

Department of Microbiology  
2023-2024

Name of Programme	Program Outcome(PO)	Program Specific Outcome(PSO)	Course Outcome(CO)
<p><b>M.Sc Microbiology</b></p>	<ul style="list-style-type: none"> <li>➤ The two year course aims to provide an advanced understanding of the core principles and topics of Microbiology and their experimental basis to enable students and acquiring a specialized knowledge by means of Lecture series and subject oriented practicals and projects.</li> <li>➤ The objective of the two year study of Master of Microbiology will impart in depth understanding of basic aspects of Microbiological Science pertaining to industrial applications.</li> <li>➤ It will equipped the students with the knowledge of fermentation technology, Genetic engineering, Microbial Genetics, Bio analytical techniques, Microbial Physiology, Immunology, Biostatistics and Computer Applications, Food and Dairy Technology, Pharmaceutical</li> </ul>	<p style="text-align: center;"><b>MSc-I Semester</b></p> <p style="text-align: center;"><b>Paper-I</b></p> <p style="text-align: center;"><b>Bacteriology</b></p> <ul style="list-style-type: none"> <li>➤ Morphology, Ultra structure, Classification of Bacteria its cultivation, nutrition, reproduction, growth characteristics.</li> </ul> <p style="text-align: center;"><b>Paper-II</b></p> <p style="text-align: center;"><b>Virology</b></p> <ul style="list-style-type: none"> <li>➤ Brief outline of discovery of viruses, classification and nomenclature of viruses.</li> <li>➤ Cultivation of Virus, Assay of Viruses, Bacteriophages, Plant Viruses, Animal Viruses, DNA viruses, Viral vaccines.</li> </ul> <p style="text-align: center;"><b>Paper-III</b></p> <p style="text-align: center;"><b>Mycology and Phycology</b></p> <ul style="list-style-type: none"> <li>➤ General features, classification, structure, reproduction of Fungi. Salient features, Life cycle and economic importance of representative members of various</li> </ul>	<ul style="list-style-type: none"> <li>➤ Students will acquire and demonstrate competency in laboratory skills</li> <li>➤ Microbiological research will able to communicate sci concepts clearly and concisely both verbally and writing will involve in internship activities will be able to retain knowledge on distribution morphology and physiology of microorganism in addition to skills in asptic procedures isolation and identification.</li> <li>➤ The course also includes some more area covering bacteriology virology immunology mycology microbial genetics and physiology food dairy enzyme and fermentation technology</li> <li>➤ After the completion of this course student will mastered a set of fundamental skill which would be useful to function actively as professionals and to their continue development and learning with in the field of Microbiology.</li> <li>➤ This skills include scientific nature and scientific enquiry laboratory skills data collection and analysis skills critical thinking ability problem solving skill communication skill cooperation and social responsibilities moral values.</li> </ul>

Department of Microbiology  
2023-2024

		divisions. Fungi and Ecosystem,	
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Department of Microbiology  
2023-2024

	<p>Microbiology and Environmental Microbiology.</p>	<p>Bioremediation, Fungal diseases, Mycorrhiza, Classification nutrition, reproduction, pigmentation of algae and Lichens.</p> <p><b>Paper-IV</b> <b>Fundamentals of Immunology</b></p> <ul style="list-style-type: none"><li>➤ Key concepts in immunology. overall organization of the immune system.</li><li>➤ Host parasite relationships.</li><li>➤ Structure types and properties of immunoglobulins</li><li>➤ Salient features of antigen antibody reaction &amp; its uses in diagnostics.<ul style="list-style-type: none"><li>➤ Organ and tissue transplantations in Humans.</li></ul></li><li>➤ Immunohaematology, Autoimmunity.</li><li>➤ Hypersensitivity reactions, cytokines and Lymphokines.</li></ul>	<p><b>Employability sector</b></p> <ul style="list-style-type: none"><li>➤ Quality control executive</li><li>➤ Hospitals and laboratories</li><li>➤ Pathology and cytology laboratories</li><li>➤ Waste management techniques</li><li>➤ Pharmaceutical companies</li><li>➤ Agrochemical companies</li><li>➤ Food standard agencies</li><li>➤ Food and beverages companies</li><li>➤ Preservation Sectors</li><li>➤ Microbiologist</li><li>➤ Assistant Professors</li><li>➤ Water Companies</li><li>➤ Environmental Consultants</li></ul>
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Department of Microbiology  
2023-2024

**Msc-II Semester**

**Paper-I**

**Molecular biology**

- Terms and terminologies related to molecular biology, properties, structure and function of DNA and RNA at the molecular level.
- Conceptual knowledge about DNA as a genetic material,
- Superhelicity in DNA replication strategies, molecular mechanisms involved in transcription and translation, importance of genetic code and wobble hypothesis,.
- Regulation of gene expression in Prokaryotes.

**Paper-II**

**Microbial Genetics**

- Molecular mechanisms underlying mutations, detection of mutations and DNA damage and repair mechanisms
- Concept of recombination, gene transfer mechanisms in

Department of Microbiology  
2023-2024

		<p>Prokaryotes.</p> <p>➤ Plasmids as a vector and their replication, Structure of Phage and Life cycle, Genetics of Phage</p> <p style="text-align: center;"><b>Paper-III</b> <b>Microbial Physiology</b></p> <p>➤ Basics aspects of Bioenergetics, Brief account of photosynthesis and photosynthetic pigments, Metabolic pathways of carbohydrate anabolism, Chemolithotrophy, methanogenesis and luminescence, Respiratory metabolism &amp; various pathways, Fermentation of carbohydrate, Nitrogen metabolism, Synthesis of amino acids and polysaccharides.</p> <p style="text-align: center;"><b>Paper-IV</b> <b>Biostatistics and Computer Application</b></p> <p>➤ Statistical inference, Presentation of data, Basics of Measures of tendency and dispersion, Correlation regression, Significance test analysis of Variance Introduction to computer and internet</p>	
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Department of Microbiology  
2023-2024

**Msc-III Ssemester**  
**Paper-I**  
**Cellular microbiology**

- Cellular biology underlying prokaryotic and eukaryotic ultrastructure genome expression structure pathogenesis
- Genome evolution in microbes phylogenetic trees
- Prokaryotic and eukaryotic signaling mechanism- eukaryotic cell to cell signaling endocrine signaling, cyclins
- Bacterial invasion of host cell survival after invasion. Transport by vesicle formation Exocytosis , Endocytosis.
- Protein toxin; agents of disease and examples
- Immune responses
- Macrophages; Cytokines and interferon
- Acquired immune response
- Cell cycle Apoptosis, Oncogenes

**Paper-II**  
**Medical Microbiology**

- Microbial Flora of Human Body,

Department of Microbiology  
2023-2024

		<p>Host microbe interaction, Sources of Infection. Pathogenesis, Classification of pathogenic bacteria organisms belonging to different classes.</p> <ul style="list-style-type: none"><li>➤ General properties of Virus</li></ul> <p>Structure of different viruses Fungal Infections.</p> <ul style="list-style-type: none"><li>➤ Laboratory Diagnosis protozoal disease, nosocomial infection</li></ul> <p>Laboratory control and antimicrobial therapy</p> <p style="text-align: center;"><b>Paper-III</b></p> <p style="text-align: center;"><b>Food and Dairy Microbiology</b></p> <ul style="list-style-type: none"><li>➤ Food as substrate of microorganism, Principles of Food preservation, Factors influencing microbial growth in food, Contamination and spoilage, Food borne infections, food sanitation.</li><li>➤ Application of microbial enzymes, Food produced by microbes, Role of Microorganism in beverages</li></ul> <p style="text-align: center;"><b>Paper-IV</b></p> <p style="text-align: center;"><b>Instrumentation</b></p> <ul style="list-style-type: none"><li>➤ Microscopy, pH meter, Centrifugation, Chromatography and its types, Electrophoresis and its</li></ul>	
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Department of Microbiology  
2023-2024

types, Spectroscopy and its types,  
Radio isotopic techniques

**MSc-IV Semester**

**Paper-I**

**Environmental Microbiology**

➤ Concept of Biotic and Abiotic Environment, Concept of Biosphere, Communities & Ecosystem, Microbiology of Wastewater and solid Waste water, Bioaccumulation of heavy metals, Xenobiotics, Soil Pollution, Genetically modified organism, Ozone depletion, Biogeochemical cycle.

**Paper-II**

**Enzyme Technology**

➤ Enzyme classification  
➤ Enzyme Purification, Enzyme fractionation by precipitation  
➤ Enzyme crystallization techniques  
➤ Enzyme kinetics; Micheles Menten equation.  
➤ Mechanism of enzyme action  
➤ Metalloenzymes and metal ions as co-factors and enzyme activators  
Properties of immobilized enzymes  
➤ Microbial enzymes in textile



Department of Microbiology  
2023-2024

,leather wood industries and  
detergents

- Enzymes in clinical diagnostic
- Enzymes as therapeutic agents.

**Paper-III**

**Fermentation and Microbial  
technology**

- Metabolic  
pathways,Industrial production of  
citric acid ,Lactic acid enzymes  
etc,Microbial production of  
therapeutic compounds,  
Biotransformation of steroids and  
vitamins, production of Bioplastic  
and Bio insecticides, Biopolymer,  
Biofertilizer, Single Cell Protein,  
Biofuels, Microbial Production of  
Hydrogen gas, Biodiesel,  
Intellectual Property right ,Patents  
and copyrights.

**Paper- IV**

**Pharmaceutical Microbiology**

- Antibiotics and synthetic  
antimicrobial agents antifungal  
antibiotics antitumor substances,  
chemical disinfectants antiseptics  
and preservatives. Mechanism of  
action of antibiotics, Molecular  
Principle of drug targeting,

Department of Microbiology  
2023-2024

		Quinolones , Mode of action of antimicrobial agents, Microbial Contamination and spoilage of pharmaceutical products, New vaccine technologies, DNA vaccine, Financing RD capital, Government regulatory practices, Reimbursement of Drug, Rational drug design, Biosensor, Application of Microbial Enzymes in pharmaceutical.	
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## Department of Microbiology

Name of Programme	Program Outcome(PO)	Program Specific Outcome(PSO)	Course Outcome(CO)
<b>B.Sc-I Semester Microbiology</b>	➤ To study structural organization and economic importance of microbes including Bacteria, Viruses, Algae, Fungi, Protozoa and microbial techniques as well as scope of Microbiology with practical knowledge.	<p style="text-align: center;"><b>DSC Semester-I Microbial world and principle of Microbiology</b></p> ➤ Understanding the Introduction to major groups of microorganisms and fields of Microbiology.  ➤ General bacteriology and microbial techniques for isolation of pure cultures of bacteria, fungi and algae ➤ Master aseptic techniques and be able to perform routine culture handling tasks safely and effectively ➤ Various Physical and Chemical growth requirements of bacteria and get equipped with various methods of bacterial growth measurement.	<p><b>Upon completion of this course students will be able :</b></p> <ul style="list-style-type: none"> <li>➤ To acquire, articulate, retain and apply specialized language and knowledge relevant to microbiology.</li> <li>➤ To understand the complete picture about the taxonomical classification of microbes.</li> <li>➤ To communicate scientific concepts, experimental results clearly both verbally and writing.</li> <li>➤ To understand the relation between human immune response towards infection of microorganism.</li> <li>➤ To develop idea of role of microorganism in ecosystem and their impact on environment.</li> <li>➤ To develop the ability to handle various instruments and cultures including preservation and maintenance</li> </ul> <p><b>Employability sector</b></p> <ul style="list-style-type: none"> <li>➤ Waste management companies</li> <li>➤ Pharmaceutical companies</li> <li>➤ Water Purifier plants</li> <li>➤ Agrochemical industries</li> <li>➤ Educational Institutes</li> </ul>

## Department of Microbiology

	<p>➤ To study microbial world, Physiochemical and biological characteristics; General characteristics of Cellular microorganisms,</p>	<p style="text-align: center;"><b>GE</b> <b>I Semester</b> <b>Microbial World</b> <b>and Diversity</b></p> <p>➤ Physiochemical and biological characteristics; Characteristics of Acellular microorganisms (Viruses); Baltimore classification, general structure with special reference to viroids and prions. Whittaker's five kingdom classification systems .</p> <p>➤ archaebacteria, eubacteria, wall-less forms, - archaebacteria, eubacteria, wall-less forms - MLO (mycoplasma and spheroplasts)</p> <p>➤ Characteristics, occurrence, thallus organization and classification of Algae.</p> <p>➤ General characteristics of fungi including habitat, distribution, nutritional requirements, ultrastructure, , mode of reproduction.</p>	<p><b>Upon completion of this course students will be able :</b></p> <p>➤ Have developed a good knowledge of the development of the discipline of Microbiology and the contributions made by prominent scientists in this field.</p> <p>➤ Has acquired a fairly good understanding of the Diversity of the microbes.</p> <p>➤ Has acquired practical skills of handling microorganisms in the laboratory for study</p> <p>➤ Has acquired a fairly good understanding of the activities/importance of microbes.</p>
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## Department of Microbiology

Name of Programme	Program Outcome(PO)	Program Specific Outcome(PSO)	Course Outcome(CO)
<p><b>B.Sc II Semester (DSC)</b></p>	<p>To Study Morphology and ultrastructure of Bacteria, Nutritional requirements in bacteria and nutritional categories; discovery of viruses, classification of viruses, reproduction of bacterial.</p>	<p style="text-align: center;"><b>DSC Semester-II Bacteriology and Virology</b></p> <ul style="list-style-type: none"> <li>➤ Bacteria: Cell size, shape and arrangement, capsule, flagella, fimbriae and pili. Cell-wall: Composition and detailed structure of Gram-positive and Gram-negative cell walls, Bacterial Cell Membrane, Cytoplasm.</li> <li>➤ . Physical methods of microbial control.</li> <li>➤ Distinctive properties of viruses, morphology and ultrastructure of virus.</li> <li>➤ Multiplication and Economic importance of viruses. Growth Phases of Bacteria.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Describe characteristics of bacterial cells, cell organelles, cell wall composition and various appendages like capsules, flagella or pili.</li> <li>➤ Describe the different types of bacteria ; nutritional requirements of bacteria for growth.</li> <li>➤ Understood what are viruses and the chemical nature of viruses, different types of viruses.</li> <li>➤ Explain multiplication and Economic importance of viruses; calculate generation time of growing bacteria.</li> </ul>
<p><b>B.Sc II Semester (GE)</b></p>	<p>To study Soil Microbiology, Microbial Control of Soil Borne Plant Pathogens, Biofertilization, Phytostimulation, Bioinsecticide, biogas, biofuels.</p>	<p style="text-align: center;"><b>GE Semester-II Microbes in Sustainable Agriculture and Development</b></p> <ul style="list-style-type: none"> <li>➤ Soil as Microbial Habitat, Soil profile and properties, Soil formation, Diversity and distribution of microorganisms in soil. Microbial Activity in Soil and Green House Gases-</li> </ul>	<ul style="list-style-type: none"> <li>➤ Has acquired a fairly good understanding of microbes in the soil.</li> <li>➤ Has developed a fairly good understanding of the use of microbes in sustainable agriculture namely role in biogeochemical recycling, nitrogen fixing, organic matter degradation, use as bio fertilizers, as bio pesticides, production of bio fuels.</li> </ul>

## Department of Microbiology

		<p>Carbon dioxide, methane, nitrous oxide, nitric oxide – production and control.</p> <ul style="list-style-type: none"><li>➤ Microorganisms used as biocontrol agents against Microbial plant pathogens, Insects, Weeds.</li><li>➤ Plant growth promoting bacteria, biofertilizers – symbiotic (Bradyrhizobium, Rhizobium, Frankia), Non Symbiotic (Azospirillum, Azotobacter, Mycorrhizae, MHBs, Phosphatesolubilizers, algae).</li><li>➤ GM crops: Advantages, social and environmental aspects, Bt crops, golden rice.</li></ul>	
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## Department of Microbiology

Name of Programme	Program Outcome(PO)	Program Specific Outcome(PSO)	Course Outcome(CO)
<b>B.Sc III Semester (DSC)</b>	<ul style="list-style-type: none"> <li>➤ To study Carbohydrates and proteins; Lipid ,Nucleic acids, vitamins; Enzymes; Microbial metabolism and transport system.</li> </ul>	<p style="text-align: center;"><b>DSC III Semester Biochemistry and Physiology</b></p> <ul style="list-style-type: none"> <li>➤ Structure, classification and properties of Carbohydrates. Proteins (Primary, Secondary and Tertiary and Quaternary structure).</li> <li>➤ Structure, classification and properties of Lipids;. Nucleic acid Base composition. Structure and functions of DNA and RNA. Concept and types of vitamins and their role in metabolism.</li> <li>➤ Structure of enzyme, Classification of enzymes, Mechanism of action of enzymes, Enzyme inhibition.</li> <li>➤ Bacterial photosynthesis and Chemosynthesis: Glycolysis, TCA cycle and Oxidative Phosphorylation.; Fat Biosynthesis.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Have developed how the carbohydrates make the structural and functional components such as energy generation and as storage food molecules for the bacterial cells.</li> <li>➤ Developed a very good understanding of Lipids , nucleic acid and Vitamins.</li> <li>➤ Well conversant about multifarious function of proteins.</li> <li>➤ Have developed a very good understanding of the Mechanism of action of enzyme, enzyme inhibition.</li> <li>➤ Are able to explain microbial metabolism, Transport System.</li> </ul>

## Department of Microbiology

<p><b>B.Sc III Semester (DSE)</b></p>	<p>➤ To study the principle &amp; working of various instruments and Bio-techniques.</p>	<p><b>DSE III Semester Instrumentation and Bio- techniques</b></p> <p>➤ Microscopy and Centrifugation: Bright field and dark field microscopy, Fluorescence Microscopy, Phase contrast Microscopy, Electron Microscopy. Centrifugation.</p> <p>➤ Principle of pH meter, Principles and applications of paper chromatography, Thin layer chromatography. Gel filtration chromatography, ion- exchange chromatography and affinity chromatography, HPLC.</p> <p>➤ Principle of electrophoresis and applications, SDS polyacrylamide gel electrophoresis, 2D gel electrophoresis, Isoelectric focusing, and Agarose gel electrophoresis.</p> <p>➤ Principle and use of study of absorption spectra of biomolecules. Analysis of biomolecules using UV and visible range.</p>	<p>➤ Developed understanding of principals, and applications of different microscopic and spectrophotometric methods.</p> <p>➤ Developed understanding of principals, and applications of different separation techniques especially chromatographic, electrophoretic and centrifugation techniques.</p> <p>➤ Skills in handling and use of light microscope, spectrophotometer and centrifugation equipment to study/analyze various microbiological samples.</p>
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## Department of Microbiology

<p><b>B.Sc III Semester (SEC)</b></p>	<p>➤ To study the Microbial Diagnostics and Public health.</p>	<p><b>SEC III Semester Microbial Diagnostics and Public health</b></p> <p>➤ Cocept of Air Borne Disease, Water borne diseases: types, Symptoms, treatment, prevention.</p> <p>➤ Clinical diseases: Diabetes, Asthma, multiple sclerosis, rheumatoid arthritis, cancer. Symptoms, Treatment and prevention.</p> <p>➤ Disease Diagnosis: Methods based on Ag-Ab interaction-precipitation, agglutination, ELISA, RIA, Immuno-electrophoresis, PCR based diagnosis method for infectious diseases. Testing for Antibiotic Sensitivity in Bacteria</p>	<p>➤ Developed understanding of principals, and applications of different microscopic and spectrophotometric methods.</p> <p>➤ Developed understanding of principals, and applications of different separation techniques especially chromatographic, electrophoretic and centrifugation techniques.</p> <p>➤ Skills in handling and use of light microscope, spectrophotometer and centrifugation equipment to study/analyze various microbiological samples.</p>
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# Department of Microbiology

<b>Name of Programme</b>	<b>Program Outcome(PO)</b>	<b>Program Specific Outcome(PSO)</b>	<b>Course Outcome(CO)</b>
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## Department of Microbiology

<p><b>B.Sc IV Semester (DSC)</b></p>	<p>➤ To Study Microbial Physiology and Genetics.</p>	<p><b>DSC IV Semester Microbial Physiology and Genetics</b></p> <ul style="list-style-type: none"><li>➤ DNA replication-mechanism, process and enzymes/proteins involved in replication. Homologous and site specific recombination.</li><li>➤ Transcription- -initiation, elongation, termination. Translation initiation, elongation, termination. Factors involved in transation. Genetic code.</li><li>➤ Introduction and types of Gene mutation – Base substitution, frame shift mutation, mutagens -physical and chemical. DNA repair mechanism.</li><li>➤ GENE REGULATION Concept of Gene-Cistron, Recon, Muton, Operon concept -Lac operon, tryptophsn operon, His operon, Activators, coactivator and repressor.</li></ul>	<ul style="list-style-type: none"><li>➤ Have developed a very good understanding of DNA replication and Recombination.</li><li>➤ Good understanding of concepts of Transcription, Translation.</li><li>➤ Has acquired a fairly good understanding mechanisms of genetic exchange, mutations and their implications.</li><li>➤ Has acquired knowledge of gene, their expression and regulation of expression.</li><li>➤ Has developed practical skill for isolation of bacteria/plasmid DNA and its visualization in gel after separation by electrophoresis.</li></ul>
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## Department of Microbiology

<p><b>B.Sc IV Semester (DSE)</b></p>	<ul style="list-style-type: none"><li>➤ To study Concepts of cell, Experimental evidences for nucleic acid as genetic material. Cell cycle and Programmed cell death.</li></ul>	<p><b>DSE IV Semester Cell and Molecular Biology</b></p> <ul style="list-style-type: none"><li>➤ Prokaryotic &amp; Eukaryotic cells. Cell organization of Prokaryotic cells with special reference to Bacteria. Eukaryotic cells - cell wall &amp; plasma membrane; structure &amp; function of cell organelles and inclusions.</li><li>➤ Structure of DNA; Models of DNA replication. Enzymes, proteins .Mechanism of DNA replication in prokaryotes &amp; eukaryotes.</li><li>➤ Eukaryotic Cell Cycle, Regulation of Cell cycle progression, Events of Mitotic Phase, Meiosis and Fertilization.</li><li>➤ intracellular control of cell cycle events, Apoptosis, extracellular control of cell growth and apoptosis. Growth phase in Bacteria.</li></ul>	<ul style="list-style-type: none"><li>➤ Good understanding of concepts of Prokaryotic and Eukaryotic cells.</li><li>➤ Describe characteristics of bacterial cells, cell organelles, cell wall composition and various appendages like capsules, flagella.</li><li>➤ Have developed a very good understanding of the nucleic acid, structure of DNA and DNA replication.</li><li>➤ Are able to explain the cell cycle, control of cell cycle events and Apoptosis.</li></ul>
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## Department of Microbiology

<p><b>B.Sc</b> <b>IV Semester</b> <b>(SEC)</b></p>	<p>➤ To study Fermented Foods, Milk Based Fermented Foods, Grain Based Fermented Foods, Fermented Meat and Fish.</p>	<p><b>SEC</b> <b>IV Semester</b> <b>Food Fermentations and Domestic Application</b></p> <ul style="list-style-type: none"><li>➤ Fermented Foods: Definition, types, advantages and health benefits, fermented foods used by Common public, domestication.</li><li>➤ Dahi, Yogurt, Buttermilk (Chach) and cheese: Preparation of inoculums, types of microorganisms and production process</li><li>➤ Soy sauce, Bread, Idli and Dosa: Microorganisms and production process, Preparation and preservation.</li><li>➤ microorganisms involved, fermentation process, Probiotic Foods.</li></ul>	<ul style="list-style-type: none"><li>➤ Have developed a very good understanding of practical aspects commercially produced food and fermentative products.</li><li>➤ Have developed a very good understanding of practical use of microbiology for better production of home based food and fermentation products for day to day use.</li></ul>
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## Department of Microbiology

- To study the Medical Microbiology and Immunology.

### **B.Sc. Final Paper-I MEDICAL MICROBIOLOGY AND IMMUNOBIOLOGY**

- Concept of Air Borne Disease, Water borne diseases: types, Symptoms, treatment, prevention.
- Clinical diseases: Diabetes, Asthma, multiple sclerosis, rheumatoid arthritis, cancer. Symptoms, Treatment and prevention.
- Basic Concept of immunity: Immune system, Types of Immunity, Antigen-Antibody, Immunoglobulin: Structure types, Properties and their function Theory of antibody production.
- Methods based on Ag-Ab interaction-precipitation, agglutination, ELISA, RIA, Immunoelectrophoresis, PCR based diagnosis method for infectious diseases.

## Department of Microbiology

To study Air, water, Soil Microbiology, Industrial Microbiology, Agriculture Microbiology with the practical Knowledge.

### **B.Sc Part-Final Paper-II ENVIRONMENTAL, INDUSTRIAL AND AGRICULTURAL MICROBIOLOGY**

- Basics of Aerobiology, Microbes in atmosphere, source of microorganism in air, droplet nuclei, infectious dust, and bio-aerosol.
- Basic concept, water zonation, eutrophication, microbial community in natural water. Determining the quality of water quality of water
- Soil as an environment culture medium, microbes of soil. Brief account of microbial interactions, Microbiological examination of soil. rhizosphere and non rhizosphere micro-flora. Mycorrhiza.
- History of Agricultural Microbiology; Microbes and their importance in maintenance of soil, Biogeochemical cycles.