Deccan Education Society's FERGUSSON COLLEGE (AUTONOMOUS), PUNE

Syllabus for Fourth Year B. Sc. (MICROBIOLOGY) with honours

[NEP 1.0]

(B.Sc. Semester-VII and VIII)

With Effect From

2026-2027

Deccan Education Society's
Fergusson College (Autonomous), Pune-4
Department of Microbiology

Syllabus NEP 1.0 Implemented from Academic Year 2026-27

UG4/B.Sc.

Program Specific Outcomes (PSOs)

PSO	Outcomes
PSO1	Academic competence: i) Describe microbial processes that can be used for the development of biochemical and immunological tools to improve the quality of human life. ii) Study the cytology, biochemistry, growth as well as application of environmentally and industrially important microbes with a specific emphasis on improving environmental sustainability and human health. iii) Describe and understand the concepts of the role of microorganisms in geochemical processes like leaching of metals and bioremediation methods.
PSO2	Personal and Professional competence: i) Apply tools of molecular taxonomy and bioinformatics to the study of diverse microbial groups. ii) Evaluate industrially important microbial products in terms of their purity, safety and ethically acceptable application for the benefit of mankind. iii) Combine public presentation skills of effective articulation and nonverbal communication with a sound understanding of microbial science to effectively communicate ideas.
PSO3	Research competence: i)Validate scientific hypothesis and editorialize experimental scientific data by using statistical tools applicable to biological sciences. ii) Integrate principles of biology and physical sciences to standardize detection and quantification methods using sophisticated techniques.
PSO4	Entrepreneurial and Social Competence: i) Employ skill sets related to Quality assurance and testing of pharmaceutically important products in accordance with internationally accepted standards. ii) Evaluate the importance of new groups of consumer goods such as prebiotics, probiotics and nutraceuticals. iii) Apply the concepts of microbial interactions in basic and advanced treatment of waste water treatment processes.

Course Structure UG4 B.Sc. NEP 1.0

Semester	Paper Code	Paper Title	Theory/Practical	Credits	Exam Type
VII	MIC-401	Diversity and Taxonomy of Microorganisms	Theory	4	CE+ESE
	MIC-402	Biochemical Processes in Microorganisms	Theory	4	CE+ESE
	MIC-403	Applied Environmental Microbiology	Theory	4	CE+ESE
	OR				
	MIC-404	Cellular and Developmental Processes in Organisms	Theory	4	CE+ESE
	MIC-445	Research Methodology	Theory	4	CE+ESE
	MIC-411	Practical – 11	Practical	2	CE+ESE
	MIC-412	Practical - 12	Practical	2	CE+ESE
	Total Semester Credits			**20**	
VIII	MIC-451	Advanced Metabolic Processes in Microorganisms	Theory	4	CE+ESE
	MIC-452	Molecular Advances in Microbial Systems	Theory	4	CE+ESE
	MIC-453	Principles of Virology	Theory	4	CE+ESE
	OR				
	MIC-454	Advances in Bionanosciences	Theory	4	CE+ESE
	MIC-495	On Job Training	Theory	4	CE+ESE
	MIC-461	Practical - 13	Practical	2	CE+ESE
	MIC-462	Practical - 14	Practical	2	CE+ESE
	Total Semester Credits			**20**	
Total UG4 Credits				**40**	

SEMESTER VII		
	MIC-401: Diversity and Taxonomy of Microorganisms **Major Theory**	
	Number of Credits: 04 **No. of Hours:60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	List the various methods used for sequencing the genomes of micro-organisms. State the reasons for the entry of microorganisms into the unculturable state.	1
CO2	Differentiate between Bergey's manuals of Determinative and Systematic Bacteriology. Explain the mechanisms used by extremophiles to survive under extreme conditions.	2
CO3	Apply the knowledge of the different approaches used for classifying and identifying microorganisms and predict their presence in different unexplored environments.	3
CO4	Relate the unculturable microbial diversity to different problems such as disease outbreaks. Explain the different methods used for sequencing the microbial genome.	4
O5	Evaluate the microbial diversity of a habitat using culture dependent as well as the metagenomics approach.	5
CO6	Combine the use of bioinformatics tools with the traditional methods of identification of microorganisms	6

MIC-401: Diversity and Taxonomy of Microorganisms
(Major- Theory)
Course Contents

Unit No.	Title of Unit and Contents	No. of hours
1	**Microbial Diversity and Introduction to Bergey's manuals:** **A. Microbial Diversity** i. The expanse of microbial diversity ii. Measurement of microbial diversity using culture – dependent and culture – independent molecular methods **B. Introduction to Bergey's manuals** i. The 5-Kingdom classification system, the 3-Domain classification system ii. Determinative bacteriology (Phenetic approach) iii. Systematic bacteriology (Phylogenetic approach) iv. Chemotaxonomy v. Numerical Taxonomy Polyphasic approach	**15**

2	**Study of Extremophiles and extreme environments:** **Study of Extremophiles**: Isolation, classification, adaptation mechanisms and biotechnological applications of extremophiles i. Thermophiles ii. Alkaliphiles iii. Halophiles iv. Barophiles	**15**
3	**Identification of Micro-organisms:** **A. Gene sequencing** i. Objectives and challenges of gene sequencing ii. Vectors used in gene sequencing iii. Maxam Gilbert's method of sequencing iv. Sanger's method of sequencing and automated sequencing v. Newer methods of sequencing such as Pyrosequencing, Ion torrent sequencing, Solexa Illumina Sequencing vi. Strategies for whole genome sequencing vii. Whole Genome Shotgun Sequencing viii. Applications of gene sequencing (identification of organisms) **B. Introductory Bioinformatics** i. Types of Databases- primary, secondary, sequence, structure, metabolic ii. Biological data retrieval iii. Pairwise and multiple sequence alignment iv. Scoring matrices v. Needleman-Wunsch Algorithm and Smith-Waterman Algorithm BLAST and FASTA	**15**
4	**Exploration of Unculturable bacteria** i. Concept of unculturable bacterial diversity ii. Methods of extracting total bacterial DNA from the environment iii. Concept of metagenomics Culture-independent molecular methods for identification of unculturable bacteria	**15**

Learning Resources

Sr. No.	References
1.	Jacquelyn G. Black (2013). Microbiology: Principles and Explorations, 6th Edition. John Wiley and sons Inc.
2.	Keller M. and Zengler K. (2004). Tapping in to Microbial Diversity. Nature Reviews 2, 141-150.
3.	Pace N. (1997). A Molecular View of Microbial Diversity and the Biosphere, Science, 276, 734-740.
4.	John G. Holt et al. (1994). Bergey's manual of determinative bacteriology 9th edition. Lippincott Williams and Wilkins.
5.	Bergey's manuals of Systematic bacteriology - 1st edition – all volumes.

6.	Michael T. Madigan et al. (2012). Brocks Biology of Microorganisms. 13th Edition Prentice Hall International Inc
7.	Dhamodharan Ramasamy et al. (2014) A polyphasic strategy incorporating genomic data for the taxonomic description of novel bacterial species. International Journal of Systematic and Evolutionary Microbiology, 64, 384–391
8.	Horikoshi K. and Grant W. D. Extremophiles (1998). Microbial Life in extreme environments. Wiley Liss Publications
9.	Horikoshi K. and K. Tsujii. Extremophiles in deep sea environments (1999). Springer Japan Publications Horikoshi K. Alkaliphiles – Genetic properties and applications of enzymes (2006). Kodansha Springer.

	MIC-402: Biochemical Processes in Microorganisms **Major Theory**	
	Number of Credits: 04 **No. of Hours:60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall and use fundamental thermodynamic laws and equations applicable to biological systems	1
CO2	Compare the types of noncovalent chemical bonds important in the stability of biomolecules in terms of their prevalence, strength and focus on their importance in biological processes.	2
CO3	Apply the knowledge to represent the data obtained from inhibition of enzymes graphically to predict the nature of the inhibitor and its significance. Calculate the thermodynamic transactions occurring in biological systems.	3
CO4	Categorize the use of biomolecules as buffering agents based on their dissociation properties and isoelectric pH values.	4
O5	Evaluate the use of molecular transducers and transport proteins in biological systems based on their energy requirements, prevalence and relate the constitutive use of these mechanisms with their biological functions.	5
CO6	Specify important allosteric enzymes from biochemical pathways and propose their importance as key regulators of metabolism in biological systems.	6

MIC-402: Biochemical Processes in Microorganisms
(Major- Theory)
Course Contents

Unit No.	**Title of Unit and Contents**	**No. of hours**
1	**Bioorganic Chemistry** A. Concept of isomerism in biomolecules- tautomers, epimers, enantiomers,stereo isomers etc. B. Bonding other than covalent: i. H-bonds ii. Van der Wall's interaction iii. Ionic bonding, Ion dipole iv. Hydrophobic interactions v. Host-guest interactions C. Reactions of organic molecules: A brief overview of important reactions in Organic chemistry: Substitution, Addition, Elimination, Rearrangement, Oxidation, Reduction, etc. D. Bioorganic mechanism of enzyme catalyzed reactions: i. Acid – base ii. Covalent catalysis	**15**

	iii. Metal ion catalysis with examples of respective enzymes F. Concept of pH of weak acids and weak bases i. Henderson- Hasselbalch equation, ii. Concept of buffer, Strength and buffer value iii. Important biological buffers. G. Properties of water as a universal solvent Problem solving on above topics	
2	**Bioenergetics** A. Laws of thermodynamics, entropy, enthalpy, Free energy i. Free energy and equilibrium constant, ii. Gibbs free energy equation, iii. Determination of free energy of hydrolytic and biological oxidation reduction reactions, under standard and non-standard conditions, Determination of feasibility of reactions, B. An overview of electron transport and High energy compounds C. Coupled reactions D. Atkinson's energy charge E. Phosphorylation potential and its significance Problem solving on above topics	**15**
3	**Membrane Transport** A. The composition and architecture of Membrane and membrane dynamics B. Solute transport across membranes: i. Concepts of active and Passive transport ii. Facilitated transport iii. Primary and secondary active transport using P, V and F type ATPases iv. Ionophores v. Ion mediated transport vi. Transport of ions across membranes (ion pumps) C. Ligand and voltage gated ion channels D. Liposomes and model membranes E. Aquaporins Problem solving on above topics	**15**
4	**Enzyme Kinetics** A. Revise concepts of Kinetics of single substrate-enzyme catalyzed reaction. B. Kinetics of reversible inhibitions enzyme catalyzed reactions focusing on LB plots and secondary plots to determine value of ki C. King Altman approach to derive – two substrate enzyme catalysed reactions D. Types of two substrate enzyme catalyzed reactions, E. Concept of allosterism, positive and negative co-operativity F. Models of allosteric enzymes (Monod, Wyamann and Changuax model, Koshland, Nemethy and Filmer model), G. Kinetics of allosteric enzyme, Hill plot, examples of allosteric enzymes and their significance in allosteric regulation Problem solving on above topics	**15**

Learning Resources

Sr. No.	References
1.	Clayden, Greeves, Warren and Wothers, *Organic Chemistry*, Oxford Press
2.	Jerry March, *Advanced Organic Chemistry*, John Wiley
3.	Voet Donald and Voet Judith G. (1995) Biochemistry, 2nd Ed. John Wiley and sons, New York
4.	Conn Eric, Stumpf Paul K., Bruuening George, Doi Roy H., (1987) *Outlines of Biochemistry* 5th Ed, John Wiley and Sons, New Delhi.
5.	Nelson D. L. and Cox M. M. (2005) *Lehninger's Principles of Biochemistry*, Fourth edition, W. H. Freeman & Co. New York
6.	Segel Irvin H. (1997) *Biochemical Calculations* 2nd Ed., John Wiley and Sons, New York
7.	Garrett, R. H. and Grisham, C. M. (2004) Biochemistry. 3rd Ed. Brooks/Cole, Publishing Company, California
8.	Palmer Trevor (2001) *Enzymes: Biochemistry, Biotechnology and Clinical Chemistry*, Horwood Pub. Co. Chinchester, England
9.	Berg Jeremy, Tymoczko John, Stryer Lubert (2001) *Biochemistry* 4th Ed, W. H. Freeman, New York

	MIC-403: Applied Environmental Microbiology **Elective Theory**	
	Number of Credits: 04 **No. of Hours:60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe the role of microorganisms in biofilm formation which is responsible for destruction of metallic and wooden articles in different fields.	1
CO2	Explain different extraction methods for precious metals that are employed in various countries.	2
CO3	Outline biochemical pathways involved in bioremediation of recalcitrant xenobiotic compounds.	3
CO4	Explain different wastewater treatment methods.	4
O5	Appraise the advanced waste water treatment processes for treating industrial wastes containing toxic chemicals.	5
CO6	Write a report on the general principles of wastewater treatment processes.	6

MIC-403: Applied Environmental Microbiology
(Elective- Theory)
Course Contents

Unit No.	Title of Unit and Contents	No. of hours
1	**Geo microbiology:** **A.** Biofouling and Biocorrosion **B.** Bioleaching i. Principles of Microbial Metal Leaching: Copper, Iron ii. Leaching Mechanisms iii. Models of Leaching Mechanisms iv. Factors Influencing Bioleaching **C.** Bacterial Attachment on Mineral Surfaces	**15**
2	**Bioremediation:** **A.** Definition, Role and pathways of plants & Microbes in Bioremediation of: i. Hydrocarbons ii. Industrial Wastes iii. Xenobiotics iv. Role of microorganisms in ocean processes **B.** Bioaugmentation: i. microbial cultures and enzymes for bioaugmentation ii. Applications **C.** Biosorption **D.** Biomagnification: Role of Mercury in Biomagnification	**15**

3	**Principles of Wastewater Treatment** **A.** The need for Wastewater Treatment **B.** Measuring Pollution Load of wastewater **C.** Methods for estimating parameters used for determining treatment efficacy **D.** Layout of typical wastewater treatment plants Physico- chemical characteristics of waste water, screening, sedimentation, flotation, disinfection, sludge handling and disposal	**15**
4	**Advanced, Combined and Innovative wastewater treatment processes** **A.** Submerged Aerobic Fixed Film reactors (SAFF) **B.** Membrane bioreactors (MBRs) **C.** Rotating Biological Contactors (RBCs) **D.** Mixed Bed Bioreactors (MBBRs)	**15**

Learning Resources

Sr. No.	References
1.	Klaus Bosecker (1997) Bioleaching: Metal solubilisation by microorganisms, FEMS Microbiology reviews
2.	Axel Schippers and Wolfgang Sand (1998) Bacterial Leaching of Metal Sulfides Proceeds by Two IndirectMechanisms via Thiosulfate or via Polysulfides and Sulfur, Applied and Environmental Microbiology p. 319–321 Vol. 65, No. 1
3.	Ajay Singh, Owen P. Ward, 2004 edition, Applied Bioremediation and Phytoremediation (Soil Biology). Springer
4.	Charles R. Lane, Paul Beales, Kelvin J. D. Hughes (2012). Fungal Plant Pathogens.1st Edn. CABI Publishing
5.	John Postgate, (1998). Nitrogen Fixation. Cambridge University Press
6.	Martin Alexander (1999). Biodegradation and Bioremediation. Academic Press
7.	Matthew Dickinson, (2003). Molecular Plant Pathology. Garland Publishing Inc.
8.	Biotechnology for Water and Wastewater Treatment. Dr. Satya Prakash. Navyug Publishers & Distributors, New Delhi. 2009.
9.	Industrial Water Pollution Control. 3rd Edition. W. Wesley Eckenfelder Jr. McGraw Hill. 2000. Standard Methods for the Examination of Water & Wastewater. 21st Edition. 2005.
10.	N. S. SubbaRao. (1995). Soil Microorganisms and Plant growth. 3rd Edn. Science Pub Inc
11.	Biological Wastewater Treatment. Vol. 5. Activated Sludge and Aerobic Biofilm Reactors. Marcos von Sperling. IWA Publishing. London, New York. © 2007 IWA Publishing

	MIC-404: Cellular and Developmental Processes in Organisms Elective Theory	
	Number of Credits: 04 No. of Hours:60	
Course Outcomes (COs) On completion of the course, the students will be able to:		**Bloom's cognitive level**
CO1	Describe various events in the cell cycle.	1
CO2	Explain diagrammatically the ultrastructure of eukaryotic cells. Outline the cellular signalling mechanisms in higher organisms at the molecular level.	2
CO3	Illustrate the effect of fundamental activities such as homeostasis and morphogen gradients on the process of cellular development.	3
CO4	Explain diagrammatically trafficking of biomolecules in the compartments of eukaryotic cells.	4
CO5	Compare vertebrate and invertebrate developmental systems.	5
CO6	Write the application of advanced microscopic techniques for localization of macromolecules in eukaryotic cells.	6

MIC-404: Cellular and Developmental Processes in Organisms
(Elective- Theory)
Course Contents

Unit No.	Title of Unit and Contents	No. of hours
1	**Ultra structure and Organization of Eukaryotic Cell** **A.** Structural organization of: i. Cytoskeleton ii. Endoplasmic Reticulum iii. Golgi apparatus **B.** Protein trafficking among various cellular compartments **C.** Events in cell cycle, Regulation of cell cycle, apoptosis **D.** Localization of macromolecules using: i. Electron microscopy ii. Immunoelectron microscopy Confocal microscopy Problem solving on above topics	**15**
2	**Communication in prokaryotic and eukaryotic system** **A.** Communication and coordination in prokaryotes i. Life cycle and Molecular mechanism of quorum sensing in myxobacteria. ii. Quorum sensing in Gram positive (*Staphylococcus aureus* virulence factors) and Gram negative bacteria (*Vibrio fischeri* lux operon) iii. Biofilms: iv. Organization and Signals involved in biofilm formation and dispersal v. Applications of study on biofilms in pathogenic (*Pseudomonas aeruginosa*) and non-pathogenic environments (dental plaque) iv. Secretory systems in bacteria, competence development, sporulation **B.** Communication and coordination in eukaryotes	**15**

	i. Life cycle and Molecular mechanism of quorum sensing in *Dyctiostellium discoidum*. ii. Signaling in higher eukaryotes: autocrine, paracrine, endocrine, neurotransmitters iii. Pathways in cell signaling: GPCRs- a. adenylate cyclase pathway b. regulation of cytosolic Ca^{2+} Problem solving on above topics	
3	**Basic principles of developmental biology** **A.** Concept and principles of developmental biology, **B.** Hox code in different systems, Morphogen gradients, Apoptosis and PCD pathways **C.** Signal transduction pathways in PCD Changes in membrane architecture in PCD. **D.** Homeostasis and its significance in biological systems. Types of rhythms: Circardian and other examples. **E.** Types of cleavages and their presence in biological systems. Differentiation, trans-differentiation and de-differentiation	**15**
4	**Development in *Drosophila* and *Xenopus*** **A.** *Drosophila*: Fertilization, blastulation and gastrulation events, segmentation, details of events. **B.** *Xenopus*: Fertilization and control over the process of fertilization, organizer and its significance, blastulation, epiboly, invagination and gastrulation events.	**15**

Learning Resources

Sr. No.	References
1.	Alberts Bruce (1985) Molecular Biology of Cell. Garland Pub
2.	Metzler David E. (2001) Biochemistry: The chemical Reactions of Living Cells, Volume 1& 2, Academic Press, California.
3.	Harvey Lodish, Arnold Berk, S. Lawrence Zipursky, Paul
4.	Matsudaira, David Baltimore, and James Darnell (2000) Molecular Cell Biology, 4th edition, W. H. Freeman & Co., NewYork
5.	Reactions of Living Cells, Volume 1&2, Academic Press California
6.	Hamilton W. Allan, (1987) Biofilms: Microbial Interactions and Metabolic activities, in Ecology of Microbial Communities, (Eds. M. Fletcher, T. R. G. Gray and J. G. Jones) Cambridge University Press, Cambridge
7.	Peters J. E. (1969) Isolation, cultivation and maintenance of Myxobacteria, Methods in Microbiology (Eds. Norris J. R. and W. Ribbons) Vol. 3B, Academic Press London, 185-210
8.	Toole 'O' George, H. B. Kaplan, R. Kolter,(2000) Biofilm formation as microbial development Annual Review of Microbiology, Vol. 54, 49-79
9.	Christopher M. Waters and Bonnie L. Bassler (2005) Quorum sensing:cell-to-cell communication in bacteria. Annu. Rev.Cell Dev

10.	Melissa B. Miller and Bonnie L. Bassler (2001) Quorum sensing in bacteria. Annu. Rev. Microbiol. Vol. 55, 165–99
11.	Munehiko Asayama and Yasuo Kobayashi (1993) Signal transduction and sporulation in Bacillus subtilis: autophosphorylation of SpoOA, a sporulation initiation gene product. Molecular and General Genetics. Vol. 238
12.	Nelson D. L. and Cox M. M. (2005) Lehninger's Principles of Biochemistry, Fourth edition, W. H. Freeman & Co. New York
13.	Gibert Scott F. (2003). Developmental Biology. 7th Ed. Sinauer Associates Inc. Mass. USA
14.	Muller W.A. (1997) Developmental Biology, SpringlerVerlag, New York,Inc.
15.	Wolpert Lewis (1998) Principles of Developmen. Oxford University Press Oxford

	MIC-411: Practical- 11 **Major Practical**	
	Number of Credits: 02 **No. of Hours: 60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Tell the different methods, culture media and culture conditions used for the cultivation of different microorganisms.	1
CO2	Classify the microorganisms into different categories based on their characteristics. Compare between the different types of microorganisms.	2
CO3	Examine the culture conditions or media to obtain the expected results. Perform experiments in the wet as well as the dry lab.	3
CO4	Analyze the results of the different conducted experiments and relate them with the previous findings.	4
CO5	Evaluate the microbial diversity of a habitat using culture dependent methods. Predict the identity of the microorganisms using bioinformatics tools.	5
CO6	Formulate culture media for the cultivation of microorganisms.	6

MIC-411: Practical- 11
(Major- Practical)
Course Contents

Unit No.	Title of Unit and Contents	No. of hours
1	**Isolation and identification of Eubacteria** Isolation of the following types of bacteria from natural samples. Identification of the bacteria to at least the Genus level using the Bergey's Manuals: A. Mesophilic bacteria B. Actinomycetes C. Cyanobacteria D. Yeasts E. Molds The identification key must be designed for each isolate and Identified bacterium. Students are expected to isolate at least one genus from each group	**30**
2	**Molecular Taxonomy** A. Isolation of isolated chromosomal DNA of bacteria B. Checking the purity of the isolated bacterial DNA using spectrophotometer C. Estimation of of bacterial DNA D. Detection of bacterial DNA using the UV Transilluminator E. Sequence matching by BLAST analysis.	**30**

Learning Resources

Sr. No.	References
1.	Lodder J. (1974). The Yeasts: A Taxonomic Study, North Holland Publishing Co. Amsterdam
2.	Barnett, H. L. and Hunter, B. B. 1960. Illustrated Genera of Imperfect Fungi. Burgess Publishing Co., Minnesota
3.	Sandy Primrose, Richard Twyman, Bob Old (2001), Principles of Gene Manipulation 6th Edition, Blackwell Science Ltd
4.	Sambrook, J., Fritsch, E. F. And Maniatis, T. (1989) Molecular Cloning: A laboratory Manual, 2nd ed. Cold Spring harbour NY: Cold Spring Harbour Laboratory Press
5.	Ausbel F. M and Brent R. (1994) Current Protocols in Molecular Biology, John Wiley & Sons Inc, New York
6.	Breed and Buchanan. Bergey's Manual of Determinative Bacteriology. 9th Edition, 1982
7.	Breed and Buchanan. Bergey's Manual of Systematic Bacteriology. 2nd Edition, (Volumes. 1 – 5) (2001 – 2003)

	MIC-412: Practical- 12 **Major Practical**	
	Number of Credits: 02 **No. of Hours: 60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Outline Good Laboratory Practices (GLPs) and laboratory safety with day to day working in microbiology laboratory.	1
CO2	Describe protocols to prepare buffers of biological importance.	2
CO3	Construct enzyme purification methods from biological sources.	3
CO4	Analyze kinetic parameters of enzyme action on its substrate by carrying out appropriate experiments and evaluate the allowed conformation of proteins using Ramachandran plot.	4
CO5	Test the ecological potential of microorganisms such as degradation of recalcitrant compounds. Choose experiments to isolate bacterial pigments and to assess biofilm formation by bacteria.	5
CO6	Design experiments for the degradation of natural wastewater and artificial wastewater by microorganisms.	6

MIC-412: Practical- 12
(Major- Practical)
Course Contents

Unit No.	Title of Unit and Contents	No. of hours
1	**Biochemistry** **A.** Good laboratory practices: Laboratory safety, hazard from chemicals, handling of chemicals, disposal of chemicals and cultures, designing SOP and maintenance of instruments **B.** Buffer preparation: i. Determination of pKa of a monoprotic weak organic acid by tirimetric and graphical method ii. Preparation of buffers using KH_2PO_4 and K_2HPO_4, acetic acid and sodium acetate, K_2HPO_4 and H_3PO_4 **C.** Purification of enzyme by ammonium sulfate precipitation, organic solvent precipitation, gel filtration and establishment of enzyme purification chart **D.** Determination of kinetic parameters (K_M and Vmax) of any hydrolytic enzyme by graphical method **E.** Establishment of enzyme purification chart	**30**
2	**Applied Microbiology, Cell and Developmental Biology** **A.** Isolation and characterization of pesticide/ hydrocarbon degrading bacteria **B.** Estimation of pollution load of a natural sample (e.g. riverwater/	**30**

	industrial wastewater) **C.** Setting up a laboratory experiment to assess the degradability of synthetic wastewater. **D.** Studying the stages of mitosis in growing tips of onion roots. **E.** Isolation and characterization of any one bacterial pigment **F.** Biofilm preparation: Development of biofilms and testing of biofilm production	

Learning Resources

Sr. No.	References
1.	Naphade S.R. et al., (2012) Isolation, characterization and identification of pesticide tolerating bacteria from garden soil. Pelagia Research Library, 2 (5):1943-1951
2.	Heusch S et al., (2010) Simulation of wastewater treatment plant within integrated urban wastewater models. Water Sci Technol, 61(10):2645-52
3.	Haddix PL and Shanks RMQ (2018) Prodigiosin pigment of *Serratia marcescens* is associated with increased biomass production. Arch Microbiol, 200(7):989-999
4.	Segel Irvin H. (1997) Biochemical Calculations 2nd Ed., John Wiley and Sons, NewYork
5.	Sandy Weinberg (2002) Good Laboratory Practice Regulations, Revised and Expanded, CRC Press
6.	Robert K. Scopes (2013) Protein Purification: Principles and Practice, 3rd Ed., Springer Science & Business Media
7.	Clive Dennison (2002) A guide to protein isolation, Kluwer Academic Publishers Pattabhi
8.	V. and Gautham, N. (2002) Biophysics. Kluwer Academic Publishers, New York and Narosa Publishing House, Delhi
9.	David J Holme, Hazel Peck (1998) Analytical Biochemistry, 3rd ed., Prentice Hall, Pearson Education Limited, Harlow, England
10.	Nölting, B. (2006) Methods in modern biophysics. Second Edition. Springer, Germany
11.	Parton RM et al., (2010) Collection and mounting of Drosophila embryos for imaging. Cold Spring Harb Protoc., (4) prot5403
12.	Cotterill, R. M. J. (2002) Biophysics: An Introduction. John Wiley & Sons, England

SEMESTER VIII		
	MIC-451: Advanced Metabolic Processes in Microorganisms **Major - Theory**	
	Number of Credits: 04 **Number of hours: 60**	
Course Outcome (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall key steps in the biological fixation and assimilation of nitrogen along with the biocatalytic agents involved and focus on the regulation of nitrogen turnover in microbial communities.	1
CO2	Discuss the composition of electron transport chains present in various biological systems with energy conservation in the form of high energy compounds and compare their efficiency.	2
CO3	Compute the energy output for a variety of respiratory and fermentative pathways in microbial systems and explain their ecological significance.	3
CO4	Categorize inhibitors and uncouplers of phosphorylation in biological energy conservation mechanisms.	4
CO5	Compare the photosynthetic potential and evolution of photosynthetic bacteria with higher photosynthetic systems.	5
CO6	Write the interactions between proteins and nucleic acids and justify the importance of these interactions in biological systems.	6

MIC-451: Advanced Metabolic Processes in Microorganisms
(Major- Theory)
Course Contents

Unit No.	Title of Unit and Contents	No. of lectures
1	**Biochemistry- proteins and nucleic acids** **A.** Biochemistry of Proteins: i. partial double bond nature of peptides, determination of primary structure of polypeptide (N-terminal, C-terminal determination method of sequencing of peptides) ii. Physical and chemical properties of amino acids iii. Ramchandran plot **B.** Biochemistry of nucleic acids: i. Tm value Cot curves ii. Structure of t-RNA, r-RNA, and m-RNA **C.** Interactions between proteins and nucleic acid i. Histones and DNA ii. SSBPs and DNA	**15**

	iii. Transcription Factors and DNA – Helix Turn Helix v. Transcription Factors and DNA – Helix Loop Helix vi. Translation –Initiation/ Elongation Factors and RNA vii. Problem solving on above topics	
2	**Aerobic and Anaerobic respiration** A. Aerobic respiration i. Sites of aerobic respiration in eukaryotes and prokaryotes ii. Components and organization of bacterial and mitochondrial electron transfer system iii. Structure and function of F1F0 ATPase iv. Generation and maintenance of proton motive force v. Energetics of Oxidative phosphorylation vi. Inhibitors and un-couplers of electron transport chain and oxidative phosphorylation vii. Types of Chemolithotrophs: Energy conservation B. Anaerobic respiration:Concept of anaerobic respiration i. Components of electron transfer system ii. Energy conservation in bacteria where nitrate, sulfate and carbonate act as terminal electron acceptor iii. Assimilatory and dissimilatory mechanisms. a. Ammonia oxidizing bacteria v. Methanogens: Mechanism of methanogenesis and energy conservation	**15**
3	**Nitrogen metabolism** A. Biochemistry of biological nitrogen fixation i. Properties of nitrogenase and its regulation ii Ammonia assimilation with respect to glutamine synthetase, glutamate dehydrogenase, glutamate synthetase, their properties and regulation B. Biosynthesis of five families of amino acids and histidine C. Biosynthesis of purine and pyrimidine bases D. Mechanism of denitrification Problem solving on above topics	**15**
4	**Photosynthesis** A. Energy considerations in photosynthesis, light and dark reactions B. Plant systems: electron carriers in photosystems, I and II, cyclic and noncyclic flow of electrons, Z scheme, Hills reaction and photolysis of water C. Eubacterial photosynthesis: scope, electron carriers, photosynthetic reaction centres, cyclic flow of electrons, bacterial photophosphorylation in various groups of phototrophic bacteria, electron donors other than water in anoxygenic photosynthetic bacteria D. Archaebacterial photosynthesis: Bacteriorhodopsin Problem solving on above topics	**15**

Learning Resources

Sr. No.	References
1.	Cox M. M., Nelson D. L., (2008) Lehninger Principles of Biochemistry,Fifth edition, W. H. Frreman and Company New York
2.	Berg Jeremy, Tymoczko John, Stryer Lubert (2001) *Biochemistry* 4th Ed, W. H.

	Freeman, New York.
3.	Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry.* 3rd Ed. Brooks/Cole, Publishing Company, California
4.	Segel Irvin H. (1997). *Biochemical Calculations*. 2nd Ed.John Wiley and Sons, New York.
5.	Segel Irvin H. (1997). *Biochemical Calculations*. 2nd Ed.John Wiley and Sons, New York.
6.	Moat Albert G. and Foster John W. (1988) *Microbial Physiology* 2nd Ed. John Wileyand Sons New York.
7.	Michael T. Madigan, John M. Martinko, David A. Stahl, David P. Clark (2012) *Brock Biology of Microorganisms*, 13th edition, Benjamin Cummings, San Francisco.
8.	White David (2000) *Physiology and Biochemistry of Prokaryotes.* 2nd Ed. Oxford University Press, New York.
9.	Mandelstam Joel and McQuillen Kenneth (1976) *Biochemistry of Bacterial Growth*, Blackwell Scientific Publication London.

	MIC-452: Molecular Advances in Microbial Systems Major - Theory	
	Number of Credits : 04 **Number of hours: 60**	
Course Outcome (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe the concepts of epigenetic and the changes which affect the gene expression and the structure, organization and regulation of chromatin.	1
CO2	Compare the complexity of genomes in different species and differentiate between prokaryotic and eukaryotic transcription.	2
CO3	Illustrate different control mechanisms involved in prokaryotic transcription.	3
CO4	Explain the fine control of prokaryotic transcription in metabolism of sugars and amino acids	4
CO5	Distinguish between the controlling elements of different types of transposons	5
CO6	Justify the importance of retroviral transposons and other eukaryotic transposable elements	6

MIC-452: Molecular Advances in Microbial Systems
(Major - Theory)
Course Contents

Unit No.	Title of Unit and Contest	No. of hours
1	**Chromatin organization and function** **A.** Structure of chromatin, nucleosome, chromatin organization and remodeling, Higher order organization - chromosome, centromere, telomere **B.** Concept of epigenetics: DNA methylation, histone modifications, epigenetic inheritance, genomic imprinting, effect of environment on epigenetic changes **C.** C value paradox and genome size, cot curves, repetitive and non-repetitive DNA sequence, Cot ½ and Rot ½ values	**15**
2	**Eukaryotic transcription and processing of RNA** **A.** Eukaryotic RNA polymerases I, II and III and their promoters, Enhancers, TATA box Binding Protein (TBP) **B.** Processing of RNA: RNA splicing- group I, group II introns, Capping of mRNA and polyadenylation **C.** mRNA processing: splicing (with example of immunoglobulin heavy or light chain genes), capping, polyadenylation **D.** rRNA processing: tRNA processing **E.** Non-coding RNAs and their role: RNA interference; siRNA, micro- RNA role in gene silencing, RNA editing	**15**

3	**Fine Control of Prokaryotic transcription** **A.** Lactose operon: repressor-operator interactions, mechanism of repression, Positive control of lac Operon-Mechanism of CAP action **B.** The Arabinose operon: Ara operon repression loop, evidence for repression loop, auto regulation of Arabinose operon **C.** The tryptophan operon: - control of tryptophan operon by attenuation, defeating attenuation, Riboswitches **D.** Lambda lytic lysogenic interconversion Sigma factor Switching: - Phage infection- SPO1 infection in *B. subtilis*	**15**
4	**Mobile DNA elements** **A.** Transposable elements in bacteria, IS elements, composite transposons **B.** Replicative, non-replicative transposons **C.** Controlling elements in Tn A, Tn 5 and Tn 10 transposition **D.** Transposons in Maize and Drosophila **E.** Retroviruses and retrotransposon, Ty elements in yeasts **F.** SINES, LINES and Alu elements	**15**

Learning Resources

Sr. No.	References
1.	James D. Watson, Tania Baker, Stephen P. Bell, Alexander Gann, Michael Levine, Richard Loswick (2004) Molecular Biology of the Gene, 5th Edition, Pearson Education, Inc. and Dorling Kindersley Publishing, Inc.
2.	Lewin's Genes XI, (2014) Jones and Bartelett Publishers Inc.
3.	Bruce Albert et. al., Molecular Biology of the Cell, 6th Edn., Garland Sciences.
4.	Lodish H, Berk A, Zipursky SL et al. (2012) Molecular Cell Biology, 7th edition. New York: W H Freeman
5.	Weaver R., (2007) Molecular Biology, 4th Edition, McGrew Hill Science.
6.	Mechanism of subcellular mRNA localization, 2002, CSH, 108:533-44.
7.	Micro RNAs in cell proliferation, Cell death and tumorigenesis, B.J. of Cancer, 2006, 94.
8.	Taft et.al., Recent progress in structure, biology and tRNA processing and modification. Mol Cell., 19(2), 2005, 157-66
9.	W.S. Klug and M.R. Cummings, Concepts of Genetics, (2005) Pearson education

	MIC-453: Principles of Virology **Elective Theory**	
	Number of Credits : 04 **Number of hours: 60**	
Course Outcome (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	List the various emerging, re-emerging viral diseases and their causative agents. State the reasons for their emergence and re-emergence. Name the different methods used for the cultivation and 2detection of viruses.	1
CO2	Illustrate the structure of viruses. Explain the different methods for cultivating viruses.	2
CO3	Illustrate the different methods of replication of DNA and RNA viruses. Calculate the titre of viruses using the various methods of detection of viruses.	3
CO4	Compare the different aspects of the life-cycles of different viruses and classify them according to Baltimore's and ICTV methods of classification.	4
CO5	Summarize the mode of actions of different anti- viral agents. Compare the different types of viral vaccines.	5
CO6	Compile the various diagnostic methods for viral infections. Prepare models based on the structure of different viruses. Design posters to explain the life cycles of different viruses and steps in the replication of different viruses.	6

MIC-453: Principles of Virology
(Elective Theory)
Course Contents

Unit No.	Title .of Unit and Contents	No. of lectures
1	**General Virology:** **A. Structure of viruses** i. Enveloped and Non-enveloped viruses ii. Capsid symmetries: Icosahedral and Helical iii. Structural components of virus: Protein - Envelope proteins, Matrix proteins and Lipoproteins, Genome – dsDNA, ssDNA, dsRNA, ssRNA (positive sense, negative sense and ambisense), linear, circular, segmented iv. Virus related structures: Viroids and Prions **B. Unique features of viral:** w.r.t genome and its organization, size, shape, growth and multiplication **C. Classification & nomenclature of viruses** i. ICTV nomenclature ii. Baltimore classification	**15**

2	**Replication of viruses:** **A.** Mechanism of virus adsorption and entry into host cell **B.** Genome replication **C.** Reverse transcription and Integration **D.** Post transcriptional processing **E.** Synthesis of viral proteins: polyprotein and proteolytic cleavage **F.** Protein nucleic acid interactions and genome packaging Assembly, exit and maturation of progeny virions	**15**
3	**Principles of Practical Virology:** **A.** Cultivation of viruses: i. In ovo: using embryonated chicken eggs ii. In vivo: using experimental animals iii. Ex vivo / In vitro: using various cell cultures – primary, secondary cell lines, continuous cell lines and suspension cell cultures B. Diagnostic and detection methods: i. Direct methods of detection: Light microscopy (inclusion bodies), Electron microscopy and Fluorescence microscopy ii. Immuno-diagnosis: Hemagglutination and Hemagglutination inhibition tests, Complement fixation, Neutralization, Western blot, Radioactive Immuno -Precipitation Assay (RIPA), Flow Cytometry and Immunohistochemistry iii. Nucleic acid based diagnosis: Nucleic acid hybridization, Polymerase Chain Reaction (PCR), Microarray and Nucleotide sequencing, LINE probe assay iv. Infectivity assay for animal and bacterial viruses: Plaque method, Pock counting, End point methods - LD50, ID50, EID50, TCID50 v. Infectivity assays of plant viruses	**15**
4	**Control of viral diseases:** A. Life cycle of representative viruses i. Baculovirus: Autographa californica Nuclear polyhedrosis virus ii. Bacteriophage: T4 phage B. Emerging and re-emerging viruses i. Causes of emergence or re-emergence of viruses ii.Life- cycles and epidemiology of emerging and re-emerging viruses such as Zika Virus, Nipah virus and SARS-CoV2 virus iii. Prevention measures for emergence and re-emergence of viruses C. Antiviral chemotherapy and viral vaccines i. Role of interferons in viral infections ii. Anti-virals: Nucleoside inhibitors, Reverse transcriptase inhibitors, Protease inhibitors iii. History of viral vaccines iv. Viral Vaccines: Live attenuated vaccines, inactivated vaccines, sub- unit vaccines, Anti-idiotype vaccines, DNA vaccines	**15**

Learning Resources- References

Sr. No.	References
1.	Flint S. J., V. R. Racaniello, L. W. Enquist, V. R.Rancaniello, A. M. Skalka, (2015).
2.	Edward K. Wagner, Martinez J. Hewlett, (2004), Basic Virology, Blackwell Publishing
3.	Baltimore D. (1971), Expression of Animal Virus Genomes, Microbiology and molecular Biology Reviews, 35(3), 235 – 241.
4.	Knipe David M., Peter M. Howley, Diane E. Griffin, Robert A. Lamb, Malcolm A. Martin, Bernard Roizman, Stephen E. Straus, (2007), Field's Virology, 5th Ed. Lippincott Williams & Wilkins
5.	Hull R (2002) Matthew's Plant Virology, 4th edition. Academic Press.
6.	Gibbs Adrian & Bryan Harrison, Plant Virology -The Principles. Edward Arnold Press.
7.	http://ictvonline.org/codeOfVirusClassification_2012.asp
8.	Dimmock N. J. et al. (2007). Introduction to modern virology 6th edition. Blackwell Publishing.
9.	Mahy B. WJ. And Kangro H.O., (1996), Virology Methods Manual, Academic Press.
10.	Bartlett Publishers. Hull R (2002) Matthew's Plant Virology, 4th edition. Academic Press.

	MIC-454: Advances in Bionanosciences Elective Theory	
	Number of Credits : 04 **Number of hours: 60**	
Course Outcome (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe the use of food Nano biomaterials and biocompatibility	1
CO2	Articulate theoretical aspects of surface physics, biomaterials, and methods of the interaction with surfaces and fibres of biomolecules.	2
CO3	Write the processes for production of various types of nanostructured materials.	3
CO4	Explain applications of nanomaterials in bio separation, diagnostics, drug delivery and bio implants.	4
CO5	Select the technique for applications within bio separation, diagnostics, drug delivery and bio implants.	5
CO6	Design a membrane model by utilization of lipid/polymer nanoparticles for formulation/ administration of drugs.	6

MIC-454: Advances in Bionanosciences
Elective Theory
Course Contents

Unit No.	Title of Unit and Contents	No. of lectures
1	**A.** Nano biomaterials and biocompatibility, structural & functional principles of bio nanotechnology, protein and DNA based nanostructures and Nano bio-analytics **B.** Nanotechnology in food, medicine and health science	**15**
2	**A.** Examples and production of various types of nanostructured materials [Carbon Nanotubes (CNT), Fullerenes (C60, C300) Nano Peapods, Quantum Dots and Semiconductor. **B.** Nanoparticles Metal-based Nanostructures (Iron Oxide Nanoparticles), Nanowires Polymer-based Nanostructures (Dendrimers), Nano rods, Nano cages, Nano shells with usage and potential within biotechnology. Using biomaterials and biomolecules as bases for inorganic structures.	**15**
3	**A.** Introduction to surface physics and biomaterials. Methods for derivatisation and characterisation of surfaces and other carrying structures. **B.** Theory and methods for studies of the interaction with surfaces and fibres of biomolecules. Applications within bio separation, diagnostics, the drug delivery and bio implants.	**15**
4	**A.** Theory for how lipid/polymer nanoparticles can be utilised as model membranes and for formulation/administration of drugs. Molecular prints of biomolecules. **B.** Production and applications of inorganic replicas of biological materials. Enzyme reactors based on nanostructured materials.	**15**

Learning Resources

Sr. No.	References
1.	Nanobiotechnology: Concepts, Applications and Perspectives (2004), Christof M. Niemeyer (Editor), ChadA. Mirkin (Editor), Wiley VCH.
2.	Nanobiotechnology - II more concepts and applications. (2007) - Chad A Mirkin and Christof M. Niemeyer (Eds), Wiley VCH.
3.	Nanotechnology in Biology and Medicine: Methods,Devices, and Applications.
4.	Nanobiotechnology, Edited by C. Niemeyer, C. Mirkin, Wiley-VCH (2007). ISBN: 978-3-527-30658-9
5.	Introduction to Protein Structure, 2nd ed. Carl Branden & John Tooze (1999) Garland Publishing, Inc., New York.

	MIC-461: Microbiology Practical-13 Major Practical	
	Number of Credits: 02 **Number of Hours: 60**	
Course Outcome (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Identify the microorganisms, which can degrade complex polysaccharides like cellulose and chitin.	1
CO2	Determine the transformation of bacterial cells with recombinant DNA	2
CO3	Examine the ability of rhizosphere flora to exhibit PGP traits.	3
CO4	Analyze different methods of isolation of anaerobic bacteria.	4
CO5	Measure the quantity of extracted plasmid DNA using analytical techniques.	5
CO6	Design an experiment for induction of lactose operon and determine the activity of β- galactosidase	6

MIC-461: Microbiology Practical-13
Major Practical
Course Contents

Unit No.	Title of Unit and Contents	No. of hours
1	**Microbial metabolism** **A.** Different methods of isolation and cultivation of anaerobic bacteria **B.** Isolation and characterization of (as nitrogen fixers) **C.** Isolation and characterization of phosphate solublizing bacteria **D.** Isolation and characterization of chitin degrading bacteria **E.** Isolation and characterization of cellulose degrading bacteria	**30**
2	**Molecular biology** **A.** Extraction and purification of Plasmid DNA **B.** Competence development in non-competent bacterial culture **C.** Transformation of bacteria **D.** Induction of lac operon **E.** Determination of beta-galactosidase activity	**30**

Learning Resources- References

Sr. No.	References
1.	K. Wilson and J. Walker, 'Principles and techniques of biochemistry and Molecular Biology', (2005), 7th Edition, Cambridge university Press
2.	Sambrook and Russel, 'Molecular cloning: A laboratory manual', Volume 1, 2 and 3 (2001), 3rd Edition, Cold spring harbor laboratory press, New York
3.	Scott Witherow, H. Miller and Sue Carson, 'Molecular biology Techniques: A classroom laboratory manual', 3rd edition, Elsevier

4.	Reetha S. et al., (2014) Isolation of indole acetic acid (IAA) producing rhizobacteria of Pseudomonas fluorescens and Bacillus subtilis and enhance growth of onion (Allim cepa.L) Int.J.Curr.Microbiol.App.Sci, 3(2): 568-574
5.	Louden et al.(2011) Use of Blue Agar CAS Assay for Siderophore Detection, J Microbiol Biol Educ. 12(1): 51–53.
6.	William J. Martin (1971) Practical Method for Isolation of Anaerobic Bacteria in the Clinical Laboratory. Appl Microbiol. 22(6): 1168–1171.
7.	Zhu R. et al. (2011) Isolation and Characterization of a Phosphate-Solubilizing Halophilic Bacterium Kushneria sp. YCWA18 from Daqiao Saltern on the Coast of Yellow Sea of China. Hindawi.
8.	Saima M. et al. (2013) Isolation of novel chitinolytic bacteria and production optimization of extracellular chitinase. Journal of Genetic Engineering and Biotechnology. 11(1) 39-46
9.	Sethi S. et al. (2013) Optimization of Cellulase Production from Bacteria Isolated from Soil. International Scholarly Research Notices

	MIC-462: Microbiology Practical-14 Major Practical	
	Number of Credits : 02 **Number of hours: 60**	
Course Outcome (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe the different parts of an embryonated hen's egg.	1
CO2	Estimate the titre of viruses by performing hemagglutination tests	2
CO3	Produce nanoparticles using biological sources. Use the various routes for inoculation of viruses in embryonated eggs.	3
CO4	Analyze the nanoparticles using different biophysical techniques	4
CO5	Measure the titre of viruses using plaque assays	5
CO6	Plan an experiment to understand the phage infectivity in bacteria.	6

MIC-462: Microbiology Practical-14
Major Practical
Course Contents

Unit No.	Title of Unit and Contents	No. of hours
1	**Virology (Animal, Bacterial and Plant Viruses)** A. Egg inoculation technique for virus cultivation by various routes- embryo, yolksac, allantoic fluid, amniotic cavity, chorioallontoic membrane B. Animal virus titration by Hemagglutination test C. Qualitative and quantitative detection of bacteriophage D. One step growth curve of bacteriophage E. Chloroplast agglutination test	**30**
2	**Bionanotechnology** A. Bacterial synthesis of metal nanoparticles B. Fungal synthesis of metal nanoparticles C. Characterization of nanoparticles using UV- visible spectroscopy D. Determination of anti-microbial activity of nanoparticles E. Partial purification of nanoparticles	**30**

Learning Resources

Sr. No.	References
1.	Practical Plant Virology- Protocols and Exercises (1998). Jeanne Dijkstra and Cees P. De Jager. Springer.
2.	Bacteriophages: methods and protocols Volume 4 (2018). Martha Clokie et al. Springer.
3.	Nanotechnology in Biology and medicine: methods, devices and applications. 1st edition (2007). Tuan Vo-Dinh. CRC Press.