# University of Pune

**Three Year B. Sc. Degree Course in**

## MICROBIOLOGY

**Syllabus**

**(To be implemented from Academic Year 2013-14)**

## Preamble:

Microbiology is a branch of science that studies “Life” taking an example of microorganisms such as bacteria, protozoa, algae, fungi, bacteria, viruses, etc. These studies integrate cytology, physiology, ecology, genetics and molecular biology, evolution, taxonomy and systematics with a focus on microorganisms; in particular bacteria. The relevance and applications of these microorganisms to the surrounding environment including human life and Mother Nature becomes part of this branch. Since inception of this branch of science, Microbiology has remained a field of actively research and ever expanding in all possible directions; broadly categorized as pure and applied science. Different branches of Pure Microbiology based on taxonomy are Bacteriology, Mycology, Protozoology and Parasitology, Phycology and Virology; with considerable overlap between these specific branches over each other and also with other disciplines of life sciences, like Biochemistry, Botany, Zoology, Cell Biology, Biotechnology, Nanotechnology, Bioinformatics, etc. Areas in the applied Microbial Sciences can be identified as: Medical, Pharmaceutical, Industrial (Fermentation, Pollution Control), Air, Water, Food and Dairy, Agriculture (Plant Pathology and Soil Microbiology), Veterinary, Environmental (Ecology, Geomicrobiology); and the technological aspects of these areas.

Knowledge of different aspects of Microbiology has become crucial and indispensable to everyone in the society. Study of microbes has become an integral part of education and human progress. Building a foundation and a sound knowledge-base of Microbiological principles among the future citizens of the country will lead to an educated, intellectual and scientifically advanced society. Microbiological tools have been extensively used to study different life processes and are cutting edge technologies. There is a continual demand for microbiologists in the work force – education, industry and research. Career opportunities for the graduate students are available in manufacturing industry and research institutes at technical level.

## Introduction:

The syllabi till today had been sufficient to cater for the needs of students for building up their careers in industry and research. However, with the changing scenario at local and global level, we feel that the syllabus orientation should be altered to keep pace with developments in the education sector. The need of the hour is proper syllabi that emphasize on teaching of technological as well as the administrative aspects of modern biology. Theory supplemented with extensive laboratory expertise will help these students, to avail these opportunities. Both these aspects i.e. theory and more of practical needs to stressed, such that a graduate student can start work directly in applied fields (industry or institutions), without any additional training.

Thus, the university / college itself will be developing the trained and skilled man-power. We even find a lack of trained teachers who can share their experiences on different aspects in microbiology. And we plan to restructure the syllabus in this viewpoint. The restructured syllabus will combine the principles of chemistry and biological sciences (molecular and cell biology, genetics, immunology and analytical tools) with technological disciplines to produce goods and services and for environmental management.

Microbiology curricula are operated at two levels viz. undergraduate and postgraduate. The undergraduate curricula are prepared to impart basic knowledge of the respective subject from all possible angles. In addition, students are to be trained to apply this knowledge particularly in day-to-day applications of Microbiology and to get a glimpse of research.

## Objectives to be achieved:

- To enrich students' knowledge and train them in the pure microbial sciences
- To introduce the concepts of application and research in Microbiology
- To inculcate sense of scientific responsibilities and social and environment awareness
- To help students build-up a progressive and successful career

## Eligibility

**1. First Year B.Sc.:**

a. Higher Secondary School Certificate (10+2) or its equivalent Examination with English and Biology; and two of the science subjects such as Physics, Chemistry, Mathematics, Geography, Geology, etc. OR

b. Three Years Diploma in Pharmacy Course of Board of Technical Education conducted by Government of Maharashtra or its equivalent. OR

c. Higher Secondary School Certificate (10+2) Examination with English and vocational subject of + 2 level (MCVC) - Medical Lab. Technician (Subject Code = P1/P2/P3 )

**2. Second Year B.Sc.:**

Keeping terms of First Year of B. Sc. with Microbiology as one of the subjects. In addition to the above qualification students who have passed the Diploma course in Pharmacy are eligible however such cases should be approved by equivalence committee of Faculty of Science of the University of Pune.

**3. Third Year B. Sc.:**

Student shall clear all First Year B. Sc. Microbiology courses and satisfactorily keeping terms of Second Year of B. Sc. with Microbiology as one of the subjects.

Admissions will be given as per the selection procedure / policies adopted by the respective college keeping in accordance with conditions laid down by the University of Pune.

Reservation and relaxation will be as per the Government rules.

## Standard of Passing

i. In order to pass in the first year theory examination, the candidate has to obtain 40 marks out of 100 in each course. (Minimum 32 marks must be obtained in the University Theory Examination.)

ii. In order to pass in the Second Year and Third Year theory examination, the candidate has to obtain 20 marks out of 50 in each course of each semester. (Minimum 16 marks must be obtained in the University Theory Examination.)
iii. In order to pass in practical examination, the candidate has to obtain 40 marks out of 100 in each course. (Minimum 32 marks must be obtained in the University Examination.)

## Award of Class

The class will be awarded to the student on the aggregate marks obtained during the second and third year in the Principle subject only. The award of the class shall be as follows:

| | | |
|---|---|---|
| 1 | Aggregate 70% and above | First Class with Distinction |
| 2 | Aggregate 60% and more but less than 70% | First Class |
| 3 | Aggregate 55% and more but less than 60% | Higher Second Class |
| 4 | Aggregate 50% and more but less than 55% | Second Class |
| 5 | Aggregate 40% and more but less than 50% | Pass Class |
| 6 | Below 40% | Fail |

## ATKT Rules

While going from F. Y. B. Sc. to S. Y. B. Sc. at least 8 courses (out of total 12) should be cleared; however all F. Y. B. Sc. courses should be cleared while going to T. Y. B. Sc.

While going from S. Y. B. Sc. to T. Y. B. Sc., at least 12 courses (out of 20) should be cleared (Practical Course at S. Y. B. Sc. will be equivalent to 2 courses).

## Equivalence of Previous Syllabus

No equivalence required at F. Y. B. Sc. level, the course titles are same as previous syllabus.

## External Students

There shall be no external students.

## University Terms

Dates for commencement and conclusion for the first and second terms will be declared by the University authorities. Terms can be kept by only duly admitted students. The term shall be granted only on minimum 80 percent attendance at theory and practical course and satisfactory performance during the term.

## Course Structure:

**Duration:** The duration of B.Sc. (Microbiology) Degree Program shall be three years.

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

To accommodate more advanced topics in the syllabi, it is necessary to understand the base science knowledge level of the students that have chosen the Microbiology discipline. Curricula of courses of state and central boards of higher secondary level were reviewed to avoid repetitions of introductory cell biology.

At **first year of under-graduation**, students will be given the basic information that includes – characteristics of microbial world. The microorganisms will be studied for morphological, structural characterization, isolations techniques from natural and extreme environments and their prominent features. The methodology for observation i.e. different microscopy techniques, staining techniques and nutritional requirements will be taught in detail; including these aspects at laboratory level as well. Introduction to biochemical characterization of components of micro-organism e.g. proteins, lipids, nucleic acids and carbohydrates and instrumental techniques to estimate these components qualitatively and quantitatively from micro-organisms or other natural sources will be the focus for second theory paper. Relevant experimentation on these topics will be included in practical course. In practical course, students will be trained in preparing laboratory manuals, standard operating practices and log books.

At **second year under-graduation**, principles of taxonomy and classification of major groups of microorganisms can be studied in one of the papers. This paper will also include the physiological studies on these groups of micro-organisms. Second paper will deal with Air and Water Microbiology; role of micro-organisms in environment in regards to pollution and biodegradation; water and sewage treatment. Practical for the second year students will be less defined i.e. kept more flexible, designed to evolve project themes on environment, agriculture and pollution aspects and acquiring laboratory related skills. Practical at this level will also include application of biostatistics principles and computers for data analysis and interpretation, and introduction to scientific writing and report preparation. These aspects can be practiced better while carrying out the mini-projects.

At **third year under-graduation**, six theory papers deal with broad applied areas of microbiology that are interactive with higher living forms. Five such areas are – medical microbiology, microbial physiology, microbial (prokaryotic and eukaryotic) genetics, immunology and immunopathology, fermentation technology. The sixth course will be Applied Microbiology that will include – Dairy Microbiology, Food Microbiology, Fermentation Technology, Agriculture Biotechnology, Fungal Biotechnology, etc. The practical at third year will be planed more intensively, with exposure to applied fields.

# F. Y. B. Sc. Microbiology

| Paper | Course Title | Marks | Lectures |
|---|---|---|---|
| Paper - I | Introduction to Microbiology | 100 | Three Periods/Week per Paper (Total 36/Paper per Term) |
| Paper - II | Basic Techniques in Microbiology | 100 | |
| Practical Course | Practical Course | 100 | *Four Hours / Week (Total 96 – Term I & II) |
| ***Practical to be conducted as two hours each day on two consecutive days / Batch** | | | |

**Examination Pattern**

| | | |
|---|---|---|
| Theory paper: | University Examination | – 80 marks (at the end 2nd term) |
| | Internal Examination | – 20 marks |
| Practical course: | University Examination | – 80 marks (at the end of 2nd term) |
| | Internal Examination | – 20 marks |

**Theory examination** will be of three hours duration for each theory course. There shall be 5 questions each carrying equal marks. The pattern of question papers shall be:

| | |
|---|---|
| Question 1 | 8 sub-questions, each of 2 marks; answerable in 2 -3 line and based on entire syllabus |
| Question 2 and 3 | 4 out of 6– short answer type questions; answerable in 6 – 8 lines |
| Question 4 | 2 out of 4 – long answer type questions; answerable in 12 – 16 lines |
| Question 5 | 1 out of 2 –essay / long answer type question; answerable in 25 – 30 lines |

**Internal examination**: Internal assessment of the student by respective teacher will be comprehensive and continuous, based on written test, 10 marks each term. The written test shall comprise of objective type questions – Multiple Types Questions, True / False, Definitions, Tricky computational problems with minimum calculations. There shall be 20 questions, each question of 0.5 marks.

**Practical Examination:** Practical examination shall be conducted by the respective college at the end of the academic year. Practical examination will be of minimum 4 hours duration, carried over on two subsequent days. There shall be 10 marks for laboratory log book and journal, 10 marks for viva-voce and minimum three experiments. Certified journal is compulsory to appear for practical examination. There shall be two experts and two examiners per batch for the practical examination.

**Setting question papers:** Questions should be designed to test the conceptual knowledge and understanding of the basic concepts of the subject.

# S. Y. B. Sc. Microbiology

| | Paper | Course Title | Marks | Lectures |
|---|---|---|---|---|
| **Semester I** | MB - 211 | Bacterial Systematics and Physiology | 50 | Four Periods/Week per Paper (Total 48/Paper per Semester) |
| | MB - 212 | Microbial Genetics | 50 | |
| **Semester II** | MB – 221 | Analytical Microbiology | 50 | |
| | MB - 222 | Air and Water Microbiology | 50 | |
| **Semester I & II** | Practical Course | Practical Course | 100 | ***Four Hours / Week (Total 96 – Semester I & II) |
| ***Practical to be conducted as two hours each day on two consecutive days / Batch** | | | | |

**Examination Pattern**

Theory paper: University Examination – 40 marks (at the end of each semester)
Internal Examination – 10 marks
Practical course: University Examination – 80 marks (at the end of 2nd semester)
Internal Examination – 20 marks

**Theory examination** will be of two hours duration for each theory course. There shall be 4 questions each carrying equal marks. The pattern of question papers shall be:

| | |
|---|---|
| Question 1 | 10 sub-questions, each of 1 marks; objective type and based on entire syllabus |
| Question 2 and 3 | 2 out of 3 sub-questions, each of 5 marks; short answer type questions; answerable in 10 – 15 lines |
| Question 4 | 1 out of 2 – long answer type questions; answerable in 20 – 25 lines |

**Internal examination**: Internal assessment of the student by respective teacher will be comprehensive and continuous, based on written test, 10 marks each semester. The written test shall comprise of objective type questions – Multiple Types Questions, True / False, Definitions, Tricky computational problems with minimum calculations. Different sets of question papers may be given in the same class-room. There shall be 20 questions to be answered in 40 minutes, each question of 1mark.

**Practical Examination:** Practical examination will be of minimum 4 hours duration, carried over on two subsequent days. There shall be 10 marks for laboratory log book and journal, 10 marks for viva-voce and minimum three experiments. Certified journal is compulsory for appearing for practical examination. There shall be two experts and two examiners per batch for the practical examination. One of the examiners will be external.

**Setting question papers:** Questions should be designed to test the conceptual knowledge and understanding of the basic concepts of the subject.

# T. Y. B. Sc. Microbiology

**Theory Papers**

| | Paper | Paper Title | Marks | Lecturers |
|---|---|---|---|---|
| **Semester III** | MB 331 | Medical Microbiology – I | 50 | Four Periods/Week per Paper (Total 48/Paper per Semester) |
| | MB 332 | Genetics & Molecular Biology - I | 50 | |
| | MB 333 | Enzymology | 50 | |
| | MB 334 | Immunology -I | 50 | |
| | MB 335 | Fermentation Technology -I | 50 | |
| | MB 336 | Applied Microbiology - I | 50 | |
| **Semester IV** | MB 341 | Medical Microbiology - II | 50 | |
| | MB 342 | Genetics & Molecular Biology - II | 50 | |
| | MB 343 | Metabolism | 50 | |
| | MB 344 | Immunology -II | 50 | |
| | MB 345 | Fermentation Technology -II | 50 | |
| | MB 346 | Applied Microbiology - II | 50 | |

**Practical Courses**

| | Course | Course title | Marks | |
|---|---|---|---|---|
| **Semester III & IV** | MB 347 | Practical course – I<br>Applied Microbiology | 100 | ***Four Hours / Week per course (Total 96/Course per Semester)** |
| | MB 348 | Practical course – II<br>Biochemistry & Molecular Biology | 100 | |
| | MB 349 | Practical course – III<br>Diagnostic Microbiology & Immunology | 100 | |
| ***Practical to be conducted as four hours each day on three consecutive days / Batch** | | | | |

**Examination Pattern**

Theory paper: University Examination – 40 marks (at the end of each semester)
Internal Examination – 10 marks
Practical course: University Examination – 80 marks (at the end of 2nd semester)
Internal Examination – 20 marks

**Theory examination** will be of two hours duration for each theory course. There shall be 4 questions each carrying equal marks. The pattern of question papers shall be:

| | |
|---|---|
| Question 1 | 10 sub-questions, each of 1 marks; objective type and based on entire syllabus |
| Question 2 and 3 | 2 out of 3 sub-questions, each of 5 marks; short answer type questions; answerable in 10 – 15 lines |
| Question 4 | 1 out of 2 – long answer type questions; answerable in 20 – 25 lines |

**Internal examination**: Internal assessment of the student by respective teacher will be comprehensive and continuous, based on written test, 10 marks each semester. The written test shall comprise of objective type questions – Multiple Types Questions, True / False, Definitions, Tricky computational problems with minimum calculations. Different sets of question papers may

be given in the same class-room. There shall be 20 questions to be answered in 40 minutes, each question of 1mark.

**Practical Examination:** Practical examination will be of minimum 6 hours duration, carried over on three subsequent days. There shall be 10 marks for laboratory log book and journal, 10 marks for viva-voce and minimum three experiments per practical course. Certified journals are compulsory for appearing for practical examination. There shall be two experts for each practical course and two examiners per batch; one of the examiners will be external.

**Setting question papers:** Questions should be designed to test the conceptual knowledge and understanding of the basic concepts of the subject.

## Qualification of Teachers:

With minimum undergraduate and postgraduate degree in Microbiology (B. Sc. and M. Sc. Microbiology) and qualified as per UGC regulations.

# F. Y. B. Sc. Microbiology

## Theory Paper I: Introduction To Microbiology

### Paper I: Term I

| Sr. No. | Topic | Lectures |
|---|---|---|
| 1. | **Frontiers of Microbiology** | **2** |
| 2. | **A. History of Microbiology**<br>I. Discovery of microscope<br>II. Micrographia of Anton von Leeuwenhoek and Robert Hooke<br>III. Abiogenesis v/s biogenesis<br>• Aristotle's notion about spontaneous generation<br>• Redi's experiment<br>• Louis Pasteur's & Tyndall's experiments | **6** |
| | **B. Development of Microbiology in 19th century**<br>I. Observations and role of microorganisms in transformation of organic matter.<br>• Germ theory of fermentation<br>• Discovery of anaerobic life & physiological significance of fermentation<br>II. Discovery of microbes as pathogens<br>• Surgical antisepsis<br>• Germ theory of disease – Koch's postulates & River's postulates | **4**<br><br>**4** |
| | **C. Developments in 20th and 21st Centuries with respect to:**<br>• Vaccination and Chemotherapy<br>• Contributions of Nobel Laureates in Immunology, Molecular Biology & Biotechnology | **4** |
| 3. | **Morphological and differentiating characters of microorganisms:**<br>• Bacteria<br>• Rickettsia<br>• Protozoa<br>• Algae<br>• Fungi (Molds and Yeasts)<br>• Viruses, viroids and prions<br><br>Principles in classification of Bacteria (Introduction to Bergey's Manual of Determinative and Systemic Bacteriology) and viruses (ICTV) | **12** |
| 4. | **Applications of Microbiology:**<br>i. Significance of normal flora and probiotics in human health<br>ii. Microbes as Biofertilizers and Biocontrol Agents (e.g. Nitrogen fixers, Phosphate Solubilizers and *Bacillus thuringensis*) | **4** |

## Paper I: Term II

| Sr. No. | Topic | Lectures |
|---|---|---|
| 5. | **I.** Covalent and non-covalent bonding in biomolecules<br>**II.** Concepts of pH and redox potential | 4 |
| | Chemistry of Biomolecules<br>• Carbohydrates (Starch, Glycogen, Cellulose, Peptidoglycan)<br>• Lipids (Triglycerides and phospholipids)<br>• Structural and Functional Proteins (Hemoglobin, Immunoglobulin; flagellin and cytoskeletal proteins in bacterial cell)<br>• Nucleic acids ( DNA and RNA) | 16 |
| 6. | **Bacterial Cytology**<br>Studies on structure, chemical composition and functions of the following components in bacterial cell:<br>• Cell wall<br>• Cell membrane<br>• Endospore<br>• Capsule<br>• Flagella<br>• Fimbriae and Pili<br>• Ribosomes<br>• Chromosomal & extra-chromosomal material<br>• Cell inclusions ( Gas vesicles, carboxysomes, PHB granules, metachromatic granules and glycogen bodies) | 16 |

# THEORY PAPER II: BASIC TECHNIQUES IN MICROBIOLOGY

## Paper II: Term I

| Sr. No. | Topic | Lectures |
|---|---|---|
| 1. | a. Units of measurement. Modern SI units (Length, volume, Weight)<br>b. Microscopy :<br>• Bright field microscopy: Structure, working of and ray diagram of a compound light microscope; Concepts of magnification, numerical aperture and resolving power.<br>• Types, ray diagram and functions of – condensers, eye-pieces and objectives<br>• Aberrations in lenses - spherical, chromatic, comma and astigmatism<br>• Principles, construction, working and applications of:<br>i. Dark field microscopy<br>ii. Fluorescence microscopy<br>• Confocal microscopy | 12 |

| | | |
|---|---|---|
| **2.** | Staining Techniques :<br>• Definitions of Stain; Types of stains (Basic and Acidic),<br>• Properties and role of Fixatives, Mordants, Decolorisers and Accentuators<br>• Principles of staining techniques for following:<br>i. Monochrome staining and Negative (Relief) staining<br>ii. Differential staining - Gram staining and Acid fast staining | **8** |
| **3.** | Sterilization and Disinfection | |
| | 1. Physical Agents - Heat, Radiation, Filtration | **6** |
| | 2. Chemical agents and their mode of action - Aldehydes, Halogens, Quaternary ammonium compounds, Phenol and phenolic compounds, Heavy metals, Alcohol, Dyes, Detergents and Ethylene oxide.<br>3. Characteristics of an ideal disinfectant<br>4. Checking of Efficiency of Sterilization – Biological and Chemical Indicators<br>5. 5. Checking of Efficiency of Disinfection - Phenol Coefficient | **10** |

## Paper II: Term II

| Sr. No. | Topic | Lectures |
|---|---|---|
| **4.** | **Cultivation of Microorganisms** | |
| | 1. Nutritional requirements and nutritional classification | **3** |
| | 2. Design and preparation of media – Common ingredients of media and types of media | **3** |
| | 3. Methods for cultivating photosynthetic, extremophilic and chemolithotrophic bacteria. | **4** |
| | 4. Concept of Pure Culture, Enrichment, Isolation and Preservation techniques. Maintenance of bacterial and fungal cultures | **6** |
| | 5. Culture collection centers and their role. Requirements and guidelines of National Biodiversity Board for Culture collection centers | **2** |
| **5.** | **Bacterial Growth** | |
| | Growth Kinetics and growth curve; definitions of Generation time, Growth rate and specific growth rate | **4** |
| | Methods of enumeration:<br>1. Microscopic methods (Direct Microscopic Count, Counting cells using Neubauer, Petroff and Hausser's chambers)<br>2. Plate counts (Total Viable Count)<br>3. Estimation of Biomass (Dry mass, Cell volume)<br>4. Chemical methods (Cell Carbon and Nitrogen estimation)<br>5. Turbidometric methods (Nephalometry) | **6** |
| | Factors affecting bacterial growth ( pH, Temperature, Solute Concentration (Salt and Sugar) and Heavy metals | **4** |
| | Diauxic growth | **1** |
| | Synchronous culture | **3** |

# Practical Course
# (Term I & II)

| **BASED ON THEORY PAPER I & II** | | **(96)** |
|---|---|---|
| **Expt. No.** | **Topic** | **Hours** |
| **1-2** | Preparation of Standard Operating Procedures (SOPs) for common microbiology laboratory instruments e.g. Incubator, Hot Air Oven, Autoclave, Colorimeter, pH Meter, Distillation Unit, Chemical Balance, Laminar air flow hood, Clinical Centrifuge | **2** |
| **3** | Construction (mechanical and optical), working and care of bright field microscope | **1** |
| **4** | Observation of microorganisms using bright field microscope - Bacteria, Protozoa, Molds and Yeasts, Algae – from natural habitat | **1** |
| **5-7** | Observation of microorganisms using staining techniques:<br>a. Monochrome staining and<br>b. Negative /Relief staining (Capsule staining)<br>c. Gram staining of bacteria | **3** |
| **8-9** | Observation of motility in bacteria using:<br>a. Hanging drop method and Cragie's tube method<br>b. Swarming growth methods | **2** |
| **10** | Enumeration of yeast cells using a counting chamber | **1** |
| **11-12** | Cultivation of microorganisms:<br>a. Preparation of simple laboratory nutrient media (solid and liquid) and using them to cultivate bacteria.<br>b. Observation of the growth of cultures and reporting of colony and cultural characteristics (Nutrient and MacConkey's agar) | **2** |
| **13** | Isolation of bacteria by streak plate technique | **1** |
| **14-15** | Enumeration of bacteria from fermented food / soil / water by:<br>a. Spread plate method<br>b. Pour plate method | **2** |
| **16** | Aseptic transfer techniques (slant to slant, broth to broth, broth to agar and Agar to Agar) | **1** |
| **17** | Preservation of cultures on slants, soil and on grain surfaces; revival of these cultures and lyophilized cultures. | **1** |
| **18** | Checking sterilization efficiency of autoclave using a biological indicator (*B. stearothermophilus*) | **1** |
| **19** | Demonstration of checking of efficacy of chemical disinfectant: Phenol Coefficient Rideal Walker method) | **1** |
| **20** | Preparation of Winogradsky column and observation of different types of microorganisms using bright filed microscope. | **1** |
| **21-22** | Study of normal flora of skin:<br>a. Cultivating and observing different morphoforms of bacteria from skin<br>b. Study of effect of washing skin with soap and disinfectant on it's microflora | **2** |
| **23-24** | a. To study the effect of different parameters on growth of *E. coli*: pH, temperature, sodium chloride concentration<br>b. Study of Oligodynamic action of heavy metal | **2** |

## Recommended Books:


1. Daniel Lim, Microbiology, 2nd Edition; McGraw-Hill Publication
2. Ingraham J. L. and Ingraham C.A. (2004). Introduction to Microbiology. 3nd Edition. Thomson Brooks / Cole.
3. Madigan M.T., Martinko J.M. (2006). Brock's Biology of Microorganisms. 11th Edition. Pearson Education Inc.
4. Michael J Pelczar, JR. E.C.S. Chan, Noel R. Krieg. (1993) Microbiology, 5th Edition, Tata MacGraw Hill Press.
5. Prescott L.M., Harley J.P., and Klein D.A. (2005). Microbiology, 6th Edition. MacGraw Hill Companies Inc.
6. Prescott, Lancing. M., John, P. Harley and Donald, A. Klein (2006) Microbiology, 6th Edition, McGraw Hill Higher Education
7. Willey J. M., Sherwood L. M. and Woolverton C. J. (2013) Prescott's Microbiology, 8th Edition, McGraw-Hill Higher Education
8. Salle A.J. (1971) Fundamental Principles of Bacteriology. 7th Edition. Tata MacGraw Hill Publishing Co.
9. Stanier R.Y., Adelberg E.A. and Ingraham J.L. (1987) General Microbiology, 5th Edition. Macmillan Press Ltd.
10. Tortora G.J., Funke B.R., Case C.L. (2006). Microbiology: An Introduction. 8th Edition. Pearson Education Inc
11. Wilson K. and Walker J.M. (2005) Principles and Techniques of Biochemistry and Molecular Biology. 6th Edition. Cambridge University Press.
12. Hans G. Schlegel (1993) General Microbiology, 8th Edition, Cambridge University Press
13. David T. Plummer (1993) An Introduction To Practical Biochemistry, 3rd Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi