DR. BABASAHEB AMBEDKAR MARATHWADA UNIVERSITY, AURANGABAD.

Curriculum under Choice Based Credit & Grading System

M.Sc. I & II Year

Microbiology

Semester–I to IV

run at college level from the Academic Year 2015-16 & onwards

DR. BABASHEB AMBEDKAR MARATHWADA UNIVERSITY, AURANGABAD

M.Sc. MICROBIOLOGY REVISED SYLLABUS
(CBCS System)

(Effective from June 2011)

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M.Sc. MICROBIOLOGY REVISED SYLLABUS

(CBCS System)

(Effective from June 2011 Phase wise)

REVISED SYLLABUS AT A GLANCE

COURSE STRUCTURE

M. Sc. (MICROBIOLOGY)

Paper No.	Title of the theory paper	Marks/ Credits	Practical	Marks/ Credits
Semester I				
Th-I	Biostatistics Computer Applications and Research Methodology	100/04	P-I	50/02
Th-II	Bioenergetics and Enzymology	100/04	P-II	50/02
Th-III	Bioinstrumentation Techniques and Applications	100/04	P-III	50/02
Th-IV	Industrial Food and Dairy Microbiology	100/04	P-IV	50/02
Semester II				
Th-V	Recent Trends in Virology.	100/04	P-V	50/02
Th-VI	Molecular Immunology.	100/04	P-VI	50/02
Th-VII	Microbial Physiology.	100/04	P-VII	50/02
Th-VIII	Microbial Diversity and Extremophiles.	100/04	P-VIII	50/02
Semester III				
Th-IX	Enzyme Technology	100/04	P-IX	50/02
Th-X	Bioprocess Engineering and Technology.	100/04	P-X	50/02
Th-XI	Molecular Microbial Genetics.	100/04	P-XI	50/02
Th-XII	Environmental Microbial Technology	100/04	P-XII	50/02
Semester IV				
Th-XIII	Recombinant DNA Technology	100/04	P-XIII	50/02
Th-XIV	Fermentation Technology	100/04	P-XIV	50/02
Th-XV	Bioinformatics, Microbial Genomics and Proteomics.	100/04	P-XV	50/02
Th-XVI	Pharmaceutical	100/04	P-XVI	50/02

	Microbiology			

* Semester IV Practical (P- XV and XVI) or a research project of 100 marks.

M.Sc. MICROBIOLOGY SYLLABUS

M.Sc. Microbiology Course of two years is divided into four semesters.

Each semester is of 300 marks.

Each semester (I, II, III) will have four (04) theory papers each of 50 marks and four practical papers each of 25 marks.

Last semester will have four (04) theory papers each of 50 marks/04 Credits and four practical papers each of 25 marks/02 Credits. In the last semester instead of two practical papers research project of 50 marks/02 Credits will be assigned between three students.

Semester I

Paper-Th-I- Biostatistics Computer Applications and Research Methodology (04 Credits)

Paper-Th-II-Bioenergetics and Enzymology (04 Credits)

Paper-Th-III- Bioinstrumentation Techniques and Applications(04 Credits)

Paper-Th-IV- Industrial Food and Dairy Microbiology(04 Credits)

Practical papers P-I to P-IV based on four theory papers. (02X4= 08 Credits)

---------- Total 16 Theory + 08 Practical = 24 Credits/ Semester

Semester II

Paper-Th-V- Recent Trends in Virology (04 Credits)

Paper-Th-VI-Molecular Immunology (04 Credits)

Paper-Th-VII-Microbial physiology (04 Credits)

Paper-Th-VIII- Microbial Diversity and Extremophiles (04 Credits)

Practical papers P-V to P-VIII based on four theory papers. (02X4= 08 Credits)

---------- Total 16 Theory + 08 Practical = 24 Credits/ Semester

Semester III

Paper-Th-IX- Enzyme Technology (04 Credits)

Paper-Th-X- Bioprocess Engineering and Technology (04 Credits)

Paper-Th-XI- Molecular Microbial Genetics (04 Credits)

Paper-Th-XII-Environmental Microbial Technology (04 Credits)

Practical papers P-IX to P-XII based on four theory papers. (02X4= 08 Credits)

---------- Total 16 Theory + 08 Practical = 24 Credits/ Semester

Semester IV

Paper-Th-XIII- Recombinant DNA Technology (04 Credits)

Paper-Th-XIV-Fermentation Technology (04 Credits)

Paper-Th-XV- Bioinformatics, Microbial Genomics and Proteomics (04 Credits)

Paper-Th-XVI- Pharmaceutical Microbiology (04 Credits)

Practical papers P-XIII to P-XVI based on four theory papers or a research project of 50 marks each. (02X4= 08 Credits)

---------- Total 16 Theory + 08 Practical = 24 Credits/ Semester

---------- Overall 24X04 = 96 Credits

INFRASTRUCTURE, INSTRUMENTAL LIBRARY & OTHER FACILITIES REQUIRED FOR M. Sc. COURSE IN MICROBIOLOGY (for 25 Students INTAKE CAPACITY).

1. Two laboratories (for Part I and Part II) each measuring at least 1000 Sq. Ft. With sufficient no. of tables and Stools. Lab should be provided with basic Instruments such as autoclave, incubator, oven, pH meter, hot plate, cyclo mixers, water bath shakers, colorimeter, fridge, distillation plant etc.
2. A culture room with a laminar air flow measuring 300 Sq. Ft.
3. An Instrumentation Room with Double door, Air Conditioner, and inverter, power generator for sophisticated Instruments measuring 500 Sq. Ft.
4. Two Lecture halls (for Part I and Part II) with Overhead projector facility and measuring 400 Sq. Ft. with tables and chairs.
5. A media preparation and a store room at least 400 Sq. Ft.
6. A computer in Bioinformatics Laboratory with 4 – 5 computers (P – IV) with printer and internet facility.

LIST OF BASIC INSTRUMENTS REQUIRED FOR M. Sc. PRACTICALS

1. Laminar Air Flow.
2. Compound Microscope
3. Autoclave
4. Incubators
5. Hot Air Oven.
6. BOD Incubators
7. pH Meter
8. Water Bath Incubator Shaker
9. Colorimeter
10. Spectrophotometer
11. Hot Plate.
12. Cyclomixer.
13. Electrophoretic Apparatus
14. Orbital Incubator Shaker
15. High Speed Centrifuge - (10000 RPM)
16. Distillation Apparatus (Single & Double)
17. Refrigerators
18. Paper Chromatography Cabinet
19. Rough Balances
20. Bacterial Filter Assembly
21. General Purpose Centrifuge.
22. Vortex Mixers
23. Magnetic Stirrers
24. UV Cabinet
25. TLC Apparatus
26. Dissolved Oxygen Meter
27. Metler Balances
28. Digital Balances
29. Water Bath Shakers
30. Colony Counter
31. Rotary Shaker
32. Columns for Chromatography
33. Fraction Collector
34. Gas Burners
35. LPG Cylinders
36. Distillation Apparatus.

LIST OF SOPHESTICATED INSTRUMENTS REQUIRED FOR PRACTICAL

1. UV – Vis Spectrophotometer.
2. Gas Chromatography
3. Sonicator
4. High Speed Refrigerated Centrifuge
5. Microprocessor based pH Analyser
6. Horizontal Paper Electrophoresis Unit
7. Vertical Electrophoresis Unit
8. Submarine Electrophoresis Unit
9. Immuno Electrophoresis Apparatus
10. Power Pack With Constant Voltage or Current Adjustment
11. PAGE Electrophoresis Unit
12. DNA Sequencer
13. ELISA Reader
14. PCR (Thermal Cycler)
15. Gel Documentation Unit
16. Semi Dry Transfer Apparatus
17. Deep Freezer (-30^0C)
18. Fermenter
19. Atomic Absorption Spectrophotometer
20. COD & BOD Analyser
21. Phase Contrast Microscope
22. Binocular Microscope
23. HPLC
24. Lyophilizer
25. Pentium IV Computer With Printer
26. Micropipette
27. CO_2 Incubator

OTHER REQUIREMENTS

The department should have required chemicals, DEHYDRATED MEDIA, STAINS, ACIDS, SOLVENTS, FINE CHEMICALS, ENZYMES, ANTI SERA IMMUNODIAGNOSTIC KITS, and SPECIFIC MICROBIAL CULTERS WITH KNOWN GENETIC MARKERS AND GLASSWARES to conduct the prescribed syllabus. Cold room facility is preferred.

LIBRARY FACILITY

The library should have ample no of prescribed text books, reference books recommended in the prescribed syllabus and the library should also subscribe National and International and Scientific Magazines.

INSTRUCTIONS

1. M.Sc. Course of Microbiology is divided into four semesters.
2. Each Semester will have four theory papers and four practical papers, except in the IV semester, either there will be four practical papers or two practical papers and a research project equivalent to two practical papers i.e. for 50 marks. The decision to have practical or research project will be the discretion of the department and will depend upon the avalibility of chemicals, instruments, lab space, budget and other facilities, etc.
3. The department should complete a minimum of six practicals of each paper.
4. The workload of research project will be equivalent to the workload of 2 practical papers.
5. One theory paper will have 4 lectures each of 60 min. Duration per week and practical will have 6 hrs. duration.
6. There should be regular seminars and tutorials on immerging topics of subject concerned for students.
7. It is mandatory for students to have not less than 75% of attendance in each semester.
8. Department should organise lectures of subject experts and should also arrange study tours to industries and National research institutes.

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REVISED SYLLABUS OF M. Sc. (MICROBIOLOGY) SEMESTER - I

Paper No.	Title of the theory paper	Marks/ Credits	Practical	Marks/ Credits
Semester I				
Th-I	Biostatistics Computer Applications and Research Methodology	100/04	P-I	50/02
Th-II	Bioenergetics and Enzymology	100/04	P-II	50/02
Th-III	Bioinstrumentation Techniques and Applications	100/04	P-III	50/02
Th-IV	Industrial Food and Dairy Microbiology	100/04	P-IV	50/02

[Semester I] PAPER TH-I

BIOSTATISTICS, COMPUTER APPLICATIONS AND RESEARCH METHODOLOGY

Marks 100/ Credits 04

Unit –1 Introduction to Biostatistics (0.8 Credits)

Basic definitions and applications. Sampling: Representative sample, sample size, sampling bias and sampling techniques. Data collection and presentation : Types of data, methods of collection of primary and secondary data, methods of data presentation, graphical representation by histogram, polygon, ogive curves and pie diagram.

Unit –2 Measures of central tendency (0.8 Credits)

Measures of central tendency: Mean, Median, Mode.

Measures of variability: Standard deviation, standard error, range, mean deviation and coefficient of variation. Correlation and regression: Positive and negative correlation and calculation of Karl-Pearsons co-efficient of correlation. Linear regression and regression equation and multiple linear regression, ANOVA, one and two way classification.

Calculation of an unknown variable using regression equation.

Unit – 3 Tests of significance (0.8 Credits)

Tests of significance : Small sample test (Chi-square t test, F test), large sample test (Z test) and standard error. Introduction to probability theory and distributions, (concept without deviation) binomial, poison and normal (only definitions and problems)

Computer oriented statistical techniques. Frequency table of single discrete variable, bubble spot, computation of mean, variance and standard Deviations, t test , correlation coefficient

Unit- 4 Introduction to computers and computer applications (0.8 Credits)

Introduction to computers: Computer application, basics, organization, PC, mainframes and Super-computers, concept of hardware and software, concept of file, folders and directories,

commonly used commands, flow charts and programming techniques. Introduction to Q basic and C. Introduction in MS Office software concerning Word processing, spreadsheets and presentation software. www., introduction to internet, Medline and Pubmed for accessing biological information.

Unit - 5 Research Methodology (0.8 Credits)

Research institutes, research schemes (minor and major), preparation of research scheme proposals, formats, funding agencies, scientific writing: research article, dissertation, review, abstract, synopsis, technical report.

Literature search, analysis of scientific report, compilatio0n of data, presentation of experimental data, tabulation, graph, diagrams, histograms, interpretation of tables, graphs, photographs, and diagrams.

PRACTICAL

PAPER P-I

BIOSTATISTICS, COMPUTER

APPLICATIONS AND RESEARCH METHODOLOGY

Marks: 50/ (02 Credits)

1. Representation of Statistical data by

a) Histograms b) Ogive Curves c) Pie diagrams

2. Determination of Statistical averages/ central tendencies.

a) Arithmetic mean b) Median c) Mode

3. Determination of measures of Dispersion

a) Mean deviation

b) Standard deviation and coefficient of variation

c) Quartile deviation

4. Tests of Significance-Application of following

a) Chi- Square test b) t- test c) Standard error

5. Computer operations-getting acquainted with different parts of

Computers. [DOS] and basics of operating a computer.

6. Creating files, folders and directories.

7. Applications of computers in biology using MS-Office.

A] MS-Word B] Excel C] Power Point

8. Creating an e-mail account, sending and receiving mails.

9. An introduction to INTERNET, search engines, websites, browsing and Downloading.

10. Searching research articles in Medline and Pubmed.

11. writing of abstracts, synopsis, research paper.

12. Presentation and analysis of experimental data.

13. oral presentation of research article.

References

1. Statistics in biology, Vol. 1 by Bliss, C.I.K. (1967) Mc Graw Hill, NewYork.

2. Practical Statistics for experimental biologist by Wardlaw, A.C. (1985).

3. Programming in C by E. Ballaguruswamy

4. How Computers work - 2000. by Ron White. Tech. Media

5. How the Internet Work 2000 by Preston Gralla Tech. Media.

6. Statistical Methods in Biology - 2000 by Bailey, N.T. J. English Univ. Press.

7. Biostatistics - 7th Edition by Daniel

8. Fundamental of Biostatistics by Khan

9. Biostatistical Methods by Lachin

10. Statisticsfor Biologist by CampbellR.C.(1974)Cambridge University Press , UK.

11. INTERNET – CDC publication, India.

12. UGC, DST and DBT web-sites.

PAPER TH-II BIOENERGETICS AND ENZYMOLOGY

Marks 100 / (04 Credits)

Unit – 1 Carbohydrate catabolic pathways and microbial growth on C1 Compounds (0.8 Credits)

EMP, HMP, ED, Phosphoketolase pathway, TCA cycle, Glyoxylate bypass. Anaplerotic sequences, catabolism of different carbohydrates (Fructose, Lactose, Manose, Allose, Gluconate, Manitol, Sorbitol, Arabinose, Xylose), Polyol, glycol and 2,3 butanidiol metabolism, regulation of aerobic and anaerobic carbohydrate metabolism,

Microbial growth on C1 Compounds (Cyanide, Methane, Methanol, methylated amines and carbon monoxide) with reference to microorganisms and biochemical reactions with enzymes involved.

Unit - 2 Bacterial fermentations and Biosynthesis (0.8 Credits)

Principal classes of carbohydrate fermentations. Catbon energy and balance. Alcohol, lactate, mixed acid, butyric acid, acetone-butanol, propionic acid, succinate, methane, and acetate, butanediol, acettoin fermentations. Fermentation of single nitrogenous compounds [amino acids] - alanine, glutamate and glycine with reference to microorganisms and biochemical reactions with enzymes involved.

Biosynthesis of amino acids (formation of glutamic acids, conversion of glutamic acid to glutamine, proline and arginine, formation of alanin, serinine, glycine and cysteine), Biosynthesis of nicotinic acid and pantothenic acid, biosynthesis of Purines and Pyrimidines.

Unit – 3 Endogenous metabolism and degradation of aliphatic and aromatic compounds. (0.8 Credits)

Functions of endogenous metabolism, types of reserve materials, enzymatic synthesis, degradation and regulation of reserve materials - glycogen, polyphosphates and polyhydroxybutyrate (PHB), PHB production and its futuristic applications.

Microbial degradation of aliphatic hydrocarbons (microorganisms involved, mon-terminal, biterminal oxidation of propane, decane, etc.) and aromatic hydrocarbons and aromatic compounds (via catechol, protocatechuate, meta-cleavage of catechol and protocatechuate, dissimilation of catechol and protocatechuate, homogentisate and other related pathways).

Unit – 4 Properties of Enzymes (0.8 Credits)

Classification of enzymes into six major groups with suitable examples. Numerical classification of enzymes. Different structural conformations of enzyme proteins (Primary, secondary, tertiary and quaternary structures). Forces that mentain protein structures. Sources of enzyme. Enzymes as biocatalysts, catalytic power, activation energy, substrate specificity, active site, theories of mechanisms of enzyme action (Induced fit and lock and key). Mechanism of action of lysozyme, chymotrypsin and ribonuclease.

Monomeric, Oligomeric and multienzyme complex, isozymes and allosteric enzymes.

Extremozymes - thermostable, solventogenic and non- aqueous enzymes. Synthetic enzymes, Ribozymes and abzymes

Unit – 5 Enzyme kinetics (0.8 Credits)

Importance of enzyme kinetics, factors affecting rates of enzyme mediated reactions (pH, temperature, substrate concentration ,enzyme concentration and reaction time). Derivation of Michaelis - Menton equation and its significance in enzyme kinetic studies. Lineweaver-Burke plot, Haldane-Briggs relationship, sigmoidal kinetics steady state kinetics and transient phases of enzyme reaction.

PRACTICAL

Paper P-II : BIOENERGETICS AND ENZYMOLOGY

Marks 50 / (02 Credits)

1. Isolation and Identification of Reserve food material (Glycogen / polyphosphates, PHB) of B. megaterium and Azotobacter SP.
2. Quantitative estimation of amino acids by Rosen’s method.
3. Quantitative estimation of sugars by Summner’s method.
4. Demonstration of endogenous metabolism in B megaterium or E. coli and their survival under starvation conditions

5. Quantitative estimation of proteins by Folin-Lowry / Biuret method.

6. Production of fungal alpha amylase using solid-state fermentation/ prouction of protease by bacterial species and confirmation by determining the achromic point.

7. Purification of fungal alpha-amylase or bacterial protease by fractionation, chromatographic techniques and electrophoretic separation.

8. Studies on enzyme kinetics of alpha amylase/Protease [Optimization of parameters viz. Substrate, enzyme concentration, reaction temperature, reaction pH, Km, Vmax and metal ions as activators and inhibitors).

9. Bacterial fermentation (Detection of Acetic acid, lactic acid 2,3 butanediol and acetoin)

References

1. Understanding Enzymes by Trevor Palmer

2. Enzyme Kinetics by Paul Engel. 1977. John Wiley and Sons. Inc., New York.

3. Enzymes by Dixon and Webb, 3 rd Edition 1979. Academic Press, New York

4. Biochemistry by Stryer 5th Edition WH Freeman 2001

5. Laboratory techniques in Biochemistry and Molecular Biology by Work and Work.

6. Principles of Enzyme Kinetics. 1976. by Athel Cornish - Bowden. Butterworth and Co.

7. Fundamentals of Enzymology. 3rd Edition by Price

8. Biochemistry by Chatwal

9.Methods in Enzymology by Drolittle

10.Biochemistry by Garrett

11. Principles of Biochemistry. 2 nd Edition by Horton

12. Biochemistry by Voet.

13. Methods of Biochemical Analysis by David Glick, John Wiley and Sons, New York.

14. Biotechnology Vol. VIII and VII A edited by H. J. Rehmen and G. Reed.

15. Bacterial metabolism 2nd edition by H. W. Doelle

16. Advances in microbial physiology Vol. VII and XXIV edited by A. H. Rose, J Morris D. W. Tempest.

PAPER TH-III

BIOINSTRUMENTATION TECHNIQUES AND APPLICATIONS

Marks 100 / Credits 04

Unit –1 Basic laboratory Instruments (0.8 Credits)

Principle and working of pH meter, Laminar-air flow. Biosafety cabinets Centrifugation: Types of centrifuge machines, preparative and analytical centrifuges, differential centrifugation, sedimentation velocity, sedimentation equilibrium, density gradient methods and their applications. Introduction to PCR, Gel documentation and water purification systems.

Unit – 2 Chromatographic techniques(0.8 Credits)

Theory, principles and applications of paper, thin layer, gel filtration, ion-exchange, affinity, hydrophobic, gas liquid, high pressure/ performance liquid chromatography (HPLC)

Unit – 3 Electrophoretic techniques(0.8 Credits)

Basic principles of electrophoresis, theory and application of paper, starch gel, agarose, native and denaturing PAGE, isoelectric focusing, capillary, microchip and 2 D electrophoresis.

Unit – 4 Spectroscopy(0.8 Credits)

Spectroscopic techniques, theory and applications of turbidometry, nephlometry, luminometry, UV-Visible, IR, NMR, Fluorescence, Atomic Absorption, CD, ORD, Mass, Raman Spectroscopy. Atomic force microscopy.

Unit – 5 Radioisotopic techniques(0.8 Credits)

Use of radioisotopes in life sciences, radioactive labeling, principle and application of tracer techniques, detection and measurement of radioactivity using ionization chamber, proportional chamber, Geiger- Muller and Scintillation counters, autoradiography and its applications.Dosimetry.

PRACTICAL

PAPER P-III BIOINSTRUMENTATION TECHNIQUES AND APPLICATIONS

Marks 50/ (02 Credits)

1. Studies on pH titration curves of amino acids/ acetic acid and determination of pKa values and Handerson-Hasselbach equation.
2. Separation of bacterial lipids/amino acids/sugars/organic acids by TLC or Paper Chromatography.
3. Separation of serum protein by horizontal submerged gel electrophoresis.
4. Study of UV absorption spectra of macromolecules (protein, nucleic acid, bacterial pigments).
5. Quantitative estimation of hydrocarbons/pesticides/organic Solvents /methane by Gas chromatography.
6. Demonstration of PCR, DNA sequencer.
7. Separation of haemoglobin or blue dextran by gel filtration.
8. Paper electrophoresis.
9. Friske dosimetry.
10. Density gradient centrifugation.

References

1. Instrumental Methods of Analysis. 6th Edition by H.H. Willard, L.L. Merritt Jr. and others. 1986. CBS Publishers and Distributors.
2. Instrumental Methods of Chemical Analysis. 1989 by Chatwal G and Anand, S. Himalaya Publishing House, Mumbai.
3. A Biologists Guide to Principles and Techniques of Practical Biochemistry. 1975 by Williams, B.L. and Wilson, K.

4. Spectroscopy. Volume 1. Edited by B.B. Straughan and S. Walker. Chapman and Hall Ltd.

5. Gel Electrophoresis of Proteins- A Practical Approach by Hanes.

6. Chromatography: Concepts and Contrasts- 1988 by James Miller. John Wiley and Sons. Inc., New York.

7. Analytical Biochemistry by Holme.

8. Introduction to High Performance Liquid Chromatography by R. J. Hamilton and P. A. Sewell.

9. Spectroscopy by B.P. Straughan and S. Walker.

10. Practical aspects of Gas Chromatography and Mass Spectrometry 1984 by Gordon M. Message, John Wiley and Sons, New York.

11. Gel Chromatography by Tibor Kremmery. Wiley Publications.

12. Isotopes and radiations in Biology by C.C. Thornburn, Butterworth and Co. Ltd., London.

13. The use of radioactive isotopes in the life sciences by J.M.Chapman and G.Ayrey, George Allen and Unwin Ltd., London.

14. Analytical biotechnology edited by Thomas G M Schalkhammer.

PAPER TH-IV INDUSTRIAL FOOD AND DAIRY MICROBIOLOGY

Marks 100/ (04 Credits)

Unit – 1 Industrial Food fermentations (0.8 Credits)

Introduction, food fermentation, the science and technology.

Oriental fermented foods (Soya sauce, Natto, Miso), Cerel products, mixed preparations (Idle, Dhokala, Khamang, Papadam and Jilebies), Fermented cassaea flour, fermented pea nut milk, and grape based fermented products- wine (pre fermentating, fermentative and post fermentative practices, general methods of wine preparations) , Fermented vegetables – Saurkraut, Fermented Meat – Sausages.

UNIT – 2 Industrial Dairy fermentations. (0.8 Credits)

Taxonomy of lactic acid bacteria present in fermented products,. Acid fermented milks (acidophilus milk, yoghurt). Slightly acid fermented milks (Cultured butter milk), Acid-alcoholic fermented milk (Kefir). Fermented milk production with extended self life (labneh). Starter cultures for fermented dairy products (Strptococcus thermophillus, Lactobacillus bulgaricus,). Metabolism of starter cultures, biochemical changes in fermented

milk (Fermentation of lactose to lactic acid, production of aromatic compounds, hydrolysis of proteins and lipids and Vit. B content).

Cheese- biological entities in cheese systems (Mlk, microorganisms, enzymes and other additives). Cheese production (Milk quality and composition, steps involed in mfg of cheese, preservation, classification and nutritional aspects)

Unit - 3 Advanced Food and dairy Microbiology(0.8 Credits)

Genetically modified foods . Probiotic role of lactic acid bacteria and fermented milk products. Biosensors in food, Applications of microbial enzymes in food and dairy industry [Protease, Lipases]., microbial anti oxidants, biosurfactants as emulsifiers, microbial polysaccharides as stabilizers and thinkers, flavors (esters, diaacetyl, pyrazines, lactones and terpenes, monosodium glutamate and microbial colors from molds). Production and application of Bakers Yeast, Tea,

coffee and vinegar fermentation

Unit –4 Food preservation methods and utilization of dairy waste(0.8 Credits)

Food preservation by Radiations (UV , Gamma and microwave), Food presevation by low and high Temperature, chemicals and naturally occurring antimicrobials

Biosensors in food industry. Utilization and disposal of dairy by-product - whey.

Unit – 5 Food spoilage and Quality assurance(0.8 Credits)

Food borne infections and intoxications; bacterial with examples of infective and toxic types –, Clostridium, Salmonella, Shigella, Staphylococcus, Campylobacter, Listeria.

Mycotoxins in food (Types, structures, producer organism and its toxicity).

Quality assurance: Microbiological quality standards of food. Government regulatory practices and policies. FDA, EPA, HACCP, ISI.

PRACTICAL

PAPER - P-IV INDUSTRIAL FOOD AND DAIRY MICROBIOLOGY

Marks 50 / (02 Credits)

1. Production and estimation of lactic acid by Lactobacillus Sp.

Or Streptococcus Sp.

2. Extraction and estimation of diacetyl.

3. Sauerkraut fermentation

4. Isolation of food poisoning bacteria/ fungi from contaminated foods,

Dairy products

5. Extraction and detection of afla toxin for infected foods.

6. Preservation of potato/onion by UV radiation

7. Production of fermented milk by Lactobacillus acidophilus.

8. Rapid analytical techniques in food quality control using microbial Biosensors.

9. Production of Youghart.

REVISED SYLLABUS OF M. Sc. (MICROBIOLOGY) SEMESTER - II

Paper No.	Title of the theory paper	Marks/ Credits	Practical	Marks/ Credits
Semester II				

Th-V	Recent Trends in Virology.	100/04	P-V	50/02
Th-VI	Molecular Immunology.	100/04	P-VI	50/02
Th-VII	Microbial Physiology.	100/04	P-VII	50/02
Th-VIII	Microbial Diversity and Extremophiles.	100/04	P-VIII	50/02

SEMESTER II

PAPER TH-V

RECENT TRENTS IN VIROLOGY

Marks 100/CREDITS 04

Unit-1 Classification and Morphology of Viruses. (0.8 Credits)

Brief outline on discovery of viruses. Classification and nomenclature of animal and plant viruses.Cataloging the virus through virus classification schemes of ICTV / ICNV. Morphology and ultra-structure of viruses. Virus related agents, viroids and prions.

Unit-2 Cultivation and assay of viruses (0.8 Credits)

Cultivation of viruses using embryonated eggs, experimental animals and cell cultures (Cell-lines, cell strains and transgenic systems). Purification of viruses by adsorption, precipitation, enzymes, serological methods – haeme agglutination and ELISA.

Assay of viruses – Physical and Chemical methods (Electron Microscopy and Protein and Nucleic acids studies). Infectivity Assays (Plaque and end-point) Infectivity of plant viruses.Genetic analysis of viruses by classical genetic methods.

Unit-3 Viral Multiplication. (0.8 Credits)

Bacteriophages – Lytic and lysogenic replication

Animal viruses - Mechanism of virus adsorption and entry into the host cell

DNA and RNA viruses– Mechanism of genome replication Transcription, post transcriptional changes, translation, assembly, exit and maturation of progeny virions.

Unit-4 Pathogenesis of Viruses (0.8 Credits)

Host and virus factors involved in pathogenesis, patterns of infection, pathogenesis of animal viruses Adenovirus, Herpes virus, Picorna virus, Poxvirus and Orthomyxovirus, pathogenesis of plant [TMV] Satellite viruses and their role in plant virus replication. Insect viruses [NPV] Viruses pathogenic to algae and fungi.

Host cell transformation by viruses by viruses and oncogenesis of DNA and RNA viruses.

Unit-5 Control of Viruses and Emerging Viruses (0.8 Credits)

Control of viral infections through vaccines and chemotherapeutic agents. Viruse neutralization by antibody and interferons

Structure, genomic organization, pathogenesis and control of Human immunodeficiency virus. Emerging viruses.

PAPER P-V **PRACTICAL**

RECENT TRENTS IN VIROLOGY

Marks 50 / Credits 02

1. One step growth curve for determination for virus titre.
2. Phage typing of *E. coli* bacteriophages.
3. Induction of lambda lysogen by UV radiations.
4. Studies on Specialized transduction.
5. Isolation of lambda DNA and their characterization.
6. Amplification of lambda DNA by PCR.

7. Cultivation and assay of viruses using embryonated eggs and Tissue culture Technique.

Refernces:-

1. Medical virology 10 th edition by Morag C and Tim bury M C 1994.. Churchil Livingstone , London.
2. Introduction to modern virology 4 th Edition by Dimmock N J, Primrose S. B. 1994. Blackwell scientific publications. Oxford.
3. Virology 3rd edition by Conrat H. F. ., Kimball P. C. and Levy J. A. 1994. Prentice Hall, Englewood Cliff, New Jersy.
4. Text Book on Principles of Bacteriology, Virology and Immunology, Topley and Wilson 1995.
5. Molecular Biology, Pathogenesis and Control by S. J. Flint and others. ASM Press, Washington , D. C.
6. Applied Virology. 1984. edited by Ednord Kurstak. Academic Press Inc.
7. Introduction to Modern Virology by Dimmock.
8. Prion diseases by Gaschup, M. H.
9. Clinical Virology Mannual by Steven, S. , Adinka, R. I.., Young , S. A.
10. Principles of virology. 2000 by Edward Arnold.

PAPER TH-VI

MOLECULAR IMMUNOLOGY

Marks 100/ CREDITS 04

Unit-1 Immune System (0.8 Credits)

Innate and Adaptive immune responses. Memory of self and non self discrimination. Organs and cells involved in immune system. Lymphocytes, their subpopulation, their properties and functions, membrane bound receptors of lymph cells, helper T cells, T cells suppression, lymphocyte trafficking.

Unit-2 Antigens and Immunoglobulins (0.8 Credits)

Concept of haptens, determinants, conditions of antigenicity, antigens and immunogenecity, super antigen.

Immunoglobulin: Deducing antibody Structure. Antigenic determinants on Immunoglobulin –Isotopes, Allotypes and Idiotype

Structure and properties of immunoglobulin classes. Theories of antibody formation, hybridoma technology for monoclonal antibodies and designer monoclonal antibodies. Multiple mylomas and structural basis of antibody diversity. Freund's adjuvants and its significance.

Unit-3 Antigen – Antibody reactions (0.8 Credits)

Strength of Antigen and Antibody Interactions – Antibody Affinity and Antibody Avidity.

Antigen Antibody reaction by precipitation, agglutination and complement fixation. Non-specific immune mechanism: - Surface defenses tissue defenses, opsonization. Inflammatory reaction and hormone balance.

Tissue metabolites with bactericidal properties (lysozyme, nuclein, histone, protamine, basic peptides of tissues – leukines, phagocytins, lecterins, haemocompounds)

Unit-4 Expression and Regulation of Immune Response (0.8 Credits)

Regulation of immune response: antigen processing and presentation, generation of humoral and cell mediated immune response, activation of B and T lymphocytes, cytokines and their role in immune regulation, T cell regulation, MHC restriction, immunological tolerance. Cell mediated cytotoxicity: Mechanism of T cell and NK mediated lysis antibody dependent cell mediated cytotoxicity, and macrophage mediated cytotoxicity.

Compliment system: Classical, alternate, lectin pathway of complement activation. Regulation of complement activation.

Transplantation immunology: MHC, types of grafts, grafts rejection, GVH reactions. Mechanism of graft rejection, and prevention of graft rejection.

Unit-5 Immunity and Immunoassays (0.8 Credits)

Defense against bacteria, viruses, fungi and parasites. Tumor Immunology. Immunodiagnostics and immunotherapy in virology - Serological methods for detection and quantitation of viruses including Hepatitis, Influenza, HIV and others.

Immuno-assays: SRID, ELIZA, ELISA-PCR, RIA, Western Blotting, Immunofluroscens and their application. Immune deficiencies and autoimmunity.

Vaccines: Attenuated and Inactivated viral and bacterial vaccines.

Polysaccharide vaccines, Toxoid vaccines and DNA Vaccines

PAPER P-VI **PRACTICAL**

MOLECULAR IMMUNOLOGY

Marks 50 /Credits 02

1. Diagnostic immunologic principles and methods
   Precipitation method
   - Immunodiffusion.
   - Immunoelectrophoresis.

   Agglutination method
   - Widal test.
   - Haemagglutination.
   - ELISA method.
2. Separation of serum protein by submerged agarose gel electrophoresis.
3. Purification of human immunoglobulins from serum and confirmation of its antigenicity.
4. Identification of *S. typhi* by serotyping. [Purification of H and O antigens from *S. typhi*]
5. Clinical diagnosis of Rheumatoid arthritis by purifying immunoglobulins and albumins and confirmation by lattice agglutination test.
6. Estimation of Alkaline phosphatase from patient's serum
7. Demonstration of Western blotting.
8. Detection of isozymes of Lactate dehydrogenase by PAGE.
9. Clinical diagnosis of viral diseases by PCR, ELISA.

Reference :

1. Essential of Immunology by Riott I. M. 1998. ELBS, Blackwell Scientific Publishers, London.
2. Immunology 2 nd Edition by Kuby J. 1994. W. H. Freeman and Co. New York.
3. Immunology – Understanding of Immune System by Claus D. Elgert. 1996. Wiley – Liss , New York.

4. Fundamentals of Immunology by William Paul.
5. Cellular and Molecular Immunology. 3 rd Edition by Abbas.
6. Immunobiology: The immune system in Health and Diseases. 3rd edition by Travers.
7. Immunology – A short course. 2 nd Edition by Benjamin.
8. Manual of clinical laboratory and Immunology 6th Edition. 2002 by Noel R. Rose, Chief editor: Robert G. Hamilton and Barbara Detrick (Eds.), ASM publications.
9. Pocket Guide to Clinical Microbiology. 2 nd Edition. 1998 by Patrick R. Murray. ASM Publications

PAPER TH-VII MICROBIAL PHYSIOLOGY Marks 100/ (04 Credits)

Unit – 1 Photosynthesis (0.8 Credits)

Energy consideration in photosynthesis, light and dark reaction, electron carriers in photosynthesis, Organization of photo system I and II, cyclic and non-cyclic flow of electrons, Z scheme, Hill reaction, photolysis of water. Bacterial photosynthesis: scope,

electron carriers, Photosynthetic reaction center, cyclic flow of electrons, bacterial photophosphorylation in various groups of phototrophic bacteria, electron donors other than water in anoxygenic photosynthetic bacteria.

Unit – 2 Bacterial Respiration (0.8 Credits)

Aerobic Respiration:

Mitochondrial electron transport chain, structure and function of ATPase (bacterial and mitochondrial), generation and maintenance of proton motive force, oxidative phosphorylation, inhibitors and un-couplers of electron transport chain and oxidative phosphorylation, Atkinson's energy charge, phosphorylation potential and its significance, Energy generation in all groups of chemolithotrophs.

Anaerobic Respiration:

Concept of anaerobic respiration, oxidized sulfur compounds, and nitrate as electron acceptor with respect to electron transport chain and energy generation, Biochemistry of methanogenesis, Biochemistry of ammonia oxidation, ammonia oxidation by members of Genus Nitroso group, nitrite oxidation by Nitro group of genera.

Unit –3 Bacterial Permeation (0.8 Credits)

Structure and organization of membrane

(Glyco-conjugants and proteins in membrane systems), fluid mosaic model of membrane. Methods to study diffusion of solutes in bacteria, passive diffusion, facilitated diffusion, different mechanisms of active diffusion (Proton Motive Force, PTS, role of permeases in transport, different permeases in E. coli. Transport of amino acids and inorganic ions in microorganisms and their mechanisms.

Unit – 4 Bacterial Sporulation (0.8 Credits)

Sporulating bacteria, molecular architecture of spores, induction and stages of sporulation, Influence of different factors on sporulation. Cytological and macromolecular changes during sporulation. Heat resistance and sporulation.

Unit –5 Bacterial Chemolithotrophy and Nitrogen Metabolism: (0.8 Credits)

Physiological groups of chemolithotrophs, Oxidation of molecular hydrogen by *Hydrogenomonas* species. Ferrous and sulfur/sulfide oxidation by *Thiobacillus* species.

Biochemistry of biological nitrogen fixation, properties of nitrogenase and its regulation, ammonia assimilation with respect to glutamine synthetase, glutamate dehydrogenase, glutamate synthetase, their properties and regulation

PRACTICAL

PAPER P-VII MICROBIAL PHYSIOLOGY Marks 50/ (02 Credits)

1. Isolation of Photosynthetic bacteria
2. Glucose uptake by *E. coli / Saccharomyces cerevisiae* [Active and Passive diffusion]
3. Effect of UV, gamma radiations, pH, disinfectants, chemicals and heavy metal ions on spore germination of Bacillus SP.
4. Determination of Iron Oxidation Rate of *Thiobacillus ferrooxidans*.
5. Determination of Sulfur Oxidation Rate of *Thiobacillus thiooxidans.*
6. Microbial degradation, decolorization and adsorption of organic dyes (by free and immobilized cells).
7. Estimation of calcium ions present in sporulating bacteria by EDTA method.
8. Demostration of utilization of sugars by oxidation and fermentation techniques.
9. Isolation and characterization of (as nitrogen fixers) of *Azospirillum* and detection of IAA by *Azospirillum*

References

1. Microbial Physiology and Metabolism by Caldwell D.R. 1995Brown Publishers.
2. Microbial Physiology by Moat A.G. and Foster J. W. 1999. Wiley.
3.. Prokaryotic Development by Brun. Y.V. and Shimkets L.J. 2000. ASM Press.
4. Advances in Microbial Physiology. Volumes. Edited by By A.H. Rose. Academic Press, New York.
5. Applied Microbial Physiology by Rhodes.
6. Biosynthesis by Smith.
7. The Bacteria. Volumes by I.C. Gunsalus and Rogery Stanier, Academic Press.
8. Microbial Physiology by Benjamin
9. Bacterial Metabolism by H.W. Doelle
10. Segel Irvin H. (1997) *Biochemical Calculations* 2nd Ed., John Wiley and Sons, New York.
11. Voet Donald and Voet Judith G. (1995) *Biochemistry*, 2nd Ed.. John Wiley and sons New York.

12. White Abraham, Handler Philip, Smith Emil, Hill Rober, Lehman J. (1983) Principles of Biochemistry, Edition 6, Tata Mc-Graw Hill Companies, Inc.

13. White David (2000) *Physiology and Biochemistry of Prokaryotes.* 2nd Ed. Oxford University Press, New York.

14. Zubay Geoffrey (1998) *Biochemistry*, 4th Ed., W. C. Brown, New York.

PAPER TH-VIII: MICROBIAL DIVERSITY AND EXTREMOPHILES Marks 100 (04 Credits)

Unit - 1 Biodiversity (0.8 Credits)

Introduction to microbial biodiversity – distribution, abundance, ecological niche. Types- Bacterial, Archael and Eucaryal. Whitaker's five kingdom concept, General characters of actinomycetes, fungi, algae, protozoa and yeasts

Unit – 2 Ecology (0.8 Credits)

Community ecology: community structure, benevolent interactions (control within the microbial communities of rhizosphere), antagonistic interactions, (competition, antibiosis, predation etc.). Rhizosphere, rhizoplane, siderophore, flavonide from plants, lectines, octapine, nipotine, indole acetic acid.

Mycorrhiza: Host-fungus specificity, host fungus interactions, rhizosphere environment and recognition phenomenon, interaction of mycorrhizal fungi with non-host plants, functional capability.

Marine ecosystem: Environment of marine bacteria, bacterial growth in sea and its regulation by environmental conditions, modeling of growth and distribution of marine micro plankton, mechanism of dissolved organic matter production (DOM), strategies of organic matter utilization and microbial utilization of organic matter in sea.

Unit – 3 Characteristics and classification of Archaebacteria. (0.8 Credits)

Thermophiles: Classification, hyperthermophilic habitats and ecological aspects. Extreme Thermophilic Archaebacteria, Thermophily, commercial aspects of thermophiles. Applications of thermozymes. Methanogens: Classification, Habitats, applications.

Unit – 4 Alkalophiles and Acidophiles (0.8 Credits)

Alkalophiles: Classification, alkaline environment, soda lakes and deserts, calcium alkalophily, applications.

Acidophiles: Classification, life at low pH, acidotolerence, applications.

Unit – 5

Halophiles and Barophiles (0.8 Credits)

Classification, Dead Sea, discovery basin, cell walls and membranes – Purple membrane, compatible solutes. Osmoadaptation / halotolerence. Applications of halophiles and their extremozymes.

Barophiles: Classification, high-pressure habitats, life under pressure, barophily, death under pressure.

PRACTICAL

PAPER- P-VIII MICROBIAL DIVERSITY AND EXTREMOPHILES

Marks 50 (02 Credits)

1. Isolation of thermophiles from hot water spring [Study at least one enzyme].
2. Studies on halophiles isolated from seawater. [Pigmentation and Salt tolerance]
3. Studies on alkalophiles isolated from Lonar water/sea water. [Study at least one enzyme]
4. Biogenic methane production using different wastes.

5. Isolation of *Thiobacillus ferrooxidans* and *Thiobacillus thiooxidans* cultures from metal sulfides, rock coal and acid mine waters.

6. Estimation of microbial species diversity in microecosystem

7. Detection of siderophore production by *Azospirillum* and *Pseudomonas*

8. Slide culture technique for yeast isolation.

9. Cover slip culture technique for actinomycetes identification

References:

1. Extremophiles by Johri B.N. 2000. Springer Verlag. , New York

2. Microbial Diversity by Colwd, D. 1999, Academic Press.

3. Microbial Life in Extreme Environments. Edited by D. J. Kushner. Academic Press.

4. Microbiology of Extreme Environments. Edited by Clive Edward. Open University Press. Milton Keynes.

5. Microbiology of Extreme Environments and its potential for Biotechnology. Edited by M.S. Da Costa, J.C. Duarate, R.A. D. Williams. Elsevier Applied Science, London.

6. Extreme Environment. Mechanism of Microbial Adaptation. Edited by Milton R. Heinrich. Academic Press.

7. Thermophiles. General, Molecular and Applied Microbiology. Edited by Thomas D. Brock. Wiley Interscience Publication.

8. Microbiology: Dynamics and Diversity by Perry.

9. Microbial Ecology. Fundamentals and Applications by. Ronald M. Atlas and Richard Bartha. 2nd and 4th Edition. The Benjamin Cummins Publication Co. Inc.

10. Microbial Ecology. 2nd Edition. by R. Campbell. Blackwell Scientific Publication.

11. Brocks Biology of Microorganisms. 8th Edition. (International Edition - 1997) by Michael T. Madigan, John M. Martinko. Jack Parker. Prentice Hall International Inc.

12. Advances in Applied Microbiology. Vol. 10. Edited by Wayne W. Umbreit and D. Pearlman. Academic Press.

13. Macan, T. T. (1974). *Freshwater Ecology*. Longman Group Ltd., London,.

14. Meadows, P. S. and J. I. Campbell. (1978). *An introduction to Marine Science*. Blackie & Son Ltd., Glasgow.

15. Richards, B.N. (1987). *Microbiology of Terrestrial Ecosystems*. Longman Scientific & Technical, New York.

REVISED SYLLABUS OF M. Sc. (MICROBIOLOGY) SEMESTER - III

aper No.	Title of the theory paper	Marks/ Credits	Practical	Marks/ Credits
Semester III				
Th-IX	Enzyme Technology	100/04	P-IX	50/02
Th-X	Bioprocess Engineering and Technology.	100/04	P-X	50/02
Th-XI	Molecular Microbial Genetics.	100/04	P-XI	50/02
Th-XII	Environmental Microbial Technology	100/04	P-XII	50/02

PAPER IX ENZYME TECHNOLOGY Marks 100 (04 Credits)

Unit I Extraction and Purification of Microbial Enzymes (0.8 Credit)

Importance of enzyme purification, different sources of enzymes. Extra cellular and intracellular enzymes. Physical and chemical methods used for cell disintegration. Concentration of the enzyme extract, Enzyme fractionation by precipitation using salts and solvents, liquid – liquid extraction, ion exchange chromatography, gel filtration, affinity chromatography and other special purification methods. Analysis of purity, Enzyme crystallization techniques, Criteria for purity of enzymes, tests of homogeneity of purified enzymes.

Unit II Enzyme Inhibition and Kinetics (0.8 Credit)

(i) Enzyme Inhibition- Irreversible and reversible enzyme inhibitions. Competitive, uncompetitive and non competitive enzyme inhibitions with suitable examples and their kinetic studies.

(ii) Allosteric inhibition- Positive and negative cooperativity, sigmoidal kinetics and allosteric enzymes. Models accounting cooperativity – Hill, Adair, MWC and KNF models. Cooperative binding of oxygen to haemoglobin – significance of sigmoidal behaviour. Types of allosteric inhibition and their kinetic studies and significance in metabolic regulation. Aspartate transcarbamoylase as allosteric enzyme.

(iii) Regulation of enzyme activity- Allosteric regulation, feedback regulation and cascade system (Genetic regulation), covalent modification.

Unit III Immobilization of enzymes and Bioconversion Processes (0.8 Credit)

Principles, parameters, carriers/matrices used for immobilization, techniques of enzyme immobilization viz. adsorption, covalent bonding, entrapment and membrane confinement. Economic argument for immobilization, Effect of solute partition and diffusion on the kinetic properties of enzymes. Analytical therapeutic, environmental and industrial applications of immobilized enzymes. Application of immobilized enzymes in bioconversion processes, Bioreactors using immobilized enzymes. Immobilization of whole cells versus immobilization of enzymes.

Unit IV Enzyme/Protein Engineering (0.8 Credit)

Objectives of Protein Engineering, basic strategy of enzyme engineering. Protein engineering versus enzyme engineering as a biocatalyst. Techniques of Protein Engineering, Chemical modification and Site directed mutagenesis to study the structure- function relationship of industrially important enzymes. Hybrid enzymes. Examples of Protein Engineering applications- Improvement in stability, catalytic efficiency, selectivity and substrate specificity, purification and biopharmaceutical applications etc.

Unit V Clinical Enzymology (0.8 Credit)

(i) Enzymes in clinical diagnostics (Blood Glucose, Blood Urea, Cholesterol, Diagnosis of liver disorders and heart disorders like Myocardial infarction). Enzymes and inborn errors, their use as markers in cancer and other diseases.

(ii) Enzyme sensors for clinical purposes. Enzyme immunoassay.

(iii) Enzyme therapy – Treatment of genetic deficiency diseases, Enzymes in cancer therapy, Enzyme inhibitors and drug design, therapeutic importance of ribozymes and abzymes

PRACTICAL PAPER IX ENZYME TECHNOLOGY

Marks 50 (02 Credits)

1. Microbial production, extraction, purification and confirmation of α- Amylase/ Protease/Lipase/ Invertase/ Urease.

2. Determination of efficiency of enzyme purification by measuring specific activity at various stages viz. Salt precipitation, Dialysis, Electrophoresis etc.
3. Studies on activation and inhibition of extracted enzyme. (Effect of heavy metal ions, chelating agents, activators and inhibitors)
4. Immobilization of cells and enzyme using Sodium alginate/ egg albumin and measurement of enzyme activity of immobilized α- Amylase/ Protease/Lipase/ Invertase/ Urease.
5. Impact of immobilization on enzyme activity in terms of temperature tolerance, Km/ Vmax using various forms of α- Amylase/ Protease/Lipase/ Invertase/ Urease.
6. Determination of molecular weight of enzymes using PAGE technique.
7. Preparation of Urease biosensor and determination of its activity.
8. Determination of blood glucose by glucose oxidase biosensor.

REFERENCES

1. Methods in Enzymology Volume 22- Enzyme purification and related techniques. Edited by William B. Jakoby, Academic Press, New York.
2. Allosteric Enzymes – Kinetic Behaviour, 1982 by B.I. Kurganov, John Wiley and Sons. Inc., New York.
3. Biotechnology Volume 7A – Enzymes in Biotechnology, 1983. Edited by H.J. Rehm and G.Reed, Verlag Chemie.
4. Handbook of Enzyme Biotechnology by Wiseman.
5. Enzyme as Drugs Edited by John S. Holcenberg and Joseph Roberts, John Wiley and Sons. Inc., New York.
6. Methods of Enzymatic Analysis by Hans Ulrich, Bergmeyer, Academic Press
7. Methods in Enzymology by W.A.Wood, Academic Press
8. Advances in Enzymology by Alton Meister, Interscience Publishers.
9. Topics in Enzyme and Fermentation Biotechnology by L.N. Wiseman, John Wiley and Sons. Inc., New York.
10. Fundamentals of Enzymology by Nicholas C. Price and Lewis Stevens, Oxford University Press.
11. Biocatalysts and Enzyme technology by Klaus Buchholz, Volker Kasche, Uwe T. Bornscheuer, Wiley- VCH Verlag GmbH and Co., Germany.
12. Protein Purification techniques Edt. Simon Roe, Oxford University Press.

13. Enzymes- Biochemistry, Biotechnology, Clinical chemistry by Trevor Palmer. East- West Press Edition.

PAPER X

BIOPROCESS ENGINEERING AND TECHNOLOGY
Marks 100/ (04 Credits)

Unit-I: Introduction to Industrial Bioprocess Engineering (0.8 Credits)

Definition of bioprocess engineering, bioprocess engineer, biotechnology and bioprocess engineering, approach of biologist and engineers towards research, regulatory constraints of bioprocess. Batch growth (growth pattern and kinetics in batch culture, environmental factors affecting growth kinetics), Monod's equation, continuous culture, Chemostat and turbitostat (construction and working), mixed culture in nature, industrial utilization of mixed culture.

Unit-II : Bioreactors (0.8 Credits)

Design of basic bioreactor, bioreactor configuration, design features, individual parts, baffles, impellers, foam separators, spargers, culture vessel, cooling and heating devices, probes for on-line monitoring computer control of fermentation process, measurement and control of process. Ideal batch reactor, ideal continuous flow stirred tank reactor, packed bed reactor bubble column reactor, fluidized bed bioreactor, Trickle bed reactor (Their basic construction, working, and distribution of gases).

Unit III: Mass Transfer and Sterilization (0.8 Credits)

Transport phenomena in bioprocess system: Gas liquid mass transfer in cellular systems, basic mass transfer concept, Rate of metabolic oxygen utilization, Determination on oxygen transfer rates, determination of Kla, Heat transfer, aeration / agitation and its importance. Sterilization of bioreactors, nutrients, air supply, product and effluents, process variable and control, scale up of bioreactor.

Unit-IV: Upstream processes (0.8 Credits)

Inoculum development, formulation of production media, sterilization of media, maintenance of stock culture, scale up of the process from shake flask to industrial level. Growth of culture in fermenter , choosing cultivation methods , Modifying batch and

continuous reactors, immobilization cell systems, active and passive immobilization , solid state fermentation process.

Unit-V: Down Stream Process (0.8 Credits)

Down stream processes : Introduction , Recovery of particulates filtration , centrifugation , sedimentation , emerging technologies for cell recovery , product isolation , extraction , solvent extraction , aqueous two phase system , sorption , precipitation , reverse osmosis, ultra filtration. Product recovery traits: Commercial enzymes, Intracellular foreign proteins from recombinant E. coli, polysaccharide and biogum recovery, antibiotic, organic acids, ethanol, single cell protein

PAPER P-X
BIOPROCESS ENGINEERING AND TECHNOLOGY
Marks 50 (02 Credits)

1. Isolation of industrially important microorganisms for microbial processes (citric / lactic / alpha amylase) and improvement of strain for increase yield by mutation.
2. Determination of Thermal Death Point (TDP) and Thermal Death Time (TDT) microorganisms for design of a sterilizer.
3. [A] Determination of growth curve of a supplied microorganism and also determine substrate degradation profile. [B] Compute specific growth rate (m), growth yield ($Y_{1/2}$) from the above.
4. Extraction of Citric acid / Lactic acid by salt precipitation.
5. Monitoring of dissolved oxygen during aerobic fermentation.
6. Preservation of industrially important bacteria by lyophilization.
7. Product concentration by vacuum concentrator.
8. Cell disruption for endoenzymes by sonication.

References:

1. James E .Bailey and David F Ollis, Biochemical Engineering Fundamentals, McGraw Hill Publication.
2. Shuler and Fikret Kargi, Bioprocess Engineering basic concepts, 2nd edition , Prentice Hall Publication.
3. Stanbury PF, Whitekar, A And Hall SJ, Principles of fermentation Technology, Pergamon Press.

4. Peppler and Perlmen , Microbial Technology, Vol I and II , Academic Press.

5. Cruger and Cruger , Biotechnology : A text Book of Industrial Microbiology.

6. Fermentation- A practical Approach

7.Bioprocess Technology: Fundamentals and Applications, Stockholm KTH.

8. Biochemical Reactors by Atkinson B., Pion Ltd. London

9. Fermentation Biotechnology: Industrail Perspectives by S. Chand and Co.

10. Biotechnology : A text book of Microbiology by Cruger

11.Biotechnology, Vol. 3 Edited by H.J. Rehm and G.Reed Verlag Chemie 1983.

12. Advances in Biochemical Engineering by T.K. Bhosh, A. Fiechter and N. Blakebrough, Springer, Verlag Publications, New York.

13. Bioprocess Engineering Kinetics, Mass Transport, Reactorsand Gene Expressions by Veith, W.F., John Wiley and Sons.

14. Applied Microbiology Series.

15. Industrial Microbiology by L.E. Casida, Wiley Eastern.

16. Bioseperation: Down Stream Processing for Biotechnology by Belter P.A., Cussler E.L. and Hu W.S., John Wiley and Sons, New York.

17. Seperation Processes in Biotechnology by Asenjo J.A., Eds. Marcel dekker, New York.

18. Bioprocess Engineering Priciples by Doran, Academic Press, London.

19. Bioprocess Engineering Principles by Neilsen J. and Villadesen, Plenum Press, New York.

20. Fermentation, Biocatalysis and Bioseperation, Encyclopedia of Bioprocess technology by Chisti Y., Vol. 5, John Wiley and Sons., New York.

PAPER TH-XI
Molecular Microbial Genetics

Marks 100 / (04 Credits)
Unit – 1 (0.8 Credits)

Deoxyribonucleic acid

Differences in organization of prokaryotic & Eukaryotic Genome

Primary structure - linear polyncleotide, Secondary structure- double stranded helical structure (Watson and Crick model), Tertiary Structure: negative and positive superhelices, geometry of superhelical DNA, enzymatic activity altering DNA supercoiling (Role of Top I & II),

Types of nucleotide sequences- non-repetitive and repetitive.

Physical characteristics of DNA- Bouyant density, Adsorption in uv, denaturation, renaturation and hybridization, Cot curve & C-Value Paradox, bends in DNA

Forms of DNA: A , B, C and Z forms.,

Left handed DNA- negative supercoiling stabilizes Z DNA, biological role

Types of DNA molecules-linear single stranded and duplex, closed circular duplex

DNA Replication – Basic rules of replication, methods of replication-circular DNA, Duplex linear dsDNA molecules, Replications proteins in prokaryotes, Structure of Replisome.

Replication in bacterium E.coli_ Initiation, elongation and termination

DNA Modification – Post Replication Process – Role of Methylase in Modification & Regulation of Gene Expression.

Mutations at Molecular Level – Transitions, Transversions, Misscence Mutations, Suppressions & Reversions

Mutagens modifying replicating DNA – 5- Bromouracil, 2 aminopurine.

Mutagens altering resting DNA - Nitrous acid, Hydroxyl amine, Alkylating & Intercalating agent. U. V. Mutagenesis. Advance applications of mutation: Site directed mutagenesis

Repair Mechanisms: - Photoreactivation, Exicision, Retrieval systems, Mismatch repair & SOS Repair

Unit -2 (0.8 Credits)

Prokaryotic Transcription and Translation.

Types of RNA- primary and molecular structures and functions of m RNA- Mesenger RNA-polycistronic, polyribosomal, structure and function of SD sequence

rRNA-16S, 23S rRNA, configuration of 70S rRNA and tRNA-primary,secondary and tertiary structures, antisense RNA, Ribozymes a small catalytic RNA, Silent features of prokaryotic Transcriptions, Structure of Transcription Bubble, Structure of Pribno box, DNA Foot printing, electron crystallographic structure, Properties & Function of RNA Polymerase, types and functions of sigma factors, Molecular Mechanism of Initiation-models of formation of closed and open complexes, elongation in Transcription, (Inchworm model-model of an elongating RNAP). Mechanism of *Rho* Dependent & Independent Transcription, Anti-Termination (Role of N, Q, ancillary proteins, Nus proteins, ribosomal configuration)

RNA Processing - Differences in Prokaryotic & Eukaryotic RNA Processing, Processing for t-RNA & r-RNA. In prokaryotes, Polyadenylation, capping and introns splicing in Eukaryotes.Genetic code- Discovery, silent features of genetic code, Degeneracy of genetic code and wobble hypothesis

Steps involved in transcription-Initiation,elongation and termination-. Role of IF1,IF2,IF3,EFTU, EFTS, EFG, RF1,RF2 and RF3 in Protein synthesis,types and properties of aminoacyl synthetase, charging of tRNA, structure of coagnate, Differences between fmet t RNA and other amonoacyl tRNA.

Antibiotics and Chemical compounds as Inhibitors of protein synthesis

Post/Co translational modification- modifications in primary proteins, role of chaperons, cell and protein signaling for proper cellular uptake.

Differences in prokaryotic and Eukaryotic systems of transcription and translation.(Overview)

Unit – 3 Regulation of gene expression in prokaryotes (0.8 Credits)

Regulation at the level of transcription- Operon concept, Constitutive genes and Regulating genes, types and properties of promoters for constitutive and Regulated expression, Co-ordinated control of structural genes, stringent response, catabolite repression, instability of bacterial RNA,

Positive regulation in *E. coli* [Arabinose operon] and

Negative regulation in *E. coli* [lac operon],- Basic operon model, Molecular structure and organization of inducers and repressors, Inducible operon, role of CAP-CAMP ,Repression, fate of mutation in Cis and Trans acting genes of lac operon, Regulation by attenuation by trp operon., Regulation of cI repressor (Lambda operon) , Insertion of Tn element in switch off of expression.,Regulation of DNA Repair genes.

Regulation at the level of translation

Antisense t RNA technology, regulation of synthesis Tn m RNA

Unit – 4 Transposition and Molecular mapping (0.8 Credits)

Differences in Homologous and non homologous recombination, Role of Rec proteins in homologous Recombination, Models of recombination.

Mapping by conjugation- Intermittent matting experiment with Hfr cell.

Transposons – Discovery, types of transposons- Insertion sequences and composite transposons, Transposons in Prokaryotes(Bacteria and Phages, animal viruses) , transposons in maize, Mechanism of transposition- duplication of target sequences, replicative, non-replicative and conservative transposition, role of integrase and resolvase in Cointegrate formation, Role of transposons in acquisition of multiple drug resistance, Detection of transposition, Mutations i.e., Deletions, Inversions and Frame-shift due to transposition.

Unit – 5 Phage Genetics (0.8 Credits)

T4 virulent phage: structure, life cycle, genetic map , properties of T4 DNA, Structure of T4 replisome, Silent features of T4 DNA Replication- availability of nucleotide precursors, Synthesis of HMC , Control in synthesis of cytosine, Glycosylation, In vivo and In vitro packeging' .

Lamda temperate phage: Structure, genetic map, lytic and lysogenic cycle, replication of lambda phages ,lytic and lysogenic casacad, mechanism of antitermination to synthesize seven different mRNA from Lambda DNA,, role of regulator proteins, lysogenic regulation,

autoregulation of cI Repressor, Induction of lysogen, Immunity to superinfection

Filamentous bacteriophages- M13- Structure, life cycle (pattern of DNA replication)

Structure and replication of phage phi x 174

Molecular recombination in phages

Applications of phages in molecular biology (Role in recombination and gene cloning)

PRACTICAL

PAPER - P-XI MOLECULAR MICROBIAL GENETICS
Marks 50 (02 Credits)

1. Isolation and Purification of genomic DNA from E.coli / Bacillus sp.
2. Isolation and purification of Plasmid from plasmid bearing E.coli by alkaline lysis method
3. Detection and location of DNA : Spectrophotometrically, Diphenyl amine test, agarose gel electrophoresis
4. Isolation and purification of RNA from yeast, Quantitative estimation of RNA by Orcinol test.
5. Determination of LD50 value for E.coli using ultraviolet radiations (UV survival pattern of E. coli/yeast)
6. Studies on light and dark repair mechanisms in E. coli/yeast using UV radiations
7. Isolation of antibiotic resistant mutants by chemical mutagenesis.
8. Ampicillin selection method for isolation of auxotrophic mutant.(Replica plate method)
9. Studies on regulation of synthesis of inducible enzyme beta galactosidase in E.coli
   Inducible operon-Effect of different inducers
   Catabolite inactivation;
   Effect of UV radiations on Regulator, Promotor and operator regions of lac operon.
10. Studies on gene transfer by conjugation\Transformation in E. coli.

PAPER TH-XII
(ENVIRONMENTAL MICROBIAL TECHNOLGY)
Marks 100 (04 Credits)

Unit – 1 Environment and Ecosystems (0.8 Credits)

Definitions, biotic and abiotic environment. Interaction between biota and its environment, Environmental segments. Composition and structure of environment. Concept of Habitat, Concept of biosphere, communities and ecosystems. Ecosystem characteristics structure and function. Homeostasis of ecosystem, Food chains, food webs and trophic structures. Ecological pyramids..

Unit – 2 Eutrophication (0.8 Credits)

Water pollution and its control: Need for water management. Sources of water pollution. Measurement of water pollution, Eutrophication: Definition, causes of eutrophication, and microbial changes in eutrophic bodies of water induced by various inorganic pollutants. Effects of eutrophication on the quality of water environment, factors influencing eutrophication. Qualitative characteristics and properties of eutrophic lakes. Measurement of degree of eutrophication. Algae in eutrophication, algal blooms, their effects

and toxicity, coloured waters, red tides, and cultural eutrophication. Physicochemical and biological measures to control eutrophication.

Unit –3 Effluent treatment techniques (0.8 Credits)

Microbiology of wastewater and solid waste treatment: -Waste-types-solid and liquid waste characterization, physical, chemical, biological, aerobic, anaerobic, primary, secondary and tertiary treatments. Anaerobic processes: Anaerobic digestion, anaerobic filters, and upflow anaerobic sludge. Treatment schemes for effluents of dairy, distillery, tannery, sugar and antibiotic industries (Types, microbes used, types of Effluent Treatment Plants). Biochemistry of nitrate and sulphate reduction with a special reference to waste treatment, Bioconversion of Sold Waste and utilization as fertilizer. Bioaccumulation of heavy metal ions from industrial effluents.

Unit – 4 Bioremediation of Xenobiotics (0.8 Credits)

Definition of recalcitrant/ xenobiotic compounds, their presence in the natural ecosystem, Concept and consequences of biomagnification, Microbiology of degradation of xenobiotics in the environment, ecological considerations, decay behavior, biomagnification and degredative plasmids, hydrocarbons, substituted hydrocarbons, oil pollution, surfactants and pesticides. Genetically Modified Organisms released and its environmental impact assessment and ethical issues.

Unit – 5 Global environmental problems (0.8 Credits)

Concept of sustainable development. Need of sustainable development, Role of Microbial technology for achieving sustainable development, Improving and restoration of Barron/ degraded lands, Renewable energy sources using microorganisms, Biodiversity and its conservation, Ozone depletion, UV-B, green house effect and acid rain, their impact and biotechnological approaches for management. . Containment of acid mine drainage applying biomining [with reference to copper extraction from low grade ores].

PAPER P-XII
ENVIRONMENTAL MICROBIAL TECHNOLOGY
Marks 50 (02 Credits)

1. Physical analysis of sewage / industrial effluent by measuring total solids, total dissolved solids and total suspended solids.
2. Determination of indices of pollution by measuring BOD / COD of different effluents.
3. Bacterial reduction of nitrate from ground waters.

4. Isolation and purification of degradative plasmid of microbes growing in polluted environments.
5. Recovery of toxic metal ions of an industrial effluent by immobilized cells.
6. Utilization of microbial consortium for the treatment of solid waste [Municipal Solid Waste].
7. Biotransformation of toxic chromium (+6) into non-toxic (+3) by Pseudomonas species.
8. Tests for the microbial degradation precuts of aromatic hydrocarbons / aromatic compounds.
9. Reduction of distillery spent wash (or any other industrial effluent) BOD by bacterial cultures.
10. Microbial dye decolorization / adsorption.

References:

1. Bioremediation by Baker K.H. and Herson D.S. 1994, McGraw Hill Publications, New York.
2. Waste Water Engineering- Treatment, Disposal and Re-use by Metcalf and Eddy, Tata McGraw Hill, New York
3. Pollution: Ecology and Biotreatment by Ec Eldowney S., Hardman D.J. 1993 Longman Scientific Technical.
4. Environmental Microbiology edited by Ralph Mitchell, John Wiley and Sons., New York.
5. Waste Water Microbiolgy, 2 nd Edition by Bitton.
6. Chemistry and Ecotoxicology of Pollution, Edited by Des. W. Connell, G.J. Miller, Wiley Interscience Publications.
7. Environmental Biotechnology Edited by C.F. Forster and D.A. John Wase, Ellis Horwood Ltd.
8. Advances in Waste water Treatment Technologies 1998 Vol. I and II by R.K. Trivedy, Global Science Publications.
9. Biocatalysis and Biodegradation: Microbial transformations of organic compounds. 2000, by Lawrence P. Wacekett, C. Douglas Hershberger, ASM Publications
10. A Manual of Environmental Microbiolgy 2 nd edition 2001 by Christon J. Hurst(Chief Editor), ASM Publications.
11. Biodegradation and Bioremediation, Academic Press, San Diego.

12. Biotechnology in the sustainable environment, Plenum Press, New York.

13. Basic Principles of Geo Microbiology by A.D. Agate, Pune.

M. Sc. (MICROBIOLOGY)
SEMESTER - IV

Paper No.	Title of the theory paper	Marks/ Credits	Practical	Marks/ Credits
Semester IV				
Th-XIII	Recombinant DNA Technology	100/04	P-XIII	50/02
Th-XIV	Fermentation Technology	100/04	P-XIV	50/02
Th-XV	Bioinformatics, Microbial Genomics and Proteomics.	100/04	P-XV	50/02
Th-XVI	Pharmaceutical Microbiology	100/04	P-XVI	50/02

[Semester IV]

PAPER TH - XIII RECOMBINANT DNA TECHNOLOGY

Marks 100 (04 Credits)

Unit – 1 Introduction, Core technique and Enzymes in gene manipulation (0.8 Credit)

Classical genetics to Modern Genetics, Approach of genetic engineering, advantages and limitations, Common steps in core technique. Enzymes in gene manipulations (DNA/RNA) : Classification, types, properties and mechanism of action of-Restriction endonuclease, ligase (T4 & E.coli ligase), Reverse transcriptase. Role of alkaline phosphatase, polynucleotide kinase ,Nucleotidyl transferase, Bal 31 and S1 nuclease, DNA polymerase, RNAse , Ribozymes etc. in gene manipulation.

Unit-2 Tools and Techniques involved in genetic engineering (0.8 Credit)

Electrophoretic techniques in DNA analysis-Agarose gel electrophoresis, PAGE, Pulse field gel electrophoresis, DISC gel electrophoresis, electroelution, autoradiography, Restriction mapping, DNA sequencing-Maxam-Gilbert, Sanger's dideoxy and automated methods of DNA sequencing. Gene silencing, Principle, technique and applications of chromosome walking, chromosome jumping, RFLP, RAPD, AFLP, DNA fingerprinting

Chromosome microdissection and microcloning, Microarray- principle, methodology, advantages and applications.

Unit-3 Vectors used in gene cloning (0.8 Credit)

Strategies of -Cloning vectors and expression vectors

Vectors of E.coli_ : Plasmid vectors: Properties of plasmids, PBR 322-genetic evolution, map and function, pUC vectors

Phage vectors: Lambda phage vectors: gt phages , Charon vectors, EMBL vectors, M13 mp vectors

Higher capacity vectors: Cosmids, Phagmid bluescript vectors

High level expression/production vectors: PET vectors, PINPOINT vectors, BAC

Vectors for yeast : 2 µ plasmid vector, ARS vectors, mini chromosome vectors and YAC . Shuttle vectors: SV 40 plasmid vectors, retrovirus vectors.

Vectors of plant: Ti plasmid vector

Unit -4 Technique of gene cloning (0.8 Credit)

Isolation of gene of desired interest: Physical and Enzymatic using Restriction endonucleases, modification of cut ends, Chemical synthesis of genes and methods of

joining the fragments into vectors, Ideal hosts in gene cloning, Different methods of transformation, Isolation of recombinant clones.

Construction of genomic and cDNA libraries: concept of library construction, differences and ideal examples of each library.Selection and Identification of clones containing recombinant vectors: Selectable and scorable markers, Insertional inactivation, colony hybridization, plaque lift assay, In Vitro translation:-Hybrid arrested translation, Hybrid release translation. Fluorescence activated cell sorter, southern hybridization, northern hybridization, Exon cloning,mini cells and maxi cells.

Screening for protein expression- Reporter gene expression, Phage display, south-western, Immunodiffussion, Radiolabelled antibody test, ELISA and western blotting

Unit -5 Applications of genetic engineering and PCR (0.8 Credit)

Areas of applications of rDNA technology, Production of recombinant Insulin, Hepatitis B surface antigen, Production of monoclonal antibodies, rDNA in gene therapy (ADA Deficiency)

Construction of BT cotton plant and transgenic tomatos/potatos.

PCR alternative to gene cloning- advantages, principle and Procedure, optimization of PCR, Designing of primers, Identification of PCR products, Variations in basic PCR- Inverse, asymmetrical , multiplex, Hot start, ligation mediated, RT , Real-time quantitative PCR, DD PCR and Immuno PCR.

Applications- DNA cloning for sequencing, DNA-based phylogeny, or functional analysis of genes; the diagnosis of hereditary diseases; the identification of genetic fingerprints (used in forensic sciences and paternity testing); the detection and diagnosis of infectious diseases. PCR based Site directed mutagenesis, Identification of pathogens.

Practicals Based on

Paper - P-XIII RECOMBINANT DNA TECHNOLOGY Marks 50/(02 Credits)

1. Isolation of Genomic DNA from *E. coli & Pseudomonas.*
2. Agarose Gel Electrophoresis.
3. Isolation of Plasmid DNA from *E. coli*.
4. DNA Denaturation and Determination of T_m and G + C content of Genomic DNA of *E. coli & Pseudomonas*.
5. Restriction Digestion of λ DNA.
6. Studies of Back Extraction of DNA by Electroelution.

7. Studies on Ligation Chain Reaction.
8. Gene Cloning: - Cloning of GFP Gene
9. Southern Hybridization.
10. Western Blotting.
11. RAPD – Rapid Amplification of Polymorphic DNA.
12. RFLP Analysis.

References

1. Principles of Gene Manipulations 1994 by Old and Primrose Blackwell Scientific Publications.
2. DNA Cloning: A Practical Approach by D.M. Glower and B.D. Hames, IRL Press, Oxford. 1995.
3. Molecular Biotechnology 2nd Edition by S.B. Primrose. Blackwell Scientific Publishers, Oxford. 1994.
4. Genetic Engineering and Introduction to Gene Analysis and Exploitation in Eukaryotes by S.M. Kingsman and A.J. Kingsman, Blackwell Scientific Publications, Oxford 1998.
5. PCR Technology - Principles and Applications for DNA Amplification by Henry A. Erlich (Ed.) Stockton Press. 1989.
6. Biotechnology: A Guide to Genetic Engineering by Peters.
7. Weaver Molecular Biology.
8. Genetic Engineering – 2000 by Nicholl.
9. Recombinant DNA and Biotechnology: Guide for Teachers. 2nd Edition by Helen Kreuz. 2001.ASM Publications.
10. Molecular Biotechnology: Principles and Applications of Recombinant DNA. 2 nd Edition. 1998 by Bernard R. Glick and Jack J. Pastemak, ASM Publications.
11. From genes to clones by Winnaker.
12. Manipulations and expression of recombinant DNA by Robertson.
13. Gene targeting – A practical approach by Joyner.

PAPER TH-XIV: FERMENTATION TECHNOLOGY

Marks 100 (04 Credits)

Unit – 1 Microbial Fermentations (0.8 Credit)

Strain Improvement Programme, Media formulation, industrial production, Downstream Processing, Biosynthesis, Regulation and metabolic control of:

Organic acids -Citric acid, lactic acid

Enzymes - alpha-amylase, lipase, xylase, pectinases, proteases

Organic solvent - acetone- butanol and Vinegar fermentation.

Amino acids - lysine and glutamic acid.

Unit – 2 Microbial production of therapeutic compounds (0.8 Credit)

Strain Improvement Programme, Media formulation, industrial production, Downstream Processing, Biosynthesis, Regulation and metabolic control of:

Penicillin, Streptomycin, Rifamycin and Tetracycline.

Biotransformation of steroids, antibiotics..

Vitamin B12 and riboflavin fermentation.

Unit – 3 Modern trends in microbial production (0.8 Credit)

Modern trends in microbial production of bioplastics (PHB, PHA), bioinsecticies (thuricide), biopolymer (dextran, alginate, xanthan, pullulan), Biofertilizers (nitrogen fixers and Phosphate solubilizers viz. Azotobacter, Rhizobium, Azolla, Water hyacinth; Field application of biofertilizer), Biosurfactants, Single Cell Protein and single cell oil.

Bioterrorism (bacterial and viral weapons) – Historical events, types of biological agents, Modern bioterrorist incidents and limitations of bioterrorism.

Mushroom cultivation.

Unit – 4 Biofuels and Plant Tissue Culture (0.8 Credit)

Useful features of bio-fuels. The substrate digester and the microorganisms in the process of biogas production (biomethanation). Production of bioethanol from sugar, molasses, starch and cellulosic materials. Microbial production of hydrogen gas, biodiesel from hydrocarbons.

Introduction to cell and tissue culture, tissue culture media: composition and preparation, initiation and maintenance of callus and suspension culture, single cell clones, organogenesis: principle, concept and applications of somatic embryogenesis, embryo culture, anther, pollen and ovary culture for production of haploid plants and homozygous lines. Cryopreservation, slow growth and DNA banking for germplasm conservation.

Unit – 5 IPR and Patents (0.8 Credit)

Intellectual Property Rights (IPR), Patents - Patenting of biological materials, obligations with patent applications, implication of patenting, current issues, hybridoma technology etc., Trademarks, Copyrights, Secrets, Trademarks and geographical indications; IPR and plant genetic resources (PGRs) Patenting of higher plants and animals, transgenic organisms and

isolated genes, patenting of genes and DNA sequences, plant breeders right and farmers rights.

PRACTICALS

PAPER P-XIV FERMENTATION TECHNOLOGY

Marks 50/(02 Credits)

1. Citric acid fermentation by using A. niger,
   a. Production and purification.
   b. Qualitative detection by titratable acidity and paper chromatography.
   c. Quantitative estimation of citric acid by Pentabromoacetone method.
   d. Effect of different carbon, nitrogen sources and metal ions on citric acid production.
2. Microbial production of glutamic acid.
3. Production, purification and bioassay of Rifamycin/Streptomycin.
4. a. Production, distillation and estimation of ethanol using various Organic wastes /raw Material (e.g. agro wastes, different fruit juices, etc.) from free cells of yeast.
   b. Ethanol fermentation using immobilized yeast cells.
5. Production, extraction and bioassay of thuricide.
6. Laboratory scale production of biofertilizers [Nitrogen fixer/Phosphate Solubilizers].
7. Microbial production, purification, qualititative and quantitative estimation of polysaccharide from Leuconostoc mesenteroides/ Pseudomonas
8. Microbial production of single cell protein by algae/bacteria/yeast.
9. Bioassay of vitamin B12/B2.
10. Preparation of callus culture
11. Preparation of suspension culture

References: -

1. Biotechnological Innovations in Chemical Synthesis. BIOTOL. Publishers / Butterworth - Heinemann.
2. Industrial Microbiology by G. Reed (Ed), CBS Publishers (AVI Publishing Co.)
3. Biology of Industrial Microorganisms by A.L. Demain.

4. Genetics and Biotechnology of Industrial Microorgansims by C.l. Hershnergey, S.W.Queener and Q. Hegeman. Publisher. ASM. Ewesis ET. Al. 1998. Bioremediation Principles. Mac Graw Hill.
5. Annual Reports in Fermentation Processes by D. Pearlman, Academic Press.
6. Fundamentals of Biochemical Engineering by Bailey and Ollis.
7. Annual Review of Microbiology by Charles E. Cliffton (Volumes)
8. Biotechnology, A textbook of industrial Microbiology by Creuger and Creuger, Sinaeur associates.
9. Manual of industrial Microbiology and Biotechnology 2nd edition by Davis J.E. and Demain A.L. ASM publications.

PAPER TH-XV

BIOINFORMATICS, MICROBIAL GENOMICS AND PROTEOMICS.

Marks 100 (04 Credits)

UNIT- I BIOINFORMATICS AND ITS APPLICATIONS (0.8 Credit)

Introduction to Bioinformatics: Definition and History of Bioinformatics, Internet and Bioinformatics, relationship between molecular evolution and bioinformatics. Structure function relationship, Data Mining, Basic data structure, Databases: Types of Databases Nucleotide sequence databases;
Primary nucleotide sequence databases- EMBL, GenBank, DDBJ.
Secondary nucleotide sequence databases- UniGENE, SGD, EMI Genome, Genome Biology.
Protein sequence database – SWISS PROT, TrEMBL, PIR, MIPS, NRL-3D
Protein Family database – PFAM, PROSITE, PRINTS, BLOCKS, eMOTIF
Protein Structure database – PDB, SCOP, CATH
Composite database – NRDB, OWL, MIPS, SWISS-PROT + TrEMBL
Bioinformatics Softwares: Clustal V, Clustal W 1.7, RasMol, Oligo, Molscript, Treeview, Alscript, Genetic Analysis Software, Phylip
Search and retrieval of biological information and database sequence, Databank (PDB and GenBank) Accessing information (Network expasy, EMB Net, ICGEB Net) Protein domain and human genome analysis programme, Applications of Bioinformatics

UNIT – II WHOLE GENOME ANALYSIS (0.8 Credit)

Human genome project, uses and application, Genome information and special features, coding sequences, (CDS), Untranslated regions (UTR'S), cDNA library, Expressed sequence Tags (EST). Approach to gene identification, Preparation of ordered cosmid libraries, Bacterial Artificial Libraries, Shotgun Libraries and sequencing, Conventional sequencing (Sanger, Maxam and Gilbert method) Automated sequencing.

UNIT – III SEQUENCE ANALYSIS (0.8 Credit)

Algorithms; uses and applications, Local and Global sequence alignment.
Single Sequence Alignment; Pairwise alignment:
Scoring Matrix – PAM, BLOSUM, Gap penalty.
Dynamic programming – Needleman – Wunsch, Smith- waterman
Heuristic Methods- FASTA, BLAST for protein and nucleic acid.
Multiple Sequence Alignment;
ClustalW , PROFILE, PSI- BLAST, Hidden Markov Models (HMMs)
Annotation of Gene, Open reading frames (ORF), Conserved protein motifs related structure / function (PROSITE, PFAM, Profile Scan). protein motifs.
DNA analyses for repeats (Direct and inverted), palindromes, folding programmes. Use of Internet, public domain databases for nucleic acid and protein sequences (EMBL, GeneBank), database for protein structure (PDB).

UNIT- IV DNA – MICROARRAY (0.8 Credit)

Concept of micro array, Spotted arrays, Oligonucleotide arrays, Designing the experiment, Two – colour micro array experiments, Computational analysis of microarray data.

Printing of oligonucleotide and PCR products on glass slides, nitrocellulose paper. Whole genome analysis for global patterns of gene expression using fluorescent labeled cDNA or end labeled RNA probes, analysis of SNP Using DNA chips.

Tools for microarray analysis:- Soft finder, xCluster, MADAM, SAGE. Advantage, disadvantage and application of DNA microarray. Introduction and tools to phylogenetic tree analysis.

UNIT- V PROTEOMICS (0.8 Credit)

Definition, Protein sequence information, composition and properties, physicochemical properties based on sequence, database, Two dimensional separation of total cellular protein, isolation and sequencing, Analysis individual protein spot by Mass spectroscopy (MALDI- TOF), Electro Spray Ionization (ESI), Tandem mass spectroscopy (MS/MS) tryptic digestion and peptide Mass finger printing(PMF), 3D structure determination by X-ray and NMR. Protein identification programme – MASCOT, PeptIdent, Protein prospector, GFS. Advantage, disadvantage and application of protein microarray.

PRACTICAL

PAPER- P-XV: - BIOINFORMATICS, MICROBIAL GENOMICS AND PROTEOMICS.

Marks 50 (02 Credits)

Use of Internet /software for sequence analysis of nucleotides and proteins.

1. Studies of public domain databases for nucleic acid and protein sequences.
2. Determination of protein structure (PDB) by using RASMOL, CN -3D software
3. Genome sequence analysis by using BLAST algorithm
4. Protein sequence analysis by using BLAST algorithm

References

1. Bioinformatics. 1998 by Baxevanis
2. Bioinformatics 2000 by Higgins and Taylor OUP.
3. Nucleic acid Research 2001. Jan. Genome database issue.
4. The Internet and the new Biology: Tools for Genomics and Molecular Research by Peruski, Jr. and Peruske (ASM) 1997.
5. Functional Genomics. A Practical Approach Edited by Stephen P Hunt and Rick Liveey (OUP) 2000.
6. DNA microarrays: A practical approach edited by Mark Schena (OUP)
7. Bioinformatics - A Practical Guide to the Analysis of Genes and Proteins. 2nd Edition by Baxevanis.
8. Bioinformatics: Sequence, structure and Data Bank: A Practical Approach by Higgis.
9. Bioinformatics - from Genomes to drug. 2 volumes by Lenganer.
10. Bioinformatics Methods and Protocols - Misener.

11. Bioinformatics: Sequence and Genome analysis.
12. Introduction to Bioinformatics by Altwood.
13. Proteome Research: New Frontiers in Functional Genomics: Principles and Practices.
14. Genomics: The Science and Technology behind the human project.
15. Protein Biotechnology. Edited by Felix Franks. Humana Press, Totowa, New Jarsey.
16. Protein Engineering: Principles and Practice by Cleland.
17. Computer analysis of sequence data by Colte.
18. Bioinformatics and molecular evolution – P.G. Higgs & T. K. Attwood, 2005 Blackwell Publishing
19. Bioinformatics by David Mount
20. Bioinformatics- Introduction to Bioinformatics by Pevzner
21. Microarray- Gene expression Data analysis by Causton, Brazma 2003 Blackwell Publishing
22. Essential Bioinformatics by JIN XIONG 2006 Cambridge University press.
23. Microarray Data Analysis Methods and Applications Edited by Michael J. Korenberg 2007 Humana Press Inc.

Web sites for Proteomics and Genomics

1. www.geneprot.com.
2. www.hybrigenis.com
3. www.mdsproteomics.com
4. www.stromix.com
5. www.syrrx.com

Paper XVI : Pharmaceutical Microbiology
MARKS: - 100/ (04 Credits)

Unit I: Principles of Antimicrobial chemotherapy. (0.8 Credit)

Introduction and selection of antimicrobial agents

Concept of Bioassay, therapeutic index, MIC and $LD_{50.}$

Penetrating defenses, as cellular permeability barriers, Cellular transport system and drug diffusion.

Definition and classification of antibiotics, with respect to their mechanism of action, Antibacterial spectrum, Structural activity and relationship (SAR), acquisition of drug resistance, pharmacokinetics and adverse drug effect β- Lactum(Penicillin, Amoxicillin, cefuroxime), aminoglycosides (Streptomycin, Gentamicin), Tetracyclines (Tetracyclin, doxicyclin) , Macrolides (Erythromycin, Azethreomycin), Peptide antibiotics (Bacitracin, polymixin,), Sulphonamides (sulfamethoxazole), co-trimoxazole and quinolones (ciprofloxacin) Chloramphenicol, trimethoprim.

Unit II: Molecular aspects of Antimicrobial Chemotherapy. (0.8 Credit)

Definition, classification, Mechanism of action and examples of chemical disinfectants, antiseptic and preservatives.

Definition, classification, Mechanism of action and examples of antiviral (Acyclovir, zidovudine), Antifungal (amphotericin B, Fluconazole) and Antitumor (Bleomycin, ductinomycin) antibiotics.

Drug delivery system in gene therapy. Approaches and safety considerations associated with gene therapy. Immunological problems associated to gene therapy. Pre-requisites and candidate diseases for human gene therapy. Drug carrier, Macromolecular, cellular, and synthetic Viral and non viral mediated gene delivery.

Introduction, concept and types of drug targeting, cellular level events of drug targeting, targeting ligands, blood cell receptors for endogenous compounds/ ligands, carrier and vesicular system for targeting, specialized liposomes for cellular drug targeting.

Unit III: Microbial Production and spoilage of Pharmaceutical Products. (0.8 Credit)

Manufacturing procedure and in-process control of Pharmaceutical products: Bacterial and Viral vaccine, sterile injectables, Solid dosage forms, liquid orals and Ointments

New Vaccine production: DNA vaccines, synthetic, peptide vaccines, multivalent subunit vaccines, edible vaccines and their trials.

Microbial production and applications of therapeutic / diagnostic enzymes: Asparaginase, Streptokinase, beta lactamases

Microbial production contamination and spoilage of Pharmaceutical products (sterile injectables, ophthalmic preparations and implements) and their sterilization

Applications of Biosensors in pharmaceutical industries.

Unit IV: Regulatory Practices and Policies in Pharmaceutical Industries. (0.8 Credit)

FDA, Govt. regulatory practices and polices.

Concept of R & D and Financing R and D, Quality control and market planning.

Significance of IP, BP and USP.

Reimbursement of drugs, Biological and legislative aspects.
Rational drug design (Quantitative structure activity relation QSAR of drug) and computational aspect of drug design.
Screening and utilization of bioactive phytochemicals.
Patenting of drugs and Biological products

Unit V: Quality Assurance and Validation. (0.8 Credit)

Regulatory aspects of QC, QA, and QM. GMP , GLP and CMP in Pharma Industry. ISO, WHO, USFDA certification. Microbial Limit test of Pharma products. Sterility testing , pyrogen testing and LAL test of Sterile Pharma products. Sterilization- heat, D- value, Z-value and survival curve, radioactive, gaseous and filtration. Chemical and biological indicators. Designing layout for microbiology laboratory.

Practicals based on

Paper XVI : Pharmaceutical Microbiology

Marks: 50 (02 Credits)

1. Spectrophotometeric/ Microbiological methods for the determination of Griseofulvin.
2. Microbial production and Bioassay of Penicillin.
3. Bioassay of Chloramphenicol/Streptomycin by plate assay method or turbitometric assay methods.
4. Screening, Production and assay of therapeutic enzymes: Glucose Oxidase/Asperginase/beta lactamase.
5. Treatment of bacterial cells with cetrimide, phenol, and detection of Leaky substances such as amino acids, nucleic acids as cytoplasmic membrane damaging substances.
6. Determination of MIC and LD50 of Ampicillin / Streptomycin.
7. Sterility testing by using *B. sterothermophilus/ B. subtilis.*
8. Testing for microbial contamination. Microbial loads from syrups, suspensions, creams, and other preparations, Determination of D-value and Z-value for heat sterilization in pharmaceuticals.
9. Determination of antimicrobial activity of chemical compounds (like phenol, resorcinol and formaldehydes) Comparison with standard products.

REFERENCES

1. Pharmaceutical Microbiology- Edited by W. B. Hugo & A.R. Russel Sixth Edition. Blackwell Scientific Publications.
2. Lippincott's illustrative Reviews: Pharmacology Edition: 02 Maryjnycck by Lippincott's review Publisher Pheladelphia 1997.
3. Principles of medicinal chemistry Vol. 1 by Kadam S.S., Mahadik K.R., Bothra K.G. Edition: 18, Nirali Publication.
4. Pharmacognosy by Gokhle S.D., KoKate C.K.. Edition: 18, Nirali Publication.
5. Biotechnology – Expanding Horizon by B.D. Singh ., First Edition, Kalyani Publication, Delhi.
6. Analytical Microbiology- Edited by Fredrick Kavanagh volume I &II. Academic Press New York.
7. Pharmaceutical Biotechnology by S. P. Vyas & V.K. Dixit. CBS publishers & distributors, New Delhi.
8. Quniolinone antimicrobial agents- Edited by David C. Hooper, John S. Wolfson. ASM Washington DC.
9. Quality control in the Pharmaceutical industry - Edited by Murray S. Cooper Vol. 2, Academic Press New York.
10. Biotechnology- Edited by H.J. Rhem & Reed, vol 4 VCH publications, Federal Republic of Germany.
11. Good manufacturing practices for Pharmaceuticals. By Sydney H. Willing, Murray M. Tuckerman, Willam S. Hitchings IV. Second edition Mercel Dekker NC New York.
12. Advances in Applied Biotechnology series Vol.10, Biopharmaceutical in transition., Industrial Biotechnology Association by Paine Webber,. Gulf Publishing Company Houston.
13. Drug carriers in biology & medicine Edited by Gregory Gregoriadis. Acedemic Press New York.
14. Quality Assurance in Microbiology by Rajesh Bhatia, Rattan Lal Ihhpunjani. CBS publishers & distributors, New Delhi.

SERVICE COURSE - I
Applied Agricultural Microbiology
MARKS: - 100 (04 Credits)

UNIT-I (0.8 Credit)

Introduction to biofertilizers, Biofertilization processes - Decomposition of organic matter and soil fertility and vermicomposting. Mechanism of phosphate solubilization and phosphate mobilization. Nitrogen fixation - Free living and symbiotic nitrogen fixation. Ecto and endomycorrhizae and their importance in agriculture. Biotechnological application in nitrogen fixation.

UNIT-II (0.8 Credit)

Microorganisms as biofertilizers: Biofertilizers and symbiotic associations; Rhizobium - taxonomy, physiology, host-*Rhizobium* interaction, mass cultivation; Associative and non symbiotic association-*Azospirillum, Azotobacter*, Cyanobacteria (Nostoc and Anabaena) Mycorrhiza and actinorrhiza in plant nutrition and stress tolerance; Interaction of mycorrhiza with *Rhizobium* and *Pseudomonas;* Commercial production of biofertilizers, formulations and BIS specifications; their applications and limitations for Indian agriculture.

UNIT-III (0.8 Credit)

Nitrogenous Biofertilizers - Isolation and purification of Azospirillum and Azotobacter, mass multiplication of Azospirillum and Azotobacter, formulation of inoculum of Azospirillum and Azotobacter, application of inoculants of Azospirillum and Azotobacter. Isolation and purification of Rhizobium, mass multiplication and inoculum production of Rhizobium, Methods of application of Rhizobium inoculants.

UNIT-IV (0.8 Credit)

Microorganisms as biopesticides: Microbiology of plant surfaces; Principles and mechanism of biological control; biocontrol agents for insect pest and weed control. Commercial production of biopesticides with reference to *Bacillus thuringiensis*; integrated pest management; Their applications and limitations for Indian agriculture

UNIT-V (0.8 Credit)

Plant Pathology

Mode of entry of pathogens, disease symptoms, Brief account of algal disease, fungal disease,bacterial disease, viral disease, diseases caused by mycoplasmas and nematode Specially - brown spot of rice, black stem rust of wheat, stem rot of jute, rice disease by Tungo virus, grey blight of tea, red rot of sugarcane, TMV, Blast of rice, leaf blight of potato, Powdery mildew of cucurbit)- dissemination and control measurement.

Reference Books :

- Bagyaraj, D.J. and A. Manjunath. 1990. Mycorrhizal symbiosis and plant growth, Univ. of Agricultural Sciences, Bangalore, India.

- Purohit, S.S., P.R. Kothari and S.K. Mathur, 1993. Basic and Agricultural Biotechnology, Agro Botanical Pub. India.
- Subba Rao, N. S. 1988. Biological nitrogen fixation: recent developments, Mohan Primlani for Oxford and IBH Pub. Co. (P) Ltd., India.
- Subba Rao, N.S., G.S. Venkataraman and S. Kannaiyan 1993. Biological nitrogen fixation, ICAR Pub., New Delhi.
- Somani, L.L., S.C. Bhandari, K.K. Vyas and S.N. Saxena. 1990. Biofertilizers, Scientific Publishers - Jodhpur.
- Tilak, K.V.B. 1991. Bacterial Biofertilizers, ICAR Pub., New Delhi.
- Agrios G. N. 1997. Plant Pathology. Academic Press, San Diego.
- Cook R. J. & Baker K. F. 1983. The Nature and practice of Biological Control of Plant Pathogens.
- Amereca Phytopathological Society Press, St. Paul, MN.
- Forster C. F. & John DA 2000. Environmental Biotechnology. Ellis Horwood Ltd. Publication.
- Christon J. H. 2001. A Manual of Environmental Microbiology. ASM Publications.
- Rao, N.S.S. 1999. Soil Microbiology. Oxford & IBH Publishing Co., New Delhi.
- The nature and properties of soil. Authors- Harry buckman and Nyle C. brady.
- Introduction to soil Microbiology Internationals. Authors- Martin Alexander.

Service Course - II

Applied Medical Microbiology

MARKS: - 100 (04 Credits)

HAEMATOLOGY (02 Credits)

1. Methods of collection of blood.
2. Preparation and labeling of anticoagulant bulbs.
3. Preparation of various stain solutions.
4. Preparation of blood smears and staining them using different stains.
5. Hemoglobin estimation -different methods.
6. RBC count
7. WBC count by manual methods.
8. Platelet count
9. Estimation of E.S.R.
10. P.C.V.
11. Calculating absolute values.
12. Study of peripheral blood smear in different types of anaema.
13. Reticulocyte count.
14. Test for sickling.
15. Osmotic fragility test.
16. Detection of foetal haemoglobin.
17. Haemoglobin electrophoresis.
18. Differential W.B.C. count and buffy coat preparation.
19. Study of P.B.S. in different types of leukemia.
20. Cytochemical stains for leukemias.
21. Bleeding and clotting time.
22. Prothrombin time.

23. Partial thromboplastin time with Kaolin.

24. Thromboplastin generation time.

25. Routine, naked eye and microscopic examination of stool and study of parasitic ova and cysts in the stool.

26. Routine physical, chemical and microscopic examination of urine.

27. Demonstration of normal and abnormal findings in pleural, pericardial, ascitic, cerebrospinal fluid and semen.

28. The use and maintenance of the following centrifuge, colorimeter, chemical balance, haematocrit , various types of pipettes, urinometer, microhaematocrit centrifuge.

29. L.E. cell preparation. Study of parasites in the blood.

30. Study of parasistes in the blood.

TRANSFUSIONOLOGY: (02 Credits)

1. Determination of blood group by both tube and slide methods.

2. Sources of errors in group determination—their elimination.

3. Titration of blood group antibodies in serum.

4. Coomb's test.

5. Major and minor cross matching (compatibility test),

6. Investigations of transfusion reactions.

7. Tests to detect diseases that can be transmitted through blood transfusion (VDRL test, tests for HbsAg, HIV using different methods).

8.Collection and storage of blood.

REFERENCES:

1. Clinical Chemistry in Diagnosis and Treatment. - Ziwa J.F.P Peter, Mayne P.D.

2. Practical Clinical Biochemistry – Verley Publications, W.H. Heinemann

3. A Biologist Guide to principle & Techniques of Practical Biochemistry :- William & Wilson, Edward Arnold

4. Lynch Medical Laboratory Technology – Rephale D.B,W.B Saunders.

5. Practical Biochemistry – Plummer

6. Text Book of Biochemistry – Ramkrishanan, Prasman & Rajan

7. Medical Biochemistry – A.C Deb

8. Medical Biochemistry - M.N. Chatterjee, Shinde

9. Medical Biochemistry - Das

10. Clinical Laboratory Methods – john D. Bener

11. Manual of Histopathological Techniques & their Diagnostic application – John D Bancroft, Hay C.Cook, Churchill Levingston

12. Clinical Diagnosis by Laboratory Examination John A Kokmer.

13. Text Book of Pathology Vol. I & II – N.C. Dey

14. Clinical Laboratory Diagnosis – Levinson S A, Mac Fate R.D.

15. Clinical Lab. Methods & Diagnosis Vol. I & II – Alex C,S L Garelt.

16. Clinical Lab. Methods – John D Benger, Plilip G. Achermann, Gelsaon Toro

17. Handbook of Histopathological Technique – C.F.A. Culling.

18. Histopathological & Histological Technique – J.A. Kierman.

19. A New short Text Book of Microbial & Parasitic Infections – B.I. Duerden, T.M.S. Reid, J.M. Jewsbury, D.C. Turk.

20. District Laboratory Practice in Tropical Countries Part – 1 & 2 – Monica Cheesbrough. Cambridge Low- Price Edn.

21. Medical Laboratory Technology Vol. I, II & III – K.L. Mukherjee.

22. Medical Laboratory Technology – Pror. C.R. Maiti, New Central Book Agency Pvt Ltd. Kolkata.

23. Medical Parasitology – Rajesh Karyakarte, A.S. Damle. Books & Allied Pvt. Ltd Kolkata.

24. Text Book of Bacteriology – N C Day & T. K. Day

25. Parasitology – K.D. Chatterjee.

26. Text Book of Microbiology – Chakarbourty.