# Department of Microbiology

# Program: Masters in Microbiology

**Program Specific Outcome (PSO)**

1. Understands and is able to explain different branches of Microbiology such as Bacteriology, Virology, and Eukaryotic microbes
2. Understands and is able to explain about various application of Microbiology such as Environmental Microbiology, Industrial Microbiology and Food Microbiology
3. Is able to design and execute experiments related to Basic Microbiology, Molecular Biology, Recombinant DNA Technology, and Microbial Genetics
4. Is able to execute a short Research project incorporating techniques of Basic and Advanced Microbiology under supervision.

**Course Outcome (CO)**

**CO of course "DIVERSITY OF PROKARYOTIC AND EUKARYOTIC MICROBES"**

1. Describe the systematics and occurrence of Archaea.
2. Be able to differentiate between the various groups of Archaea (Crenarchaeota, Euarchaeota, Korarchaeota, Nanoarchaeota) based on their biochemical features
3. Gain an understanding of the significance of Archaea.
4. Get acquainted with biochips, methane generation, ultrafiltration membranes, production of PHB and PHA, desulphurization ofcoal and crude oil, bioleaching of metals, enzymes, compatible solutes and other potential applications of Archaea.
5. Understand conventional and molecular systematics of bacteria.
6. Know the occurrence, diversity and characteristic features of true bacteria.
7. Get familiar with the significance and potential applications of various groups of bacteria according to the Bergey's Manual of Systematic Bacteriology.
8. Describe cultivation-independent methods for studying the composition of microbial communities and for the function and occurrence of individual groups.
9. Designate genomic-based methods to study microbial diversity in nature.
10. Use bioinformatic tools and databases that are used to study microbial diversity.
11. Understand the implications of molecular and biochemical methods including rDNAanalysis, RFLP, RAPD and other fingerprinting techniques, fatty acids, polysaccharides and lipids and the role ofsecondary metabolites in systematics.
12. Become aware of fungal endophytes of tropical plants.
13. Gain knowledge about the colonization and adaptation techniques of endophytes.

14. Get insights into the role of endophytes as latent pathogens and biocontrol agents.
15. Appreciate mycorrhizal fungi
16. Describe the diversity of endo- and ecto-mycorrhizal fungi.
17. Learn detailed biology of arbuscular mycorrhizal fungi.
18. Know the signaling, penetration and colonization of mycorrhiza inside roots and their culturing.
19. Absorb the recent advances in the field ofmycorrhiza.
20. Recognise the agricultural importance of toxigenic fungi.
21. Understand the biodiversity and characterization of toxigenic fungi.
22. Be able to characterize toxic metabolites chemically and biologically.
23. Gain knowledge about the role of toxigenic fungi in sustainable agriculture with special emphasis on biopesticides.
24. Get acquainted with the industrial value secondary metabolites from fungi.
25. Learn about the synthesis of terpenes, non-ribosomal peptides, hydrophobins, peptaibols and indole alkaloids with detailed emphasis on polyketides.
26. Understand the Biodiversity of yeasts.
27. Gain basic knowledge of genetics of yeasts especially gene duplication.
28. Know the central metabolism and basic physiology of yeasts.
29. Become aware of adaptation that eventually leads to functionalevolution in yeasts.
30. Have know-how about aerobiosis/anaerobiosis and changes in regulatory circuits in yeasts that are crucial during adaptation to new environments.
31. Describe the antagonistic interactions in yeasts: mycocinogeny, diversity of mycogenic yeast strains and the genetic basis of mycocinogeny.
32. Know the characteristics ofmycocins and their mode of action.
33. Be able to exploit antagonisticyeasts for agricultural purposes.
34. Develop an understanding of biotechnological applications of yeasts such as production of bioactive molecules including pigments, lipids, organic acids and EPS.
35. Apply yeasts as probiotics.
36. Make use of yeasts in bioremediation.
37. Learn the process of making various alcoholic beverages with different types of yeasts.
38. Acquire knowledge about algal diversity, their morphology and molecular structure.
39. Realise the market importance of algal pigments and learn algae farming for their production.
40. Gain acquaintance with algal biofuels including algal oil, biodiesel and hydrogen production.
41. Be educated about important bioactive molecules of algae.
42. Be able to apply algae for a sustainable environment.

**CO of course "MICROBIAL PHYSIOLOGY AND METABOLISM"**

1. Measure microbial growth by various direct and indirect methods.
2. Understand growth physiology and cell division in prokaryotes.
3. Calculate growth yields and growth rates.
4. Gain knowledge about growth kinetics, steady state growth and continuous growth.
5. Get acquainted with primary and secondary solute transport.
6. Learn about ABC transporters and their applications in drug designing etc
7. Understand the phosphotransferase system for carbohydrate transport in bacteria
8. Get basic knowledge of non-PTS sugars and amino acid transport.
9. Develop an understanding of the central metabolic pathways
10. Understand the regulation of glycolysis, PPP and gluconeogenisis
11. Learn various types of ED pathways in bacteria
12. Be well versed withbranched TCA, reverse TCA and glyoxylate cycle.
13. Metabolic engineering of carbohydrate pathway for succinic acid over production and co-utilisation of pentose and hexose sugars
14. Have knowledge about lactose utilisation pathways
15. Know how complex polysaccharides and sugars other than glucose are utilised by microbes.
16. Understand amino acid metabolism.
17. Have know-how about amino acid biosynthesis and utilisation.
18. Be able to describe pathway modifications leading to lysine overproduction
19. Have a historical prospective and current metabolic engineering strategies for glutamine overproduction.
20. Know biosynthesis and regulation of polyamines.
21. Recognise lipid composition of various microorganisms.
22. Get familiar with the biosynthesis and degradation of lipids.
23. Understand lipid accumulation in yeasts.
24. Gain knowledge about the synthesis and degradation of hydrocarbons such as PHAs and PHBs.
25. Have a deep understanding of nucleotidebiosynthesis and regulation of synthesis of purines and pyrimidines.
26. Students will be able to recognise the inhibitors of nucleotide synthesis.
27. Learn the various physiological adaptations in bacteriain response to extreme conditions.
28. Be acquainted with the intercellular signalling in prokaryotes.
29. Be aware of the two-component system in microorganisms and learn how to utilise the signal transduction pathways for specific purposes such as inhibition of biofilm formation.
30. Gain insights into the regulatory systemsduring aerobic- anaerobic shifts
31. Have a grasp of the Arc, Fnr, Nar andFhlA regulons.

32. Understand microbial response towards alteration in phosphate supply along with functioning of the Pho regulon.
33. Students will familiarize themselves with bacterial quorum sensing.
34. They would have learnt the working of A and C signaling system.
35. Gain insights into thesignalling and physiological changes during sporulation in *Bacillus subtilis.*
36. Get knowledge about the control of competence in bacteria with emphasis towards *Bacillussubtilis*.
37. Understand various heat-shock responses in different bacterial species
38. Get introduced to the concept of homeostasis and learn how bacteria maintain internal pH and osmotic balance.

**CO of course "VIROLOGY"**

1. Student is able to describe the steps in virus infection cycle
2. Student is able to describe the principle of virus classification
3. Student is able to list the virus families
4. Student is able to describe the general properties of viruses
5. Student is able to describe methods of studying virus structure
6. Student is able to describe details of virus structure and concept of triangulation number
7. Student is able to describe the basis of virus attachment and entry in host cells
8. Student is able todescribe replication strategies used by DNA viruses
9. Student is able to describe replication strategies used by RNA viruses
10. Student is able to describe replication strategies used by retroviruses
11. Student is able to describe RNA directed RNA synthesis in RNA viruses
12. Student is able to describe translation strategies adopted by RNA viruses
13. Student is able to describe transcription and RNA processing in DNA viruses
14. Student is able to describe virus assembly reactions
15. Student is able to describe basics of virus infection in host
16. Student is able to describe host defense against virus infection
17. Student is able to explain viroids and basis of their pathogenesis
18. Student is able to describe prions and various transmissible encephalopathies caused by them
19. Student is able to describe satellite viruses and their replication strategies
20. Student is able to describe general characteristics of acute viral infections
21. Student is able to describe pathogenesis of Influenza virus
22. Student is able to describe pathogenesis of Polio virus
23. Student is able to describe pathogenesis of Measles virus
24. Student is able to describe pathogenesis of Rotavirus infection
25. Student is able to describegeneral characteristics of chronic, persistent, latent infections
26. Student is able to describe pathogenesis of Herpesviruses infection
27. Student is able to describe pathogenesis of Papillomavirus infections

28. Student is able to describe pathogenesis of Epstein Barr Virus infection
29. Student is able to describe howlive viral vaccine are made
30. Student is able to describe how inactivated viral vaccine are made
31. Student is able to describe how recombinant viral vaccine are made
32. Student is able to describe antiviral drug discovery process
33. Student is able to describe mechanism of action of antiviral drugs
34. Student is able to describe concepts in virus evolution
35. Student is able to describe concept of virus quasispecies
36. Student is able to describe basis of emergence of novel virus
37. Student is able to describe transformation of infected cells by DNA viruses
38. Student is able to describe transformation of infected cells by RNA viruses
39. Student is able to describe virus mediated tumorigenesis and oncogenesis
40. Student is able to describe classification of plant viruses
41. Student is able to describe propagation, purification, characterization and identification of plant viruses
42. Student is able to describe symptoms of plant viral diseases
43. Student is able to describe transmission of plant viral diseases
44. Student is able to describe diversity, classification and characteristics of bacteriophages
45. Student is able to explain general concept of algal, fungal and protozoan viruses

**CO of course "IMMUNOLOGY"**

1. Student is able to describe the fundamental concept in immunology
2. Student is able to describe the concept of specificity in immunology
3. Student is able to describe the concept of discrimination of self from non-self in host
4. Student is able to describe the concept of immunological memory
5. Student is able to describe detailed structure of B cells receptors
6. Student is able to describe detailed structure of T cell receptors
7. Student is able to describe structure of CD4 and CD8 molecules
8. Student is able to describe structure of MHC-I and MHC-II molecules
9. Student is able to describe pattern recognition receptors
10. Student is able to describe toll like receptors
11. Student is able to describe markers of suppressor and regulatory cells
12. Student is able to describe markers of CD4+, CD25+, Foxp3+, Treg, iNKT cells
13. Student is able to describe genetic organization of genes for B cell receptors
14. Student is able to describe genetic organization of genes for T cell receptors
15. Student is able to describe genetic organization of genes for MHC-I and MHC-II complex
16. Student is able to describe molecular mechanisms responsible for generating diversity of antibodies
17. Student is able to describe molecular mechanisms responsible for generating diversity of T cell receptors
18. Student is able to describe peptide loading and expression of MHC-I and MHC-II molecules

19. Student is able to describehybridoma technology and monoclonal antibodies
20. Student is able to describe antibody engineering
21. Student is able to describe immune response and signaling
22. Student is able to describe humoral immune response
23. Student is able to describe cell mediated immune response
24. Student is able to describe innate immune response and pattern recognition
25. Student is able to describe recent advances in innate immune response
26. Student is able to describe NK-DC interactions
27. Student is able to describe major cytokines and their role in immune mechanisms
28. Student is able to describe role of TNF-IFN, IL-1, IL-2 in immune mechanisms
29. Student is able to describe role of IL-4, IL-6, IL-10, IL-12, IL-17 and TGFb in immune mechanisms
30. Student is able to describe cell signaling through MAP kinases and NF-kB
31. Student is able to describe tolerance and autoimmunity
32. Student is able to describe central and peripheral tolerance and their mechanisms
33. Student is able to describe mechanisms of autoimmunity
34. Student is able to describe autoimmune components of diabetes mellitus
35. Student is able to describe autoimmune component of multiple sclerosis, experimental autoimmune encephalitis
36. Student is able to describe infections leading to autoimmune disease
37. Student is able to describe immunological disorders and hypersensitivity
38. Student is able to describe deficiencies and defects of T cells and B cells
39. Student is able to describedeficiencies and defects of complement and phagocytic cells
40. Student is able to describe comparative study of Type IV hypersensitivities with examples
41. Student is able to describe transplantation and tumor immunology
42. Student is able to describealloreactive response
43. Student is able to describe graft rejection and GVHD, HLA matching
44. Student is able to describe transgenic animals for xenotransplantation
45. Student is able to describetumor antigens, immune response to tumors and immunotherapy of tumors

**CO of course "ENVIRONMENTAL MICROBIOLOGY"**

1) Understand the chronological history and development of environmental microbiology.
2) Be acquainted with significant contributions of microbiologists.
3) Get insights into the emergence of environmental microbiology.
4) Be able to apply culture-dependent and culture-independent approaches for understanding microbial diversity in the environment.
5) Learn various molecular techniques for studying microbial diversity such as DNA heterogeneity by reannealing denatured environmental DNA, ARDRA, analysis of FAME profiles, measuring metabolic capabilities using BIOLOG microtiter plates, using DNA

probes and PCR primers, G+C analysis, slot-blot hybridization of community DNA, and fluorescent in situ hybridization of intact cells.

6) Be aware of the microbial diversity in normal environments.
7) Recognise the diversity of microbes in terrestrial environments ranging from agricultural to desert soils.
8) Get a grasp over diversity of aquatic microbes present in fresh water and marine environments.
9) Gain awareness about the microbial composition of the atmosphere (stratosphere).
10) Attain knowledge about animal microbiome (cattle, termites, pests such as cockroach and nematodes) with special attention towards human microbiota.
11) Learn the potential applications and implications of animal microflora.
12) Acquire know-how of microbial diversity in extreme environments.
13) Know about the occurrence, diversity, adaptations and potential applications of oligotrophs and barophiles.
14) Get knowledge about the diversity, manifestation and applicability of thermophiles and psychrophiles.
15) Get insights into occurrence and adaptations in acidophiles, alkaliphiles and halophiles.
16) Gain a basic understanding of metallophiles, organic solvent and radiation tolerants.
17) Understand the sources and variety of gases which contribute to global warming.
18) Get introduced to the obvious as well as hidden effects of global warming and remedial measures involving microbes.
19) Students will have learnt aboutlignin degradation by microbes.
20) Attain a basic understanding of lignocellulolytic enzymes- their types and microbial sources.
21) Know the enzymes and enzyme mediated processes used in bio-pulping of paper, bio-bleaching and bio-stoning of textiles at an industrial level.
22) Learnt about microbial production of bio-alcohols being used as fuels
23) Gain knowledge of animal feed production using microorganisms.
24) Be more aware about the problem of liquid waste management in a global and Indian context.
25) Understand how sewage can be treated by employing microbes at a Primary and Secondary level.
26) Learn about various tertiary water treatment methods.
27) Be able to distinguish between potable and non-potable water.
28) Students will know how to test for coliforms, enterobacteria and pathogens in drinking water
29) Be able to counttotal bacterial population present in drinking water sources.
30) Gain in-depth knowledge about treatment of Industrial effluents from distilleries
31) Know about treatment of effluents from textile factories, pulp and paper industries using xenobiotic degrading microbes
32) Get aware about the problem ofsolid waste management in our country’s context.

33) Be able to differentiate waste types & their possible usages with respect to reduction and recycling of wastes.
34) Get acquainted with landfill development and composting
35) Learn about the succession of microbial communities during composting
36) Be familiarised with bioremediation of environmental pollutants such aspetroleum hydrocarbons
37) Be familiar with role of microbes in pesticides remediation.
38) Know the use of microbes in mineral recovery
39) Acquire the basics of bioleaching of copper, gold and uranium. And how these processes are running successfully in various parts of the world.
40) Learn how microbes can be applied to solve environmental pollution problems

**CO of course "PLANT PATHOGEN INTERACTION"**

1. Student is able to understand the concept of plant diseases and plant pathogens
2. Student is able to differentiate between the terms pathogen and pathogenesis with respect to plant diseases
3. Student is able to understand the role of the environment in pathogenesis
4. Student is able to explain terms like disease triangle and disease tetrahedron
5. Student is able to understand and describe the effect of microbial infections on plant physiology
6. Student is able to understand and describe the effect of microbial infections on photosynthesis carried out by plants
7. Student is able to understand and describe the effect of microbial infections on plant respiration
8. Student is able to understand and describe the effect of microbial infections on transpiration
9. Student is able to understand and describe the effect of microbial infections on translocation
10. Student is able to establish and describe the role of enzymes like cutinases, pectinases and cellulases (hydrolytic enzymes) in pathogenesis and establishment of plant diseases
11. Student is able to establish and describe the role of microbial toxins in pathogenesis
12. Students can differentiate between different types of microbial toxins such as non-host specific or non-host selective toxins and host specific or host-selective toxins
13. Studentsis able to analyze the relevance of phytoalexins in disease management
14. Student is able to critically explain the etiological studies and symptoms of crown gall and its causative agent *Agrobacterium tumefaciens*
15. Studentscan write about the histopathological and cytopathological changes occurring in the plant due to disease establishment
16. Students are able to understand the symptoms of viral diseases
17. Students can describe the etiology of the viral causative agents

18. Students can enlist various features of tobacco mosaic virus, tomato ringspot virus, tobacco leaf curl virus etc.
19. Student is able to describe the genetics of host-pathogen interactions during disease establishment
20. Student is able to analyze the role of resistance genes and resistance mechanisms as part of plant defense mechanisms
21. Students are able to understand the principles of plant disease control
22. Student is able to describe the different physical methods of plant disease control
23. Student is able to describe the different chemical methods of plant disease control
24. Student is able to describe the different biological methods of plant disease control
25. Students are able to understand and define the concepts and practices of biocontrol agents
26. Students are able to describethe use of fungi as biocontrol agents (mycoparasitism) with focus on *Trichoderma*
27. Student can describe various commercial preparation of biocontrol agents
28. Students are able to differentiate between direct, indirect and mixed-path antagonism
29. Students can write about resident vs introduced antagonists
30. Students are able to understand the different methods of applying such antagonists as part of disease management
31. Students can write about the uses and practical constraints of biocontrol agents
32. Students are able to understand the different molecular diagnostic techniques for identification of plant pathogens e.g. LAMP PCR
33. Students can analyze the use of transgenic approaches for plant disease management and control
34. Students are able to write about the applications, constraints of various molecular diagnostic techniques
35. Students can understand various future prospects in molecular diagnosis of plant pathogens
36. Students are able to assess the relationship between disease control and disease forecasting
37. Students are able to critically analyze the relevance of disease forecasting especially in the Indian scenario
38. Students can enlist various computer based forecasting programmes
39. Students are able to cut cross-sections/ transverse sections of diseased portions of stem, root or leaf and stain them to observe the pathogen morphology under the microscope
40. Students are able to examine the external symptoms of different plant diseases by the naked eye e.g. Wilts, soft rots, canker etc.
41. Students are able to identify the morphological changes occurring due to different bacterial and viral plant pathogens
42. Students can identify the structural and microscopic features of different pathogenic fungi like *Candida, Aspergillus* and *Microsporum*sp.
43. Students are able to isolate and further identify soil borne plant pathogens by PCR based techniques for their classification

44. Students can quantify the level of soil borne pathogens by MPN and dilution end point methods
45. Students can carry out biochemical and physiological tests for detection of pathogens in fruits and vegetables

**CO of course "MICROBIAL PATHOGENISITY"**

1. Student is able to describe classical view of microbial pathogenicity
2. Student is able to define pathogenicity and virulence
3. Student is able to describe quantitative measures of virulence
4. Student is able to describe concept of minimum lethal dose, LD50, ID50, and TCID50
5. Student is able to describe virulence determinants – colonization, toxins, enzymes and invasiveness
6. Student is able to describe facultative or obligate intracellular pathogens
7. Student is able to describe molecular Koch's postulates
8. Student is able to describe multiplicity of virulence factors and coordinated regulation of virulence genes
9. Student is able to describe two component signal transduction systems and environmental regulation of virulence determinants
10. Student is able to describeclonal and panmictic nature of microbial pathogens,
11. Student is able to describetype 1-IV secretion systems, biofilms and quorum sensing.
12. Student is able to describe emerging and re-emerging pathogens
13. Student is able to describe concept of emerging and re-emerging pathogens using examples of *V.Cholerae, M.tuberculosis*, *H.pylori*, Enterohaemorrhagic*E.coli*
14. Student is able to describe basis of microbial pathogenicity inSARS virus, Bird flu, prions, AIDS, Dengue Hemorrhagic Fever
15. Student is able to describe basis of microbial pathogenicity in Lyme disease, *Cruyptosporadiumparvum, Chlamydiae* and opportunistic fungal infections.
16. Student is able to describe mechanism of emergence of new pathogens
17. Student is able to describe microbial change and adaption
18. Student is able to describe horizontal gene transfer, pathogenicity islands, and role of integrons
19. Student is able to describe objectives of microbial epidemiology
20. Student is able to describe biochemical and immunological tools
21. Student is able to describebiotyping, serotyping, phage typing
22. Student is able to describe FAME, Curie Point, pyMS, protein profiling
23. Student is able to describemultilocus enzyme electrophoresis, molecular typing
24. Student is able to describe RAPD, 16S-23S IGS, ARDRA
25. Student is able to describe different types of PCR, PFGE, AFLP
26. Student is able to describe concepts of MVLST, VNTR, SNP
27. Student is able to describe microarray and whole genome sequencing tools
28. Student is able to describe role of environmental change on infectious disease
29. Student is able to describe global warming lead increase in vector borne infectious disease

30. Student is able to describe impact of increasing urbanization and international travel and trade on infectious disease
31. Student is able to describe concepts in antimicrobial resistance
32. Student is able to describe multidrug efflux pumps
33. Student is able to describe extended spectrum b-lactamases
34. Student is able to describe X-MDR *M.tuberculosis*, Methcillin resistant *S.aureus*(MRSA)
35. Student is able to describe newer vaccines
36. Student is able to describe recombinant vaccines
37. Student is able to describe subunit vaccines, DNA vaccines
38. Student is able to describe Vaccinia, BCG and HIV- vector based vaccines
39. Student is able to describe principles of rapid diagnostic
40. Student is able to describe nucleic acid probes in diagnostic microbiology
41. Student is able to describe nucleic acid amplification methods
42. Student is able to describe real-time PCR
43. Student is able to describe diagnostic sequencing and mutation detection
44. Student is able to describe molecular typing methods
45. Student is able to describe array technology

**CO of course "MOLECULAR BIOLOGY"**

1. Student is able to describe the molecular structure of DNA
2. Student is able to describe the molecular structure of RNA
3. Student is able to describe the organization of microbial genomes
4. Student is able to describe the organization of eukaryotic genomes
5. Student is able to describe chromatin arrangement and nucleosome formation
6. Student is able to describe arrangement of replicons in genome
7. Student is able to describe various modes of DNA replication
8. Student is able to describe various replication enzymes
9. Student is able to describe replication fork and priming
10. Student is able to describe initiation of DNA replication, elongation and termination
11. Student is able to describe basis of DNA copy number maintenance
12. Student is able to describe DNA mismatch repair
13. Student is able to describe double stranded break repair in DNA
14. Student is able to describe transcription machinery of prokaryotes
15. Student is able to describe various transcription enzymes and cofactors in prokaryotes
16. Student is able to describe initiation reaction of transcription in prokaryotes
17. Student is able to describe elongation in transcription in prokaryotes
18. Student is able to describe termination reaction in transcription in prokaryotes
19. Student is able to describe transcription machinery in eukaryotes
20. Student is able to describe various forms of RNA polymerase and cofactors in eukaryotes
21. Student is able to describe initiation reaction of transcription in eukaryotes
22. Student is able to describe elongation in transcription in eukaryotes
23. Student is able to describe termination reaction in transcription in eukaryotes

24. Student is able to describe promoters, enhancers and silencers in eukaryotes transcription
25. Student is able to describe effect of chromatin structure in eukaryotic transcription
26. Student is able to describe regulation of eukaryotic transcription
27. Student is able to describe regulation of prokaryotic transcription
28. Student is able to describe regulation of lac operon
29. Student is able to describe regulation of trp operon
30. Student is able to describe the genetic code and protein structure
31. Student is able to describe mechanism of translation in prokaryotes
32. Student is able to describe mechanism of translation in eukaryotes
33. Student is able to describe formation of initiation complex in translation
34. Student is able to describe ribosome assembly in translation
35. Student is able to describe elongation process in translation
36. Student is able to describe termination of translation
37. Student is able to describe in vitro translation systems
38. Student is able to describepolycistronic and monocistronic synthesis
39. Student is able to describe regulation of translation
40. Student is able to describe basis of RNA stability
41. Student is able to describe inhibitors of translation
42. Student is able to describe post-translational processes
43. Student is able to describe protein modifications
44. Student is able to describe protein folding and chaperons
45. Student is able to describe signal hypothesis

**CO of course "RECOMBINANT DNA TECHNOLOGY"**

1. Student is able to list and describe various enzymes used in cloning DNA
2. Student is able to analyze the importance of cloning aids like linkers and adaptors
3. Student is able to describe and explain the use of various cloning vectors
4. Student is able to analyze DNA by gel electrophoresis
5. Student is able to design a cloning experiment
6. Student is able to execute the isolation and cloning of DNA fragments and plasmids
7. Student is able to analyze restriction fragment length polymorphism patterns
8. Student is able to explain the applications of restriction fragment length polymorphism patterns, such as DNA fingerprinting, disease diagnosis
9. Student is able to differentiate between Southern, Northern and Western blotting techniques
10. Student can compare and contrast the applications of Southern, Northern and Western blotting techniques
11. Student is able to design primers for PCR
12. Student is able to design and execute experiments to amplify genes
13. Student can execute the mutagenesis of genes by overlap PCR
14. Student is able to fingerprint micro-organisms using RAPD
15. Student can describe the identification of SNPs by ligation chain reaction

16. Student is able to analyze multi-gene expression by multiplex PCRs
17. Student learns the use of RACE techniques
18. Student can plan the construction of genomic and cDNA libraries
19. Student is able to discuss screening methods for libraries
20. Student is able to analyze gene expression using real time PCR
21. Student is able to describe in detail how genomes are sequenced
22. Student is able to compare and critique the different next generation sequencing methods
23. Student is able to analyze global gene expression using DNA microarray technology
24. Student can describe the utility of DNA microarrays in comparative genome sequencing
25. Student is able to plan the genome-wide identification of DNA binding sites of proteins using ChIP-on-chip
26. Student is able to design experiments to study protein-DNA interactions
27. Student is able to design experiments to analyze protein-protein interactions
28. Student is able to compare and critique the different methods to analyze protein-protein interactions
29. Student is able to design and execute experiments to map transcription start sites
30. Student is able to summarize the use and applications of reporter genes
31. Student is able to implement the use of green fluorescent protein and its derivatives
32. Student is able to analyze proteins by gel electrophoresis
33. Student is able to analyze proteome differences using two-dimensional gel electrophoresis.
34. Student is able to design an experiment to compare the proteomes of two organisms by mass spectrometry
35. Student is able to construct a plasmid for overexpression and purification of recombinant proteins in different hosts
36. Student can describe the use of baculovirus system for expression of recombinant proteins
37. Student can describe how gene knockouts are constructed
38. Student can write about the importance of transgenic plants
39. Student is able to explain how animals are cloned.
40. Student is able to critique the pros and cons of animal cloning
41. Student is able to discuss the latest technology in therapeutic cloning
42. Student is able to critique the pros and cons of therapeutic cloning
43. Student is able to judge the importance of recombinant DNA technology in creating pharmaceutical products
44. Student is able to write about pharmaceutical products of DNA technology such as insulin, hGH.
45. Student is able to write about DNA vaccines and their importance

**CO of course "MICROBIAL GENETICS"**

1. Student can discuss the importance of mutation analysis
2. Student is able to predict the phenotype of the organism based on the mutations it carries
3. Student is able to discuss the theories of inheritance: directed change versus random
4. Student is able to differentiate between reversion and suppression

5. Student is able to analyze mutations using complementation tests
6. Student is able to analyze mutations using recombination tests
7. Student learns to distinguish between spontaneous and induced mutagenesis
8. Student is able to list the different types of mutations
9. Student is able to design a strategy to create gene replacement in bacteria
10. Student is able to design a strategy to clone genes by complementation
11. Student is able to design a strategy to clone genes by marker rescue
12. Student is able to describe the fertility factor in bacteria
13. Student is able to execute a conjugation experiment between two bacteria
14. Student is able to discuss how plasmid copy number is regulated in different types of plasmids
15. Students is able to differentiate between Hfr strains and strains carrying F plasmid
16. Student is able to construct a genetic map of bacterial genome using conjugation-based method
17. Student is able to compare and critique chromosomal DNA transfer by creation of prime factors and by integrated palsmids
18. Student is able to discuss the use of Ti plasmid in creating transgenic plants
19. Student is able to list the steps in phage infection and multiplication within the host bacterium
20. Student is able to compare and contrast the lytic development cycles of T4 and T7 phage
21. Student can compare and contrast the packaging of filamentous versus icosahedral phage
22. Student is able to construct genetic linkage map using two-factor cross
23. Student is able to construct genetic linkage map using three factor cross
24. Student is able to execute the transformation of bacteria by inducing competence artificially
25. Student is able to discuss the basis of natural competence in gram-positive and gram-negative bacteria
26. Student is able to explain the regulation of competency in sporulating bacteria
27. Student is able to compare and contrast generalized versus specialized transduction
28. Student is able to list the events in the lytic phase of lambda phage life cycle
29. Student is able to list the events in the lysogenic phase of lambda phage life cycle
30. Student is able to discuss at length the regulatory factors and events they control in determining whether lambda phage enters the lytic or lysogenic cycle
31. Student is able to list the outcomes of transposition events
32. Student is able to differentiate between cut-and-paste versus replicative transposition
33. Student can design strategies to mutagenize bacteria using trasnposons
34. Student can explain the use of *loxP*-cre and FLP-*FRT* systems in constructing conditional knockouts
35. Student is able to differentiate between the life-styles of lambda phage and mu phage
36. Student is able to validate the statement that mu phage is a transposon
37. Student is able to design an experiment using mini-mu elements for creating gene fusions in reporter assays
38. Student is able to describe the regulation of the lac operon
39. Student is able to describe the regulation of the trp operon
40. Student is able to describe the regulation of the gal operon

41. Student is able to describe the regulation of the araoperon
42. Student is able to describe the regulation of the tol operon
43. Student is able to determine the phenotypes obtained in case of various mutants of these five operons
44. Student is able to differentiate between positive and negative regulation of gene expression
45. Student is able to differentiate between inducible and repressible systems

**CO of course "INDUSTRIAL AND FOOD MICROBIOLOGY"**

1. Student is able to list and describe various sources for the isolation of industrially relevant microbes.
2. Student is able to list various culture collection banks available.
3. Student is able to define the sterilization process and various techniques used for sterilization.
4. Student is able to list the methods used in strain improvement such as mutagenesis, metabolic engineering and recombinant DNA techniques.
5. Student is able to define that what fermentation is.
6. Student is able to define batch, fed-batch, and continuous mode of fermentation.
7. Student is able to define types of bioreactor such as aerated stirred tank reactor, bubble column and bioreactors for immobilized cells.
8. Student is able to define types of fermentation process i.e. solid state and submerged fermentation.
9. Student is able to list the various parts of a fermenter like impeller (their different types), sparger, baffles, and designing of fermentorvessel.
10. Student is able to calculate the microbial growth rate, yield coefficients, volumetric productivity and volumetric yield.
11. Student is able to define oxygen mass transfer rate, henry's law of gas transfer and oxygen mass transfer coefficient ($K_La$).
12. Student is able to demonstrate how to run a batch and fed-batch fermentation for production of various industrially relevant enzymes and biomolecules.
13. Student is able to list and describe methods for downstream processing of microbial products.
14. Students can define filtration, factors which influence filtration process, and what are its different types.
15. Student is able to define centrifugation, Stoke's law, and different types of centrifuges
16. Student can list methods of cell aggregation and flocculation.
17. Student is able to define and list various physical methods of cell disruption such as sonication, solid shear, liquid shear, agitation with abrasives and freeze-thawing.

18. Student is able to define and list various chemical methods of cell disruption such as use of detergents, alkali method, osmotic shock and enzymatic treatment.
19. Student is able to define the chromatography and can differentiate and define various methods of chromatography used for purification.
20. Student is able to purify different products based on their specific characteristics features like size, shape and charge.
21. Student is able to define methods for separation like ultra-filtration and reverse osmosis.
22. Student is able to list the product recovery methods like spray drying and crystallization.
23. Student is able to define liquid-liquid extraction method for secondary metabolites.
24. Student is able to implement the Ni-NTA chromatography, for the purification of His-tagged proteins.
25. Students can calculate the fermentation economics parameters.
26. Student is able to define how to make the fermentation process economically viable and reduce the recovery cost.
27. Student is able to list various methods of effluent treatment.
28. Student is able to design and list the methods for the industrial level production of antibiotics such as penicillin, streptomycin and cephalosporins.
29. Student is able to list the methods for the industrial level production of amino acids such as glutamic acid, lysine and phenylalanine.
30. Student is able to list the methods for the industrial level production of butanol and ethanol.
31. Student is able to list the methods for the production of industrially relevant enzymes and bio-therapeutics products.
32. Student is able to list the artificial sweeteners and their production at industrial level.
33. Student is able to list the various fermented milk products.
34. Student is able to list the microorganisms used as starter culture in the production of yogurt, dahi, koumiss, kefir and other milk products.
35. Student is able to list different types of Cheese and how to produce them.
36. Student is able to list different microorganisms involved in making different types of Cheese.
37. Student is able to define what plant based fermentation products are and how to produce them. This includes sauerkraut, pickles, kimchi, olives and cucumbers.
38. Student is able to list the name of microorganisms involved in the production of above mentioned plant-based fermentation products.
39. Student is able to define and list the chemical, physical and biological methods of food preservation.
40. Student is able to list fermentation processes involved in meat and fish production.
41. Student is able to list the methods for the production of alcoholic beverages.

42. Student can differentiate between lager and ale beer
43. Students can differentiate the production processes of various types of wines and distilled beverages.
44. Student is able to list the methods for vinegar production such as orlean process, trickling method and submerged fermentation.
45. Students can enlist various food borne diseases and their causative agents.

**CO of course "DISSERTATION"**

1. Student is able to conceive a problem based on current published research
2. Student is able to carry out comprehensive survey of literature on the topic of research
3. Student is able to make culture media for various microbes
4. Student is able to isolate microorganism from different environmental/ food sources
5. Student is able to identify the isolated microorganism using biochemical and molecular methods
6. Student is able to identify and isolate important bioactive molecules from the isolated strain of microbe
7. Student is able to characterize the isolated bioactive molecules using biochemical and molecular methods
8. Student is able to clone genes encoding for the identified bioactive molecule from the isolated microbe
9. Student is able to express recombinant bioactive molecules
10. Student is able to optimize the production of the recombinant bioactive molecule]
11. Student is able to use statistical tools for data analysis
12. Student is able to put together a thesis including bibliography on topic of research
13. Student is able to present their research findings before evaluation committee