St Aloysius College (Autonomous)

Mangaluru

Re-accredited by NAAC "A" Grade

Course structure and syllabus of

MICROBIOLOGY

CHOICE BASED CREDIT SYSTEM

(2019 – 20 ONWARDS)

ಸಂತ ಅಲೋಶಿಯಸ್ ಕಾಲೇಜು
(ಸ್ವಾಯತ್ತ)
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Re-accredited by NAAC with 'A' Grade - CGPA 3.62
Recognised by UGC as "College with Potential for Excellence"
College with 'STAR STATUS' conferred by DBT, Government of India
3rd Rank in "Swacch Campus" Scheme, by MHRD, Govt of India

No: SAC 40/Syllabus 2019-20 Date: 18-07-2019

NOTIFICATION

Sub: Syllabus of **Microbiology**under Choice Based Credit System.

Ref: 1. Decision of the Academic Council meeting held on 02-05-2019 vide Agenda No: 29(2019-20)
2. Office Notification dated 18-07-2019

Pursuant to the above, the Syllabus of **Microbiology** under Choice Based Credit System which was approved by the Academic Council at its meeting held on 02-05-2019 is hereby notified for implementation with effect from the academic year **2019-20**.

PRINCIPAL **REGISTRAR**

To:

1. The Chairman/Dean/HOD.
2. The Registrar Office
3. Library

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Date: -06-2020

NOTIFICATION

Sub: Syllabus of **Microbiology**under Choice Based Credit System.

Ref: 1. Decision of the Academic Council meeting held on 02-05-2019 vide Agenda No: 12(2020-21)
2. Office Notification dated 09-06-2020

Pursuant to the above, the replacement of CBCS IV Semester subject of Syllabus of **Microbiology** under Choice Based Credit System which was approved by the Academic Council at its meeting held on 09-06-2020 is hereby notified for implementation with effect from the academic year **2020-21**.

PRINCIPAL **REGISTRAR**

To:

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Learning Outcomes based Curriculum Framework (LOCF) for MICROBIOLOGY

Undergraduate Programme

Preamble

Microbiology is the study of microorganisms or microbes such bacteria, viruses, fungi, algae, cyanobacteria, protozoa and prions. They are extremely important as their diverse activities range from causation of deadly diseases in humans, animals and plants to production of highly useful products like antibiotics, enzymes, alcohol, fermented foods, and recycling of dead and decaying organic matter in the nature. Thus the science of microbiology has an important role to play in health, agriculture, environment and industry. Severaldiscoveries in the last two to three decades, which significantly impact these area have put Microbiology on the centre stage of teaching, research and development all over the globe.

The Choice Based Credit System (CBCS) curriculum for Microbiology at the undergraduate level has now been developed into a new system called Learning Outcome Curriculum Framework (LOCF) under the recommendations and guidance of University Grants Commission (UGC). The LOCF approach first envisioned the programme learning outcomes of the program in Microbiology as well as the learning outcomes of thecourses being taught under this programme, keeping in view the graduate attributes of the subject. The curriculum was then developed in tune with the learning outcomes. It is envisaged that the students trained under this curriculum will have the required attributes of knowledge, skills, temperament and ethics related to the subject of Microbiology. Besides the contents of the curriculum, the teaching learning processes have also been designed to achieve these attributes. A variety of learning assessment tasks have been included in the curriculum. Besides assessing the knowledge/skills acquired by the students, these tasks would also help to supplement the teaching learning processes.

There are 8 core courses which encompass all important aspects of the discipline of Microbiology and are all compulsory courses.

1. Introduction:

In the increasingly globalized society, it is important that the younger generation especially the students are equipped with knowledge, skills, mindsets and behaviors which may enable them to perform their duties in a manner so that they become important contributors to the development of the society. This will also help them to fully utilize their educational training for earning a decent living so that the overall standard of their families and surroundings improve leading to development of welfare human societies. To achieve this goal, it is imperative that their educational training is improved such that it incorporates the use of newer technologies, use of newerassessment tools for mid-course corrections to make sure that they become competitive individuals to shoulder newer social responsibilities and are capable of undertaking novel innovations in their areas of expertise. In the face of the developing knowledge society, they are well aware about the resources of self-development using on-line resources of learning which is going to be a major component of learning in the future. The learning should also be a continuous process so that the students are able to re-skill themselves so as to make themselves relevant to the changing needs of the society. In the face of this need, the educational curricula, teaching learning processes, training, assessment methods all need to be improved or even re-invented. The higher educational institutions (HEI) all over the globe are in the grip of this urgent task and India needs to keep pace with all these developments.

2. Learning Outcomes based approach to Curriculum Planning:

Learning Outcome based approach to curriculum planning (LOCF) is almost a paradigm shift in the whole gamut of higher education such that it is based on first and foremost identifying the outcomes of the learning required for a particular subject of study, and then planning all components of higher education so as to achieve these outcomes. The learning outcomes are the focal point of the reference to which all planning and evaluation of the end learning is compared and further modifications are made to fully optimize the educationof the individuals in a particular subject. For the subject of Microbiology the outcomes are defined in terms of the understanding and knowledge of the students in microbiology and the practical skills the students are required to
have to be competitive microbiologist so that they are able to play their role as microbiologist wherever required in the society such as the diseases caused by the microbes, their diagnosis and remedies; the role of microbiologists in the biotechnology industry and how they may be able to fit the bill in the industry.

The students are also trained in such a way that they develop critical thinking and problem solving as related to the microbiology. The curriculum developed and the teaching and the evaluation tasks are such that the students are able to apply their knowledge and training of microbiology to solve the problems of microbiology as these exist or appear from time to time in the society. The curriculum envisions that the student, once graduate as specialists in a discipline, have an important role to play in the newer developments and innovations in the future in the subject for advancement of the discipline.

2.1 Nature and extent of the Programme:

The undergraduate programme in Microbiology is the first level of college or university degree in the country as in several other parts of the world. After obtaining this degree, a microbiologist may enter into the job market or opt for undertaking further higher studies in the subject. After graduation the students may join industry, academia, public health and play their role as microbiologists in a useful manner contributing their role in the development of the welfare society. Thus the undergraduate level degree in microbiology must prepare the students for all these objectives. Thus the LOCF curriculum developed has a very wide range covering all aspects of Microbiology with reasonable depth of knowledge and skills so to as to diversify them in various specialties of the subject and play their role professionally as expected of them. It is also imperative that microbiologists are evaluated in a manner appropriate to assess their proper development as microbiologists. The current LOCF in Microbiology has been designed in keeping all these important points in mind.

2.2 Aims of Bachelor's degree programme in MICROBIOLOGY:

The aim of the undergraduate degree in Microbiology is to make students knowledgeable about the various basic concepts in a wide ranging contexts which involve the use of knowledge and skills of Microbiology. Their understanding, knowledge and skills in Microbiology needs to be developed through a thorough teaching learning processes in the class, practical skills through the laboratory work, their presentation and articulation skills, exposure to industry and interaction with industry experts, write short research-based projects where they are guided and mentored by the academic and other experts of the subject.

3. Graduate Attributes in Microbiology:

As mentioned earlier degree in Microbiology is the first college/university level degree in the country as in several parts of the world. The students graduating in this degree must have through understanding of basic knowledge or understanding of the fundamentals of Microbiology as applicable to wide ranging contexts. They should have the appropriate skills of Microbiology so as to perform their duties as microbiologists. They must be able to analyze the problems related to microbiology and come up with most suitable solutions. As microbiology is an interdisciplinary subject the students might have to take inputs from other areas of expertise. So the students must develop the spirit of team work. Microbiology is a very dynamic subject and practitioners might have to face several newer problems. To this end, the microbiologists must be trained to be innovative to solve such newer problems.

Several newer developments are taking place in microbiology. The students are trained to pick up leads and see the possibility of converting these into products through entrepreneurship. To this end, the students are made to interact with industry experts so that they may able to see the possibility of their transition into entrepreneurs. They are also made aware of the requirements of developing a Microbiology enterprise by having knowledge of patents, copyrights and various regulatory process to make their efforts a success.

Besides attaining the attributes related to the profession of Microbiology, the graduates in this discipline should also develop ethical awareness which is mandatory for practicing a scientific discipline including ethics of working in a laboratory work and ethics followed for scientific publishing of their research work in future. The students graduating in microbiology should also develop excellent communication skills both in the written as well as spoken language which are must for them to pursue higher studies from some of the best and internationally acclaimed universities and research institutions spread across the globe.

4. Qualification Descriptors:

The following may serve as the important qualification descriptors for a UG degree in Microbiology:

1. Knowledge of the diverse places where microbiology is involved.
2. Understanding of diverse Microbiological processes.
3. Basic skills such as culturing microbes, maintaining microbes, safety issues related to handling of microbes, Good Microbiological practices etc.
4. Moderately advanced skills in working with microbes such as pilot scale culturing, downstream processes, diagnostics etc.
5. Generation of new knowledge through small research projects
6. Ability to participate in team work through small microbiology projects.
7. Ability to present and articulate their knowledge of Microbiology.
8. Knowledge of recent developments in the area of Microbiology.
9. Analysis of data collected through study and small projects.
10. Ability to innovate so as to generate new knowledge.
11. Awareness how some microbiology leads may be developed into enterprise.
12. Awareness of requirements for fruition of a microbiology-related enterprise.

5. Programme Learning Outcomes of Microbiologycourse:

A candidate who is conferred an UG degree i.e. B.Sc. degree in microbiology needs to have acquired/developed following competencies during the programme of the study:

1. Acquired knowledge and understanding of the microbiology concepts as applicable to diverse areas such as medical, industrial, environment, genetics, agriculture, food and others.
2. Demonstrate key practical skills/competencies in working with microbes for study and use in the laboratory as well as outside, including the use of good microbiological practices.
3. Competent enough to use microbiology knowledge and skills to analyze problems involving microbes, articulate these with peers/ team members/ other stake holders, and undertake remedial measures/ studies etc.
4. Developed a broader perspective of the discipline of Microbiology to enable him to identify challenging societal problems and plan his professional career to develop innovative solutions for such problems.

6. Structure of Microbiology course

Subjects	Paper	Instruction hours /week	Duration of Exam in hours	Marks			Credits
				IA	Exam	Total	
First Semester Theory	Paper-G509.1 Fundamentals of Microbiology	4	3	20	80	100	2
ELECTIVE	G509.1E TECHNIQUES IN MICROBIOLOGY	2	2	10	40	50	1
Practical	G509.1P	3	3	10	40	50	1
Second Semester Theory	Paper-G509.2 Basic Microbiology	4	3	20	80	100	2
ELECTIVE	G509.2E COMMON FUNGAL AND VIRAL DISEASASE IN HUMAN	2	2	10	40	50	1
Practical	G509.2P	3	3	10	40	50	1
Third Semester Theory	Paper-G509.3Microbial Physiology and Metabolism.	4	3	20	80	100	2
ELECTIVE	G509.3E BASIC CONCEPTS OF FOOD SAFETY	2	2	10	40	50	1
Practical	G509.3P	3	3	10	40	50	1
Fourth Semester Theory	Microbial Ecology and Environmental Microbiology Paper-G509.4	4	3	20	80	100	2
ELECTIVE	G509.4E SOLID WASTE MANAGEMENT	2	2	10	40	50	1
Practical	G509.4P	3	3	10	40	50	1

Scheme of Credit Based Semester System for the V and VI Semesters for B.Sc. in Microbiology

Subjects	Paper	Instruction hours /week	Duration of Exam	Marks			Credits
				IA	Exam	Total	
Fifth Semester Theory	Paper-G509.5a Medical Microbiology and Immunology.	3	3	20	80	100	2
Practical	G509.5P	4	4	20	80	100	2
Theory	Plant Microbiology and Bioremediation Paper-G509.5b	3	3	20	80	100	2
Sixth Semester Theory	Principles of Bacterial Genetics, Genetic Engineering and Bioinformatics Paper-G509.6a	3	3	20	80	100	2
Theory	Applied Microbiology-G509.6b	3	3	20	80	100	2
COMPONENTS	PRACTICAL						
A	Practical G509P	4	4	10	40	50	1
B	Project-G509			10	40	50	1
C	Independent Practical Skill Development (IPSD)-G509	4	4	10	40	50	1

PATTERN OF QUESTION PAPER SEMESTER END EXAMINATION

Total Maximum Marks: 50
a) Internal Assessment -8marks & Class Participation: 2 marks=10 Marks and
b) End Semester Practical Exam:Experiments-35 marks + Class Record-5marks = 40 Marks.

Practical Examination Question Paper Model for I to IV semester.

Q.1. Major Experiment-Experiment to be conducted and result to be reported--- 12 Marks.

Q.2. Minor Experiment- Experiment to be conducted and result to be reported— 08 Marks.

Q.3. Identification and Comment of Spotters "A", "B" and "C"----------5 x 3 =15 Marks.

Q.4 Class Record---------- 05 Marks.

Total -40 Marks

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Practical Question Paper Model for V SEMESTER.

Maximum Marks : Internal Assessment -20 and End Semester Practical Exam - 80
Internal Assessment -a) Regularity and Class Participation: 4 marks.
b) Record Maintenance and Presentation:16 Marks.
Practical Exam:

Q.1. Major Experiments-Experiment to be conducted and result to be reported. 20 x 2 =40 Marks.

Q.2. Minor Experiments- Experiment to be conducted and result to be reported. 10x 2=20 Marks.

Q.3. Identification and Comment of Spotters "A"and "B". ---------- 5x 2 =10 Marks.

Q.4 Class Record---------- 10 Marks.

Total -80 Mark.

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Practical Question Paper Model for VI SEMESTER.

Maximum Marks : Internal Assessment -20 and Practical Exam- 80 (Component A Practical + Component B : Project / Component: C- IPS experiments)
Internal Assessment -a) Regularity and Class Participation: 4 marks. & b) Record Maintenance and Presentation:16 Marks.

Practical Exam: Component A + Component : C

Q.1. Major Experiments-Experiment to be conducted and result to be reported. 15 x 2 =30 Marks.

Q.2. Minor Experiments- Experiment to be conducted and result to be reported- 10x 2=20 Marks.

Q.3. Identification and Comment of Spotters "A"and "B". ---------- 5 x2 =10 Marks.

Q.4 Class Record---------- 20 Marks.

Total -80 Mark.

Marks Allotment for Component –A

Q.1. Major Experiments-Experiment to be conducted and result to be reported.
15 x 1 =15 Marks.

Q.2. Minor Experiments- Experiment to be conducted and result to be reported.
10x 1=10 Marks.

Q.3. Identification and Comment of Spotters "A"and "B". ----------
5 x 1 =5 Marks.

Q.4 Class Record----------10 Marks.

Total -40 Marks

Component –B: Marks: i) For the Project Report: 30 & ii) Viva Voce:10=40 marks

Theory / Elective Question Paper pattern

End Semester theory Examination will be common for all science departments. The duration of the examination is 3/ **2** hours carrying 80/40 marks. Question paper is divided into Part –A ,Part – B and Part-C**.**

Part –A objective type carrying 20/**10**marks , Part-B analytical questions carrying 60/**30** marks and part –c short answers for 20/**10** marks.

Question Paper Pattern-Microbiology

Max.Marks -100 and Time 3hours / Elective:40 marks Time 2hours

Section-A-20/10 marks / Elective A-10 marks

I . 12/**6** questions –Any 10/**5** to be answered-2x10=20/**2x5=10**

Section-B- 60 Marks-15 x4=60/15 x2=30: 4/2questions to be answered (one question compulsorily from each unit)

Section –C = 20/10 marks Short answers- 4x5=20 marks-Assorted questions from all four units.

Pattern Sample

I.Section-A –Any 10 out of 12- 2 x 10=20 marks / Elective Any 5 out of 6- 2 x 5=10 marks.

Q.I a,b,c,d,e,f,g,h,j, k, l. / Q.I a,b,c,d,e,f.

II. Section-B -Answer any ONE question "a" or "b" from each unit and 'c" is compulsory- 15 x 4=60 marks

Unit-I.Q.2A OR 2B +2C = 9+6 =15 =marks / Elective 9+6 =15 marks

Unit-2. Q.3A OR 3B = 9+6 =15 =MARKS / Elective 9+6 =15 marks

Unit.3.Q.4A OR 4B= 9+6 =15 =marks

Unit.4.Q.5A OR 5B= 9+6 =15 =

III.Section-C -20 marks = Any four - 4 x 5=20 marks / Elective any 2 x 5 =10 marks

Q.6,Q.7,Q.8, Q.9, Q.10, Q.11/ Elective Q.4,Q.5,Q.6, Q.7.

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First Year B.Sc. – I Semester-Paper-1 -Fundamentals of Microbiology-Paper–G509.1

Course Learning Outcomes

Outcome 1. Have developed a good knowledge of the development of the discipline of Microbiology and the contributions made by prominent scientists in this field.

Outcome 2. Have developed a very good understanding of the characteristics of different types of microorganisms, methods to organize/classify these into and basic tools to study these in the laboratory.

Outcome 3.Describe the nutritional requirements of bacteria for growth; developed knowledge and understanding that besides common bacteria there are several other microbes which grow under extreme environments.

Outcome 4.Perform basic laboratory experiments to study microorganisms; methods to preserve bacteria in the laboratory; calculate generation time of growing bacteria.

Outcome 5. Are able to perform basic experiments to grow and study microorganisms in the laboratory.

First Year B.Sc. – I Semester-Paper-1-Fundamentals of Microbiology-Paper–G509.1

Total 48 hours

UNIT-1

1. INTRODUCTION TO MICROBIOLOGY.

The discovery of Microorganisms .Contributions of Louis Pasteur, Robert Koch, Koch's Postulates Iwanowky,Beijerinck Spontaneous Generation.

The scope and Relevance of Microbiology,Branches of Microbiology, The Future of Microbiology.

06 hours

2.MICROSCOPY AND STAINING TECHNIQUES: Parts and Working principles of : Bright Field Microscope, Dark -Field Microscope, Phase-Contrast Microscope, Fluorescence Microscope, Electron Microscope-Scanning Electron and Transmission Electron Microscopes, Atomic Force Microscope.

Fixation, Simple and Differential staining-Gram Staining and Acid-Fast Staining.Negative staining.

Staining Specific Structures: Capsule Staining-Principle and procedure, Endospore Staining-Schaeffer –Fulton Method-principle and Procedure, Flagella Staining-Principle and Procedure.

06 hours

UNIT-2

1. MICROBIAL TAXONOMY AND PHYLOGENY: Classical Characteristics, Morphological Characteristics, Physiological and Metabolic Characteristics, Ecological Characteristics, Molecular Characteristics. Microbial Classification and Taxonomy: Phenetic Classification, Phylogenetic classification, Genotypic classification, Numerical Taxonomy

2. CLASSIFICATION AND NOMENCLATURE, BERGEY'S MANUEL: Domain*Archaea:* Phylum and Classes, Domain *Bacteria:*Phylum and Classes .**06 hours**

UNIT-3

1. CONTROL OF MICROORGANISMS BY PHYSICAL AND CHEMICAL AGENTS: PhysicalMethods –Use of Dry heat, Moist heat, Filtration, Radiations, Ultrasound.

Chemical methods: Alcohols, Aldehydes, Dyes, Halogens, Phenols, Metallic salts, Detergents, Gaseous agents. **06hours**

2.MICROBIAL NUTRITION AND THE INFLUENCE OF ENVIRONMENTAL FACTORS ON GROWTH: Uptake of Nutrients by the Cell: Passive Diffusion Facilitated Diffusion, Active Transport Group Translocation and Iron uptake.

Common Nutritional Requirements, Requirements for Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus Sulphur and Electrons. Nutritional types of Microorganisms. Growth Factors.Nutritional Classifications.Phototrophs and Chemotrophs, Autotrophs and Heterotrophs.

Temperature-Cardinal Temperatures, Temperature classes of organisms. pH: Microbial growth at low and high pH , Osmotic effects on Microbial Growth , Compatible solutes, Oxygen and Microbial Growth-Oxygen classes of Microorganisms., Toxic forms of Oxygen-Super oxide and Other Oxygen Species, Hydrostatic Pressure and Radiation.

06 hours

UNIT-4

1.BACTERIAL GROWTH CURVE: The lag Phase, The logarithmic Phase, The Stationary Phase and The Decline Phase. Synchronous Growth and Continuous Culture- Chemostat and Turbidostat.

Mathematics of Growth: Generation time and growth rate. Factors influencing growth curve.

Measurement of Microbial growth-Methods for Measuring Bacterial Growth: Microscopic Count, Electronic Counter, Plate count, Membrane filter, Turbido metric measurement, Nitrogen determination, Dry Weight determination, Measurement of biochemical activity.

06 hours.

2. METHODS OF CULTURING MICROORGANISMS: Types and uses of Different culture media: Commonly Used Media-Peptone, Meat extract, Yeast agar, Nutrient agar & Nutrient broth. Selective media, Diferencial Media, Assay media, Maintenance media, Enrichment media. Anaerobic Media, Media for culture of Fungi.
Culture of Bacteria and Fungi: Methods- The streak plate, pour plate, spread plate. Cultivation of anaerobic bacteria.

Maintenance and Preservation of Pure cultures: Methods of Maintenance and Preservation. Culture Collections. Colony Characteristics.**06 hours**

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References

1.Prescott, L.M.; J.P. Harley and D.A.Klein. 2010. Microbiology. 8th edition.McGrow Hill.

2.MichaelT.Madigan and John M. Martinko.2010.13th Edition..Brock Biology of Microorganisms, Pearson Prentice Hall.

3. Michael Pelczar.1998. Microbilogy-5th Ed ,McGraw Hill Book Company.

4. Jacquelyn G. Black .2012 .Microbiology: Principles and Explorations, 8th Edition. Wiley.

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First Year B.Sc. –I Semester-Paper-1 .
PRACTICAL : Fundamentals of Microbiology -G509.1P
(Each Practical session is 3 hours duration)

1. Instructions to the Microbiology laboratory and good laboratory practices.
2. Study of instruments IN Microbiology: Autoclave,Hot-air oven,Incubator,Laminar Air Flow Unit, Anaerobic jar, Colony counter, pH meter. Study of glass wares used in Microbiological work.
3. Study of Microscope-Use of 10x, 45x and 100x (oil immersion) objectives.
4. Smear preparation and Staining techniques-Simple staining and Gram staining.
5. Capsule staining – Wet India ink method and Dry India ink method.
6. Endospore Staining Method- Schaeffer Fulton Method.
7. Demonstration of Bacterial motility by Hanging drop Method.
8. Preparation of Culture media: Nutrient Broth and Nutrient Agar.
9. Isolation of Bacteria from soil – Serial dilution Technique. Viable count by Standard plate count method.

10 .Isolation by streak plate method & Study of Colony morphology.

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First Year B.Sc. –II Semester- Paper-2- Basic Microbiology –G509.2

Course Learning Outcomes

Course learning outcomes: At the completion of this course, the students are able to -

Outcome 1. Describe characteristics of bacterial cells, cell organelles, cell wall composition and various appendages like capsules, flagella or pili.

Outcome 2. Differentiate a large number of common bacteria and cyanobacteria by their salient characteristics; classify bacteria into groups.

Outcome 3.Are able to explain the useful and harmful activities of the microorganisms.

Outcome 4. Identity common fungi by their salient characteristics; classify fungi into groups.

Outcome 5. Differentiate viruses by their salient characteristics; classify viruses into groups.

First Year B.Sc. –II Semester- Paper-2- Basic Microbiology –G509.2

Total 48 hours

UNIT-1

1. STUDY OF BACTERIA: Prokaryotic Cell Structure and Function- Bacteria-Size, Shape & arrangement. Flagella and Motility, Pili and Fimbriae, Capsule , Cell wall Of Prokaryotic cell: Peptidoglycan, Outer membrane of Gram –Negative bacteria ,Prokaryotic cell membranes; Gas vesicles and cell inclusions ; Cytoplasmic matrix ; Nucleoid Plasmids,.

Bacterial Exospores and Endospore: Structure, Formation and Germination. Reproduction of Bacteria; Binary fission.**6 hours**

2. STUDY OF ARCHAEA: Introduction, bstructure of cell wall ,archaeal lipids and membranes,Methonogens,Halophiles and Sulfate reduces**.**

Actinomycetes, Mycoplasma and Rickettsia: General properties and classification.

06 hours

UNIT-2

1.STUDY OF VIRUSES: General properties of Viruses, Helical Capsid, Icosahedral Capsids , Viral envelopes and Enzymes.

Viruses of Bacteria**:** Classification**,** Multiplication of Bacteriophages –Lysogenic and Lytic cycle. One step growth curve of viruses. A brief account of Plants, Insects, Algal and Fungal Viruses.

Classification of viruses based on the basis of differences in their transcription processes.General account on Prions, Viroids, and Virusoides. **06 hours**.

2. VIRUSES CULTIVATION AND QUANTIFICATION: Egg and cell cultures-monolayer and continuous cell cultures and Plaque assay. **06 hours**

UNIT-3

1.STUDY OF FUNGI: General characters and Reproduction: Asexual and Sexual Reproduction. Spores and Spore dispersal .Classifications.**06 hours**

2. STUDY OF TYPES OF FUNGI: Rhizopus: Morphology: Microscopic and Macroscopic. Reproduction: Asexual and Sexual Reproduction

Yeast: Morphology: Microscopic and Macroscopic. Reproduction: Asexual and Sexual Reproduction.

Penicillium: Morphology: Microscopic and Macroscopic. Reproduction: Asexual and Sexual Reproduction and

Fusarium: Morphology: Microscopic and Macroscopic. Reproduction: Asexual and Sexual Reproduction.**06 hours**

UNIT-4

1. STUDY OF CYANOBACTERIA: General Characters and Classifications. Similarities and Dissimilarities between Cyanobacteria and Bacteria.

Study of Nostoc , Anabaena Stigonema and Scytonema. Morphology and Reproduction.

06 hours

2. STUDY OF PROTOZOA: Study *Entamoebahistolytica*:Morphology; Trophozoite and Cyst and Life cycle :Encystations and Excystation-Quadrinucleate cyst.

Plasmodium: Organism Characteristics and Life cycle in man and Mosquito. Morphological forms seen in humans: Trophozoites, Schizonts, Merozoites, Gametocytes, Forms in Liver: Sporozoites and, Merozoites.

Morphological forms in Mosquitoes: Macrogametes and Microgametes, Ookinete, OocystSporozoites.

Morphology and life cycle of Balantidium and Trichomonasvaginalis .**06 hours**

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References

1.Prescott, L.M.; J.P. Harley and D.A.Klein. 2010. Microbiology. 8th edition.McGrow Hill.
2.MichaelT.Madigan and John M. Martinko.2010.13th Edition..Brock Biology of Microorganisms, Pearson Prentice Hall.
3. Michael Pelczar.1998. Microbilogy-5th Ed ,McGraw Hill Book Company.
4.Jacquelyn G. Black .2012 .Microbiology: Principles and Explorations, 8th Edition. Wiley.

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First Year B.Sc. –II Semester - Paper-2.

PRACTICAL: Basic Microbiology - G509.2P

(Each Practical session is 3 hours duration)

1. Measurement of Bacteria by Micrometry.
2. Total count of Bacteria by Haemocytometer.
3. Demonstration of Bacteriophage Plagues.
4. Determination of Thermal Death Point.
5. Effect of pH on growth of Bacteria.
6. Effect of temperature on growth of bacteria.
7. Tease Mount & Staining Techniques for Fungi
8. Study of Yeast Wet mount and Stained specimen observation.
9. Study of permanent slides of Cyanobacteria : *Nostoc , Scytonema , Stigonema , Oscillatoria*

10. Study of permanent slides : Protozoa*: Amoeba , Entamoeba, Balantidium, Plasmodium.*
Observation of Fungal Slides: *Aspergillus, Penicillum, Rhizopus, Fusarium*.

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Second Year B.Sc. -III Semester-Paper-3-Microbial Physiology and Metabolism –G509.3

Course Learning Outcomes

Outcome 1. Understand the basics of bioenergetics and the role of ATP in Metabolism. Other Energy rich molecules structure and significance.

Outcome 2.Describing the growth characteristics of the microorganisms capable of growing under unusual environmental condition of temperature, oxygen, and solute and water activity.

Outcome 3.Describing the growth characteristics of the microorganisms which require different nutrient for growth and the associated mechanisms of energy generation for their survival like autotrophs, heterotrophs, chemolithoautotrophs etc.

Outcome 4. Differentiating concepts of aerobic and anaerobic respiration and how these are manifested in the form of different metabolic pathways in microorganisms.

Outcome 5. Describe the biogeochemical cycles and mineral transformation by microbes.

Microbial Physiology and Metabolism –G509.3

Total 48hours

UNIT-1

1.BIOENERGETICS: Standard Free energy, Free energy and Reactions. Energy coupling reactions and their significance.The role of ATP in Metabolism.Other Energy rich molecules structure and significance.Oxidation and Reduction Reactions.

06 hours

2. ENZYMES. Structure and classification of Enzymes, Mechanism of Enzyme Reactions, Effect of environment on Enzyme Activity **.**Enzyme Inhibition Control of Enzyme Activity .Allosteric Regulation .Feedback Inhibition.Coenzymes & Cofactors.

06 hours

UNIT-2

1.MICROBIAL METABOLISMS:Modes of energy yielding reactions- Respiration VsFermentation.Aerobic Respiration:Glycolysis: Glycolytic pathways-EMP pathway. Kreb's Cycle.Electron transport and Oxidative phosphorylation.ATPase.Anaerobic Respiration.

06 hours

2.FERMENTATIONS: Common Microbial Fermentations: Alcohol Fermentaion, Lactic acid Fermentation-Homo Hetro Lactic acid,Mixed Acid Frmentaion,Butanediol Fermentation, Propionic acid fermentation, Lipid Catabolism , Amino acid and Protein Catabolism.

Molecular basis of Signal transduction in bacteria- Two-component regulatory systems, Examples of Two –Component Regulatory Systems: Protein kinases and Response regulators.

06 hours

UNIT-3

1.BACTERIAL PHOTOSYNTHESIS: Photosynthetic Bacteria**:** Characteristic of Photosynthetic Bacteria-Chromatiaceae (Purple Sulphur Bacteria),Rhodospirillaceae (Purple Non Sulphur Bacteria),Chlorobiaceae (Non Motile Green and Brown Sulphur Bacteria) ,Chloroflexaceae Filamentous Gliding Green Bacteria ,Cyanobacteria (Blue Green Bacteria) and Prochlorophyta **.**Bacteriochlorophylls,Carotenois and Phycobilins. Photosynthetic apparatus in prokaryotes.Reaction Centres, Antenna Pigments and Chlorosomes.Types of Bacterial Photosynthesis**:** Photosynthesis in Purple and Green bacteria, Anoxygenic photosynthesis and OxygenisPhotosynthesis.Light reactions: Photophosphorylation-Cyclic and Non Cyclic Photophosphorylations.

Dark reactions: Reductive Pentose Pathway and Pyruvate Synthetase Pathway (Reductive Carboxylic Acid Cycle). **06 hours**

2. CHEMOLITHOTROPHY: Oxidation of Ammonium and Nitrites, Iron , Hydrogen and SulphurCompounds.Microbiologically Influenced Corrosion: Microorganisms involved and their detection.Biofilms: Formation and development and Biofilm development factors. Significance :Biofilms and infectious diseases and biofilm uses.**06 hours**

UNIT-4

1.NITRIFICATION: Bioenergetics and Enzymology of Nitrification. Anammox.Nitrogen Fixation: Nitrogen Fixing Bacteria **:**Free Living Nitrogen Fixing Bacteria **,** Symbiotic Nitrogen Fixing Bacteriaand Associative Nitrogen Fixing. Nitrogensae .Electron flow in Nitrogen fixation.Nitrogen fixation by Rhizobium: Process of root nodule formation, Leghaemoglobin.

06 hours

2.GEOMICROBIOLOGY AND MINERAL TRANSFORMATION: Biogeochemical cycle- Reservoir Cycling of Sulphur-Microorganisms involved in sulphur cycle., Acid rain. Cycling of Phosphorus-Eutrophication and Carbon cycling –Green house effect and Global warming.

06 hours.

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References

1.Prescott, L.M.; J.P. Harley and D.A.Klein. 2010. Microbiology. 8th edition.McGrow Hill.

2.MichaelT.Madigan and John M. Martinko.2010.13th Edition..Brock Biology of Microorganisms, Pearson Prentice Hall.
3. Michael Pelczar.1998. Microbilogy-5th Ed ,McGraw Hill Book Company.
4. Jacquelyn G. Black .2012 .Microbiology: Principles and Explorations, 8th Edition. Wiley.

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Second Year B.Sc. -III Semester-Paper-3
PRACTICAL : Microbial Physiology and Metabolism-G509.3P
(Each Practical session is 3 hours duration)

1. Biochemical Estimations: Colorimetric estimation of Protein by Lowry's method.
2. Colorimetric estimation of sugar by DNS method.
3. Biochemical tests used for identification of bacteria:

   Fermentation of Glucose, Sucrose, Lactose

4. Gelatin hydrolysis
5. Catalase test
6. Oxidase test
7. IMViC test
8. Urease test
9. β-galactosidase test and
10. TSI agar test

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Second Year B.Sc. - IV Semester- Paper-4- Microbial Ecology and Environmental Microbiology. –G509.4

Course Learning Outcomes

Outcome 1. Have developed a fairly good knowledge and understanding of different types of
environments and habitats where microorganisms grow including the microbiomes of the human gut and animal gut.

Outcome 2. Are able to identify the important role microorganisms play in maintaining healthy
environment by degradation of solid/liquid wastes; how these activities of microorganisms are
used in sewage treatment plants, production of activated sludge and functioning of septic tanks

Outcome 3.Have understood the significance of microbes in air and air sanitation.

Outcome 4. Have developed the practical skills for conducting experiments.

Outcome 5. Are able to understand the methods of examination of soil microbes.

Microbial Ecology and Environmental Microbiology. –G509.4

TOTAL 48 hours

UNIT-1

1.DEVELOPMENT OF MICROBIAL COMMUNITIES: Diversity and stability of Microbial communities.The structure and Functions of some Microbial communities:Rumen ecosystem – Interaction between microbes and rumen, Microbes of the rumen, Classification of rumen Bacteria, Protozoa and fungi in Rumen. Factors affecting establishment of rumen population, Commensal and Mutualistic Intestinal Symbionts.

Probiotics and Prebiotics – Definition, Probiotics Organisms, Adverse and potential benefits.

Microbiome: Microorganism of Human body and their significance.

06hours

2. MICRORGANISMS IN THEIR NATURAL HABITATS: Fresh water Environment**:** Ground water, surface water, Study of aquatic microbes, microbial communities in aquatic environment. Structure of lentic habitat, Biota of lentic habitat, Structure of lotic habitat, Biota of lotic habitat, Factors that affect microbial flora.

Marine Environment**:** Structure of the sea, Marine Zones and Stratifications, physical and chemical characteristics of marine environment, Bacterial, fungal, protozoan flora of sea, Distribution of Micro organisms in oceans and sea, Characteristics marine microorganism, Microbial activity in marine environment, advantages and limitations to microbial growth, Factors that affect marine microbial flora, Functions of marine flora.

06 hours

UNIT-2

1.AIR MICROBIOLOGY: Microbial composition of air**:** In door and out doormicroflora; source of micro organisms in air, Factors affecting air microflora, Distribution and Significance.

Techniques of trapping air borne microbes**:** Anderson, Rotorod, Burkard, Gravity slide, agar plate, liquid impingement, sieve device and filtration.**06 hours**

2. AIR BORNE DISEASES: Note on Air borne diseases (Diphtheria, Tuberculosis, Pneumonia, Small pox, Chicken pox, Measles, Mumps, and Influenza) and allergens (Hay fever, Rhinitis).

Control of air borne Microorganisms:Importance in hospitals and industry.: Ventilation, Biological safety cabinets, Isolation Systems ,Air Filtration ,Ultraviolet Irradiation, Outdoor Air Purging ,Electrostatic Precipitation ,Negative Air ionization, Vegetation. **06 hours**

UNIT-3

1.WATER MICROBIOLOGY: Water and Disease Transmission:Water borne pathogens, Sources for Water Borne Pathogensand water borne diseases: Bacterial, Viral, Protozoan, Trematode Diseases.

Sanitary Analysis of Water:Microbial examinations of water- Membrane filter technique, Most Probable Number, Standards of water quality for drinking and industry; especially food and pharmaceutical. **06hours**

2. WASTE WATER TREATMENT PROCESSES: Small scale- Cess pools, Septic Tank, Imhoff tank. .Large scale: Primary Treatment (Screening, Removal of Grit, Removal of Fatty oils, Skimming tanks), Secondary Treatment (Trickling Filters, Oxidation of Lagoon, Activated sludge process, Anaerobic Digester) and Tertiary Treatment (Disinfection, Chlorination-methods of chlorination, Break point chlorination, Super Chlorination, Chloramination, other disinfecting agents), Disposal of treated sewage.**06 hours**

UNIT -4

1. SOIL MICROBIOLOGY:Microorganisms in Soil: Bacteria, Algae, Fungi Protozoa, Viruses.

Interaction among microorgamisms in Soil**:** Positive Interactions and Negative interactions: Neutralism, Commensalisms, Synergism (proto-cooperation), Mutualism (symbiotic), Competition, Amensalism, and Parasitism & Predation.

Plant –Microbe Interactions: Rhizosphere: Microorganisms ,Factors that affect rhizosphere, and benefits and its importance, Phyllosphere&Phylloplane

Mycorrhiza- Types: Ectomycorrhizae, Endomycorrrhizae (VAM), Ericoid Mycorrhizas, MonotropoidMycorrhizas, Orchid Mycorrhizas and significance.**06 hours**

2.METHODS IN MICROBIAL ECOLOGY: Molecular (Culture Independent) Analyses of Microbial communities: a.Fluorecent Staining using DAPI , b. Viability Staining, c .Fluorescent antibodies, d. Green Fluorescent Protein as Cell Tag, e. Phylogenetic staing using FISH, f. Chromosome painting &*In situ* Reverse Transcription.

Measuring Microbial Activities: Radioisotopes, .Microelectrodes, Use of Isotopic Fractination in Microbial Ecology.**06 hours**

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References

1. Atlas, R.M. and Bartha R. 1998. Microbial Ecology: Fundamentals and Applications. 4th Ed. Redwood city.CA. Benjamin / Cummings.
2. Mitchell, R. 2010. Introduction to Environmental Microbiology.2nd Ed. Prentice - Hall. Inc. Englewood Cliffs - New Jersey.
3. Michael T.Madigan and John M. Martinko.2009.12th Edition, Brock Biology of Microorganisms. Pearson Prentice Hall.

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PRACTICAL: Microbial Ecology and Environmental Microbiology –G509.4P

(Each Practical session is 3 hours duration)

1.Isolation of bacteria and fungi from air: Gravity Settle method, Sticky slide method .and Demonstration of Air sampling equipments.

2. Isolation of bacteria and fungi from soil

3. Water examination.-Multiple Tube Method.

4. Estimation of Dissolved oxygen in water.

5. Estimation of FreeCarbondioxide in water

6.Determination of Alkalinity of water.

7. Determination of Chlorine in water.

8. Demonstration of production of ammonia from organic compounds-Ammonification.

9. Demonstration and antagonism: Bacteria Vs Bacteria, Fungi Vs Bacteria, Fungi Vs Fungi.

10. Demonstration of Endomycorrhiza .

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Third Year B.Sc. : V Semester - Paper-5- Medical Microbiology and Immunology-G509.5a

Course Learning Outcome

Outcome 1.understand the basic concepts of immunology and types of immune system.

Outcome 2..Understood the basic and general concepts of causation of disease by the pathogenic microorganisms and the various parameters of assessment of their severity including the broad categorization of the methods of diagnosis.

Outcome 3.Developed a thorough understanding of common bacterial, viral, fungal, parasitic diseases of human being including some very important diseases of the animals also.

Outcome 4. Conceptualized the protective role of the immune system of the host and developed an understanding of the basic components as well as the mechanisms underlying the immune system and its response to pathogenic microorganisms.

Outcome 5. Are able to conduct experiments for growing common bacteria in different microbiological media, antibiotic sensitivity determination and antigen antibody reaction (precipitation test in the agarose)

Medical Microbiology and Immunology-G509.5a

Total Hours-40

UNIT-1

1.INFECTION: Classification of Infection: Primary ,focal, nosocomial, iatrogenic, in apparent , atypical, exogenous and endogenous. Sources of Infection –Humans, animals, insects, soil and water and food. Methods of Transmission- Contact, inhalation, ingestion, inoculation, insects, congenital.Factors predisposing to microbial pathogenicity- pathogenicity, virulence, adhesion, invasiveness, toxigenicity. Endotoxin and Exotoxins .Types of infectious diseases.

2. IMMUNITY-Types of Immunity-Innate immunity and Acquired immunity, Factors and Mechanisms of innate immunity.Active immunity and Passive immunity-types of passive immunity.Measurement of immunity-Local immunity and Herd immunity.

10 hours

UNIT-2

1.ANTIGENS: Characteristics and types-Haptens. Determinants of antigenicity –Size, chemical nature, susceptibility to tissue enzymes, foreignness, antigenic specificity, species specificity, iso specificity, auto specificity, organ specificity, heterogenic specificity.Biological classes of antigens-T-cell dependent antigens, T-cell independent antigens, super antigens.

1. ANTIBODIES: Structure –immunoglobulin chains-heavy (large) chain and Light (small) chain. Immunoglobulin domains-variable domain and constant domain.Classes of antibodies- IgG , IgA, IgM, IgD, , and IgE. – Immunoglobulin specificities-Isotype, Allotype, and Idiotype. Antibody diversity.

10 hours

UNIT-3

1. STRUCTURE AND FUNCTIONS OF IMMUNE SYSTEM: Central lymphoid organs-Thymus and Bone marrow. Peripheral lymphoid systems-Lymph nodes and Spleen.

Cells of lymphoreticular systems- Lymphocytes-Structure, Classification and Functions.Differences between T and B cells. Types of T cells-T Helper/Inducer cells (T_H), Treg cells, Cytototoxic /Cytolyticcells(T_C), Memory cells (T_m) . Plasma cell , B cell maturation, Null cells. Phagocytic cells- Macrophages and Microphages.

2.IMMUNE RESPONSE: Humoral immune response- Production of antibodies , Primary and Secondary response,, Factors influencing antibody production-genetic factors, age, nutritional status, route of administration size and number of doses , multiple antigens, adjuvant, immunosuppressive agents. Fate of antigens in tissues, Monoclonal antibodies

Cellular Immune response.-induction of cell mediates immunity. Cytokines-Interleukins, Colony stimulating factors, Tumor necrosis factor, Interferon, Others. Immunological Tolerance-Factors.

10 hours

UNIT-4

1. HUMAN DISEASES : Bacterial Diseases- Staphylococcus, Streptococcus, Salmonella, Shigella,E.coli ,Clostridium tetani, perfringenes and botulinum Morphology, Cultural chacters,Biochemical tests, Pathogenesis, Laboratory diagnosis , Epidemiology and Control, Prevention and Prophylaxis.

2. ANTIBIOTICS AND VACCINES: Classification of antibiotics, mode of action-inhibition of cell wall, cell membrane, Protein synthesis, and nucleic acid synthesis. Antibiotic sensitivity tests- Dilution and Paper diffusion and methods- Kirby Bauer method.Antibiotic Resistance-Origin and Mechanisms.

Vaccines: Types- natural live, live attenuated vaccine, inactivated vaccine, toxoid vaccine, polysaccharide vaccine, recombinant antigen vaccine live vector vaccine and DNA vaccine. and Factors that affect the efficiency of vaccines.

10 hours

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References:

1. Ananthanarayan R. and C.K. JeyararnPaniker, Text book of Microbiology.9th Ed, 2013 .Universities Press.
2. Jewetz, E: J.L. Melnic and E.A. Adelberg . Review of Medical Microbiology. 19th edition. 2000. Lange medical Publications. U.S.A.

Third Year B.Sc.:V Semester-Paper -6-Plant Microbiology and Bioremediation-G509.5b

Course Learning Outcomes

Outcome 1. Developed a clear understanding of the multifarious roles of microorganisms in soil, in association with plants.

Outcome 2.Are able to describe the role of microorganisms in the production of plant diseases and biological control.

Outcome 3.Are able to identify the role of microorganisms in the causation of the diseases in plants.

Outcome 4. Understand the role of microorganisms in biodegradation of organic pollutants and natural compounds.

Outcome 5. Develop a clear understanding of composting the organic waste and role of microbes in composting.

Plant Microbiology and Bioremediation-G509.5b

Total Hours-40

UNIT-1

1.MICROORGANISMS IN AGRICULTURE: Biofertilizers-Types of biofertilizers: Rhizobium biofertilizer,Azospirillumbiofertihzer,Azotobacterbiofertilizer, Blue green algal biofertilizer (BGH), Azollabiofertilizer Phosphate solubilizing microorganisms as biofertilizer and its application.

2.BIOLOGICALCONTROl:Fungal antagonists-Biocontrol of soil borne diseases, biological control of diseases of aerial plant parts with fungi, biological control of post harvest diseases. Bacterial antagonists: Biocontrol of soil borne diseases, biological control of diseases of aerial plant parts with bacteria, bacterial biological control of post harvest diseases, biocontrol with bacteria of Bacteria – mediated frost injury.

10 hours

UNIT-2

1.PARASITISMS AND DISEASE DEVELOPMENT IN PLANTS: Development of diseases in plants, stages in development of disease-inoculation, penetration, infection . Dissemination of pathogens-By water, by insects, by air, by pollen seed, transplants.

Mechanical forces exerted by pathogens on host tissues, Chemical weapons of pathogens, Enzymes in plant diseases- Cuticular wax, Cutin, Pectic substances, Cellulose, hemicelluloses, Suberin, Lignin Cell wall Flavonoids,. Microbial toxins in plant Diseases-Tabtoxins, Phaseotoxin, Tentoxin, Cercosporin, Other non host specific toxins, Host specific toxins,-Victorin(HV Toxin),T toxin /Cochliobolus (Helminthosporium) heterotrophus Race T Toxin, HC Toxin, Alternaria alternate toxins.

2. STUDY OF PLANT DISEASES: Etiology, Symptoms and Control of: Sandal spike disease, Koleroga of arecanut ,Tikka disease of groundnut.

10 hours

UNIT-3

1. BIODEGRADATION OF ORGANIC POLLUTANTS : The overall process of biodegradation-contaminant structure, toxicity and biodegradability, environmental factors affecting biodegradation-redox conditions, organic matter content, nitrogen, temperature, pH, salinity, water activity. Biodrgradation of Organic pollutants-aliphatics, alicyclics,aromatics, dioxins and PCBs (polychlorinated biphenyls), and pesticides.

2.BIOREMEDIATION: Criteria for Bioremediation, biological mechanisms of transformation, Strategies of bioremediation-pasive /intrinsic bioremediation, biostimulation, bioventing, bioaugumentation, landfilling, composting, phytoremediation. Advantages and disadvantages of bioremediation.Persistence and Biomagnification.

10 hours

UNIT-4

1. DECOMPOSITION OF NATURAL COMPOUNDS : Microbiology of Cellulose degradation, factors governing decomposition, types of microorganisms involved in decomposition, enzymes of cellulose degradation, microbial degradation of hemicelluloses, lignin-enzymes in lignin degradation, pectin-pectin degrading enzymes and starch-amylases.Inulin Hydrolysis.

2. COMPOSTING OF PLANT ORGANIC MATTER: Methods of composting, microorganisms involved in degradation of plant material-aerobic anaerobic bacteria, factors that influence decomposition, soil sickness, green manure, vermicomposting, anaerobic decomposition of organic matter.Effects of Residues of Crops on Plant Growth.Humus ,humic acids and beneficial role of humic acids.**10 hours**

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References:

1. Alexender, M. Introduction to soil Microbilolgy. 1991. Krieger Pub Co.

2. George N.Agrios. Plant Pathology-5th Edition, 2005.Elsiver Academic Press.

3. SubbaRao.N.S. 1995. Soil Microorganisms and Plant Growth Oxford .& IBH Publishing Co. Pvt. Ltd.

4.David M. Sylvia , Jeffry J. Fuhrmann , Peter G. Hartel, David A. Zuberer . 2004.Principles and Applications of Soil Microbiology,2nd Ed,.Printice-Hall of India Pvt Ltd.

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Third Year B.Sc.:V Semester-Paper-5 & 6

PRACTICAL: Medical Microbiology and Immunology &Plant Microbiology and Bioremediation -G509.5P

(Each Practical session is 4 hours duration)

1. Antigen-Antibody reactions: Radial Immuno diffusion Experiment.*

2. Examination and Observation of bacteria from human skin and ,mouth.*

3. Human Serum Protein Gel Eletrophoresis.*

4. Demonstration of ELISA-Use of Student Teaching Kit.5*

5. Antibiotic Sensitivity Test: Paper disk Diffusion method.

6. Demonstration of Bacteria in root nodule & Demonstration of Anabena in Azolla.*

7.Isolation of plant fungal pathogens from soil.

8. Starch hydrolysis Test and Nitrate Reduction Test.

9. Qualitative Amylase test.*

10. Observation of Tobacco mosaic , Bacterial blight of rice, Koleroga of areca, Tikka disease of groundnut.

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Third Year B.Sc. - VI Semester- Paper-7-Principles of Bacterial Genetics, Genetic Engineering and Bioinformatics –G509.6a

Course Learning Outcomes

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1.Has acquired knowledge of gene, their expression and regulation of expression. Has acquired a fairly good understanding mechanisms of genetic exchange, mutations andtheir implications.

Outcome 2.Has developed practical skill for isolation of bacteria/plasmid DNA

Outcome 3.Has acquired a fairly good knowledge of the tools and the methods for genetic engineering.

Outcome 4. Developed skills to use computers for analysis of biological data.

Outcome 5.. Skill to use important biological databases, use tools to retrieve data, and compare the data of the biological macromolecules. Developed basic skills for data retrieval, representation, analysis and interpretation.

Paper-7-Principles of Bacterial Genetics, Genetic Engineering and Bioinformatics –G509.6a

Total Hours-40

UNIT-1

1. BACTERIA L CHROMOSOMES AND PLASMIDS: Watson and Crick Model of DNA structure-Supercoiling of DNA. Types of DNA. Replication of DNA,Semi conservative method -Enzymes involved in DNA replication-DNA Helicase, DNA Polymerase ,Primase, RNA Polymerase, SSB, DNA ligase, DNA Gyrase. Mechanisms of DNA replication in Prokaryotes. Theta Replication and Rolling Circle Replication

Plasmids – Types of Plasmids, Isolation and Purification and significance. Transposable Elements of Bacteria: Insertion Sequences and Composite transposons, Noncomposite transposons.

2. GENETIC CODE: Characteristics of Genetic Code-the degeneracy of code, wobble, the reading frame and initiation codon, termination codon, and universality of code.

Gene Regulation in Bacterial Cells: Operon Structure. Inducible and Repressible Operons – Negative inducible, negative repressible, positive inducible positive repressible.

The lac Operon of *E.coli*.

10 hours

UNIT-2

1.GENE MUTATION: Classes of Mutations: Base Substitutions, Insertion and Deletions. Spontaneous and Induced Mutations. , Mutations by Chemicals: Base Analogues, Mutations by Alkylating agents, Mutations by intercalating agents. Mutations by Radiations: X-rays and UV light. Reverting Mutations: Suppression: Intragenic and Intergenic Suppression.

Phenotypic variation of mutation.Mutation as a tool in molecular genetics.

DNA repair Mechanisms: Mismatch Repair, Direct repair, Base –Excision, Nucleotide – excision repair, Post replication repair.

2. GENETIC EXCHANGE IN PROKARYOTES: Transformation-Griiffith experiment, Competence in transformation, uptake and integration of DNA in transformation. Conjugation –Mechanisms of DNA transfer during conjugation. Formation of Hfr strains,Formation of F-Prime (F′)and Transduction -Generalized and Specialized, Low frequency and high frequency transductions.

10 hours

UNIT-3

1. GENETIC ENGINEERING: Principles of genetic engineering, Restriction sites and enzymes, Vectors (Plasmids, Cosmids, Shuttle vectors, Yeast artificial chromosomes), DNA ligation(Linkers, Adaptors, Homopolymer tail), introduction of vectors in host(Transformation, Electroporation), Screening of Recombinant plasmids(Antibiotic resistance, Blue white screening, Plaque formation, Colony Hybridization).

Applications of genetic engineering- Synthesis of Insulin, nif gene, Production of transgenic plants and GM foods.

2. MOLECULAR TECHNIQUES: Electrophoresis, High Pressure Liquid Chromatography, Southern blotting, Northern blotting, Polymerase Chain Reaction (PCR), DNA finger printing. Metagenomics- Culture independent Techniques- brief account. Biosafety and Bioterrorism.

10 hours

UNIT-4

1.BIOINFORMATICS: Introduction to Informatics**:** History, Biological sequences(nucleotide and Protein), Sequence Database- Human Genome Project, Microbial genomes, Structural Database- Protein Data bank and sequence analysis, Sequence alignment, , Similarity Searching (FASTA and BLAST), Multiple alignment of Sequence.Brief ac BLAST),

2. MICROBIAL GENOMICS: Prokaryotic Genomes:Sizes and ORF Contents-small genomes and large genomes. Prokaryotic genomes-Bioinformatis Analyses and Gene Distributions-Gene

content of prokaryotic Genomes, Uncharacterized ORFs, Gene categories as a function of genome size,gene distribution in bacteria and Archaea.**10 hours**

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References:

1. Benjamin A. Pierce.2010 Genetics: A Conceptual Approach.4th Ed.W.H. Freeman & Company .
2. Glover, D.M. 2010.Gene Cloning. The Mechanism of DNA Manipulation.Chapman and Hall. Brown, T.A..Gene Cloning.Chapman and Hall.
3. Nancy Trun, J. E. Trempy .2003 .Fundamental Bacterial Genetics, Blackwell Publisher.

4.Basic Bioinformatics.2008. ManjuBansal ,Atlantic Publisher.

5.Andreas D. Baxevanis and B. F. Francis Ouellette , 2004. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins .

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Third Year B.Sc. – VI Semester - Paper-8- Applied Microbiology –G509.6b

Course Learning Outcomes

Outcome 1.Has acquired a fairly good knowledge of microbes in food and their role in food spoilage.

Outcome 2.Has acquired knowledge of various methods of food preservation.

Outcome 3.Has acquired knowledge of spoilage of selective foods and their preservation

Outcome 4. Has acquired knowledge of fermentation types and production of organic acids, alcohols, enzymes, antibiotics and various foods in the industry.

Outcome 5. Has acquired knowledge of how microbes are involved in milk spoilage and milk preservation.

Third Year B.Sc. – VI Semester - Paper-8-Applied Microbiology –G509.6b

Total Hours-40 hours

UNIT-1

1. PRINCIPLES OF SPOILAGE: Intrinsic - pH , moisture content, oxidation-reduction potential (Eh), nutrient content ,antimicrobial constituents ,biological structures and extrinsic factors-temperature of storage, relative humidity of environment, and presence and concentration of gases in the environment. Sources of food contamination- plants and fruits, animals, water, soil, air, during handling and processing.
General principles underlying spoilage, chemical changes caused by microorganisms.Factors affecting number and kind of microorganisms.

2. PRINCIPLES AND METHODS OF FOOD PRESERVATION: Use of Low temperature-Common /cellar storage, Chilling/cold storage, Freezing /frozen storage. Effects of low temperature on microbes and food.High temperature-Factors that affect application of high temperature and penetration of heat.Pasteurization, heating about and above 100^{O}C, Canning process. Preservatives-Characters of an ideal preservatives, types of preservatives-Added and developed preservatives, an account of organic acids and their salts, sulfur dioxide and sulfites, sugar and salts, wood smoke. Radiations.-Factors affecting radiation, types of radiations in food preservation, Radappertization, Radurization and Radicidation .

10 hours

UNIT-2

1.MICROBIOLOGY OF FOODS:: Fruit and Vegetables, Meat, Fish. Canned food Spoilage-Causes of spoilage,appearances of the unopened container .Types of biological spoilage of canned foods-Spoilage by thermophile-Flat sour, TA spoilage and Sulfide Stinker.Spoilage by

mesophilic bacteria-Bacillus and Clostridium.Spoilage by non spore forming bacteria.

Food borne infections and poisoning: Types and Food Pathogens (Staphylococcal intoxication, Botulism, Salmonellosis, Shigellosis.Viral diseases from food-Polio, Hepatitis-A and E, and Rota virus.

Mycotoxins-Aflatoxins and toxins from Penicillum and Fusarium fungus.

2. MICROBIOLOGY OF MILK:The Initial Microflora of Raw Milk,Environmental Sources-animal, personnel, water, utensil, milking area.

Biochemical activities of microbes in milk. - Souring, proteolytic activity, saccharolytic activity, gassy fermentation, lactic acid fermentation. Different types of fermented milk products. Microbiology of Soft and hard cheese.

Methods of examination of milk: DMC-Breed's Method, Dye Reduction tests: Methylene blue test and Resazurintest.Milk Preservation: Pasteurization- Low temperature and High temperature, Ultra high methods.

Methods of food examinations-Standard Plate count methods-Spiral plater, membrane filters, Microscope colony counts, agar droplets and dry films. Direct Microscopic Count, Most Probable Numbers,and Dye Reduction test.

Microbial Examination of Surfaces: Swab-rinse Method, Contact (RODAC) plate, Agar syringe, Sticky films,Swab/Agar slants.

10 hours

UNIT-3

1. INDSTRIAL MICROBIOLOGY: Solid State Fermentation**,**Anaerobic FermentationAerobic Fermentation. Fomenters**:** Basic functions, design and components- body construction and temperature control, aeration, agitation systems, baffles, foam control, pH maintenance.

Isolation and Screening of Microorganisms-Screening of Microorganisms for New ProductsStrain Improvement and inoculum development.

2. INDUSTRIAL PRODUCTIONS OF BEER AND WINE :Raw material, Culture media and Microbial inoculums, Fermentation process-Malt and Malting, Brewing process, Product recovery and purification. Fermentation processes of Wine-Processes in wine making, Fermentation , Ageing and storage Clarification , Packaging.

10 hours

UNIT-4

1. MICROBIAL BIOMASS PRODUCTION: Single Cell protein production-Raw Material and production-Hydrocarbons, alcohols and waste products. Microorganisms used in SCP production. Nutritional value of SCP.

Manufacture of Baker's yeast- Production of Baker's Yeast, Yeast strain used. Culture maintenance, Factory production.

2. PRODUCTION OF VINEGAR AND ANTIBIOTIC: Types of Vinegar , Organisms Involved Manufacture of Vinegar-The Orleans (or slow) method, and The trickling generators (quick) method ,Submerged generators , Processing of Vinegar.

Antibiotic-Penicillin-Strain of organism used in penicillin fermentation, Fermentation for penicillin production, Extraction of penicillin after fermentation, Production of semi-synthetic penicillins.

10 hours

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References:

1. Frazier, W.C. and Westhoff, D.C. 1988. Food Microbiology. 4th Ed. McGraw Hill, NY.
2. James M. Jay, Martin J. Loessner, David A. Golden.2006.Modern Food Microbiology. 7th ed. Springer
3. 3. P.F. Stanbury A. Whitaker. 1984 Principles of Fermentation Technology.Pergamon

4. A.H Patel.2012. Industrial Microbiology, Macmillan Publication.

5. Prescott And Dunns .2004 .Industrial Microbiology, 4Th Edition. CBS Publishers& Distributors

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Third Year B.Sc. - VI Semester. Paper-7 & 8

PRACTICAL: Principles of Bacterial Genetics, Genetic Engineering and Bioinformatics & Industrial and Applied Microbiology–G509.6P

(Each Practical session is 4 hours duration)

1. Colorimertic estimation of DNA*

2. Colorimetric estimation of RNA*

3. DNA gel electrophoresis *

4.Isolation of bacteria and fungi from Spoiled food :Fruit and vegetable

6 .Thin layer Chromatography.

7 .Direct Microscopic count of Bacteria from milk sample

8. Phosphates test for milk.

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INDEPENDENT PRACTICAL SKILL DEVELOPMENT (IPSD) G509.6P

1. Estimation of fat in milk.
2. Lactose Estimation in milk.
3. Lactic acid estimation from fermented milk .
4. Estimation of Alcohol by Specific gravity method.*
5. Dye Reduction Test: Methylene blue test and Resazurin test.
6. Isolation of UV mutant bacteria

OR

PROJECT: G509. 6P

Laboratory Manuals:

1.LoisBeisher .1996. Microbiology in Practice.6th Ed. Harper Collins.

2.James Cappuccino Natalie Sherman .Microbiology: A Laboratory Manual .10th Edition .Pearson Education .

3. R.C. Dubey , D.K. Maheshwari2010.Practical Microbiology. S Chand & Co Ltd.

4.Thomas Jones Mackie, J. G. Collee, James Elvins McCartney.1989.Mackie& McCartney practical medical microbiology.ChurchillLivington

5. Bteey A. Forbes,Daniel F. Sahm,AliceS.Weissfeld. Bailey &Scott's Diagnostic Microbiology-11th Edition. Mosby-AnAffiate of Elservier

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ELECTIVE PAPERS UNDER CBCS

1.ELECTIVE -SUPPORTIVE ELECTIVE- FIRST B.SC. –I SEMESTER.
TECHNIQUES IN MICROBIOLOGY-G509.1E

Course Learning Outcomes

Outcome 1.Principles and applications of a number advanced types of microscopes and of analytical instruments.

Outcome 2.Aquire the knowledge of several separation techniques using chromatography.

Outcome 3.Acquire the knowledge of Spectrophotometry Principle and its application in biological research.

1.ELECTIVE -SUPPORTIVE ELECTIVE- FIRST B.SC. –I SEMESTER-TECHNIQUES IN MICROBIOLOGY

CREDIT: 1 **TOTAL HOURS: 30 HOURS**

Unit -1: Microbial Techniques

Confocal microscopy; Use of fluorochromes: (a) Flow cytometry (FACS); (b) Applications of fluorescence microscopy: Chromosome banding, FISH, chromosome painting; sample preparation for electron microscopy,cryofixation, negative staining, shadow casting, freeze fracture, freeze etching.

Unit- 2: Analytical Methods : Radioisotopes: Use in biological research, auto-radiography, pulse chase experiment , Spectrophotometry: Principle and its application in biological research. Chromatography Principle and its application: Paper chromatography, Column chromatography, TLC

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References:

1. Ausubel, F., Brent, R., Kingston, R. E., Moore, D.D., Seidman, J.G., Smith, J.A., Struhl, K. (1995). Short Protocols in Molecular Biology.John Wiley & Sons. 3rd edition.
2. Willey JM, Sherwood LM, and Woolverton CJ.(2013) Prescott, Harley and Klein's Microbiology.9th edition. McGraw Hill Higher Education
3. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms.14th edition. Pearson International Edition

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2.ELECTIVE –EXPANDED ELECTIVE- FIRST B.SC. –II SEMESTER- COMMON FUNGAL AND VIRAL DISEASASE IN HUMAN-G509.2E

Course Learning Outcomes

Outcome 1. Understand the various fungal and viral infections and organs affected.

Outcome 2. Have developed a very good understanding of preventive measures for human infections by fungi and prevention and control of mycoses.

Outcome 3. Gained knowledge of a variety of human viruses. Understanding about the transmission and prevention of viral diseases.

2.ELECTIVE –EXPANDED ELECTIVE- FIRST B.SC. –II SEMESTER- COMMON FUNGAL AND VIRAL DISEASASE IN HUMAN-G509.2E

CREDIT: 1 **TOTAL HOURS: 30 HOURS**

Unit- 1: Fungal diseases: Brief description of each of the following types of mycoses and one representative disease to be studied with respect to transmission, symptoms and prevention Cutaneous mycoses: Tineapedis (Athlete's foot),Subcutaneous:Mycoticmycetoma Systemic mycoses: Histoplasmosis, Opportunistic mycoses: Candidiasis.

Unit-2: Viral diseases: List of diseases of various organ systems and their causative agents. The following diseases with Symptoms, mode of transmission, prophylaxis and control.
Polio, Rabies, Herpes, Hepatitis, Common Arboviral Infections (Brief description): Dengue, Chikungunya, Japanese Encephalitis, Kyasanur Forest Disease (KFD), Influenza Viruses : (Swine flu, Avian flu), & AIDS.

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References:

1. Ananthanarayan R. and Paniker C.K.J. (2009) Textbook of Microbiology. 8th edition, UniversityPress Publication
2. Brooks G.F., Carroll K.C., Butel J.S., Morse S.A. and Mietzner, T.A. (2013) Jawetz, MelnickandAdelberg's Medical Microbiology. 26th edition. McGraw Hill Publication
3. Goering R., Dockrell H., Zuckerman M. and Wakelin D. (2007) Mims' Medical Microbiology. 4thedition. Elsevier.
4. Madigan MT, Martinko JM, Dunlap PV and Clark DP. (2014). Brock Biology of Microorganisms.14th edition. Pearson International Edition

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3.ELECTIVE- INTERDISCIPLINARY- THIRD B.Sc. -III SEMESTER -BASIC CONCEPTS OF FOOD SAFETY-G509.3E

Course Learning Outcomes

Outcome 1. Understand the concepts of food safety and the significance of food safety.

Outcome 2.Have developed a very good understanding of sanitation and hygiene in food sector.

Outcome 3.Gained knowledge of a variety of methods of pest control to ensure food safety.

3.ELECTIVE- INTERDISCIPLINARY- THIRD B.Sc. -III SEMESTER -BASIC CONCEPTS OF FOOD SAFETY-G509.3E

CREDIT: 1 **TOTAL HOURS: 30 HOURS**

UNIT -1:Introduction to Food Safety :

Understanding Food Safety**:** Introduction of Safe Food, Food Quality and Safety Control. Factors Affecting Food Spoilage:FATTOM ,1. Bacteria, Viruses, Parasites, Pesticides, Industrial Chemicals And Toxic Metals, Natural Toxins, Veterinary Drugs, Food Additives and Allergens. Safety: Genetically engineered foods, Bovinesomatotropin, Food irradiation, Pesticide residues in foods,Drinking water quality and Restaurant food safety.

Cleaning and Disinfections**:** Fundamentals of Cleaning:, Functions performed by cleaning agents:Deflocculation or Dispersion, Dissolving, Emulsification, Penetration, Peptization, Saponification, Suspension,Rinsability Water softening,Wetting,Synergism.Acid Type Cleaners :Organic and Inorganic acids,Factors affecting cleaning efficiency, Cleaning Method.Types of Disinfectants or Sanitizers: Physical and Chemical.

UNIT-2 :Hazards to Food Safety:

Types of Hazards: Biological Hazards: Bacteria, Viruses &Parasites, Physical Hazards: Foreign objects, Chemical Hazards: Food Additives, Allergens, Drugs &Pesticides.

Microorganisms and Food Safety: Contamination of Foods by Bacteria ,Fungi, Viruses, Parasites:Sources of Contamination-Plants, Water, Soil, Air, Animals, Handling and processing.

Pest Control & Personal Hygiene:Insect infestation , Cockroaches, Insect destruction, Rodents, Birds, Use of pesticides.Personal hygiene practices: Skin,Hair, Fingers,Finger nails, Eye, Mouth, Nose,Jewelry , Hand Washing and Disinfection, Factory Clothing,Control of indirect contamination from people .

References:

1.S.N. Mahindru , 2004.Food Safety: Concept and Reality. APH Publishing Corporation .

2.CAROL BALLARD, 2009. Food Safety.Gareth Stevens Publishing LLLP.

3.FrankYiannas, 2010.Food Safety Culture: Creating a Behavior-Based Food Safety Management System (Food Microbiology and Food Safety) [Paperback].Springer**.**

4.Ronald H. Schmidt, Gary E. Rodrick. 2003. Food Safety Handbook. Wiley

5.ISO FSMS,22000-2005 Standard.

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4. ELECTIVE -OPEN ELECTIVE -THIRD B.Sc. -IV SEMESTER -SOLID WASTE MANAGEMENT-G509.4E

Course Learning Outcomes

Outcome 1. Understand the concepts categories of solid waste

Outcome 2.Have developed a very good understanding of types of e-waste.

Outcome 3.Gained knowledge of a variety of methods of safe disposal of solid and e-waste.

4. ELECTIVE -OPEN ELECTIVE - IV SEMESTER -SOLID WASTE MANAGEMENT-G509.4E

CREDIT: 1 **TOTAL HOURS: 30 HOURS**

UNIT-1.Definition of a Solid Waste, Categories of Wastes , Municipal Solid Waste, Hazardous Waste ,Industrial, Waste. Medical Waste, Universal Waste, Electronics Waste Construction and Demolition Debris .Radioactive Waste Mining Waste, Agricultural Waste Generation of MSW, Solid Waste Management Source Reduction Recycling. Incineration Land Disposal. **Common Components in Municipal Solid Waste**

Electronics Waste: Introduction : Major Types of Electronic Equipment Computers, Cathode Ray Tube Computer Monitors Computer Desktop Telecommunications Equipment (Telephones, Fax Machines Mainframe Computers and High-End Telecommunications Equipment, Televisions with CRTs, Flat Screen Televisions, Telephones, Hazards of e-Waste: Cathode Ray Tubes, Computers Wastes Hazardous Waste ,EPA CRT Rule, Boards, Electronics Recycling Residential Collection Programs ,Reuse and Resale, Deconstruction, Processing and Recycling e-Waste Components CRT Glass Metals Circuit Boards. Central Processing Units , Computer Peripherals

UNIT-2

Composting MSW, Introduction ,Composting, Overview of the Composting Process, Role of Microorganisms in Composting , Factors Affecting the Composting Process: Preprocessing of the Feedstock ,Environmental Factors, C:N Ratio ,Aeration, Moisture Content, Temperature, PH, Composting Stage Turned Piles Turned Windrow, Aerated Static Piles, In-Vessel Systems Stage Environmental Concerns during Composting Air Quality, Odor Noise, Toxins within the Pile, Leachate, Runoff Litter.

REFERENCES:

WASTE MANAGEMENT PRACTICES Municipal, Hazardous, and Industrial, Industrial, Second EditionJohn Pichtel , CRC Press Taylor & Francis Group6000 Broken Sound Parkway NW.

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Teaching learning processes:

The teaching learning processes incorporate a variety of modes and a regular use of ICT. These
are listed below:

1. **Classroom Teaching** for topics which are intensely information-based. This a very regular feature of all the courses in Microbiology

2. **Power Point slides** for topics which involve information related to intricate biological pathways such as metabolic pathways in bacteria and other microorganisms. Use of Power Point presentations are also made whenever the lectures are to be summarized in a crisp and pointwise manner to highlight salient / important conclusions from the topics.

3. **Classroom Discussions** are a regular feature while teaching. The students are drawn into impromptu discussions by the teacher during the process of teaching.

4. **Video Displaying**, both real-time and animations, are used for topics which require 3D dimensional viewing of the biological mechanisms to drive the point home. These have proved to be very helpful while teaching concepts of molecular biology like DNA replication, transcription and translation. These are also used to convey complexities of antigen-antibody interactions and generation of antibody diversity during the teaching of Immunology.

5. **Model Making** is also used especially for understanding and building a perception of the students for the structures of viruses which cannot be seen by a light microscope and canbe seen only under expensive equipment like electron microscopes.

6. **Laboratory Practical** are an integral part of every course included in UG programme inMicrobiology. The is also a daily affair for UG students of Microbiology.

7. **Problem Solving** is encouraged during the laboratory work.

8. **Group Activity** as well as discussions with the laboratory supervisor/ among the studentsthemselves/ Mentor is also encouraged during laboratory work.

9. **Project Work** is included in the programme where students work individually or in groups to design experiments to solve/answer a problem suggested by the Mentor or identified by the students in consultation with the Mentor. The students are mentored regularly during the duration the project is in progress.

10. **Presentations by the Students** are regularly done. The students are mentored in presentation of data, interpretation of data and articulation with the students/teachers/Research Scholars during their presentation.

11. **Presentation by Experts** in different specialties of Microbiology are arranged to broaden the horizons of the students.

12. **Interaction with Experts** is also encouraged during/after presentations to satisfy/ignite curiosities of the students related to developments in the different areas of Microbiology.

13. **Visit to Industries/Laboratories** related to Microbiology like fermentation, food, diagnostics etc. are organized to acquaint the students with real-life working environments

of the professional microbiologists with a view to broaden their perspective of the subject of Microbiology

8. Assessment Tasks:

It is important that the students of UG Microbiology program achieve the desired results in terms of the learning outcomes to be professionally sound and competitive in a global society. Achieving the desired learning outcomes is also imperative in terms of job employment leading to a happy and prosperous individual further leading to a happy and prosperous family and thereby a happy and prosperous society or nation. The assessments tasks are pivotal to get an authentic feedback for the teaching learning process and for mid-coursecorrections and further improvements in future. The assessment tasks are carried out at various stages of the duration of the UG Microbiology programme like Mid-term assessments, End-term assessments, Semester examinations, Regular assessments, viva-voce etc.

The assessment tasks are listed below:

1. **Multiple Choice Questions (MCQ)** are one of the predominant form of assessment tasks. This task is used during all kinds of term and semester examinations.

2. **Short-AnswerQuestions**during term and semester examinations are used to assess the ability of the student to convey his thoughts in a coherent way where prioritization of the information in terms of their significance is tested.

3. **Surprise Quizzes** are regularly used during continuous assessment while the teaching learning process is continuing which prepares the student to quickly recall information or quickly analyze a problem and come up with proper solutions.

4. **Visual/Pictorial Quizzes** are used to sharpen the comprehension of the students after looking at all the components of a system.

5. **Impromptu Opinions** on microbiological problems are sought from student during regular teaching learning which help them to think quickly in a given context. This help build their ability to come up with solutions to problems which the students might not have confronted previously.

6. **Problem Solving** question are generally given during the laboratory work.

7. **Data Interpretation** is also another assessment task which is used to develop analytical skills of the students. This assessment is used during laboratory work as well as during conduction of project work.

8. **Analytical Skills** are assessed during work related to several experiments like enzyme kinetics, growth of bacteria and bacteriophages, mutation frequencies.

9. **Paper/ Project presentations** are used to assess the articulation skills of the student. These are carried out both during the duration of the teaching learning processes as well as during end-Semester examinations.

10. **Report Writing** is used to assess the keenness of the students for details related to microbiology while visiting laboratories / industries as students invariably are required to submit a report after such visits.

11. **Assignment Writing** are used to assess the writing abilities of the students during midterm vacations.

12. **Viva-voce** during the laboratory working hours and during laboratory examination are used to assess the over-all knowledge and intelligence of the students.

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