K. C. E. Society's
Moolji Jaitha College

NAAC Reaccredited Grade - A (CGPA : 3.15 - 3rd Cycle) |
JGC honoured "College of Excellence"
Dept. of Biotechnology, Ministry of Science & Technology honoured
"Star College" | DST(FIST) Assisted College

ESTD. 1945

के. सी. ई. सोसायटीचे
मूळजी जेठा महाविद्यालय

नॅकद्वारा पुनर्मानांकित श्रेणी – 'ए' (सी.जी.पी.ए. ३.१५ – तिसरी फेरी)
विद्यापीठ अनुदान आयोगाद्वारा घोषित 'कॉलेज ऑफ एक्सलन्स'
भारत सरकारच्या विज्ञान, तंत्रज्ञान, जैवतंत्रज्ञान विभागातर्फे
घोषित 'स्टार कॉलेज' । डी.एस.टी. (फीस्ट) अंतर्गत अर्थसहाय्य प्राप्त

Date :- 29/06/2019

NOTIFICATION

Sub :- CBCS Syllabi of B. Sc./M. Sc. in Microbiology (Sem I & II)

Ref. :- Decision of the Academic Council at its meeting held on 28/06/2019.

The Syllabi of B. Sc./M. Sc. in Microbiology (First and Second Semesters) as per CBCS-UG/PG Regulations, 2016 and approved by the Academic Council as referred above are hereby notified for implementation with effect from the academic year 2019-20.

Copy of the Syllabi shall be downloaded from the College Website (www.kcesmjcollege.in)

Chairman
Board of Studies

MOOLJI JAITHA COLLEGE, JALGAON • AUTONOMOUS • NAAC GRADE 'A' CGPA-3.15 (3rd CYCLE) ESTD. 1945

Principal,
M. J. College, Jalgaon

To :

1) The Head of the Dept., M. J. College, Jalgaon.
2) The Director, School of Life Sciences, M. J. College, Jalgaon.
3) The office of the COE, M. J. College, Jalgaon.
4) The office of the Registrar, M. J. College, Jalgaon.
5) Office File.

Khandesh College Education Society's

Moolji Jaitha College, Jalgaon

An "Autonomous College" Affiliated to KBC North Maharashtra University, Jalgaon

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SYLLABUS STRUCTURE OF

M. Sc. Microbiology

Under Choice Based Credit System (CBCS)

[w. e. f. Academic Year: 2019-20]

M. Sc. I Microbiology Course Structure

Term / Semester	Course Module	Subject Code	Title of Paper	Credit	Hours per Week
I	DSC	MB 101	Microbial Taxonomy and Diversity	4	4
	DSC	MB 102	Microbial Biochemistry	4	4
	DSC	MB 103	Methods in Microbiology	4	8
	DSC	MB104	Methods in Biochemistry	4	8
	SEC	MB 105	Techniques in Microbiology	4	4
	DSE	MB 106	Cell and Molecular Biology	4	4
II	DSC	MB 201	Microbial Genetics	4	4
	DSC	MB 202	Microbial Enzymology	4	4
	DSC	MB 203	Methods in Molecular Biology and Immunology	4	8
	DSC	MB 204	Methods in Enzymology	4	8
	GE	MB 205	Bioanalytical Techniques	4	4
	DSE	MB 206	Immunology	4	4

M. Sc. II Microbiology Course Structure

Term / Semester	Course Module	Subject Code	Title of Paper	Credit	Hours per Week
III	DSC	MB 301	Applied and Environmental Microbiology	4	4
	DSC	MB 302	Pharmaceutical Microbiology	4	4
	DSC	MB 303	Methods in Biotechnology	4	8
	DSC	MB 304	Methods in Applied Microbiology	4	8
	SEC	MB 305	Research Methodology	4	4
	DSE	MB 306	Agricultural Microbiology	4	4
IV	DSC	MB 401	Fermentation Technology	4	4
	DSC	MB 402	Applied Molecular Biology	4	4
	DSC	MB 403	Methods in Biostatistics and Bioinformatics	4	8
	DSC	MB 404	Project Dissertation	4	8
	GE	MB 405	Biostatistics and Bioinformatics	4	4
	DSE	MB 406	Entrepreneurship in Microbiology	4	4

Examination Pattern for the all Courses (60: 40)

Nature	Marks
External Marks	**60**
Internal Marks	**40**
Total Marks	**100**

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Moolji Jaitha College, Jalgaon

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SYLLABUS

Microbiology

M. Sc. I

(Semester I & II)

Under Choice Based Credit System (CBCS)

[w. e. f. Academic Year: 2019-20]

Preface

Skilled human resource is a prerequisite in the higher education and it is to be acquired thorough knowledge of theoretical concepts and hands-on laboratory methods of the subject. The present syllabus of M.Sc. part I in the subject Microbiology has been prepared as per the guidelines of UGC and cultivate a theoretical and practical know how of different fields of Microbiology. The contents of syllabus have been prepared to accommodate the fundamental aspects as well as advanced developments in various disciplines of Microbiology and to complement the needs of various applied sectors of Microbiology. Beside this, the students will be enlightened with knowledge in the newer areas of Microbial Systematic, Bioinstrumentations, Biomolecules, Microbial Genetics, virology, Immune response, etc. The present syllabus is structured to cater the present and future needs of Microbiology in research field, Industrial Sector, Environmental Sector, etc., with more emphasis on imparting hands-on skills. Hence, the curriculum is endowed with more experiments that shall run hand-in-hand with theory. The detailed syllabus of each paper is appended with a list of suggested readings.

Learning objectives

To acquaint students with:

- Basic concepts, principles and methods of Microbial Diversity, microbial Systematics
- Bioanalytical techniques used in isolation, identification of microbes and their biomolecules.
- Basic and applied aspects of bacteria, algae, fungi and viruses.
- Causes, mechanisms and consequences of defect in gene/genome of microorganisms.
- Basic concepts of microbial physiology, kinetics, regulation and industrial applications of enzymes.
- Biotechnological significance of extremophiles in agriculture, environment, medicine and industry.
- Concepts and significance of cell and molecular biology.
- Immunological mechanisms and techniques

Learning outcome: After completion of this course, students are expected to learn/understand the:

- Isolation, identification, characterization and classification of various microbes from diverse habitat.
- Impact of various groups of microbes on atmosphere, plant, human and animal health.
- Principal and applications of various bio analytical tools and techniques
- Structure, properties, pathways and applications of biomolecules in various fields
- Biochemical mechanisms, characterization, regulation and application of enzymes in various sectors.
- Basic genetic makeup of microbes, defects and their applied aspects in agriculture and industry.

Duration: The duration of M.Sc. (Microbiology) degree program shall be TWO years.

Medium of instruction: The medium of instruction for the course shall be English.

CBCS Autonomous Structure for M. Sc. - 1st Year (Microbiology)

Semester	Core Course	Paper No	Name of Course	No. of Credits	No. of Hours per Week
I	**DSC**	MB 101	Microbial Taxonomy and Diversity	4	**4**
		MB 102	Microbial Biochemistry	4	**4**
		MB 103	Methods in Microbiology	4	**8**
		MB 104	Methods in Biochemistry	4	**8**
	SEC	MB 105	Techniques in Microbiology	4	**4**
	DSE	MB 106	Cell and Molecular Biology	4	**4**
II	**DSC**	MB 201	Microbial Genetics	4	**4**
		MB 202	Microbial Enzymology	4	**4**
		MB 203	Methods in Molecular Biology and Immunology	4	**8**
		MB 204	Methods in Enzymology	4	**8**
	GE	MB 205	Bioanalytical Techniques	4	**4**
	DSE	MB 206	Immunology	4	**4**
			Total Credits	**48**	**64**

DSC MB 101: Microbial Taxonomy and Diversity

Total Hours: 60 **Credits: 4**

Course objective: To acquaint students regarding microbial diversity and taxonomic aspect

Learning outcome

Successful completion of this course students are expected to:

- Learn microbial taxonomy with respect to basic and advance approaches
- Understand habitat, physiological adaptation and applications of Archaea
- Know the ultrastructure, classification, applications of algae, fungi and special forms

Unit I Microbial Systematics **(12 Lectures)**

- Introduction to Bergey's Manual of Systematic Bacteriology 9th Edition.
- Polyphasic identification approaches: 16S rRNA, Ribotyping, Cell wall Fatty Acid Methyl Ester Analysis (FAME), BIOLOG, DNA fingerprinting, Randomly Amplified Polymorphic DNA (RAPD), Metagenomics concept
- Culturable and Non-culturable biodiversity
- Microbial metabolic diversity and Conservation of microbial diversity
- Culture collection centers in India

Unit II Extremophile bacteria (Archaea) **(12 Lectures)**

- Types, properties and cultivation of Archaea: Thermophile, Psychrophile, Barophile, Halophile, Acidophile, Alkalophile, radiation resistant bacteria, Methanogens, Xerophiles and Endoliths
- Biochemistry and physiology of adaptation to extreme environment
- Applications of extremophiles in Agricultural, Pharmaceuticals, Industries, Environment etc.

Unit III Fungi **(12 Lectures)**

- Characteristics: Fungi (Yeast, moulds and dimorphic fungi), mycorrhizal fungi
- Ultrastructure: Fungal hyphae, Flagella, Cell wall, Cell membrane, Nucleus.
- Endophytic fungi: General characteristics, Growth, Cultivation and Significance.
- Ecological significance and Biogeochemical role
- Applications of fungi: Medical significance (Mycoses), Industrial and Biotechnological applications

Unit IV Algae **(12 Lectures)**

- Ultrastructure of algal cell (Flagella, Cell Wall, Cell Membrane, Plastids)
- Nutrition: Physical and chemical requirements, Types based on pigments
- Significance of algae in biogeochemical Cycle, food, Animal feed, fertilizers, cosmetics, therapeutic supplements, extracts (Agar, Alginate, Carrageenan), Biopigments.
- Algal farming for biodiesel
- BGA : General characteristics, cultivation and significance
- Prochlorons and cyanelles

Unit V Virus **(12 Lectures)**

- Structure of virus - Virus proteins, Capsids, Virion membranes, envelope and Nucleic acid
- Ultrastructure of Animal Virus (NIPA), Plant virus (TMV) and Bacterial virus (T4 phage).
- Virus related structures – viroids and prion
- Protein nucleic acid interactions and genome packaging
- Classification of virus on the basis of genome, ICTV nomenclature and classification
- Cultivation of viruses -Basic and advance methods. *In vivo, In vitro/Ex vivo*
- Detection/Enumeration of viruses - Plaque formation & cytopathic effect.
- Emerging viruses: Zika and NIPA Virus, Soybean Vein Necrosis Virus (SVNV), Viral Haemorrhagic fever.
- Viruses in Oncogenesis: Oncogenic viruses. Source and causes of viral induced oncogenesis, Mechanism of viral induced oncogenesis and its prevention, Diagnosis and treatment.

Suggested reading

- Becker, E. W. (1994) Microalgae- Biotechnology and Microbiology, Cambridge University Press, UK. Burnett, J. H.
- Kevin Kavanagh (2005) Fungi:Biology & Applications, JohnWiley&Sons Ltd.,West Sussex,
- Jim Deacon (2006) Fungal Biology, 4th Ed. Blackwell Publishing Ltd., West Sussex
- Alexopoulous, C. J. and Mims, C. W. (1979) Introduction to Mycology, Wiley Eastern Ltd., New Delhi
- Griffin, D. H. (1994) Fungal Physiology, Wiley-Liss, New York
- Kathy Talaro and Barry Chess (2012) Foundations in Microbiology, 8th Edn., The McGraw-Hill Companies, Inc., New Delhi
- Tortora, Funke and Case (2010) Microbiology, 10th Edn., Brenjamin Cummings Inc. California
- Moselio Schaechter (2009) 2nd Ed, Desk encyclopaedia of Microbiology, Elsevier
- Prescott, Harley and Klein's (2002) Microbiology, 5th Ed. The McGraw-Hill Companies, Inc.,
- Fred A. Rainey and Aharon Oren (2006) Extremophiles, Methods in Microbiology, Volume 35 Elsevier and Academic Press,
- Martin Dworkin (Editor) (2006) The Prokaryotes A Handbook on the Biology of Bacteria Volume 2, Ecophysiology and Biochemistry, Springer-Verlag New York.
- Michael T. Madigan, John M. Martinko, Paul V. Dunlap, David P. Clark, (2009) Brock Biology of Microorganism, Benjamin Cummings, California, USA.
- Bergey's Manual of Systematic Bacteriology (2001) Editor-in-chief: Garrity, George M. Boone, David R.; Castenholz, Richard W. (Eds.), (4 Volumes) Springer/ Williams and Wilkins, USA
- Kushner, D.J. eds. (1978) Microbial life in extreme environments. Academic Press, London.
- Horikoshi, K., Grant, W.D. eds. (1998) Extremophiles, Microbial life in extreme environments. Wiley- Liss Publishers, New York.

DSC MB-102 Microbial Biochemistry

Total Hours: 60 **Credits: 4**

Course objective: To study the microbial biochemistry

Learning outcome

Successful completion of this course students are expected to:

- Learn structure and properties of Biomolecules
- Understand Transport and energy metabolism
- Know metabolism of carbohydrates, lipids, amino acid and nucleotide.
- Understand various metabolic pathways and Bioenergetics

Unit I Biomolecules (12 Lectures)

- Classification, Structure and Significance of carbohydrates, lipids, proteins and nucleic acids.
- Chemical bond formation in carbohydrates, lipids, proteins and nucleic acids: cot value & Tm
- Structural organization of proteins: Primary, secondary, Tertiary and Quaternary structure; Ramachandran plot
- Topology of DNA
- Vitamins of microbial origin: Structure, properties and Functions.

Unit II Transport and energy metabolism (12 Lectures)

- Ultrastructure of cell membrane and structural features
- Transport of molecules: Types of transport – (a) Active, (b) Passive, (c) Facilitated, (d) Translocation. Na/K+ ATPase.,(e) Ionophores and siderophores
- Energy metabolism: Free energy, bacterial and mitochondrial ETC, ATP Synthase complex, inhibitors of oxidative phosphorylation, Energetics of ETC.

Unit III Metabolism of carbohydrates (12 Lectures)

- Metabolic pathway, EMP, TCA, Glyoxylate pathway, C3 and C4 pathway, bioenergetics and regulation.
- Alternative glycolytic pathways (HMP)

Unit IV Metabolism of Lipids (12 Lectures)

- Metabolic pathway, Bioenergetics and regulation of Fatty acid synthesis
- Catabolism of lipids and FAS Complex

Unit V Amino acid and Nucleotide metabolism (12 Lectures)

- Metabolic pathway, Bioenergetics and regulation of: amino acid degradation and biosynthesis
- Transamination, Deamination, Stickland Reaction.
- Metabolic pathway, Bioenergetics and regulation : Purines and Pyrimidine biosynthesis: De novo pathway and Salvage pathway, Ribonucleotide reductase and inhibitors of nucleic acid biosynthesis

Suggested readings

- White, D. (2000) The Physiology and Biochemistry of Prokaryotes, Oxford University

Press, New York, USA
- Gottschalle, G (2004) Bacterial Metabolism, Springer, Weinheim
- Moat, A. G. and Foster, J. (1988) Microbial Physiology, Wiley Interscience Publ., New York
- Nelson, D.L. and Cox, M.M. (2000) Lehninger's Principles of Biochemistry, CBS Publications, New Delhi
- Stryer, L. (1992) Biochemistry, 4th Edn., W.H. Freeman and Co., New York, USA
- Price, N.C. and Stevens, L. (2000) Fundamentals of Enzymology, 3rd edn., Oxford University, Press, NY, USA.
- Voet, D., Voet, J.G. and Pratt C.W. (1999) Fundamentals of Biochemistry. John Wiley & Sons, Inc., Chicheter, UK
- Murray, R.K., Granner, D.K., Mayes, P.A. and Rodwell, V.W. (2003) Harper's Biochemistry. Appleton and Lange, Stamford, Connecticut.
- Jain, J.L., Jain, S. and Jain, N. (2009) Fundamentals of Biochemistry, S Chand, New Delhi
- Das, H. K. (2005) Text book of Biotechnology, 2nd Edn. Wiley Deramlech India Pvt. Ltd., New, Delhi.
- Doelle, H.W. (1975) Microbial Metabolism, 2nd Edn, Academic Press, London

DSCMB 103 (Practical) Methods in Microbiology

Total Hours: 60 **Credits: 4**

Course objective: To study advances methods used in microbiology

Learning outcome

Successful completion of this course students are expected to:

- Learn bio-safety procedures in microbiology
- Understand cultivation of algae, and fungi
- Know nucleic acid and protein separation techniques
- Get hands on advance instrumentation such as HPLC, GC, AAS

1. Biosafety: Safe Laboratory techniques (GLP), Equipment related hazards, Biosafety cabinets, Transport of infectious material/cultures, Waste disposals, Fire and electricity hazards, Immunization of staff & MSDS.
2. Identification of fungus based on morphological / biochemical features (any one fungus)
3. Isolation and cultivation of cyanobacteria/ Algae.
4. Isolation and cultural characterization of Actinomycetes.
5. Isolation and enumeration of Bacteriophages by Plaque Titer method
6. Isolation of Acidophile/ Alkalophile/ Halophile/ Thermophile/ Psychrophile bacteria from extreme environments.
7. Cultivation of anaerobic microbes using jar (candle / gas pack) method and demonstration of cultivation in anaerobic chamber
8. Cultivation of Endophytic fungi
9. Study of microbiological specimen with Phase contrast microscope / inverted microscope
10. Growth curve of yeast by Turbidity (Spectrophotometer/ Nephelometer) and Dry mass measurement
11. Separation of proteins by SDS PAGE technique

12. Separation of Nucleic acid by Agarose gel electrophoresis
13. Column chromatography – Sepharose/Agarose/XAD/Octyl/CM Cellulose/DEAE Cellulose
14. 16S r-RNA gene sequence analysis using BLAST and preparation of phylogenetic tree
15. Demonstration/ analysis of samples with HPLC/ GC/AAS

Suggested readings:

- Norris, J. R. and Ribbons, D. W. (Ed) (1969) Methods in Microbiology, Vol 1, Academic Press Inc. Ltd., London
- Harley, J. P., Lansing, M. Prescott, (2002) Laboratory Exercises in Microbiology, 5th Edn., The McGraw−Hill Companies, New York
- Benson, H. (2001) Microbiological Applications Lab Manual, 8th Edn. The McGraw Hill Co., New York
- Aneja, K.R. (1996) Experiments in Microbiology, 3rd Edn., Wishwa Prakashan, New Delhi.
- Parija, S.C. (2005) Text Book of Practical Microbiology, Ahuja Publishing House, New Delhi.
- Patil, Ulhas and Muskan, Kalyani (2009) Essential of Biotechnology, IK International, New Delhi
- Dubey, R.C. and Maheshwari, D.K. (2004) Practical Microbiology, S. Chand and Co. New Delhi.

DSC MB 104 (Practical) Methods in Biochemistry

Total Hours: 60 **Credits: 4**

Course objective: To study qualitative and quantitative techniques in biochemical analysis

Learning outcome

Successful completion of this course students are expected to:

- Learn Basic biochemistry preparations
- Understand biochemical analysis of sugar, protein & nucleic acid
- Hands on qualitative and quantitative estimations in biochemistry
- Know the bioinformatics to study the bio-molecule

1. Basic biochemical techniques: Use of hand glove, Use of pipette aid, Preparation of standard solutions and buffers, Dilution approaches and Calibration of glass wares (pipette &volumetric flask)
2. Preparation of standard operating procedure for any one process in microbiology laboratory
3. Calibration of any one instrument in microbiology laboratory viz. balance, pH meter, spectrophotometer, oven, incubator etc.
4. Preparation of buffers of various pH and determination of pKa of a buffer system
5. Isolation and characterization of bacterial pigment
6. Qualitative analysis of biomolecules by Thin Layer Chromatography: Sugars and amino acids
7. Quantitative analysis reducing sugar by DNSA method.
8. Quantitative estimation of Total carbohydrate - Phenol sulphuric acid method.
9. Quantitative estimation of protein - Folin-Ciocalteu method/Biuret Method.
10. Quantitative estimation of amino acids by ninhydrin method.
11. Quantitative estimation of free fatty acids by titration
12. Quantitative estimation of lipids using Iodine number and acid value.
13. Quantitative estimation of DNA by Diphenyl amine method.

14. Quantitative estimation of RNA by Orcinol method.
15. Study of biomolecules using RasMol/ SPDBV software.

Suggested readings:

- Thomas, G.M. and Shalkhammer, (2004) Analytical Biotechnology, Springer, New Delhi
- Thimmaiah, S.R. (2006) Standard Methods of Biochemical Analysis, Kalyani Publishers, New Delhi.
- Plummer, D.T. (2001) An Introduction to Practical Biochemistry, 3rd edn., McGraw Hill Ltd. New Delhi
- Sawhey, S.K. and Singh, R. (2002) Introductory Practical Biochemistry, Narosa Publication House, New Delhi.
- Jayramann, J. (2008) Laboratory Manual in Biochemistry, New Age International, New Delhi.
- Schmauder, H.P, Schweizer, M. and Schewizer, L.M. (2003) Methods in Biotechnology, Taylor and Francis Ltd., London

SEC MB-105 Techniques in Microbiology

Total Hours: 60 **Credits: 4**

Course objective: To study important techniques associated in microbiology

Learning outcome

Successful completion of this course students are expected to:

- Understand basic concept of enzyme and protein techniques
- Learn the diagnostic methods in virology
- To understand the cell culture technique in plant and animals
- Know the concept of biomarker and biosensor

Unit I Enzyme technology **(12 Lectures)**

- Basic principle of enzyme assay
    - Initial velocity, progressive curve, transient kinetics & relaxation
- Standardization and optimization of enzyme assay
    - Concentration of substrate, activators & inhibitors
    - Optimum pH, Ionic strength and temperature
- Enzyme preparation
- Measurement of enzyme activity
    - Direct & fixed incubation method - continuous and discontinuous assay
    - Indirect / kinetic study
- Immobilization of enzyme
    - Adsorption, covalent binding, entrapment & membrane confinement
    - Kinetics of immobilized enzyme
    - Effect of diffusion and productivity
    - Application of immobilized enzyme

Unit II protein purification **(12 Lectures)**

- Sample preparation
    - Define properties of target protein

    - Develop analytical assay
    - Sample extraction and clarification
- Three phase purification strategy
    - Capture – removal of contaminant Streamlining
    - Intermediate purification
    - Polishing
- Example of any one purification strategy e.g. enzyme / antigen / membrane protein
- Sample storage conditions

Unit III Diagnostic and detection methods for Viruses (12 Lectures)

- Sampling techniques and Processing of samples – Enrichment and concentration
- Direct methods of detection – light microscopy (inclusion bodies), electron microscopy and fluorescence microscopy
- Immnuodiagnosis, hemagglutination and hemagglutination-inhibition tests, Complement fixation, neutralization, Western blot, Radioactive Immuno precipitation Assay (RIPA), Flow cytometry and Imunohistochemistry.
- Nucleic acid based diagnosis: Nucleic acid hybridization, polymerase chain reaction, microarray and nucleotide sequencing, LINE probe assay
- Infectivity assay for animal and bacterial viruses - plaque method, pock counting, end point methods, LD50, ID50, EID50, TCID50
- Infectivity assays of plant viruses

Unit IV Tissue culture (12 Lectures)

- Animal tissue culture
    - Facilities for animal tissue culture – infrastructure, equipment, vessels etc.
    - Contamination, Sterilization and aseptic conditions
    - Culture media and cell lines
    - Advantage and limitations
    - Applications in pharmaceutical, genetic engineering etc.
    - Risk, safety and biohazards
- Plant tissue culture
    - Concept, benefits and types
    - Types of culture – cell, callus etc.
    - Requirements of PTC - Media, laboratory, equipment's
    - Principle, protocol and Methods in PTC
    - Applications of PTC

Unit V Biomarkers and Bioreporters (12 Lectures)

- Concept and approaches to metagenomics analysis & ecological inference
- Biomarker gene (antibiotic and heavy metal resistance genes, ice nucleation, bioluminescence genes, green fluorescent genes)
- Bioreporter genes
- Biosensor: Types, components, principle, working and applications

References:

- Dayananda K. S. (2007) Protein purification theory and techniques, Viva Books Pvt. Ltd.

New Delhi
- Nooralabettu Krishna Prasad (2011) Enzyme technology – pacemaker of biotechnology, PHI learning Pvt. Ltd., New Delhi
- Kulkarni N. S. and Deshpande M. S. (2007) General enzymology, Himalaya publishing, Delhi
- Edward K. Wagner, Martinez J. Hewlett, (2004), Basic Virology, Blackwell Publishing
- Flint S. J., V. R. Racaniello, L. W. Enquist, V. R. Rancaniello, A. M. Skalka, (2003), Principles of Virology: Molecular Biology, Pathogenesis, and Control of Animal Viruses, American Society Microbiology
- Haaheim L. R., J. R. Pattison and R. J. Whitley, (2002), A Practical Guide to Clinical Virology. 2nd Ed. Edited by, John Wiley & Sons, Ltd.
- Knipe David M., Peter M. Howley, Diane E. Griffin, Robert A. Lamb, Malcolm A. Martin, Bernard Roizman, Stephen E. Straus, (2007), Field's Virology, 5th Ed. Lippincott Williams & Wilkins
- Brian W.J. Mahy, Hillar O. Kangro, (1996), Virology Methods Manual, Elsevier Science & Technology Books.
- Stephenson John R. (Editor), Alan Warnes, (1998), Diagnostic Virology Protocols: Methods in Molecular Medicine, Humana Press
- U Satyanarayana (2005) Biotechnology, Books and Allied (P) ltd, Kolkata
- Chawla HS (2002) Introduction to plant biotechnology, Oxford and IBH publishing Co Pvt. Ltd. New Delhi
- Das H. K. (2005) Text book of Biotechnology, Wiley Dreamtech India Pvt. Ltd., New Delhi

DSE MB-106 Cell and Molecular Biology

Total Hours: 60 **Credits: 4**

Course objective: To study cellular and molecular aspect of microbial cell

Learning outcome

Successful completion of this course students are expected to:

- Understand basic concept of cell structure and molecular biology
- Learn the process of DNA replication and mechanism of damage / repair
- To understand the process of transcription, translation,
- Know the mechanism of protein targeting and degradation.

Unit I Cell Biology **(12 Lectures)**

- Structure, Function, oxidative Metabolism in the Mitochondrion, Role of Mitochondria in the formation of ATP
- Translocation of Protons and the establishment of a proton-motive force, machinery for ATP formation – Peroxisomes.
- Genome studies of Mitochondria.
- Chloroplast structure and function: An overview of photosynthetic metabolism, components of cytoskeleton, Microtubules, Intermediate filaments – Microfilaments,
- Protein trafficking, Cell- to -Cell Signaling: Hormones and Receptors, Intracellular signalling in Development and Disease,
- Transport across Cell Membranes,
- Protein Sorting: Organelle Biogenesis and Protein secretion

Unit II Cell Components (12 Lectures)

- Cell components and their functions (Prokaryotic/ Eukaryotic)
- Dynamic structure, functions and biogenesis of cell wall and plasma membrane
- New insights in structure and function of cytoplasmic cell organelles and biopolymers;
- Nucleus: its components, chromatin structure in eukaryotes, condensation and packaging of DNA in prokaryotes

Unit III DNA replication (12 Lectures)

- DNA Structure and Replication: DNA replication machinery in Prokaryotes and eukaryotes, Replication fork.
- Enzyme of DNA Replication: dNA polymerase (I, II, III), primases, ligases, helicases, topoisomerases, gyrases and SSBP.
- Models of DNA Replication: theta mode of replication, rolling circle model of replication, unidirectional replication, Bidirectional replication, replication of linear, Regulation of DNA replication and inhibitors of DNA replication.
- Concept of Operon: Structure and regulation of lac, ara, his and tryptophan operons. Regulation of lytic and lysogenic pathway in lamda bacteriophage
- Gene regulation in eukaryotes: DNA rearrangements, Chromatin modification, Cis-acting site, RNA Silencing

Unit IV Transcription and Translation (12 Lectures)

- Types of RNA polymerase (prokaryotic and eukaryotic), Process of transcription
- mRNA processing, editing: capping, adenylation, splicing, RNA transport
- Transcriptional regulation: transcriptional bursting/pulsing, specificity factors, enhancers, repressors, activators and general transcription factors
- Post-transcriptional modifications: RNA degradation, nuclear transport, mRNA localization, anti-sigma factors, RNAi (siRNA, miRNA and CRISPR mechanism)
- Genetic code and its properties
- Ribosome (structure and composition), Activation of tRNA, tRNA synthetase
- Steps: Initiation: factors and their regulation, Elongation, Termination Inhibitors
- Post translational modification of proteins and protein degradation
- Translational regulation: Cytoplasmic polyadenylation, UTR sequence elements, RNA binding proteins, ribosomal regulation, non-sense mediated RNA decay, 5` decapping

Unit V DNA Damage and Repair (12 Lectures)

- DNA damage: deamination, oxidative damage, alkylation, pyrimidine dimmers, mechanical and chemical damage
- DNA mutations: Spontaneous and inducible and mutagenic agents.
- DNA repair pathways: Methyl directed mismatch repair, very short patch repair, nucleotide excision repair, base excision repair, recombination (Specific and Nonspecific), mismatch, SOS

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- Alberts B, Johnson A, Lewis J, Raff Martin, Roberts K and Walter P. (2007) Molecular Biology of the Cell. Garland Publ., NewYork.
- Bonifacino JS, Dasso M, Harford JB, Liipincott-Schwartz J and Yamada KM. (2004) Short Protocols in Cell Biology. John Wiley & Sons, NewJersey.
- Bregman AA (1987) Laboratory Investigations in Cell Biology. John Wiley & Sons, New

York.
- Hawes C and Satiat-Jeunemaitre B (2001) Plant Cell Biology: Practical Approach. Oxford University Press,Oxford.
- Hirt RP and Horner DS (2004) Organelles, Genomes and Eukaryote Phylogeny: An evolutionary synthesis in the age of genomics. CRCPress.
- Karp G. (2008) Cell and Molecular Biology: Concepts and Experiments. John Wiley & Sons.
- Lodisch H, Berk A, Kaiser CA, Krieger M, Scott MP, Bretscher A, Ploegh H and Matsudaire P (2008) Molecular Cell Biology. WH Freeman & Co., NewYork.
- Ruzin SE (1999) Plant Micro-technique and Microscopy. Oxford Univ. Press,Oxford.
- Wischnitzer S. (1989) Introduction to Electron Microscopy. PergamonPress,

Semester II

DSC MB 201: Microbial Genetics

Total Hours: 60 **Credits: 4**

Course objective: To study various genomic aspects of microorganism

Learning outcome

Successful completion of this course students are expected to:

- Learn Basic genome organization of microbes
- Understand microbial genome vocabulary
- Know the biology of plasmid and their applications
- Learn implications of mutation and DNA biotechnology

Unit I Genome organization (12 Lectures)

- General features of genome: Bacteria, Viruses, Algae and Fungi.
- Genome: *E. coli*, Phage (T4, T7, cpX174), Algae (BGA/Spirulina) and Fungi (Neurospora).
- Genome vocabulary: Operon, interrupted genes, gene families, structure of chromatin and chromosomes, unique and repetitive DNA, heterochromatin, euchromatin, allele, transposons.

Unit II Virus Genome replication (12 Lectures)

- General aspects of viral genome replication: Gapped, Segmented, Positive, strands of DNA, Negative strands of DNA, Positive strands of RNA, Negative strands of RNA.
- Replication: DNA replication (Initiation, elongation and termination), Double stranded RNA replication. Single-stranded RNA replication.
- Mechanism of reverse transcription and viral interference

Unit III DNA Implication of Mutation (12 Lectures)

- Effects of mutation on the gene product: loss of the function of mutants (null, leaky mutations), gain of function of mutants, random or adaptive mutations,
- Significance of mutants: Uses of bacterial and fungal mutants in strain improvement. Bacteriophage mutants in viral genetics, Plasmids in emergence of Multiple Drug Resistance.
- Detection and isolation of mutant – Replica plate, resistance selection, substrate utilization, carcinogenicity test
- Use of Mutants in microbiology: determination of function, demonstration of metabolic pathway and regulation, correlation of biochemical entity and function, locating site of action of external agents, production of useful products.

Unit IV Plasmid biology (12 Lectures)

- Characteristics and Features of bacterial plasmid: Size, Conformation, origin of replication, replication proteins, regulation of plasmid copy number, amplification, segregation and compatibility. Curing of plasmids and plasmid incompatibility.
- Types of plasmid in: Bacteria (R, F, Ti, Vi, Ri, Deg, Col) and Saccharomyces (Snapfast).
- Plasmid segregation: Random diffusion, par regions, post-segregational killing.
- Plasmid isolation: Isolation and purification techniques for bacterial plasmids

Unit V DNA Biotechnology (12 Lectures)

- History and prospects of recombinant technology/ Genetic engineering

- Strategies of Genetic engineering:
  - Formation of DNA fragment with restriction enzyme, use of linkers, adaptors and homopolymer tails
  - Splicing of DNA into vectors – DNA ligases, cloning vectors and insertion of foreign DNA
  - Mechanism of transformation of r DNA to recipient cell and its expression
  - Selection of clones – colony and plaque hybridization, southern blotting
- Gene cloning in Eukaryotic microbes
  - Transformation in filamentous fungi, Ti Plasmid, gene gun, genomic library
- Application of gene technology – production of pharaceuticals, diagnosis of disease, insect pest control, pollution control etc.

Suggested readings

- Streips, U. N. and Yasbin, R. E. (2002) Modern Microbial Genetics, 2nd Edn., Wiley-Liss, New York
- Maloy, S. and Freifelder, D. (1994) Microbial Genetics, Jones and Barlett Publishers, London
- Dale, J. W. (1994) Molecular Genetics, John Wiley and Sons, Hoboken, NJ, USA
- Upadhyay, A., and Upadhyay, K. (2005) Molbio: Fundamentals of Molecular Biology, Himalya Publication House, Mumbai
- Trun, Nancy Jo and Trempy, J. E.(2006) Fundamental Bacterial Genetics, Blackwell Publishers, New York
- Verma, P.S. and Agrawal, V.K. (2005) Cell Biology, Genetics, Molecular Biology, Evolution and Ecology, S Chand and Co., New Delhi
- Gupta, P.K. (2008) Cell and Molecular Biology, Rastogi Publications, Meertut
- Rastogi, V. B. (2008) Fundamentals of Molecular Biology, Ane Books, New Delhi
- Larry, Snyder and Wendy, Champness (2007) Molecular Genetics of Bacteria, 3rd Edn, ASM Press, Washington, USA.
- Malacinski, G.M. (2005) Freifelder's Essentials of Molecular Biology, 4th Edn., Narosa Publishing House, New Delhi
- Dubey RC and Maheshwari DK (2005) Text book of Microbiology, S. Chand & co, New Dehli

DSC MB 202: Microbial Enzymology

Total Hours: 60 **Credits: 4**

Course objective: To study advance enzymology and its utility in industry

Learning outcome

Successful completion of this course students are expected to:

- Learn concepts in Enzymology
- Understand Catalytic mechanisms and regulation
- Learn Enzyme kinetics and inhibitions
- Know the Industrial applications of enzymes and extremozymes

Unit I Concepts in Enzymology (12 Lectures)

- General characteristics of enzyme, Ribozyme, Abzyme and Coenzymes
- Enzyme Nomenclature, classes of enzymes, enzyme activity, Specific activity, catal,

Substrate specificity, Enzyme turnover number: Concept and significance

- Enzyme active site
- Effect of pH, temperature, substrate concentration and activator on enzyme activity
- Isoenzyme: Concept and properties e.g. LDH
- Multienzyme complexes- pyruvate dehydrogenase (PDH) and fatty acid synthetase, advantages of multienzyme complex

Unit II Enzyme Kinetics (12 Lectures)

- Elementary reactions, Reversible reactions, Rates of reactions, Transition state theory
- The Michaelis-Menten Equation, Concept of Km and Vmax, Double reciprocal plot and Brigg's Haldane plot, Analysis of Kinetic Data.
- Enzyme Inhibition : Competitive Inhibition, Non-competitive, Uncompetitive Inhibition and Mixed Inhibition, Bi-substrate kinetics and Oligomeric enzymes

Unit III Mechanism and regulation of enzyme catalysis (12 Lectures)

- Acid-Base Catalysis: Covalent Catalysis, Metal Ion Catalysis, Electrostatic Catalysis, Catalysis through Proximity and Orientation Effects, Catalysis by Preferential Transition State Binding
- Serine Proteases : Kinetics and Catalytic Groups, X-Ray Structures, Catalytic mechanism, Testing Catalytic Mechanism, Zymogens
- Enzyme regulation: Feedback inhibition, enzyme repression, induction and degradation, enzyme regulation by cAMP, covalent modification, allosteric regulation of enzymes (ATCase)

Unit IV Industrial applications of enzymes (12 Lectures)

- Perspective of use of enzyme in industry
- Source, Significance and biotechnological applications of: Cellulases (Cellulose hydrolysis), Proteases (protein hydrolysate). Amylases (maltodextrin preparation), Lipases (oil industry), Pectinases (clarification of fruit juices), Laccases (delignification) and Asperaginase

Unit V Extremozymes (12 Lectures)

- Microbial source, characteristics and biotechnological significance of extremozymes from thermophiles, psychrophiles, acidophiles, alkalophiles, halophiles. Solvent resistant enzymes.
- Non aqueous enzymology and Biosurfactants

Suggested readings

- Stryer, L. (2004) Biochemistry, 5th Edn., W. H. Freeman and Co., New York
- Palmer, T. (2004) Enzymes: Biochemistry, Biotechnology and Clinical Chemistry, Affiliated East- West Press Pvt. Ltd., New Delhi
- Price, N. C. and Stevens, L. (2000) Fundamentals of Enzymology, Oxford University Press, New York.
- Dixon, M. Webb, E. C., Throne, C.J.R. and Tipton, K. F., Enzymes, Academic Press, New York
- Pandey, A., Webb, C., Soccol, C.R, and Larroche, C. (2005). Enzyme Technology, Asiatech Publishers Inc., New Delhi
- Cook, Paul, F. and Cleland, W.W. (2007) Enzyme Kinetics and Mechanism, Garland Science, New York.
- Nooralabettu, K. P. (2011) Enzyme Technology Pacemakar of Biotechnology, PHI Learning

Pvt. Ltd., New Dehli
- Shanmugam, S. and Sathishkumar, T. (2009) Enzyme Technology, I K International, New Delhi
- Satyanaryana, T. (1999) Biochemistry, Books and Allied Pvt. Ltd., Calcutta
- Jain, J.L, Jain, S, and Jain, N (2005) Fundamental Biochemistry, S. Chand and Co., New Delhi
- Nelson, D.L. and Cox, M.M. (2000) Lehninger's Principles of Biochemistry, CBS Publications, New Delhi.

DSC MB 203 (Practical) Methods in Molecular Biology and Immunology

Total Hours: 60 **Credits: 4**

Course objective: To study methods in Molecular Biology and Immunology

Learning outcome

Successful completion of this course students are expected to:

- Learn methods used in molecular biology of microorganism
- Understand process of DNA amplification using PCR technique
- Learn technique of isolation of plasmid and microbial DNA
- Know the immunological techniques useful in microbiology

1. Bacterial transformation.
2. Bacterial conjugation.
3. Isolation and detection of bacterial/ Fungal DNA.
4. Isolation of RNA from yeast cells
5. Detection and quantification of purity of DNA/ Protein using spectrophotometer
6. Isolation of plasmid
7. Curing of plasmid.
8. Restriction digestion by endonucleases.
9. PCR amplification of DNA.
10. Effect of physical/Chemical mutagen on growth of bacteria
11. Immuno-diffusion by Ouchterlony double diffusion
12. Immuno-electrophoresis
13. Bacterial gene expression using IPTG /X-gal
14. Detection of antigen/ antibody using ELISA technique
15. Blotting technique : Westem/Southem/Northern blot

Suggested readings:

- Schmauder, H. P., Schweizer, M. and Schweizer, L. M. (2003) Methods in Biotechnology. Taylor and Francis, London
- Joe Sambrook (2001) Molecular Cloning: A Laboratory Manual, 3rd Edn., (3 volume set) Cold Spring Harbor Laboratory Press,
- Sawhey, S.K. and Singh, R. (2002) Introductory Practical Biochemistry, Narosa Publication House, New Delhi.
- Thimmaiah, S.R. (2006) Standard Methods of Biochemical Analysis, Kalyani Publishers, New Delhi.
- Davis, L.G., Dibner, M.D. and Battey, J.F. (1986) Basic Methods in Molecular Biology, Appleton and Lange, Norwalk.

DSC MB 204 (Practical) Methods in Enzymology

Total Hours: 60 **Credits: 4**

Course objective: To study the practical orientation on enzymology

Learning outcome

Successful completion of this course students are expected to:

- Learn qualitative and quantitative enzyme assay and basic enzymology
- Understand Effect of environmental factors on enzyme
- Learn Enzyme kinetics, inhibitions and immobilization
- Know the purification process of enzymes

1. Quantitative estimation of enzyme (Enzyme activity, specific activity, IU)
2. Effect of pH on enzyme activity
3. Effect of temperature on enzyme activity
4. Effect of organic solvent on enzyme activity
5. Effect of activator on enzyme activity and determination of kinetic parameters
6. Determination of enzyme kinetics using suitable software (Sigma Plot)
7. Screening and evaluation of inhibitor on enzyme and determination of Ki and Vmax
8. Inoculum development, Production and recovery of any suitable enzyme
9. Purification of enzyme by salting out and dialysis
10. Purification of enzyme by column chromatography and determination of purification fold and yield parameters
11. Detection of enzyme by zymography: Substrate gel electrophoresis
12. Electrophoretic determination of Molecular weight of enzyme by PAGE: SDS, Native
13. Demonstration of structural prediction of suitable enzyme with ExPasy server
14. Enzyme stabilization by immobilization technique (Gel entrapment/ Crosslinking)
15. Production of maltodextrin using amylase (% conversion method/Degree of hydrolysis method)

NB: Use any ONE enzyme from the following: Amylase, Protease, Phytase, Laccase, Lipase, 3-Galactosidase, Xylanase, Cellulase

Suggested readings:

- Thimmaiah, S.R. (2006) Standard Methods of Biochemical Analysis, Kalyani Publishers, New Delhi.
- Bisswanger, Hans (2011) Practical Enzymology, Wiley-VCH, Germany.
- Robert Eisenthal and Michael Danson (2002) Enzyme Assays: A Practical Approach, 2nd Edn. Oxford University Press, USA.
- Plummer D.T. (2001) In introduction to Practical Biochemistry, 3rd edn., McGraw Hill Ltd. N. Delhi.
- Sawhey, S.K. and Singh, R. (2002) Introductory Practical Biochemistry, Narosa Publication House, New Delhi.
- Jayramaim, J. (2008) Laboratory Manual in Biochemistry, New Age International, New Delhi

GE MB -205 Bioanalytical Techniques

Total Hours: 60 **Credits: 4**

Course objective: To study concepts in Immunology and immunotechniques

Learning outcome

Successful completion of this course students are expected to:

- Learn Principles of biophysical chemistry
- Understand Methods of separation techniques
- Learn Radio-labeling techniques
- Know the Microscopic techniques for electron microscopy

Unit I Basic Techniques **(12 Lectures)**

- Basic techniques: Lab maintenance and sterilization techniques
- Preservation of materials – types of fixatives, macerations, peeling, mounting.
- Microtome: - types of microtome, serial sectioning.
- Staining: - types and procedure of staining (double and multiple staining).
- General principles of biophysical chemistry: -pH, pH meter, types of electrodes and working.
- Thermodynamics, conductivity, buffer, turbidity.

Unit II Advance Microscopy **(12 Lectures)**

- Microscopic techniques historical microscopy, principle of microscopy
- Types and working of light microscope, electron microscope(SEM and TEM), dark field microscopy, fluorescence microscopy, phase contrast microscope, flow cytometry, confocal microscopy.
- Micrometry: - metric units, principles and techniques. Properties of light-wavelengths and resolving power of microscope.

Unit III Separation Techniques **(12 Lectures)**

- Centrifugation techniques: - principles and working of centrifuge
- RPM, rotors and its types, types of centrifuge (high speed centrifuge, ultra-centrifuge, and gradient centrifuge)
- Chromatographic techniques: - basic principles of chromatography
- Rf value calculation, adsorption, absorption, solvents and solutes
- Paper chromatography, column chromatography, gel filtration, ion exchange chromatography, HPLC, gas chromatography.
- Electrophoresis: - gel electrophoresis (one and two dimensional)
- SDS-PAGE, AGAROSE. Various methods and agents used in detection of bands.
- Blotting techniques – southern blotting, northern blotting, and western blotting, south western blotting.

Unit IV Spectroscopy **(12Lectures)**

- Spectroscopic techniques: - relation of wavelength and energy, principles and working of visible spectrophotometer,
- U.V. spectrophotometer, I.R. spectrophotometer, flow cytometry, NMR and mass spectrometry, Atomic absorption spectrophotometer

Unit V Radiotechnique and immotechique (12 Lectures)

- Radio labeling and radioactive techniques
- Properties of different types of radioisotopes in biological system, radio degradation, half-life period, radio dating, radio labeling, auto radiography, dosimetry, safety guidance.
- Rocket immunoelectrophoresis, and Ouchterlony double diffusion method

Reference Books:

1. Krishnamurthy K.V. (1988) Methods in Plant Histochemistry.S. Wiswanathan Printers & Publishers
2. De Roberti's and De Roberti's (2005) Cell and Molecular Biology, Lippincott Williams, Philadelphia. [B.I Publications Pvt. Ltd. New Delhi].
3. Powar C.B 2005 (Third Edition). Cell Biology, Himalaya Publishing, Mumbai.
4. Verma P.S and Agarwal V.K (2006) Cell Biology, Genetics, Molecular Biology, Evolution, Ecology. S.Chand and Company, New Delhi.
5. Upadhyay, Upadhyay, Nath (2010)''Biophysical chemistry Principals and Techniques" Himalaya publication Mumbai.
6. Jacquelyn G Black (2011) "Microbiology principles and exploration 6th edition 2005 john Wiley and sons USA.
7. Sadasivam S., Manikam A. (2018) "Biochemical analysis" New age publication, New Delhi.

DSE MB -206 Immunology

Total Hours: 60 **Credits: 4**

Course objective: To study concepts in Immunology and Immunotechniques

Learning outcome

Successful completion of this course students are expected to:

- Learn Immune system and immune response
- Understand detail procedure of hyper immune response
- Learn Immune response to infections and diseases
- Know the Histochemical and immune techniques

Unit I Overview of the Immune System (12 lectures)

- Morphology and functions of organs of the immune system.
- Morphology, formation and functions of cells of immune system.
- Antibody diversity - Somatic gene recombination, Genesis of light and heavy chain diversity.
- Major Histocompatibility Complex: Structure, Properties and distribution.
- Graft rejection: Mechanisms, HLA typing.

Unit II Mechanisms of immune response (12 lectures)

- Cell mediated Immune response : T-cell, Types of T cells, T cell activation
- Humoral Immune response: B cell. Plasma cell, B cell activation (T dependent and T-independent pathway)
- Complement system - Pathway and Role, Complement deficiency.
- Inflammatory response - Functions, Types and Mechanisms.

- Immunotolerance : General features of immunologic tolerance , T and B lymphocyte tolerance , Tolerance induced by foreign protein antigens

Unit III Hyper immune response (12 lectures)

- Hypersensitivity: Types (I-IV) and mechanism of each type.
- Autoimmune diseases: Mechanisms for induction of autoimmunity, Organspecific and systemic, Treatment of autoimmune diseases.

Unit IV Immune response to infections and diseases (12 lectures)

- Immunity against bacterial, viral, Fungal and protozonal infections.
- Tumor immunology: Types of tumors, oncogenesis and tumor antigens (TATAs, TSTA), Immune response to tumors.
- Immunodeficiency diseases (e.g. SCID, CVI, AIDS)

Unit V Histochemical and immunotechniques (12 lectures)

- Production and applications of monoclonal antibodies
- Detection of Ag/Ab - ELISA, RIA, Western blot, Immunoprecipitation, immunofluorescence and Flow Cytometry
- In situ localization by FISH and GISH

Suggested readings:

- Goldsby, R. A., Kindt, T.J. and Osborne, B. and Kuby, A. (2003) Immunology, 5th edn., W. H. Freeman and Company, New York.
- Roitt, I. (2000) Essentials of Immunology, 5th edn., Blackwell ELBS Science Publication, Oxford.
- Paul, W. E (2003) Fundamental Immunology, 5th edn., Lippincott Williams and Wikins Publishers, USA
- Tizard, I. R. (1995) Immunology: An Introduction, Saunders College Publishing, Philaldelphia
- Banerjee, A. K. and Baneijee, N. (2006) Fundamentals of Microbiology and Immunology, New Central Book Agency (Pvt.) Ltd., Kolkata
- Coleman, R.M., Lombard, M.F. and Sicard, R.E. (2000) Fundamental Immunology, 4th edn.,
- WmC Publications, London
- Rao, C. V. (2007) Immunology, Narosa Publishing House, New Delhi
- Shastri, N.V. (2005) Principal of Immunology, Himalya Publication House, Mumbai
- Barrett, James T. (1998) Microbiology and Immunology Concepts, Lippincott Williams & Wilkins, Philadelphia, PA
- Janeway, Charles, Travers, Paul, Walport, Mark and Shlomchik, Mark (2004) Immunobiology, Garland Science.