Thymus, Lymph Node, Spleen, GALT, MALT, CALT

Unit 3 Antigens

No. of Hours: 4

Characteristics of an antigen (Foreignness, Molecular size and Heterogeneity); Haptens; Epitopes (T& B cell epitopes); T-dependent and T-independent antigens; Adjuvants

Unit 4 Antibodies

No. of Hours: 6

Structure, Types, Functions and Properties of antibodies; Antigenic determinants on antibodies (Isotypic, allotypic, idiotypic); VDJ rearrangements; Monoclonal and Chimeric antibodies

Unit 5 Major Histocompatibility Complex

No. of Hours: 5

Organization of MHC locus (Mice & Human); Structure and Functions of MHC I & II molecules; Antigen processing and presentation (Cytosolic and Endocytic pathways)

Unit 6 Complement System

No. of Hours: 4

Components of the Complement system; Activation pathways (Classical, Alternative and Lectin pathways); Biological consequences of complement Activation

Unit 7 Generation of Immune Response

No. of Hours: 10

Primary and Secondary Immune Response; Generation of Humoral Immune Response (Plasma and Memory cells); Generation of Cell Mediated Immune Response (Self MHC restriction, T cell activation, Co- stimulatory signals); Killing Mechanisms by CTL and NK cells, Introduction to tolerance

Unit 8 Immunological Disorders and Tumor Immunity

No. of Hours: 10

Types of Autoimmunity and Hypersensitivity with examples; Immunodeficiencies - Animal models (Nude and SCID mice), SCID, DiGeorge syndrome, Chediak- Higashi syndrome,

Leukocyte adhesion deficiency, CGD; Types of tumors, tumor Antigens, causes and therapy for cancers.

Unit 9 Immunological Techniques

No. of Hours: 10

Principles of Precipitation, Agglutination, Immunodiffusion, Immunoelectrophoresis, ELISA, ELISPOT, Western blotting, Immunofluorescence, Flow cytometry, Immunoelectron microscopy.

CC-12: IMMUNOLOGY (PRACTICAL)
SEMESTER –V

TOTAL HOURS: 60

CREDITS: 2

1. Identification of human blood groups.
2. Perform Total Leukocyte Count of the given blood sample.
3. Perform Differential Leukocyte Count of the given blood sample.
4. Separate serum from the blood sample (demonstration).
5. Perform immunodiffusion by Ouchterlony method.
6. Perform DOT ELISA.
7. Perform immunoelectrophoresis.

SUGGESTED READINGS

1. Abbas AK, Lichtman AH, Pillai S. (2007). Cellular and Molecular Immunology. 6th edition Saunders Publication, Philadelphia.
2. Delves P, Martin S, Burton D, Roitt IM. (2006). Roitt's Essential Immunology. 11th edition Wiley-Blackwell Scientific Publication, Oxford.
3. Goldsby RA, Kindt TJ, Osborne BA. (2007). Kuby's Immunology. 6th edition W.H. Freeman and Company, New York.
4. Murphy K, Travers P, Walport M. (2008). Janeway's Immunobiology. 7th edition Garland Science Publishers, New York.
5. Peakman M, and Vergani D. (2009). Basic and Clinical Immunology. 2nd edition Churchill Livingstone Publishers, Edinburgh.
6. Richard C and Geiffrey S. (2009). Immunology. 6th edition. Wiley Blackwell Publication.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

DSE-1: BIOINFORMATICS (THEORY)

SEMESTER –V

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Introduction to Computer Fundamentals

No. of Hours: 8

RDBMS - Definition of relational database

Mode of data transfer (FTP, SFTP, SCP), advantage of encrypted data transfer

Unit 2 Introduction to Bioinformatics and Biological Databases **No. of Hours: 14** Biological databases - nucleic acid, genome, protein sequence and structure, gene expression databases, Database of metabolic pathways, Mode of data storage - File formats - FASTA, Genbank and Uniprot, Data submission & retrieval from NCBI, EMBL, DDBJ, Uniprot, PDB

Unit 3 Sequence Alignments, Phylogeny and Phylogenetic trees **No. of Hours: 16**

Local and Global Sequence alignment, pairwise and multiple sequence alignment. Scoring an alignment, scoring matrices, PAM & BLOSUM series of matrices

Types of phylogenetic trees, Different approaches of phylogenetic tree construction - UPGMA, Neighbour joining, Maximum Parsimony, Maximum likelihood

Unit 4 Genome organization and analysis

No. of Hours: 10

Diversity of Genomes: Viral, prokaryotic & eukaryotic genomes

Genome, transcriptome, proteome, 2-D gel electrophoresis, Maldi Toff spectroscopy Major features of completed genomes: *E.coli*, *S.cerevisiae*, *Arabidopsis*, Human

Unit 5 Protein Structure Predictions

No. of Hours: 12

Hierarchy of protein structure - primary, secondary and tertiary structures, modeling Structural Classes, Motifs, Folds and Domains

Protein structure prediction in presence and absence of structure template Energy minimizations and evaluation by Ramachandran plot

Protein structure and rational drug design

DSE-1: BIOINFORMATICS (PRACTICAL)
SEMESTER –V

TOTAL HOURS: 60

CREDITS: 2

1. Introduction to different operating systems - UNIX, LINUX and Windows
2. Introduction to bioinformatics databases (any three): NCBI/PDB/DDBJ, Uniprot, PDB
3. Sequence retrieval using BLAST
4. Sequence alignment & phylogenetic analysis using clustalW & phylip
5. Picking out a given gene from genomes using Genscan or other softwares (promoter region identification, repeat in genome, ORF prediction). Gene finding tools (Glimmer, GENSCAN), Primerdesigning, Genscan/Gene tool.
6. Protein structure prediction: primary structure analysis, secondary structure prediction using psi-pred, homology modeling using Swissmodel. Molecular visualization using jmol, Protein structure model evaluation (PROCHECK)
7. Prediction of different features of a functional gene

SUGGESTED READING

1. Saxena Sanjay (2003) A First Course in Computers, Vikas Publishing House
2. Pradeep and Sinha Preeti (2007) Foundations of Computing, 4th ed., BPB Publications
3. Lesk M.A.(2008) Introduction to Bioinformatics . Oxford Publication, 3rd International Student Edition
4. Rastogi S.C., Mendiratta N. and Rastogi P. (2007) Bioinformatics: methods and applications, genomics, proteomics and drug discovery, 2nd ed. Prentice Hall India Publication
5. Primrose and Twyman (2003) Principles of Genome Analysis & Genomics. Blackwell

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

DSE-2: MICROBIAL BIOTECHNOLOGY (THEORY)

SEMESTER –V

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Microbial Biotechnology and its Applications

No. of Hours: 10

Microbial biotechnology: Scope and its applications in human therapeutics, agriculture (Biofertilizers, PGPR, Mycorrhizae), environmental, and food technology

Use of prokaryotic and eukaryotic microorganisms in biotechnological applications Genetically engineered microbes for industrial application: Bacteria and yeast

Unit 2 Therapeutic and Industrial Biotechnology

No. of Hours: 10

Recombinant microbial production processes in pharmaceutical industries - Streptokinase, recombinant vaccines (Hepatitis B vaccine)

Microbial polysaccharides and polyesters, Microbial production of bio-pesticides, bioplastics
Microbial biosensors

Unit 3 Applications of Microbes in Biotransformations

No. of Hours: 8

Microbial based transformation of steroids and sterols

Bio-catalytic processes and their industrial applications: Production of high fructose syrup and production of cocoa butter substitute

Unit 4 Microbial Products and their Recovery

No. of Hours: 10

Microbial product purification: filtration, ion exchange & affinity chromatography techniques
Immobilization methods and their application: Whole cell immobilization

Unit 5 Microbes for Bio-energy and Environment

No. of Hours: 12

Bio-ethanol and bio-diesel production: commercial production from lignocellulosic waste and algal biomass, Biogas production: Methane and hydrogen production using microbial culture.

Microorganisms in bioremediation: Degradation of xenobiotics, mineral recovery, removal of heavy metals from aqueous effluents

Unit 6 RNAi

No. of Hours: 6

RNAi and its applications in silencing genes, drug resistance, therapeutics and host pathogen interactions

Unit 7 Intellectual Property Rights

No. of Hours: 4

Patents, Copyrights, Trademarks

DSE-2: MICROBIAL BIOTECHNOLOGY (PRACTICAL)

SEMESTER –V

TOTAL HOURS: 60

CREDITS: 2

1. Study yeast cell immobilization in calcium alginate gels.
2. Study enzyme immobilization by sodium alginate method
3. Pigment production from fungi (*Trichoderma / Aspergillus / Penicillium*)
4. Isolation of xylanase or lipase producing bacteria
5. Study of algal Single Cell Proteins

SUGGESTED READING

1. Ratledge, C and Kristiansen, B. (2001). Basic Biotechnology, 2nd Edition, Cambridge University Press.
2. Demain, A. L and Davies, J. E. (1999). Manual of Industrial Microbiology and Biotechnology, 2nd Edition, ASM Press.
3. Swartz, J. R. (2001). Advances in Escherichia coli production of therapeutic proteins. Current Opinion in Biotechnology, 12, 195–201.
4. Prescott, Harley and Klein's Microbiology by Willey JM, Sherwood LM, Woolverton CJ (2014), 9th edition, Mc Graw Hill Publishers.
5. Gupta PK (2009) Elements of Biotechnology 2nd edition, Rastogi Publications,
6. Glazer AN and Nikaido H (2007) Microbial Biotechnology, 2nd edition, Cambridge University Press
7. Glick BR, Pasternak JJ, and Patten CL (2010) Molecular Biotechnology 4th edition, ASM Press,
8. Stanbury PF, Whitaker A, Hall SJ (1995) Principles of Fermentation Technology 2nd edition., Elsevier Science
9. Crueger W, Crueger A (1990) Biotechnology: A text Book of Industrial Microbiology 2nd edition Sinauer associates.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

CC-13: MEDICAL MICROBIOLOGY (THEORY)

SEMESTER –VI

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Normal microflora of the human body and host pathogen interaction

No. of Hours: 8

Normal microflora of the human body: Importance of normal microflora, normal microflora of skin, throat, gastrointestinal tract, urogenital tract

Host pathogen interaction: Definitions - Infection, Invasion, Pathogen, Pathogenicity, Virulence, Toxigenicity, Carriers and their types, Opportunistic infections, Nosocomial infections.

Transmission of infection, Pathophysiologic effects of LPS

Unit 2 Sample collection, transport and diagnosis

No. of Hours: 5

Collection, transport and culturing of clinical samples, principles of different diagnostic tests (ELISA, Immunofluorescence, Agglutination based tests, Complement fixation, PCR, DNA probes).

Unit 3 Bacterial diseases

No. of Hours: 15

List of diseases of various organ systems and their causative agents. The following diseases in detail with Symptoms, mode of transmission, prophylaxis and control

Respiratory Diseases: *Streptococcus pyogenes*, *Haemophilus influenzae*, *Mycobacterium tuberculosis* Gastrointestinal Diseases: *Escherichia coli*, *Salmonella typhi*, *Vibrio cholerae*, *Helicobacter pylori* Others: *Staphylococcus aureus*, *Bacillus anthracis*, *Clostridium tetani*, *Treponema pallidum*, *Clostridium difficile*

Unit 4 Viral diseases

No. of Hours: 14

List of diseases of various organ systems and their causative agents. The following diseases in detail with Symptoms, mode of transmission, prophylaxis and control

Polio, Herpes, Hepatitis, Rabies, Dengue, AIDS, Influenza with brief description of swine flu, Ebola, Chikungunya, Japanese Encephalitis

Unit 5 Protozoan diseases

No. of Hours: 5

List of diseases of various organ systems and their causative agents. The following diseases in detail with Symptoms, mode of transmission, prophylaxis and control

Malaria, Kala-azar

Unit 6 Fungal diseases

No. of Hours: 5

Brief description of each of the following types of mycoses and one representative disease to be studied with respect to transmission, symptoms and prevention

Cutaneous mycoses: Tinea pedis (Athlete's foot) Systemic mycoses: Histoplasmosis Opportunistic mycoses: Candidiasis

Unit 7 Antimicrobial agents: General characteristics and mode of action

No. of Hours: 8

Antibacterial agents: Five modes of action with one example each: Inhibitor of nucleic acid synthesis; Inhibitor of cell wall synthesis; Inhibitor of cell membrane function; Inhibitor of protein synthesis; Inhibitor of metabolism

Antifungal agents: Mechanism of action of Amphotericin B, Griseofulvin Antiviral agents: Mechanism of action of Amantadine, Acyclovir, Azidothymidine Antibiotic resistance, MDR, XDR, MRSA, NDM-1

CC-13: MEDICAL MICROBIOLOGY (PRACTICAL)

SEMESTER –VI

TOTAL HOURS: 60

CREDITS: 2

1. Identify bacteria (any three of *E. coli*, *Salmonella*, *Pseudomonas*, *Staphylococcus*, *Bacillus*) using laboratory strains on the basis of cultural, morphological and biochemical characteristics: IMViC, TSI, nitrate reduction, urease production and catalase tests
2. Study of composition and use of important differential media for identification of bacteria: EMBAgar, McConkey agar, Mannitol salt agar, Deoxycholate citrate agar, TCBS
3. Study of bacterial flora of skin by swab method
4. Perform antibacterial sensitivity by Kirby-Bauer method
5. Determination of minimal inhibitory concentration (MIC) of an antibiotic.
6. Study symptoms of the diseases with the help of photographs: Polio, anthrax, herpes, chicken pox, HPV warts, AIDS (candidiasis), dermatomycoses (ring worms)
7. Study of various stages of malarial parasite in RBCs using permanent mounts.

SUGGESTED READING

1. Ananthanarayan R. and Paniker C.K.J. (2009) Textbook of Microbiology. 8th edition, University Press Publication
2. Brooks G.F., Carroll K.C., Butel J.S., Morse S.A. and Mietzner, T.A. (2013) Jawetz, Melnick and Adelberg's Medical Microbiology. 26th edition. McGraw Hill Publication
3. Goering R., Dockrell H., Zuckerman M. and Wakelin D. (2007) Mims' Medical Microbiology. 4th edition. Elsevier
4. Willey JM, Sherwood LM, and Woolverton CJ. (2013) Prescott, Harley and Klein's Microbiology. 9th edition. McGraw Hill Higher Education
5. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms. 14th edition. Pearson International Edition.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)
CC-14: RECOMBINANT DNA TECHNOLOGY (THEORY)
SEMESTER –VI

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Introduction to Genetic Engineering

No. of Hours: 2

Milestones in genetic engineering and biotechnology

Unit 2 Molecular Cloning- Tools and Strategies

No. of Hours: 20

Cloning Tools; Restriction modification systems: Types I, II and III. Mode of action, nomenclature, applications of Type II restriction enzymes in genetic engineering

DNA modifying enzymes and their applications: DNA polymerases. Terminal deoxynucleotidyl transferase, kinases and phosphatases, and DNA ligases

Cloning Vectors: Definition and Properties Plasmid vectors: pBR and pUC series Bacteriophage lambda and M13 based vectors Cosmids, BACs, YACs

Use of linkers and adaptors

Expression vectors: *E.coli* lac and T7 promoter-based vectors, yeast YIp, YEp and YCp vectors, Baculovirus based vectors, mammalian SV40-based expression vectors

Unit 3 Methods in Molecular Cloning

No. of Hours: 16

Transformation of DNA: Chemical method, Electroporation,

Gene delivery: Microinjection, electroporation, biolistic method (gene gun), liposome and viral-mediated delivery, *Agrobacterium* - mediated delivery

DNA, RNA and Protein analysis: Agarose gel electrophoresis, Southern - and Northern - blotting techniques, dot blot, DNA microarray analysis, SDS-PAGE and Western blotting.

Unit 4 DNA Amplification and DNA sequencing

No. of Hours: 10

PCR: Basics of PCR, RT-PCR, Real-Time PCR

Sanger's method of DNA Sequencing: traditional and automated sequencing Primer walking and shotgun sequencing

Unit 5 Construction and Screening of Genomic and cDNA libraries **No. of Hours: 6**

Genomic and cDNA libraries: Preparation and uses, Screening of libraries: Colony hybridization and colony PCR, Chromosome walking and chromosome jumping

Unit 6 Applications of Recombinant DNA Technology

No. of Hours: 6

Products of recombinant DNA technology: Products of human therapeutic interest - insulin, hGH, antisense molecules. Bt transgenic - cotton, brinjal, Gene therapy, recombinant vaccines, protein

engineering and site directed mutagenesis

CC-14: RECOMBINANT DNA TECHNOLOGY (PRACTICAL)
SEMESTER- VI

TOTAL HOURS: 60

CREDITS: 2

1. Preparation of competent cells for transformation
2. Demonstration of Bacterial Transformation and calculation of transformation efficiency.
3. Digestion of DNA using restriction enzymes and analysis by agarose gel electrophoresis
4. Ligation of DNA fragments
5. Cloning of DNA insert and Blue white screening of recombinants.
6. Interpretation of sequencing gel electropherograms
7. Designing of primers for DNA amplification
8. Amplification of DNA by PCR
9. Demonstration of Southern blotting

SUGGESTED READING

1. Brown TA. (2010). Gene Cloning and DNA Analysis. 6th edition. Blackwell Publishing, Oxford, U.K.
2. Clark DP and Pazdernik NJ. (2009). Biotechnology: Applying the Genetic Revolution. Elsevier Academic Press, USA
3. Primrose SB and Twyman RM. (2006). Principles of Gene Manipulation and Genomics, 7th edition. Blackwell Publishing, Oxford, U.K.
4. Sambrook J and Russell D. (2001). Molecular Cloning-A Laboratory Manual. 3rd edition. Cold Spring Harbor Laboratory Press
5. Wiley JM, Sherwood LM and Woolverton CJ. (2008). Prescott, Harley and Klein's Microbiology. McGraw Hill Higher Education
6. Brown TA. (2007). Genomes-3. Garland Science Publishers
7. Primrose SB and Twyman RM. (2008). Genomics: Applications in human biology. Blackwell Publishing, Oxford, U.K.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)

DSE-3: PLANT PATHOLOGY (THEORY)

SEMESTER –VI

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Introduction and History of plant pathology

No. of Hours: 5 Concept of

plant disease- definitions of disease, disease cycle & pathogenicity, symptoms associated with microbial plant diseases, types of plant pathogens, economic losses and social impact of plant diseases. Significant landmarks in the field of plant pathology- Contributions of Anton DeBary, Millardet, Burrill, E. Smith, Adolph Mayer, Ivanowski, Diener, Stakman, H.H. Flor, Van Der Plank, molecular Koch's postulates. Contributions of eminent Indian plant pathologists.

Unit 2 Stages in development of a disease

No. of Hours: 2

Infection, invasion, colonization, dissemination of pathogens and perennation.

Unit 3 Plant disease epidemiology

No. of Hours: 5 Concepts of

monocyclic, polycyclic and polyetic diseases, disease triangle & disease pyramid, forecasting of plant diseases and its relevance in Indian context.

Unit 4 Host Pathogen Interaction

No. of Hours: 19

A. Microbial Pathogenicity

Virulence factors of pathogens: enzymes, toxins (host specific and non specific) growth regulators, virulence factors in viruses (replicase, coat protein, silencing suppressors) in disease development. Effects of pathogens on host physiological processes (photosynthesis, respiration, cell membrane permeability, translocation of water and nutrients, plant growth and reproduction).

B. Genetics of Plant Diseases

Concept of resistance (R) gene and avirulence (avr) gene; gene for gene hypothesis, types of plant resistance: true resistance– horizontal & vertical, apparent resistance.

C. Defense Mechanisms in Plants

Concepts of constitutive defense mechanisms in plants, inducible structural defenses (histological- cork layer, abscission layer, tyloses, gums), inducible biochemical defenses [hypersensitive response(HR), systemic acquired resistance (SAR), phytoalexins, pathogenesis related (PR) proteins, plantibodies, phenolics, quinones, oxidative bursts].

Unit 5 Control of Plant Diseases

No. of Hours: 10 Principles

& practices involved in the management of plant diseases by different methods, viz. regulatory - quarantine, crop certification, avoidance of pathogen, use of pathogen free propagative material

cultural - host eradication, crop rotation, sanitation, polyethylene traps and mulches
chemical - protectants and systemic fungicides, antibiotics, resistance of pathogens to chemicals.
biological - suppressive soils, antagonistic microbes-bacteria and fungi, trap plants
genetic engineering of disease resistant plants- with plant derived genes and pathogen derived genes

Unit 6 Specific Plant diseases

No. of Hours: 19

Study of some important plant diseases giving emphasis on its etiological agent, symptoms, epidemiology and control

A. Important diseases caused by fungi White rust of crucifers - *Albugo candida*

Downy mildew of onion - *Peronospora destructor* Late blight of potato - *Phytophthora infestans*

Powdery mildew of wheat - *Erysiphe graminis* Ergot of rye - *Claviceps purpurea*

Black stem rust of wheat - *Puccinia graminis tritici*

Loose smut of wheat - *Ustilago nuda*

Wilt of tomato - *Fusarium oxysporum* f.sp. *lycopersici*

Red rot of sugarcane - *Colletotrichum falcatum*

Early blight of potato - *Alternaria solani*

B. Important diseases caused by phytopathogenic bacteria: Angular leaf spot of cotton, bacterial leafblight of rice, crown galls, bacterial cankers of citrus

C. Important diseases caused by phytoplasmas: Aster yellow, citrus stubborn

D. Important diseases caused by viruses: Papaya ring spot, tomato yellow leaf curl, banana bunchy top, rice tungro

E. Important diseases caused by viroids: Potato spindle tuber, coconut cadang cadang

DSE-3: PLANT PATHOLOGY (PRACTICAL)

SEMESTER –VI

TOTAL HOURS: 60

CREDITS: 2

1. Demonstration of Koch's postulates in fungal, bacterial and viral plant pathogens.
2. Study of important diseases of crop plants by cutting sections of infected plant material - *Albugo*, *Puccinia*, *Ustilago*, *Fusarium*, *Colletotrichum*.

SUGGESTED READINGS

1. Agrios GN. (2006). Plant Pathology. 5th edition. Academic press, San Diego,
2. Lucas JA. (1998). Plant Pathology and Plant Pathogens. 3rd edition. Blackwell Science, Oxford.
3. Mehrotra RS. (1994). Plant Pathology. Tata McGraw-Hill Limited.
4. Rangaswami G. (2005). Diseases of Crop Plants in India. 4th edition. Prentice Hall of India Pvt. Ltd., New Delhi.
5. Singh RS. (1998). Plant Diseases Management. 7th edition. Oxford & IBH, New Delhi.

B.Sc (HONOURS) MICROBIOLOGY (CBCS STRUCTURE)
DSE-4: INSTRUMENTATION AND BIOTECHNIQUES (THEORY)
SEMESTER –VI

TOTAL HOURS: 60

CREDITS: 4

Unit 1 Microscopy

No. of Hours: 10

Brightfield and darkfield microscopy, Fluorescence Microscopy, Phase contrast Microscopy, Confocal Microscopy, Electron Microscopy (Scanning and Transmission Electron Microscopy) and Micrometry.

Unit 2 Chromatography

No. of Hours: 14

Principles and applications of paper chromatography (including Descending and 2-D), Thin layer chromatography. Column packing and fraction collection. Gel filtration chromatography, ion-exchange chromatography and affinity chromatography, GLC, HPLC.

Unit 3 Electrophoresis

No. of Hours: 14

Principle and applications of native polyacrylamide gel electrophoresis, SDS- polyacrylamide gel electrophoresis, 2D gel electrophoresis, Isoelectric focusing, Zymogram preparation and Agarose gelelectrophoresis.

Unit 4 Spectrophotometry

No. of Hours: 10

Principle and use of study of absorption spectra of biomolecules. Analysis of biomolecules using UV and visible range. Colorimetry and turbidometry.

Unit 5 Centrifugation

No. of Hours: 12

Preparative and analytical centrifugation, fixed angle and swinging bucket rotors. RCF and sedimentation coefficient, differential centrifugation, density gradient centrifugation and ultracentrifugation.

DSE-4: INSTRUMENTATION AND BIOTECHNIQUES (PRACTICAL)

SEMESTER –VI

TOTAL HOURS: 60

CREDITS: 2

1. Study of fluorescent micrographs to visualize bacterial cells.
2. Ray diagrams of phase contrast microscopy and Electron microscopy.
3. Separation of mixtures by paper / thin layer chromatography.
4. Demonstration of column packing in any form of column chromatography.
5. Separation of protein mixtures by any form of chromatography.
6. Separation of protein mixtures by Polyacrylamide Gel Electrophoresis (PAGE).
7. Determination of λ_{\max} for an unknown sample and calculation of extinction coefficient.
8. Separation of components of a given mixture using a laboratory scale centrifuge.
9. Understanding density gradient centrifugation with the help of pictures.

SUGGESTED READINGS

1. Wilson K and Walker J. (2010). Principles and Techniques of Biochemistry and Molecular Biology. 7th Ed., Cambridge University Press.
2. Nelson DL and Cox MM. (2008). Lehninger Principles of Biochemistry, 5th Ed., W.H. Freeman and Company.
3. Willey MJ, Sherwood LM & Woolverton C J. (2013). Prescott, Harley and Klein's Microbiology. 9thEd., McGraw Hill.
4. Karp G. (2010) Cell and Molecular Biology: Concepts and Experiments. 6th edition. John Wiley & Sons. Inc.
5. De Robertis EDP and De Robertis EMF. (2006). Cell and Molecular Biology. 8th edition. Lipincott Williams and Wilkins, Philadelphia.
6. Cooper G.M. and Hausman R.E. (2009). The Cell: A Molecular Approach. 5th Edition. ASM Press & Sunderland, Washington D.C., Sinauer Associates, MA.
7. Nigam A and Ayyagari A. 2007. Lab Manual in Biochemistry, Immunology and Biotechnology. Tata McGraw Hill.