# UNIVERSITY OF RAJASTHAN
# JAIPUR

## SYLLABUS

# M.Sc. Microbiology

## Semester Scheme

## I[st] & II[nd] Semester Exam 2016-17

Dy. Registrar (Acad.)
University of Rajasthan
JAIPUR

**MAX MARKS -100** **PASS MARKS- 36**

**THEORY PAPER DURATION: 3 HRS.** **PRACTICAL: 4 HRS.**

## First Semester with laboratory work

| S.No. | Subject code | Course title | Course category | Credit |
|---|---|---|---|---|
| 1 | MBC 701 | General Microbiology | CCC | 4 |
| 2 | MBC 702 | Techniques in Microbiology | CCC | 4 |
| 3. | MBC 703 | Microbial Biochemistry | CCC | 4 |
| 4. | MBC 711 | Lab.(Based on MBC 701, MBC 702 &MBC 703) | | 6 |
| 5. | MBE 701 | Molecular Biology | ECC | 4 |
| 6. | MBE 702 | Biostatistics | ECC | 4 |
| 7. | MBE 703 | Bioinformatics | ECC | 4 |
| 8. | MBE 704 | Bioinstrumentation | ECC | 4 |
| 9. | MBE 712 | Lab. (Based on any three electives only) | | 6 |

## Second Semester with laboratory work

| S.No. | Subject code | Course title | Course category | Credit |
|---|---|---|---|---|
| 1 | MBC 801 | Bacteriology | CCC | 4 |
| 2. | MBC 802 | Microbial Metabolism &Physiology | CCC | 4 |
| 3. | MBC 803 | Medical Microbiology | CCC | 4 |
| 4. | MBC811 | Lab.(Based on MBC 801,MBC 802 &MBC 803) | | 6 |
| 5. | MBE 801 | Food Microbiology | ECC | 4 |
| 6. | MBE 802 | Environmental Microbiology | ECC | 4 |
| 7. | MBE 803 | Genetic Engineering | ECC | 4 |
| 8. | MBE 804 | ExtremophilicMicroorganisms | ECC | 4 |
| 9. | MBE812 | Lab.(based on any three electives) | | 6 |



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## SCHEME OF EXAMINATION MICROBIOLOGY (2016-2017)

- As per discussion of academic council, the student will require to earn 120 credits for PG course out of total 144 credits.
- In theory, 15 hrs of teaching is equal to one credit.
- In practical's, 45 hrs of laboratory works is equal to 2 credits.
- Each Semester of PG course shall have 36 credits.
- Each Semester will have continuous assessment which will include internal assessment in theory and practical by internal examination /seminar/oral examination- Viva voce etc. and the maximum marks will be 30.
- Each theory paper shall carry 100 marks. It will be of 3 (three) hrs duration.
- Part A of question paper shall contain 10 (Ten) very short answer type questions covering the entire syllabus. Each question will carry 2 (two) marks i.e. part A will be of total 20 marks.
- In part B, there will be 4 questions, one per unit with internal choice. Each question will carry 20 marks i.e. total of 80 marks.
- Each practical examination will be of 4 hrs duration and will involve laboratory experiments / exercises and Viva –voce examination.

### SCHEME OF PRACTICAL EXAMINATION

For first and second Semesters the scheme of practical examination is as follows:

MM: 100 Duration 4 hrs

| | | |
|---|---|---|
| 1. | Major Exercise | 15 Marks |
| 2. | Major Exercise | 15 Marks |
| 3. | Minor Exercise | 8 Marks |
| 4. | Minor Exercise | 8 Marks |
| 5. | Spotting | 24 Marks |
| 6. | Seminar | 10 Marks |
| 7. | Record | 10 Marks |
| 8. | Viva- voce | 10 Marks |
| | **Total** | **100 Marks** |

## Syllabus M.Sc. Microbiology

## Semester I

## MBC 701: General Microbiology

**Max. Marks -100**
**60Hrs**

### Unit I

Discovery of microbial world : History of Microbiology and contributions of Anton Von Leeuwenhoek, Joseph Lister, Paul Ehrlich, Edward Jenner, Louis Pasteur, Robert Koch, Martinus Beijerinck, Sergei Winogradsky, Alexander Fleming, Selman Waksman; Spontaneous generation controversy; Current thoughts on microbial evolution including the origin of life; Scope and relevance of microbiology.

### Unit –II

System of Classification- Binomial classification, Whittaker's five kingdom scheme, Three domain system of classification and eight kingdom system of classification, Bergey's system of bacterial classification, Characteristics & Classification of Archaebacteria & Cynobacteria, Difference between prokaryotic and eukaryotic microorganisms.

### Unit –III

General characteristics: Acellular microorganisms (Viruscs, viroids & Prions), Nomenclature and classification of viruses.

### Unit-IV

Cellular microorganisms with emphasis on distribution, occurrence, morphology, mode of reproduction and economic importance: **Bacteria**: *Cyanobacteria, Spirochaetes, Rhizobium, Nitrosomanas, Clostridium, Lactobacillus,Streptococcus & Staphyococcus.*

**Fungi** : *Sacchromyces cerevisae,Dictyostelium discodium,Penicillum & Candida albicans.*

**Algae** : *Diatoms & Dinoflagellates.*

**Protozoa**:*Entamoeba,Toxoplasma,Plasmodium,Trypanosoma & Giardia.*

### Practicals:

1. Identification of various bacteria.
2. Identification of various algae.
3. Identification of various fungi.

4. Identification of various protozoans (Free living & Parasitic protozoa).
5. Identification of Cyanobacteria.

**Suggested Books:**


1. Aneja K.R., Jain P. and Aneja R., 2008, A text book of basic and applied microbiology, New Age Int. Publications. New Delhi.
2. Atlas R.M., 1995, Principles of Microbiology Mosby publishers, St. Louis.
3. Balows A., Truper, H. G., Dworkin M., Harder, W. and Schleifer, K. H., 1992, The Prokaryotes. A handbook on the biology of bacteria: ecophysiology, isolation, identification, applications. Volumes I-IV, Springer-Verlag, New York.
4. Berg J.M., Tymoczko J.L. and Stryer L., 2007, Biochemistry Edition W.H. Freeman and Company, New York.
5. Holt J.G, and Krieg,N.R., 1984-1989, Bergey's Manual of Systematic Bacteriology 1st Edition (Volumes 1-4) Williams and Wilkins Co Baltimore, Springer.
6. Holt J.G., and Krieg N.R., Sneath P.H.A., Staley J.T. and Williums J.T., 1994, Bergey's Manual Determinative Bacteriology 9th Edition, Williams and Wilkins Co Baltimore, Springer.
7. Logan, A. and Logan N.A., 1994, Bacterial Systematics, Wiley-blackwell.
8. Nelson D. and Cox M.M., 2009, Principles of Biochemistry Edition W.H. Freeman and Company, New York.
9. Prescott L.M., Harley J.P. and Klein D.A., 2007, Microbiology 7th Edition, Mc Grow Hill.
10. Talaro K.P. and Talaro A., 2006, Foundations in Microbiology, Mc Graw Hill Publications.
11. Tortora G.J., Funke B.R. and Benjamin C.L.C., 2008, Microbiology: An Introduction, Cummings Publishing Company.
12. Wilson K. and Walker J., 2008, Principles and Technique of Biochemistry and Molecular Biology. 6th Edition Cambridge University Press.
13. Woese C.R., 1981, Archeabacteria, Sci. Am. 244:98-122.
14. Woese C.R., Kandler O. and Wheelis M.L., 1990, Towards a Natural System of Organisms: Proposal for the Domains Archea, Bacteria and Eucarya. Proc. Natl, Acad, Sci., 87: 4576- 4570.
15. Woese C. R., 1987, Bacterial evolution, Microbiological Reviews. 51: 221-271.

## MBC 702: Techniques in Microbiology

**Max. Marks -100**
**60 Hrs**

**Unit –I**

Basic principles and methods of sterilization & disinfection: Control of microorganisms by physical methods: heat, filtration and radiation; Chemical methods: Phenolics, alcohols, halogens, heavy metals, quaternary ammonium compounds, aldehydes and sterilizing gases; evaluation of antimicrobial agent effectiveness; Principle and function of Laminar air flow hood (LAF).

**Unit-II**

Basic principles for preparing microbes for light, dark field, phase contrast, confocal, fluorescent and electron (transmission and scanning) microscopy; Micrometry; Specimen collection, preparation and basic principles of simple, Gram, negative, capsule, endospore, flagella, acid- fast and flurochrome staining.

**Unit-III**

Culture characteristics: Types of culture media, preparation of medium, Minimal requirements, Nutritional types; Methods of isolation and maintenance of pure cultures (Pour plate method, streak plate method & spread plate method); Cultivation of bacteria: aerobic & anaerobic; Growth curve of bacteria; Cultivation and morphology of molds; Yeast morphology; Cultivation and isolation of viruses; Preservation of culture: Short term & long term; Disposal of cultures.

**Unit-IV**

Principal and theory of biochemical activities of the microorganisms: Triple sugar –Iron agar test, ImVic test, Methyl red test, Citrate utilization test, Urease test, Catalase test, Oxidase test, Coagulase test, Sugar fermentation test, Hydrogen sulphide test and Nitrogen reductase test.

**Practicals:**

1. Laboratory rules and requirement, Bio safety equipments.
2. Microscopy (a) Dissecting, compound & phase contrast.
   (b) Micrometry.
3. Media preparation: Liquid & solid and Sterilization.
4. Streak plate technique, Pour plate technique & Spread plate technique.
5. Use of selective and differential medium; Use of indicator media.

6. Aerobic / Anaerobic cultivation.
7. Cultural characteristics of microorganisms; Preservation of cultures.
8. Biochemical tests-Catalase test, Triple sugar –Iron agar test, ImVic test & Methyl red test.

**Suggested Books:**


1. Atlas R.M., 1997, Principles of Microbiology. 2nd Edition, Mc Graw Hill Publications
2. Balows A.A.G., Thuper M., Dworker W., Harder K. and Schleifer, 1991, The Prokaryotes, Springer.
3. Berg J.M., Tymoczko J.L. and Stryer L., 2007, Biochemistry Edition W.H. Freeman and Company, New York.
4. Davis R.Y. Adeberg E.A. and Ingram J.L., 1991, General Microbiology.
5. Nelson D. and Cox M.M., 2009, Principles of Biochemistry Edition W.H. Freeman and Company, New York.
6. Potter G.W.H and Potter G.W., 1995, Analysis of Biological Molecule: An Introduction to Principles, Instrumentation and techniques, Kluwer Academic publishers.
7. Prescott, L.M., Harley J.P. and Klein D. A., 2007, Microbiology, 7th Edition, Mc Grow Hill.
8. Stainer, General Microbiology, 5th Edition, Printice Hall of India, Pvt. Ltd. New Delhi.
9. Talaro K.P. and Talaro A., 2006, Foundations in Microbiology, Mc Graw Hill Publications.
10. Verlog, Gunsales and Stainer, The Bacteria, Volumes I-V, Academic press.
11. Wilson K. & Walker J., 2008, Principles and Techniques of Biochemistry and Molecular Biology. 6th Edition, Cambridge University Press

## MBC 703: Microbial Biochemistry

**Max. Marks -100**

### Unit-I

Chemical properties of water: ionization and acid base chemistry; Carbohydrates-classification; configuration and conformation of monosaccharides, disaccharides polysaccharides,(structural–cellulose,peptidogycan,storage-glycogen)and glycoproteins; Lipids : General characters and classification, biosynthesis of saturated and unsaturated fatty acids; Structure and functions of triglycerides, phospholipids, glycolipids and steroids.

### Unit –II

Structure of amino acids; Classification of essential amino acids based on polarity; Proteins: structure –secondary tertiary, quaternary & protein folding and stability; Properties of proteins: acid - base & solubility; Ramchandran plot; Methods of purification: General approach; Protein solubility chromatography, electrophoresis & ultracentrifugation; Sequencing of proteins: Preliminary steps, polypeptide cleavage, Edman degradation & reconstruction of protein sequence.

### Unit –III

Laws of thermodynamics: First and second law, concept of free energy, oxidation reduction reactions; Enzymes: Classification and nomenclature, mechanism of enzyme action, enzyme inhibition, allostery, cofactors, coenzymes and prosthetic groups; Enzyme kinetics: Derivation of Michaelis - Menton equation and its significance, Lineweaver-Burke plot & Haldane-Briggs relationship.

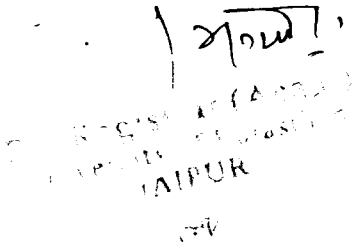
### Unit-IV

Chemical analysis of microbial cells for- carbohydrates, amino acids, proteins, lipids and nucleic acids; Structure and classification of secondary metabolites: Antibiotics (penicillin, streptomycin etc), alkaloids (Ergot toxins), flavanoids, vitamins and bacterial toxins.

### Practicals:

1. Calibration of standard curve – Glycogen & Protein.
2. Quantitative estimation of total proteins (Lowry *et al.*, method).
3. Quantitative estimation of blood glucose & glycogen.
4. Quantitative estimation of lipids & total cholesterol.
5. Quantitative estimation of DNA & RNA.
6. Quantitative estimation of any enzyme.





7. Quantitative estimation of polyphenol & carotenoids.
8. Quantitative estimation of secondary metabolites- flavanoids.

**Suggested Books:**


1. Alexander R.R. and Griffith J.M., 1993, Basic Biochemistry Methods, 2nd Edition, Wiley.
2. Atlas R.M., 1997, Principles of Microbiology, 11th Edition, McGraw Hills.
3. Berg J.M., Tymoczko J.L. and stryer L., 2007, Biochemistry, W.H. Freeman and Company.
4. Cohen, 2011, Microbial Biochemistry, 2nd Edition, Springer.
5. Conn E.E. and Stumpf P.K., 2006, Outlines of Biochemistry, 5th Edition, John Wiley & Sons.
6. Moat A.G. and Foster J.W., 2002, Microbial Physiology, 3rd Edition, John Wiley and Sons.
7. Nelson D.L.and Cox M.M., 2009, Lehninger Principles of Biochemistry, 5th Edition, W.H. Freeman and Company.
8. Plummer D., 1988, An Introduction to Practical Biochemistry, 3rd Edition, Tata McGraw Hills.
9. Potter G.H.W. and Potter G.W., 1995, Analysis of Biochemical Molecules: An Introduction to Principles, Instrumentation and Techniques, Kluwer Academics Publisher.
10. Stryer, 2001, Biochemistry, Fifth Edition, WH Freeman.
11. Talaro K.P. and Talaro A., 2006, Foundation in Biochemistry, 6th Edition, Tata McGraw Hills.
12. Voet D. and Voet J.G., 1995, Biochemistry, 4th Edition, John Willey and Sons Inc.
13. Willey J., Sherwood L. and Woolverton C., 2007, Prescott Harley/Klein's Micriobiology, McGraw Hills.
14. Wilson E.K. and Walker J., Principles and techniques of practical biochemistry, 5th Edition, Cambridge.
15. White D., 2000, The Physiology and Biochemistry of Prokaryotes, 2nd Edition, Oxford University Press.
12. Zubzy G.L., 2008, Biochemistry, 4th Edition, Addison-Welsey Educational Publishers Inc.

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## MBE 701: Molecular Biology

**Max. Marks -100**
**60 Hrs**

**Unit –I**

Nucleic acids: DNA structure; Chargaff's rule; Types of DNA; Reannealing and hybridization; DNA replication in prokaryotes and eukaryotes: Polymerases, replication origin, initiation, elongation and termination; Synthesis of telomeric DNA; topological properties: linking number, superhelicity, mechanism of topoisomerases; Drugs & inhibitors of DNA synthesis.

**Unit –II**

Transcription: Prokaryotes - polymerase, promoter, initiation, elongation and termination; Eukaryotes- promoters, initiation, elongation, termination and post translational modification of mRNA [capping & polyadenylation, Splicing: L & Y splicing (Group I and II introns) hRNA using spliceosome/snurposome]; Ribozymes; Inhibitors of transcription.

**Unit –III**

Types of RNA: Structural features (mRNA, rRNA, tRNA); Genetic code: Degeneracy of the code, three rules governing the code; Protein synthesis in prokaryotes and eukaryotes: initiation, elongation and termination; Protein synthesis on membrane bound ribosomes: signal hypothesis, post translation modification in ER and Golgi complex; Drugs & inhibitors of protein synthesis.

**Unit –IV**

Regulation of gene expression: Operon concept, negative & positive regulation, inducers, corepressors and catabolite repression; Negative regulation-Lac operon; Positive regulation- Ara operon; Regulation by attenuation –trp operon; Anti termination –N protein and nut sites in lambda.

**Practicals:**

1. Preparation of buffer and solutions.
2. DNA isolation from different cell types-microbes and eukaryotic cell.
3. Check for purity of isolated DNA sample.
4. Quantification of DNA using spectrophotometer.
5. DNA denaturation and determination of $T_m$ and G+C content.
6. Agarose gel electrophoresis of DNA.

7. Total RNA isolation from bacterial cells.

**Suggested Books:**


1. Bale J.W.,1994, Molecular Genetics of Bacteria, John Wiley & Sons.
2. Biology of the Gene, 6th Edition, CSHL Press.
3. Clarke D.P., 2005, Molecular Biology. 1st Edition, Elsevier Academic Press.
4. Friedberg C., Walker G.C. and Wolfman S., 1995, DNA repair and mutagenesis. ASM Publications.
5. Friefelder D., 1995, Molecular Biology. 2nd Edition. Narosa Publishing House
6. Gardner E.J., Simmons M.J. and Snustad D.P., 1991, Principles of Genetics. 8th Edition. John Wiley & Sons Inc.
7. Larry S. and Wendy, 1997, Molecular Genetics of Bacteria. ASM Publications,
8. Lewin, 2000, Gene VII. Oxford University Press.
9. Maloy, 1994, Microbial Genetics. Jones & Bartlett Publishers
10. Pierce B.A., Genetics- A Conceptual Approach, 2nd Edition, W. H. Freeman & Co.
11. Sambrook J. and Russell D. 2001 Molecular Cloning: A laboratory manual. 3rd Edition, CSHL press.
12. Streip and Yashbin, 1991, Modern Microbial Genetics. Niley Ltd.

## MBE 702: Biostatistics

**Max. Marks -100**
**60 Hrs**

**Unit-I**

1. Introduction to Biostatistics
   - 1.1 Definitions of biostatistics
   - 1.2 Scope and applications of biostatistics
   - 1.3 Collection, organization and representation of data (graphical & diagrammatic)

2. Measures of Central tendency & Dispersion (Direct, Short cut and Step deviation methods where ever applicable)
   - 2.1 Mean, median & mode
   - 2.2 Mean deviation
   - 2.3 Standard deviation & standard error
   - 2.4 Variance & coefficient of variation
   - 2.5 Confidence interval and level of confidence

**Unit II**

3. Correlation and Regression
   - 3.1 Types of correlation
   - 3.2 Methods of studying correlation
   - 3.3 Regression analysis

4. Probability
   - 4.1 Basic concepts related to probability theory
   - 4.2 Classical, Posteriori, Personalitic & Axiomatic probability
   - 4.3 Theorems of probability & Probability distributions
   - 4.4 Properties of Binomial, Poisson, Normal and skewed distribution & their application in biology

**Unit III**

5. Tests of Significance
   - 5.1 Hypothesis testing & level of significance

5.2 Type I & II errors
5.3 Significance of difference between means
5.4 Z-test
5.5 Students t-test (Unpaired & Paired)
5.6 F-test (Variance ratio)

6. Analysis of Variance
6.1 One way classification
6.2 Two way classification

**Unit IV**

7. Chi Square test
7.1 Testing Goodness of fit
7.2 Chi Square distribution and characteristics
7.3 Applications of Chi-square test
7.4 Yate's correction

8. Computational statistics using MS Excel.

**Practicals:**

1. Preparation of frequency tables, Graphical representation of data: bar diagram, histogram, frequency polygon, frequency curve and ogives or cumulative frequency curve and pie diagram.
2. Measures of central tendency, Mean deviation, standard deviation and standard error (Individual, discrete and continuous series)
3. Plotting of scatter diagram and regression lines. Calculation of correlation coefficient, regression equation and regression analysis.
4. Test of significance by student's t- test, chi-square test, one way and two way ANOVA.
5. Use of M.S. Word.
6. Statistical calculations using MS Excel /SPS software.
7. Preparation of graphs using computers.

**Suggested Books:**

1. Bailey N.T.J., 2000, Statistical Methods in Biology, English Univ Press.
2. Bansi L., 1968, Mathematics of Probability of Statistics, S.Chand & Co., Delhi.
3. Baxevanis A.D. and Ouellette, 2005, Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, 3rd Edition, John Wiley and Son Inc.

4. Campbell R.C., 1974, Statitics for Biologist, Cambridge University Press.
5. Gralla P., 2000, How the Internet Work, Tech Media.
6. Kenny J.F. and Keeping E.S., 1964, Mathematics of Statistics Part I & II, Affiliated East-West Press Ltd, New Delhi.
7. Mount D.W., 2004, Bioinformatics Sequence and Genome Analysis, CSHL Press.
8. Shina P.K., 2002, Fundamentals of Computers, BPa Publications, New Delhi
9. Snedecor G.W. and Cochram W.G., 1968, Statistical Methods, Oxford & IBH, Delhi.
10. Tramontano A., 2007, Introduction to Bioinformatics, Chapman & Hall/CRC.
11. White R., 2000, How Computer Works, Tech Media.
12. Zvelebil M. and Baum, 2008, Understanding Bioinformatics, Chapman & Hall/CRC.

## MBE 703: Bioinformatics

**Max. Marks -100**
**60 Hrs**

**Unit I**

**1. Introduction of Bioinformatics**

1.2 Definitions & scope of bioinformatics
1.3 Applications of bioinformatics
1.4 Bioinformatics in India

**2. Biological Database**

2.2 Primary, secondary and composite databases
2.3 Nucleotide sequence databases
2.4 Protein sequence databases
2.5 Structural databases

**Unit-II**

**3. Sequence Analysis**

3.2 Types of sequence alignment
3.3 Methods of sequence alignment
3.4 Scoring scheme
3.5 Gaps and gap penaltics

**Unit-III**

**4. Genomics and proteomics**

4.2 Classification of genomics
4.3 Classification of proteomics
4.4 Classification of proteomics
4.5 Significance of genomics and proteomics

**Unit IV**

**5. Mutation & Amino acid sequences in protein**

5.1 Sanger technique for amino acid sequence determination
5.2 Altered amino acid sequence in mutants
5.3 Suppressor mutation

5.4 Mutation for functional genome research

5.4.1 Gene inactivation with & without homologous recombination

5.4.2 Gene inactivation through chemical mutagenesis

5.4.3 Site –directed mutagenesis

**6. Computers**

6.1 Basic components of computer

6.2 Soft ware: Operating system &applications of software

6.3 Basics of networking

**Practicals:**

1. Use of search engines.
2. Retrieve the sequence for the database.
3. Genome sequencing techniques.
4. Exercise based on various methods of sequence alignment.
5. Nucleotide and protein sequence databases.
6. Gene bank flat file format.
7. Data mining in proteomics.
8. Web based tools for sequence searchers and homology screening.

**Suggested Books:**


1. Lesk A. M (2005) Introduction to Bioinformatics. 2nd ed., Oxford Press.
2. Krane Dan E. (2005) Fundamental Concepts of Bioinformatics, Pearson education (Singapore) Pte. Ltd.
3. Tisdall J. D. (2001) Beginning Perl for Bioinformatics, O'relly, California, USA.
4. David W. Mount (2004), Bioinformatics: Sequence and Genome Analysis, Second edition Cold Spring Harbor laboratory Press, New York.
5. Jae, K. Lee (2010) Statistical Bioinformatics: A Guide for Life and Biomedical Science Researchers, John Wiley & Sons, New York.
6. Andreas D. Baxevanis and B. F. Francis Ouellette (2004) Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, John Wiley & Sons, Newyork.
7. Jenny Gu and Philip E. Bourne (2009) Structural Bioinformatics, Wiley Blackwell.
8. International I. (2013) Bioinformatics: Concepts, Methodologies, Tools, and Applications edited by information Resources Management Association, IGI Global publishers.
9. Henry Horng-Shing Lu, Bernhad Scholkopf and Hongyu Zhao (2011) Handbook of Statistical Bioinformatics, Springer publishers.
10. Stephen Misener and Stephen A. Krawetz (199) Bioinformatics Methods and Protocols, Humana press Inc.

## MBE 704: Bioinstrumentation

### Unit I

Microscopy: Principles of microscopy, magnification power, resolution limit, resolving power, numerical aperture; Principles and application of light microscopy, properties of light, bright field, dark field, phase contrast and fluorescent microscopy; Principles and application of electron microscopy- transmission and scanning electron microscopy; Newer techniques in microscopy- confocal microscopy, scanning probe microscopy (scanning tunneling microscope and atomic force microscope).

### Unit II

pH meter, Centrifugation: Basic principles of analytical and preparative centrifuge, differential and density gradient, zonal and isopycnic centrifuge, High speed centrifuge and ultra centrifuge ; Sedimentation coefficient, factors affecting sedimentation coefficient and application.

### Unit III

Chromatography: Principles, types and applications of partition, adsorption, gel filtration, paper and thin layer chromatography; Affinity, ion exchange and gas chromatography; High performance liquid chromatography and Fast Performance Liquid Chromatography (FPLC).

Electrophoresis: Principle, types and applications, frontal and zonal electrophoresis, paper, starch gel, Polyacrylamide and agarose gel electrophoresis; Isoelectric focussing and Isotachophoresis; Two dimentional gel electrophoresis and pulse field gel electrophoresis; Immunological techniques: immunoelectrophoresis,immunodiffusion & immuno fluoroscence.

### Unit IV

Spectroscopy: Basic principles, principles and application of visible, ultraviolet, infrared and mass spectroscopy; Principles and application of NMR and ESR; Principles and application of colorimetry, fluorescence flame photometry, Atomic Absorption spectroscopy & Raman spectroscopy.

Radioisotopes –Types ;Radioactive units ; Radioactive Decay – Types and Measurement, Principles and Applications of Geiger Muller counter , Liquid Scintillation counter, Proportional counter ,Gamma counter, Film badge, Pocket dosimeter, Thermoluminescence dosimeter ,Trefoil , Autoradiography, Radio immunoassay (RIA) & Radiation dosimetry

**Practicals:**

1. Studies on pH titration curves of amino acids/ acetic acid.
2. Determination of pKa values and Henderson-Hasselbach equation.
3. Preparation of samples using different centrifuge.
4. Separation of bacterial lipids/amino acids/sugars/organic acids by TLC or Paper chromatography.
5. Separation of biomolecules by Ion exchange / Gel permeation / Affinity chromatography.
6. Separation of DNA and serum protein by gel electrophoresis.
7. Study of UV absorption spectra of macromolecules (protein, nucleic acid & bacterial pigments).
8. Quantitative estimation of hydrocarbons/pesticides/organic solvents /methane by Gas chromatography /HPLC.

**Suggested Books:**


1. Freilder D. Physical Biochemistry: Application to Biochemistry and Molecular Biology. Freeman Publications.
2. Walker J. & Wilson K. Principle & Technique - Practical Biochemistry 5th Ed. ,2000 .
3. Wilson & Keith. Principles and Techniques of Practical Biochemistry.Cambridge Publications.
4. Rana SVS. Biotcchniques . Rastogi Publications,Meerut.

## Semester II

## MBC 801: Bacteriology

**Max. Marks -100**
**60 Hrs**

### Unit I

Microbial evolution and diversity ,Taxonomic ranks, Phenetic classification, Numerical taxonomy,16s rRNA,Major characteristics used in taxonomy,Microbial phylogeny-Molecular characrteristics, Phylogenetic trees, rRNA, DNA & proteins as indicators of phylogeny, Polyphasic taxonomy.

### Unit II

Morphology and ultrastructure of bacteria: Size , shape and arrangement of bacteria, structure and chemical compostion of cell wall of Gram positive and Gram negative bacteria and Archaea; Structure , composition and function of cell membrane, capsule, flagella, pili, gas vesicles, cytoplasmic matrix reserve food materials, nucleoid, plasmids.

### Unit III

Bacterial life cycles, nutrition, respiration & reproduction; Economic importance of bacteria. Endospore : structure, formation and stages of sporulation; Chemoautotrophs, chemoheterotrops, Nutritional categories among microorganisms, Nutritional requirements in bacteria and nutritional categories, the requirement of carbon, nitrogen and sulphur, growth factors, the role of oxygen, continuous culture, their applications, chemostats and turbidostats.

### Unit IV

Antibacterial agents: General consideration and classification; Bacterial resistance to antibacterial agents-Acquisition of bacterial resistance, Mechanism of bacterial resistance, Bacterial resistance to drug classes & antibiotic susceptibility testing.

### Practicals:

1. Cultivation of microorganisms- nutritional & physical requirements.
2. Quantitation of viable cells in bacterial culture.
3. Growth dynamics of bacterial culture.
4. Micrometry of bacterial cells.
5. Study of microorganism morphology: Hanging drop method and wet mount.

6. Preparation of bacterial smears.
7. Simple staining & Negative staining.
8. Differential staining –Gram staining, Acid –Fast staining & Spore staining.
9. Biochemical: Carbohydrate fermentation & Citrate utilization test.

**Suggested Books**:


1. Morrey CB. The Fundamentals of Bacteriology.
2. Snyder L, Joseph E. Peters, Tina M. Henkin ,Wendy Champness , Molecular Genetics of Bacteria .4th edition ASM Press, 2007.
3. Brown A. Benson's Microbiological Applications Complete Version. (Kindle edition).
4. Baron S. Medical Microbiology. 4th edition., Galveston (TX) 1996.
5. Lehmann KB. Atlas and Principles of Bacteriology and Text-Book of Special Bacteriologic Diagnosis. (Karl Berhard ) Andesite Press.

## MBC 802: Microbial Metabolism & Physiology

**Max. Marks -100**
**60 Hrs**

**Unit –I**

Microbial nutrition & growth: Nutritional categories of microorganisms; Nutritional requirements; Measurement of microbial growth, direct & indirect measurement of microbial growth; Influence of environmental factors on microbial growth.

**Unit-II**

Respiratory metabolism: Glycolytic pathway of carbohydrates breakdown, glycolysis, (Embden Meyerhoff pathway), Kreb's cycle and Entner – Duoderoff pathway, Phosphoketolase pathway, Pentose phosphate pathway, Oxidative and substrate level phosphorylation, Gluconeogenesis, Glycogen metabolism, glyoxylate cycle, fermentation of carbohydrates and homo- & hetero-lactic fermentation.

**Unit-III**

Bacterial photosynthesis: Classification of photosynthetic bacteria,(Anoxygenic,oxygenic); photoheterotrophs; Members of prochlorophyta; Unclassified bacteria; Photosynthetic pigments: Bacteriochlorophylls ; Metabolism in photosynthetic bacteria; photosynthetic electron transport system; mechanism of photosynthesis (cyclic & noncyclic ); Calvin Benson cycle.

**Unit –IV**

Nitrogen fixation in symbiotic and free living system; oxygen and hydrogen regulation of nitrogen fixation; nitrification, denitrification and ammonifying bacteria; Pathway of nitrate assimilation in photosynthetic and non photosynthetic systems; transamination and deamination reaction; Synthesis of essential & non essential amino acids and Synthesis of peptidoglycans & polyamines.

**Practicals:**

1. Physiological differentiation of microorganisms of TSIA differential media.
2. Study of nitrification.
3. Isolation and identification of symbiotic nitrogen fixer (Rhizobium) from root nodules.
4. Isolation and Identification of free living nitrogen fixer from soil.
5. Study of ammonification.
6. Fermentation of carbohydrates.

7. Study of chemolithotrophs.
8. Litmus milk-homo-fermentation/ hetero-fermentation.
9. Effect of temperature and pH on bacterial growth.
10. Determination of microbial growth.

**Suggested Books:**


1. Atlas R.M., 1997, Principles of Microbiology. 2nd Edition, Mc Graw Hill Publications.
2. Berg J.M., Tymoczko J.L. and Stryer I., 2007, Biochemistry. 6th Edition, W.H. Freeman and company, New York.
3. Nelson D. L. and Cox M. M., 2009, Lehninger's Principles of Biochemistry, W. H. Freeman.
4. Potter G.W.H and Potter G.W., 1995, Analysis of Biological Molecules: An introduction to principles, instrumentation and technique, Kluwer Academic Publications.
5. Prescott L.M., Harley J.P. and Klein D.A., 2007, Microbiology, 7th Edition, Mc Graw Hill.
6. Stryer, 2001, Biochemistry. 5th Edition, W.H. Freeman.
7. Talaro, K.P. and Talaro A., 2006, Foundations in Microbiology, Mc Graw Hil. Publications.
8. Willey J., Sherwood L. and Woolverton C., 2007, Prescott V Harley/Klein's Microbiology, Mc Graw Hill.

## MBC 803: Medical Microbiology

**Total Marks 100**
**60 Hrs**

### Unit I

Normal microbial flora in human ( skin, mouth,upper respiratory tract &eye) and its role, Normal human flora as pathogen, Anatomic position of normal flora; Pathogenic properties of bacteria –Colonization, invasion, production of toxins (exotoxins & endotoxins); Antimicrobial defences of host ; Cellular mechanisms of antimicrobial defences; Pathogenesis of viral infections.

### Unit II

General characteristics, Morphology, Growth, Pathogenicity,Laboratory diagnosis and Therapy of pathogenic bacteria: *Pneumococci, Neisseriae, Enteric bacilli, Pseudomonas* and other non fermenting bacilli, *Haemophilus, Bordetella, Clostridia, Mycobacteria, Actinomycetes, Rickettsias, Mycoplasmas, Shigella,Vibrio &Yersinia.*

### Unit III

Structure , Reproduction, Pathogenicity, Diagnosis, Therapy and Epidemiology of disease caused by Fungus: *Crytococcus neoformans, Blastomyces dermatitidis, Trichophyton ,Histoplasma capsulatum, Coccidioides immites, Candid albicans, Aspergillus fumigates, Phacomycetes, Sporothrix schenckii, Eumycotic Mycetoma & Microsporum spp.*

### Unit IV

Properties,Pathogenesis, Laboratory diagnosis, Epidemiology, Control &Treatment of virus: Herpes virus (*H.simplex,H.zoster, Epstein-Barr viruses*), Pox viruses, Picornaviruses, Adenoviruses & Rubella virus.

Multiplication, Pathogenesis and Oncogenic activity: (a) Oncogenic DNA viruses (Papovaviruses-Papilloma viruses,Hepatitis B virus,Oncogenic Herpes viruses)

(b) Oncogenic RNA viruses (Lentivirus, HIV, Primate and Human type C Oncovirus).

### Practicals:

1. Laboratory rules and regulation in Pathological laboratory.

2. Collection of specimen –Basic concepts,Transport containers for anaerobic specimens & collection.
3. Techniques for transfer of clinical specimens &selection of primary culture media, Interpretation of culture.
4. Identification based on metabolic characteristics.
5. Antibiotic susceptibility testing.
6. New Technologies in the laboratory diagnosis of infectious diseases.

**Suggested Books :**


1. Baron S. Medical Microbiology, 4th ed. Galveston (TX) 1996.
2. Geo. F. Brooks & Stephen A. Morse. Jawetz, Melnick, & Adelberg's Medical Microbiology 26th edition. McGraw-Hill.
3. Kenneth J. Ryan, C. George Ray. Sherris Medical Microbiology, 5edition
4. Kenneth J. Ryan, MD; Sean Elliott, MD; Lynn Joens, PhD; Chuck Sterling, BS, PhD (Tucson, AZ) ,Paul Pottinger, MD (Seattle, WA) . Sherris Medical Microbiology, 6th ed. McGraw-Hill Education , 2014.
5. Murray PR, Rosenthal KS , Kobayashi GS & Pfaller MA .Medical Microbiology 8th ed. MosbyInc. St Louis,Missouri,2015.

## MBE 801: Food Microbiology

**Max. Marks -100**
**60 Hrs**

**Unit: 1**

Important microbes involved in spoilage of food: Meat, poultry, vegetables & dairy products; Microbial deterioration of cereals, pulses, fish & sea foods during storage; Feed for cattle: Use of microbes and microbial enzymes in the improvement of nutritive quality of feed.

**Unit: II**

Toxins: Bacterial and mycotoxins, important microbes secreting toxins, chemical nature of important toxins, their role in food poisoning; Physiology and mechanism of action, modification and detoxification, prevention and control of toxin contamination. Starter cultures- their biochemical activities, Production and preservation of fermented foods- Soya sauce, sauerkraut, meat – sausages & baker's yeast.

**Unit III**

Microbial biomass and single cell proteins; Uses of microbes in meats and poultry products vegetables etc.; Low calorie sweeteners, flavour modifiers & food additives; Food quality monitoring Indian fermented food.

**Unit IV**

Microbial enzymes in food industry, Tea and coffee fermentations, Vinegar, Wine & Beer production; Food preservation methods, Use of low & high temperature, radiations – UV, Gamma and Microwave, chemicals and naturally occurring anti microbials.

**Practicals:**

1. Statutory tests for microbiological analysis of canned foods.
2. Single cell Protein (SCP) cultivation.
3. Preparation of fermented food & beverages: Sauer Kraut, Koji & Soya sauce.
4. Sampling & analysis of microbial load on food contact surfaces.
5. Isolation and identification of common microorganisms spoiling food: Bacteria & fungi.
6. Aflatoxin production from fungi.

**Suggested Books:**


1. Banwart GJ, Basic Food Microbiology. CBS Publishers &Distributers
2. Frazier WC and Westhoff D C, Food Microbiology. Tata McGraw-Hill Publishing Company Limited, New Delhi.
3. Adams MR and Moss MO, Food Microbiology. New Age International Ltd.

## MBE 802: Environmental Microbiology

**Max. Marks -100**
**60 Hrs**

**Unit-I**

Microbial diversity; Microbiology of air, soil & water; Microbes in extreme environments; Environment induced genetic and physiological adaptation in microbes; Disinfection of potable water supplies and hospital wastes; Bacterial indicators of water safety ; Microbial assessment of water quality; Standard for tolerable levels of fecal contamination.

**Unit-II**

Biodegradation and Bioremediation: Microbial degradation of lignocellulosic substances, keratin and chitin; Bioremediation: Microbial degradation of herbicides, pesticides, hydrocarbons including polycyclic (petroleum, gas production, fossil fuel & polychlorinated biphenyls etc.), oil spills, heavy metals, chlorinated and polychlorinated compounds; Biological treatment of effluents of sugar, pulp and paper industry.

**Unit –III**

Biodeterioration: Biodeterioration of buildings and monuments of cultural heritage, microbial deterioration of paper, textile, leather, rubber, glass, paints and metals; Principal methods for their protection.

**Unit –IV**

Techniques in environmental microbiology : Methods for determination of numbers, biomass and activities of microbes in soil, water, plant surfaces and dead organic materials; Bioremediation techniques:*in situ* (Bioventing, air sparging , liquid delivery system, aerobic bioremediation & phytoremediation) and *ex situ* (land farming, compositing, biopiling & slurry –phase).

**Practicals:**

1. Enumeration of micro-organisms from air.
2. Enumeration of micro-organisms from soil.
3. Micro-organisms degrading oil/textile dyes/petrol.
4. Biodeterioration of paper/textile.
5. Membrane filtrations.
6. Bacteriological examination of water (Potable /hospital wastes):
   a. Presumptive test
   b. Confirmed test
   c. Completed test

7. Pathogen identification.
8. Chemical Oxygen Demand (COD) & Biological Oxygen Demand (BOD).

**Suggested Books:**


1. Atlas R.M. and Bartha R., 1993, Microbial Ecology, Benjamin Cummings Publishing Co, Redwood City, CA.
2. Baker K.H. and Herson D.S., 1994, Bioremediation, McGraw Hills Inc., NY.
3. Christon J.H., 2001, A Manual of Environmental Microbiology, ASM Publications.
4. Colwd D., 1999, Microbial Diversity, Academic Press.
5. Forster C.F. and John D.A., 2000, Environmental Microbiology, Ellis Horwood Ltd. Publications.
6. Grant W.D. and Long P.E., 1981, Environmental Microbiology, Kluwer Academic Publishers.
7. Hurst C.J., Crawford R.L., Garland J.L., Lipson D.A. and Mills A.L., 2007, Manual of Environmental Microbiology, ASM Press.
8. Jjemba P.K., 2004, Environmental Microbiology: Principles and Applications, Science Publishing Inc.
9. Johri B.N., 2000, Extremophiles, Springer Verlag, NY.
10. Maier R., Pepper I., and Gerba C., 2008, Environmental Microbiology, Academic Press.
11. Mitchel R., 2009, Environmental Microbiology, 2nd Edition, Wiley-Blackwell.
12. Pepper I., Gerba C.P. and Brusseau M.L., 2006, Environmental and Pollution Science, Academic Press, USA.
13. Ralph M.A., 1997, Environmental Microbiology, John Wiley and Sons Inc.
14. Singh A., Kuhad R.C. and Ward O.P., 2009, Advances in Applied Bioremediation, Springer.
15. Varman A.H. and Evans M.G., 2000, Environmental Microbiology, Manson Publishing Ltd.

## MBE 803: Genetic Engineering

**Max. Marks -100**
**60 Hrs**

**Unit I**

Basics of recombinant DNA technology: Enzymes used in recombinant DNA technology: Nuclease, DNA ligase, polymerase, reverse transcriptase, terminal deoxy-nucleotidyl transferase, alkaline phosphatise; Modification of restriction fragment ends: Sticky and blunt end ligation with linkers & adapters and homo-polymer tailing.

**Unit-II**

Cloning vectors: Properties of plasmids, yeast plasmid (YAC), shuttle vectors, bacteriophages, cosmids, bacterial artificial chromosomes, Ti based vectors, retroviruses; Isolation and purification of genomic and plasmid DNA; Gene libraries: Genomic library, screening of libraries (shot gun approach) & cDNA library.

**Unit –III**

Introduction of recombinant vectors into bacterial and non bacterial cells; Selection of recombinant clones; Colony hybridization, Plaque hybridization, immunochemical methods; Application of genetic engineering: Scientific,medical, industrial, agricultural and environmental applications; Human genome project.

**Unit-IV**

Polymerase chain reaction (PCR): Basic principle, components of PCR, PCR techniques: Standard PCR, Inverse PCR, reverse transcriptase mediated PCR, Anchored PCR, Asymmetric PCR & Real time PCR; DNA sequencing: dideoxy method (Sanger sequencing), Chemical degradation (Maxum-Gilbert method); Strategies for sequencing large DNA fragments; Automated sequencing and pyro sequencing; Brief description of Probes: Types; RFLP, AFLP and RAPD; Southern, Western and Northern blotting.

**Practicals:**

1. Isolation of genomic DNA
2. Visualization and documentation of genomic DNA using gel doc system.
3. Restriction digestion of DNA.
4. Ligation of restricted DNA sample.
5. Recovery of genomic DNA embedded in Agarose gels (freeze squeeze, column).
6. SDS PAGE.
7. Demonstration of Southern hybridization technique.
8. PCR techniques.

**Suggested Books:**


1. Adams M.R and Moss M.O., 1995, Food Microbiology, Royal Society of Chemistry Publications, Cambridge.
2. Alberts B., Johnson A., Lewis J., Raff M., Roberts K. and Walter P., 2007, Molecular Biology of the Cell, 5th Edition, Garland Science, New York and London.
3. Banwart G.J., 1993, Basic Food Microbiology, CBS Publishers and Distributors, Delhi.
4. Berg J.M., Tymoczko J.L., Stryer L., Freeman W.H. and Company, 2008, Biochemistry, 5th Edition, New York, USA,
5. Cruegar W. and Cruegar A., 1990, Biotechnology: A textbook of industrial microbiology, 2nd Edition, Sinauer Associates .Inc.
6. Frazier W.C. and Westhoff D.C., 1998, Food Microbiology, Tata Mc Graw Hill Publishing Company Ltd, New Delhi.
7. Hobbs B.C and Roberts D., 1993, Food poisoning and Food Hygiene, 6th Edition Edward Arnold (A division of Hodder and Stoughton, London).
8. Jay J.M., 1992, Modern Food Microbiology, 4th Edition, Van Nostraand Reinhold Co., New York.
9. Lewin B., 2007, Gene IX, Jones and Bartlett Publishers, Sudbury, Massachusetts.
10. Robinson R.K., 1990, Dairy Microbiology, Elsevier Applied Sciences, London.
11. Stanburg P.E., Whittaker A. and Hall S.J., 1995, Principles of fermentation technology, 2nd Edition, Pergamon Press.
12. Watson J.D., Baker T.A., Bell S.P., Gann A., Levin M. and Losick R., 2007, Molecular Biology of the Gene, 6th Edition, Benjamin Cummings, San Francisco, USA.
13. Weaver R.F., 2007, Molecular Biology, 4th Edition, McGraw Hill, New York, USA.

## MBE 804: Extremophilic Microorganisms

**Max. Marks -100**
**60 Hrs**

**Unit I**

Microbial World: Concepts and Scope; Types of diversity: Morphological, Structural, Metabolic, Biological, Ecological and Evolutionary diversity (Genetic diversity) of microbial world, Extremophiles -Life at high temperatures, low temperatures, extreme pH levels, brine, high pressure and radiation.

**Unit II**

Concept of microcosms and eco-niches; Expanse of microbial diversity; Estimates of total number of species; Measures and indices of diversity; Newer approaches for exploring unculturable bacteria from environmental samples ; Culture independent molecular methods for understanding microbial community structure.

**Unit III**

Concept of extremophiles v/s conventional microbial forms; Extreme communities in following econiches: deserts (Thar); rhizospheres; Ore deposits and mining areas – Cu, Mn & Fe, animal systems (rumen) and deep biosphere (terrestrial and marine), hydrothermal vent.

**Unit IV**

Major characteristics, unique physiological features and molecular adaptation strategies of various extremophiles. :- Anaerobes: oxygen toxicity and regulation ;*Clostridium* Barophiles/Peizophiles: *alpha proteobacteria*;Cryophiles/ Psychrophiles:*Polaromonas*; Thermophiles:*Thermus;* Oligotrophs: *Pelagibacter* ;Osmophiles: Osmophilic *Lactobacilli* Halophiles: *Halomonas*; Xerophiles: *Frankia*; Radiophiles: *Deinococcus.* Metallophiles: *Geobacillus*; Alkaliphiles/ basophiles: *Alkalimonas*; Acidophiles: *Picrophilus* Neutrophiles. Extremophiles as a source for novel organic compounds and enzymes and their applications.

**Practicals:**

1. Culturing of anaerobic bacteria.
2. Culturing of oligotrophic bacteria.
3. Examination of UV resistance in bacteria.
4. Isolation of halophiles from soils.

5. Metal tolerance of bacterial cultures.
6. Culturing of osmophilic cultures.
7. Isolation of thermophiles.
8. Buffering capacity of alkaliphiles.
9. Isolation of psychrophiles.
10. Isolation of xerophiles.

**Suggested Books:**


1. Adams, M. W. W. and R. M. Kelly: "Enzymes from microorganisms in extreme environments," Chemical and Engineering News, 1995, vol. 73, pages 32-42.
2. Blöchl, E., R. Rachel, S. Burggraf, D. Hafenbradl, H. W. Jannasch, and K. O. Stetter: "Pyrolobus fumarii, gen. and sp. nov. represents a novel group of archaea, extending the upper temperature for life to 113°C," Extremophiles,1997, vol. 1, pages 14-21.
3. Brock, T. D.: Thermophilic Microorganisms and Life at High Temperatures, Springer, New York, 1978.
4. Harmsen, H. J. M., D. Prieur, and C. Jeanthon: "Distribution of microorganisms in deep-sea hydrothermal vent chimneys investigated by whole-cell hybridization and enrichment culture of thermophilic subpopulations," Applied Environmental Microbiology, 1997, vol. 63, pages 2876-2883.
5. Horikoshi, K. and W. D. Grant: Extremophiles-Microbial Life in Extreme Environments, Wiley, New York, 1998.
6. Javor, B. J.: Hypersaline Environments-Microbiology and Biogeochemistry, Springer-Verlag, Berlin., 1989.
7. Kamekura, M.: "Diversity of extremely halophilic bacteria," Extremophiles, 1998, vol. 2, pages 289-295.
8. Madigan M. T., J. M. Martinko, and J. Parker: Brock Biology of Microorganisms, 9th edition, Prentice Hall, Upper Saddle River, NJ, 2000. In press.
9. Madigan, M. T., and A. Oren: "Thermophilic and halophilic extremophiles," Current Opinions in Microbiology, 1999. In press.
10. Madigan, M. T., B. L. Marrs: "Extremophiles," Scientific American, 1997, vol. 276, pages 82-87.
11. Oren, A. (ed.): Microbiology and Biogeochemistry of Hypersaline Environments, CRC Press, Boca Raton, FL, 1999, 368 pages.
12. Rainey, F. A. and Oren, A. Extremophile microorganisms and the methods to handle them. In: Extremophiles, Methods in Microbiology, vol.35, edited by F.A. Rainey and A. Oren, Elsevier, Amsterdam, pp1-25.
13. Stetter, K. O.: "Hyperthermophilic prokaryotes," Federation of European Microbiological Societies, Microbiology Reviews, 1996, vol. 18, pages 149-158.
14. Ventosa, A., J. J. Nieto, and Oren A.: "Biology of moderately halophilic aerobic bacteria," Microbiology and Molecular Biology Reviews, 1998, vol. 62, pages 504-544.
15. Wiegel, J. and M. W. W. Adams (eds): Thermophiles-The Keys to Molecular Evolution and the Origin of Life?, Taylor and Francis, London, 1998, 346 pages.
16. Woese, C. R.: "Bacterial evolution," Microbiological Reviews, 1987, vol. 51, pages 221-271.