GOA UNIVERSITY
Taleigao Plateau, Goa 403 206

R E V I S E D M I N U T E S

of the 11th Meeting of the

X ACADEMIC COUNCIL

Day & Date

Friday, 9th December, 2022

Time

10.00 a.m.

Conference Hall
Administrative Block
Goa University

	The House authorized the Vice-Chancellor to approve the same on behalf of the Academic Council. **(Action: Assistant Registrar Academic – PG)**
D 3.27	**Minutes of the Board of Studies in MBA (Financial Services) meeting held on 08.08.2022.** The Academic Council approved the minutes of the Board of Studies in MBA (Financial Services) meeting held on 08.08.2022 with the following suggestions: 1. The entire content of the syllabus to be shown in a proper standard format having details of Number of hours, Credits, Prerequisites, Course objectives, Learning outcomes, Pedagogy, References/Readings, year of publication etc and to be listed in the alphabetical order. 2. It was suggested that the Need for the Course and Description of the Course indicated under the syllabus to be removed/deleted. **(Action: Assistant Registrar Academic – PG)**
D 3.28	**Minutes of the Board of Studies in Geography meeting held on 21.10.2022.** The Academic Council approved the minutes of the Board of Studies in Geography meeting held on 21.10.2022 with the following suggestions: 1. Prerequisites for the PG Courses to be included. 2. Texts bold under 'Learning Outcomes' to be un-bold. 3. New Reference books for the Course to be added/identified. 4. Prerequisite for Research Methodology Ph.D. course work to be deleted. 5. Research and Publication ethics Ph.D. course work was not approved, as common syllabus was already approved by Board of Studies in Interdisciplinary and Transdisciplinary studies. **(Action: Assistant Registrar Academic – PG)**
D 3.29	**Minutes of the Board of Studies in Psychology held on 22nd October & 26th October, 2022.** The Academic Council approved the minutes of the Board of Studies in Psychology held on 22nd October & 26th October, 2022 with the suggestion to recommend at least one additional Elective Course to be offered in Semester IV. The House authorized the Vice-Chancellor to approve the same on behalf of the Academic Council. **(Action: Assistant Registrar Academic – PG)**
D 3.34	**Minutes of the Board of Studies in Microbiology meeting held on 05.11.2022.** The Academic Council approved the minutes of the Board of Studies in Microbiology meeting held on 05.11.2022 recommending the syllabus with the following suggestions and requested to submit the revised copy in January 2023: 1. Year of publication for the reference books to be added. 2. Number of hours for the Course to be clearly specified. 3. Question paper pattern was not approved, it was reiterated that the Question paper pattern shall be designed by the teachers teaching the Course. **(Action: Assistant Registrar Academic – PG)**

X AC- 11
09-12-2022

GOA UNIVERSITY
Taleigao Plateau, Goa 403 206

F I N A L A G E N D A

For the 11th Meeting of the

X ACADEMIC COUNCIL

Day & Date

Friday, 9th December, 2022

Time

10.00 a.m.

Venue
Conference Hall
Administrative Block
Goa University

	i) Recommendation regarding general academic requirements in the Programmes of University or affiliated Colleges. - NIL **PART E** i) Recommendation of text books for the courses of study at the undergraduate Level NIL ii) Recommendation of text books for the courses of study at the post –graduate level. – NIL **Part F.** Important points for consideration/approval of Academic Council i. The important points/recommendations of BoS that require consideration/approval of Academic Council (points to be highlighted) as mentioned below a) NIL b) NIL ii. The declaration by the Chairperson that the minutes were readout by the Chairperson at the meeting itself. Date: 31/10/2022 Sd/- Place: Goa University Signature of the Chairperson **Part G**. The Remarks of the Dean of the Faculty i. The minutes are in order. ii. The minutes may be placed before the Academic Council with remarks if any. iii. May be recommended for approval of Academic Council. iv. Special remarks if any. Date: 31/10/2022 Sd/- Place: Goa University Signature of the Dean **(Back to Index)**
D 3.34	**Minutes of the Board of Studies in Microbiology meeting held on 05.11.2022.** **Part A** i) Recommendations regarding courses of study in the subject or group of subjects at the under-graduate level. Not in the agenda ii) Recommendations regarding courses of study in the subject or group of subjects at the Post-graduate level. **1.Course structure of M.Sc. Microbiology Part 2 for Semester 3 and Semester 4 as per 80 credits - (Annexure I Refer page No. 1213)** **2. Course content of M.Sc. Microbiology Part 2 for Semester 3 and Semester 4 as per 80 credits - (Annexure II Refer page No. 1214)** **Part B** (i) Scheme of examinations at under-graduate level. Not in the agenda (ii) Panel of examiners for different examinations at the under-graduate level. (a) Panel of Examiners for SEA papers for Semester V and VI of T.Y. B.Sc. Microbiology - (Sealed Envelope)

(b) Scrutiny of applications of teachers for identifying as paper setter and examiner for T.Y. B.Sc. Microbiology as per OA-11:

a) Applications from 5 teachers of P.E.S's.R.S.N. College of Arts, & Science, Farmagudi teaching B.Sc. were scrutinized as per OA-11. Among the 5 teachers, FOUR (4) teachers fulfil the requirements and therefore recommended by BOS as examiners for including in the panel for paper setter and examiner. Among the 5 teachers, ONE (1) teacher does not fulfil the requirement and therefore candidature was rejected by the BOS. (Sealed envelop).

b) Applications from 2 teachers of Government College of Arts, Science and Commerce Khandola teaching B.Sc. were scrutinized as per OA-11. Among the 2 teachers, ONE (1) teachers fulfil the requirements and therefore recommended by BOS as examiner for including in the panel for paper setter and examiner. Among the 2 teachers, ONE (1) teacher does not fulfil the requirement and therefore candidature was rejected by the BOS. (Sealed envelop)

(iii) Scheme of examinations at the post-graduate level.

a) Question paper formats for SEA of M.Sc. Microbiology - Annexure III (Refer page No. 1255)

(iv) Panel of Examiners for different examinations at post-graduate level.

a) Panel of Examiners for SEA of Core papers (Theory) for Semester 1 M.Sc. Part1 Microbiology - (Sealed envelop)

Part C

a) Recommendations regarding preparation and publication of selection of reading material in the subject or group of subject or group of subjects and names of persons recommended for appointment to make the selection. Not in the agenda

Part D

a) Recommendations regarding general academic requirements in the Departments of University or affiliated colleges. Not in the agenda

b) Recommendations of the Academic Audit Committee and status thereof: Not in the agenda

Part E

a) Recommendations of the text books for the courses of study at the undergraduate level: Not in the agenda

b) Recommendations of text books for the courses of study at the post-graduate level: **Recommended text books and reading materials are listed along with the course content of M.Sc. Microbiology Part 2 for Semester 3 and Semester 4 as per 80 credits.**

Part F

Important points for consideration/approval of Academic Council:

(i) The important points/recommendations of BOS that require consideration/ approval of Academic Council (points to be highlighted) are mentioned below:

(a). Course structure of M.Sc. Microbiology Part 2 for Semester 3 and Semester 4 as per 80 credits.

(b). Course content of M.Sc. Microbiology Part 2 for Semester 3 and Semester 4 as per 80 credits.

(c). Panel of Examiners for SEA papers for Semester V and VI of T.Y. B.Sc. Microbiology - (Sealed Envelope)

(d). Scrutiny of applications of teachers for identifying as paper setter and examiner for T.Y. B.Sc. Microbiology as per OA-11:

(d)(a) Applications from 5 teachers of P.E.S's.R.S.N. College of Arts, & Science, Farmagudi teaching B.Sc. were scrutinized as per OA-11. Among the 5 teachers, FOUR (4) teachers fulfil the requirements and therefore recommended by BOS as examiners for including in the panel for paper setter and examiner. Among the 5 teachers, ONE (1) teacher does not fulfil the requirement and therefore candidature was rejected by the BOS. (Sealed envelop)

(d)(b) Applications from 2 teachers of Government College of Arts, Science and Commerce Khandola teaching B.Sc. were scrutinized as per OA-11. Among the 2 teachers, ONE (1) teachers fulfil the requirements and therefore recommended by BOS as examiner for including in the panel for paper setter and examiner. Among the 2 teachers, ONE (1) teacher does not fulfil the requirement and therefore candidature was rejected by the BOS (Sealed envelop)

(e). Question paper formats for SEA of M.Sc. Microbiology.

(f). Panel of Examiners for SEA of Core papers (Theory) for Semester 1 M.Sc. Part1 Microbiology - (Sealed envelop)

(g). Recommended text books and reading materials are listed along with the course content of M.Sc. Microbiology Part 2 for Semester 3 and Semester 4 as per 80 credits

(h). Syllabus of "Paper - 1 - Research Methodology" for Ph.D. in Microbiology - **Annexure IV (Refer page No. 1257)**

(ii) The declaration by the Chairman, that the minutes were read out by the Chairman at the meeting itself.

Sd/-
Signature of the Chairperson

Date: 05.11.2022
Place: Microbiology Classroom 1, Science Block E, SBSB.

Part G The remarks of the Dean of the faculty

(i) The minutes are in order.
(ii) The minutes may be placed before the Academic Council with remarks if any.
(iii) May be recommended for approval of Academic Council.
(iv) Special remarks if any.

Sd/-
Dean,School of Biological Sciences and Biotechnology

Date : 21/11/2022
Place: Office of Dean, School of Biological Sciences and Biotechnology

D 3.34 Minutes of the Board of Studies in Microbiology meeting held on 05.11.2022.

Annexure I

Course structure of M.Sc. Microbiology Part 2 for Semester III and Semester IV as per 80 credits

M.Sc. Microbiology - Course structure

COURSE STRUCTURE

CODE	COURSE	CREDIT(S)		Contact Hours
		Theory	Practical	
	Semester III			
	Generic Elective courses (GE)			
MITG-501	Microbial Bioprospecting [T]	4	-	60
MITG-502	Pharmaceutical Microbiology [T]	4	-	60
MITG-503	Genetic Engineering [T]	3	-	45
MIPG-503	Genetic Engineering [P]	-	1	30
MITG-504	Food Microbiology [T]	3	-	45
MIPG-504	Food Microbiology [P]	-	1	30
MITG-505	Medical Microbiology and Epidemiology [T]	3	-	45
MIPG-505	Medical Microbiology and Epidemiology [P]	-	1	30
MITG-506	Marine Microbiology [T]	3	-	45
MIPG-506	Marine Microbiology [P]	-	1	30
MITG-507	Entrepreneurship in Microbiology	4	-	60
MIPG-508	Field Trip to industries/institutions in Goa	-	1	30
MIPG-509	Field Trip to industries/institutions across India	-	1	30
MIPG-510	Field Trip to coastal ecosystems and allied industries	-	1	30
MIPG-511	Internship in Industry/Institution	-	2	60
	Semester III			
	Research Specific Elective courses (RSE)			
MITR-501	Research Methodology and Advanced Biostatistics	4	-	60
MITR-502	Microbial Technology [T]	3	-	45
MIPR-502	Microbial Technology [P]	-	1	30
MITR-503	Extremophilic Microorganisms [T]	3	-	45
MIPR-503	Extremophilic Microorganisms [P]	-	1	30
MITR-504	Aquatic Virology [T]	2	-	30
MITR-505	Introduction to Bioinformatics [T]	2	-	30
	Semester IV			
	Research Specific Elective courses (RSE)			
MITR-506	Marine Microbial Interactions [T]	3	-	45
MIPR-506	Marine Microbial Interactions [P]	-	1	30
MITR-507	Medical Virology [T]	3	-	45
MIPR-507	Medical Virology [P]	-	1	30
MIPD-501	Discipline Specific Dissertation	-	16	-

Under GE/RSE Optional Courses - theory course is a prerequisite for respective practical course.

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Annexure II

Programme: M.Sc. (Microbiology)
Course Code: MITG-501
Title of the Course: MICROBIAL BIOPROSPECTING [T]
Number of Credits: 4, Theory
Contact hours: 60
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students should have a basic understanding of biomolecules.	
Objective:	● To describe the concept of bioprospecting and applications of microbes for obtaining various biologically significant biomolecules. ● To discuss the applications of biomolecules derived from microorganisms in industries and medical field.	
Content:		
1.		**(20)**
1.1	Introduction to bioprospecting & bioactive molecules from microorganisms. Characteristics of econiches to obtain microorganisms with novel properties and microorganisms producing novel bioactive molecules: geothermal springs (*Thermus aquaticus*), hydrothermal vents (*Pyrococcus furiosus*), polar regions (*Methanogenium frigidum / Polaromonas*), mining areas (ectomycorrhizae & *Pseudomonas*), desert (*Chroococcidiopsis / Phormidium*); salt pans (*Halobacterium salinarum*); acidic (*Acidithiobacillus ferrooxidans*), alkaline (*Bacillus alcalophilus / Nesterenconia*), seaweed / sponge associated microbes. Cartagena protocol, Bonn declaration on access and benefit-sharing (ABS).	**12**
1.2	**Culture dependent bioprospecting:** enrichment procedures; plating on selective media. Function based screens (proteomics and metabolomics). **High throughput screening strategy:** extinction culture technique; culturomics; optical tweezers; FACS.	**8**
2.		**(22)**
2.1	**Culture independent bioprospecting:** Metagenomics (DGGE, phylochip analysis; metagenomic library-functional screening and sequence-based screening); metatranscriptomics (ISRT-FISH; MAR-FISH);	**15**

	metaproteomics; metabolomics; microbiome; microbial genome guided bioprospecting / genome mining (GALAXY platform). Substrate induced gene expression screens (SIGEX) - catabolic gene expression screens. Systematic evolution of ligands by exponential enrichment (SELEX); microarrays. Introduction to predictive functional analyses (Tax4Fun2, PICRUSt)	
2.2	**Directed evolution for bioprospecting:** Metabolic pathway engineering; Assembly of designed oligonucleotides; site directed mutagenesis. Incorporation of metabolic pathway from eukaryotes and archaea into bacteria. Indigo production, ascorbic acid production. Artimisinin synthesis through synthetic biology.	**7**
3	**Bioactive and industrially important biomolecules: e**nzymes – extremozymes, food additives/ quality enhancers; pigments– food colorants, fabric dyes; biopolymers – biodegradable plastics: PHAs; EPS, biosurfactants and bioemulsifiers.; Pharmaceuticals- Antimicrobials, therapeutics, antitumour agents, drug carriers, quorum quenching molecules; nutraceuticals - PUFAs, β-carotenes, antioxidants; cosmeceuticals & medicine; probiotics - probiotic bacteria in aquaculture/human heath; microbial lectins - roles and applications; biofuel. Microbial natural product libraries/data bases.	(**18)**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	● Barcelo, D, Analysis of Marine samples in search of bioactive compounds. Comprehensive analytical chemistry. Elsevier. ● Bhaumik, DS, & Rawat, DS, Bioactive marine natural products. Springer. ● Borkar, S, Bioprospects of coastal eubacteria. Springer Publishers. ● Bramhachari, G, Biotechnology of Microbial enzymes: Production, biocatalysts and industrial applications. Academic Press. ● Bull, AT, Microbial Diversity and Bioprospecting. ASM Press. ● Colin, M, Marine microbiology: Ecology and applications. Garland science. ● Du, G-H, Natural small molecules drugs from plants. Springer. ● Gupta, VK, Sharma, GD, Tuohy, MG, Gaur, R, The handbook of Microbial bioresourses. CABI. ● Hernandez-Ledesma, B, & Herrero, M, Bioactive compounds from marine foods, plant and animal sources. Wiley Blackwell. ● Madigan, MT, Bender, KS, Buckley, DH, Sattley, WM, Stahl, DA, Brock biology of microorganisms. Pearson. ● Medina-Framco, JL, New approaches for discovery of pharmacologically active natural Compounds. MDPI. ● Meena, SM, & Naik, MM, Advances in Biological Science Research: a practical approach. Elsevier	

	• Naik, MM, & Dubey, SK, Marine pollution and Microbial remediation. Springer. • Paterson, R & Lima, N, Bioprospecting: Success, potential and constraints. Springer. • Ravi, I, Baunthiyal, M, & Saxena, J, Advances in Biotechnology. Springer. • Reddy, SM, Charya, MAS, & Girisham, S, Microbial diversity: Exploration and bioprospecting, Scientific Publishers. • Suleria, HAR & Barrow, C, Bioactive compounds from plant origin: Extraction, applications and potential health benefits. CRC press. • Thomas, TR, Kavlekar, DP, & Lokabharathi, PA, Marine drugs from sponge-microbe association: a review. Marine Drugs, 8: 1417-1468. • Willey, JM, Sherwood, LM, & Woolverton, CJ, Prescott's Microbiology. McGrawHill Education.	
Learning out comes	• To analyse and produce novel bioactive molecules from microorganisms. • To assess industrial potential of microorganisms from different econiches. • To design directed evolution for bioprospecting of molecules with desire properties. • To evaluate culture dependent and culture independent techniques for bioprospecting of microorganisms with unique properties from diverse econiches.	

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Programme: M.Sc. (Microbiology)
Course Code: MITG-502
Title of the Course: PHARMACEUTICAL MICROBIOLOGY [T]
Number of Credits: 4, Theory
Contact hours: 60
Effective from Academic Year: 2022-23

Prerequisites:	Students should have basic knowledge of industrial microbiology, fermentation technology, maintenance and identification of cultures.	
Objectives:	• To understand the role and importance of microorganisms in pharmaceutical industries. • To summarize the concept of aseptic handling and preparation of sterilized pharmaceuticals processing. • To examine the quality maintenance and manufacturing of pharmaceutical formulations. • To demonstrate microbiological standardization of pharmaceuticals.	

Content:		
1.	**Introduction to Pharmaceutical Microbiology**	**(20)**
1.1	**History of Pharmaceutical Microbiology:** Contributions of Louis Pasteur, Edward Jenner, Alexander Fleming, Joseph Lister, Paul Ehrlich, Selman Waksman Milestones and developments in pharmaceutical microbiology History of profession of Pharmacy in India in relation to pharmacy education.	
1.2	**Organization structure and layout of a pharmaceutical Industry:** Organizational structure and different departments in pharmaceutical industries, Location and layout of a pharmaceutical plant, Features of a good layout. **Good Practices:** Good Manufacturing Practices (cGMP) and Good Microbiology Laboratory Practices in a pharmaceutical industry.	
1.3	**Regulatory approvals for Pharmaceutical Industry Certification (Sections relevant to microbiology):** Central Drugs Standard Control Organization (CDSCO), USFDA, MHRA (Medicines and Healthcare Products Regulatory Agency), PGA (Pharmacy Guild of Australia), WHO, The pharmacy Act, Drugs and Cosmetics Act, FSSAI, The Food Safety and Standards Act. **Guidance Documents for a Pharmaceutical Industry:** Indian Pharmacopoeia, British Pharmacopoeia/ European Pharmacopoeia, US Pharmacopoeia, Japan Pharmacopoeia **Documentation and Data Integrity:** ALCOA Principle, and ALCOA Plus.	
1.4	**Biosafety Levels in Pharmaceutical Industries:** Biosafety cabinets, Working of biosafety cabinets, Protective clothing, Specification for BSL1, BSL-2, BSL-3, and BSL-4, Importance of biosafety in manufacturing pharmaceutical products.	
1.5	**Discarding biohazardous waste:** Methodology of Disinfection, Autoclaving and Incineration.	
2.	**Microbiological Quality Control and Sterility Assurance**	**20**
2.1	Concepts of Qualification, Validation & Calibration of equipment and instruments in microbiology laboratory. **Classes and types of pharmaceutical products:** Sterile and non-sterile formulations. **Sampling practices:** General principles, sampling of raw material, intermediate, finished products, primary packaging material, water, compressed air, and nitrogen gas.	

	Environmental monitoring: Utilities, settle plate technique, air sampling, surface monitoring, and monitoring of personal gear. **Testing of utilities:** compressed air, nitrogen.	
2.2	**Microbiological methods for pharmaceutical analysis:** **Media**: Preparation, Growth promoting and inhibitory properties of media, Sample preparation. **Enumeration:** Standard plate count, Direct microscopic counts, membrane filtration technique, most probable number, turbidimetric methods, Bioburden Test. **Microbiological examination of non-sterile products:** Pour plate, Membrane Filtration, MPN, Tests for specific microorganisms - Total Aerobic Microbial Count (TAMC), Total Yeast and Mold Count (TYMC), Tests for *E. coli*, *Salmonella, Pseudomonas aeruginosa,* and *S. aureus*. **Sterility Testing:** Membrane Filtration and Direct Inoculation Method. **Rapid Microbiological Methods**: ATP bioluminescence, Impedance, and Chemiluminescence. **Antimicrobial Effectiveness Testing:** Bioassay	
2.3	**Advanced Identification systems of Microorganisms:** Automated Microbiological Identification Systems (BBL crystal identification system, BioMerieux Vitek, and Biolog). **Culture maintenance:** Basic culture and preservation methods, Lyophilization, Cryopreservation.	
2.4	**Endotoxins and Pyrogens:** LAL Assay. Principles of Gel Clot Method, chromogenic end-point method, Kinetic turbidimetric assay, and Kinetic chromogenic assay.	
2.5	**Sterilization Methods:** Pharmaceutical products, Autoclave Validation. Manufacturing of aseptically filled and terminally sterilized products. **Testing of disinfectants:** Surface challenge test	
3.	**Drug Development**	**(10)**
3.1	**Preclinical development:** Toxicity testing – acute, sub-acute and chronic toxicity	
3.2	Clinical development: Clinical trials (I, II, III and IV), Ethics in pharmaceutical industries.	
3.3	**Pharmacokinetics:** Absorption Distribution Metabolism Excretion (ADME) and Bioavailability studies	
3.4	Role of FDA in drug development (INDA, NDA)	

3.5	Carriers and delivery systems, targeted drug delivery, sustained release	
4.	**Production and Applications of Microbially Derived Pharmaceutical Agents:**	**(10)**
4.1	**Vaccines:** AIDS/ Malaria/ Covid-19	
4.2	**Antimicrobial:** Streptomycin (antibacterial), Atazanavir (antiviral), Artimisinin (antiprotozoal)	
4.3	Pre-biotics or Pro-biotics	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	• Anjaneyulu Y, & Marayya R, Quality Assurance & Quality Management in Pharmaceutical Industry, Pharma Book Syndicate. • Baird R.M., Hodges N.A. & Denyer S.P. Handbook of Microbiological Quality Control in Pharmaceutical and Medical Devices, Taylor and Francis Inc. • D'Souza J., Killedar S.G., Biotechnology and Fermentation Process, Nirali Prakashan. • Hugo W.B. & Russel A.D., Pharmaceutical Microbiology, Blackwell Scientific publications, Oxford London. • Jain N.K., Pharmaceutical Product Development, CBS Publication. • Kokare C. Pharmaceutical Microbiology, Nirali Prakashan. • Lachman L., Lieberman H.A., Kanig J.L., The Theory and Practice of Industrial Pharmacy, Varghese Publishing House. • Loftus B.T. & Nash R.A., Pharmaceutical Process Validation, Drugs and Pharmaceutical Science Series, Volume 23, Marcel Dekker Inc. • Shargel L. & Andrew B.C., Applied Biopharmaceutics & Pharmacokinetics, McGraw Hill Education. • Latest Pharmacopeias, Acts, and Guidelines (as listed in the syllabus)	
Learning Outcomes	• To integrate and connect the importance of microbiology in pharmaceutical • To apply the knowledge of good manufacturing practices. • To appraise, evaluate and implement the rules and regulations pertaining to microbiological standards in industry. • To create microbially derived pharmaceutical product.	

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Programme: M.Sc. (Microbiology)
Course Code: MITG-503
Title of the Course: GENETIC ENGINEERING [T]
Number of Credits: 3, Theory

Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	Knowledge of bacterial and animal genetics, basic molecular biology and microbiology.	
Objective:	● Introduces the fundamental and state-of the-art tools and techniques required for molecular cloning and protein expression. ● Elaborates the applications of genetic engineering in agriculture, therapeutics, industry and bioremediation.	
Content:		
1.	**Introduction to genetic engineering and tools involved in genetic manipulation**	**(20)**
1.1	**Introduction to genetic engineering**	
1.2	**Tools and techniques involved in genetic manipulation**	
A.	DNA modifying enzymes: restriction endonucleases, exonucleases, DNA ligases (T4 DNA Ligase and *E. coli* DNA ligase), Terminal DNA transferase, DNA Polymerases (Taq, Amplitaq, Vent, Exo-vent, Pfu, T4 etc), Reverse transcriptase, T4 polynucleotide kinase, Alkaline phosphatase, S-1 Nuclease, Mung bean nuclease, RNases.	
B.	Gene cloning systems/Hosts: Gene cloning in *E. coli*, *Bacillus subtilis*, *Saccharomyces cerevisiae* and other microbial eukaryotes	
C.	Cloning vectors: Plasmids (Col plasmid, pUC19, pBR322 and their derivatives), λ phage based vectors, cosmid vectors, phasmid vectors, shuttle vectors, high capacity cloning vectors (BAC and YACs).	
D.	Sequencing vectors: pUC 19 and M-13 phage vector.	
E.	Manipulation of gene expression in Prokaryotes; Strong and regulatable promoters (lac, trp, tac, SV 40, T7, T3) for induction of gene expression; Prokaryotic expression vectors – pET, pGEX-2T and others; Fusion proteins; Genetic manipulation to increase recombinant protein stability and secretion	
F.	Construction of recombinant DNA molecule and its transfer to appropriate host (bacteria/yeast/plant cell/animal cell) using suitable techniques: transformation, electroporation, transfection, gene gun.	
G.	Gene cloning strategies: Cohesive end and blunt end cloning, universal TA cloning, shotgun cloning and directed cloning; genomic DNA cloning, reverse-transcriptase mediated synthesis of cDNA and cDNA cloning, screening of gene libraries for recombinant clones.	
H.	Other recombinant DNA techniques: Use of radioactive and non-radioactive nucleotides for DNA probe preparation and detection of hybrids, gel retardation assay, restriction mapping, RFLP, PCR, real time PCR, microarray, DNA sequencing using Sanger's dideoxy chain termination method, capillary sequencing and next-generation sequencing; chromosome walking, hybrid release and hybrid arrest translation to screen clones, site directed mutagenesis.	

2.	**Genetic Engineering in Biology, forensics and medicine**	**(10)**
A.	Screening of genetic diseases using DNA probes (DNA diagnostics)	
B.	Production of recombinant proteins and drugs (insulin, tissue plasminogen activator, erythropoietin, human growth hormones, Antibodies (including bispecific antibodies), vaccines, interferons, DNA vaccines: merits and demerits; Edible vaccines: merits and demerits.	
C.	Application of recombinant DNA technology in solving parental disputes and criminal cases (DNA fingerprinting).	
3.	**Genetic Engineering in Agriculture**	**(05)**
A.	Development of transgenic crops resistant to insect pests, bacterial, fungal and viral pathogens.	
B.	Strategies to develop transgenic crops and horticulture plants using various tools of recombinant DNA technology: Development of Bt Brinjal, Golden Rice and *flavr savr* tomato.	
C.	Importance of *Agrobacterium tumefaciens* in genetic manipulation of plants (Role of Ti plasmids), Role of *Bacillus thuringiensis* (*Bt* genes) to develop insect/pest resistant crops.	
D.	CRISPR-Cas mediated gene editing for improvement of farm animals and crops	
4.	**Applications of Genetic Engineering in Industry**	**(05)**
A.	Genetic manipulation of microbes to over-produce industrially valuable enzymes.	
B.	Production of recombinant pharmaceuticals, nutraceuticals and other biomolecules.	
C.	Production of fermentation products using recombinant organisms.	
D.	Production of microbial SCPs.	
5.	**Genetic engineering of microbes for biomonitoring, bioremediation and biohydrometallurgy.**	**(05)**
	Genetic manipulation of microbes to develop biosensors for monitoring toxic organic and inorganic pollutants, bioremediation of xenobiotics, toxic heavy metals and organometals, Biohydrometallurgy for recovery of precious metals	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	● *Brown, T.A., Gene cloning and DNA Analysis: An Introduction, Blackwell Science.*	
Latest editions	● *Davis, L. G., Dibner, M. D. & Battey, J. F., Basic Methods in Molecular Biology, Elsevier.*	
	● *Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier.*	
	● *Glick, B.R., Pasternak, J.J. & Patten, C.L., Molecular Biotechnology: Principles and Applications of Recombinant DNA, ASM Press.*	
	● *Glover, D. M., Gene cloning: The Mechanics of DNA Manipulation, Springer-Science+Business Media, B. V.*	

	• *Green, M.R. & Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York.*	
	• *Grinsted, J. & Bennett, P.M., Methods in Microbiology, Vol. 21, Plasmid Technology, Academic Press.*	
	• *Old, R.W. and Primrose, S.B., Principles of Gene Manipulation: An introduction to Genetic Engineering, University of California Press.*	
	• *Williamson, R., Genetic Engineering, Volumes 4-7, Academic Press.*	
Learning Outcomes	• Apply tools and techniques involved in molecular cloning. • Formulate strategies for effective protein expression in prokaryotic hosts. • Evaluate the applications of genetic engineering techniques in medical and forensic fields • Appraise the potential of GMOs in industry and bioremediation.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPG-503
Title of the Course: GENETIC ENGINEERING [P]
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	Theoretical understanding of chromosomal DNA, plasmid DNA, selection media and preparatory microbiology.	
Objective:	• Hands-on experience of the workflow of a typical genetic engineering experiment.	
Content:		**(30)**
1.	Restriction mapping of bacterial plasmid.	
2.	Assessment of DNA ligation activity of T4 DNA ligase	
3.	Preparation of competent cells and transformation of *E. coli* host with plasmid DNA using heat shock method and electroporator; confirmation of positive transformants by blue-white screening.	
4.	Demonstration of insertional inactivation of marker gene.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	*As given under Theory Course **MITG-503***	
Learning Outcomes	• Apply the technique of restriction mapping; • Clone a desired gene in a prokaryotic system. • Interpret experimental results on the basis of gel profiles. • Design experiments for obtaining specific outcomes in gene cloning and expression.	

Programme: M.Sc. (Microbiology)
Course Code: MITG-504

Title of the Course: FOOD MICROBIOLOGY [T]
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students know the nutritional quality of food to microorganisms and presence and types of different microorganisms in the food.	
Objective:	● Student will understand the beneficial and harmful association of microorganisms with the food. ● Student will learn prospective applications of the microorganisms in food industry. ● Student will learn the different methods of controlling the type and number of microorganisms in the food as per requirement. ● Student will gain the knowledge about the role of food regulatory bodies and measures of food safety and quality control.	
Content:		
1.	**Microbial Food Spoilage and Food Preservation**	**(15)**
A.	Predictive food microbiology - Types of foods and their spoilage.	
B.	Factors affecting the growth and survival of microorganisms in foods: Intrinsic, Extrinsic.	
C.	Preservation methods: Heat processing, low temperature storage, control of water activity, irradiation, high pressure processing, modified atmospheres, preservatives: chemicals, natural organic molecules (nisin).	
2.	**Microbiology in Food Processes**	**(15)**
2.1	**Fermented and processed foods**	
A.	Indian fermented foods.	
B.	Oriental mold modified foods.	
C.	Fermented meats and fish: - sausage, fish sauce.	
D.	Fermentations: wine, vinegar.	
2.2	**Genetically engineered microorganisms in the Food Industry**	
A.	Concept, advancements, principles.	
B.	Role of genetically engineered microbes in the food industry.	
3.	**Food Safety and Quality Assurance**	**(15)**
3.1	**Food borne diseases**	
	Bacterial, with emphasis on emerging pathogens such as *E. coli* EHEC O157:H7 and other strains; *L. monocytogenes*, *H. pylori*; Fungal, Algal, Viral, Prions and other non-bacterial forms.	
3.2	**Quality control and Validation**	
A.	Microbiological examination of foods – sampling, culturing/analysis including newer methods such as PCR, magnetic separation.	
B.	Plant sanitation.	

C.	Hazard Analysis and Critical Control Point (HACCP) concept.	
D.	Food Safety Act and Trade Regulations.	
E.	Good Manufacturing Practice (GMP) and Quality Systems.	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	• Adams, M. R. and Moss, M. O., Food Microbiology, New Age International (P) Limited Publishers, New Delhi.	
(Latest edition)	• Bacteriological Analytical Manual (BAM), US FDA Administration, https://www.fda.gov/food/laboratory-methods-food/bacteriological-analytical-manual-bam	
	• Da Silva, N., Taniwaki, M. H., Junqueira, V. C. A., Silveira, N. F. A., Nascimento, M. S. do. and Gomes, R. A. R., Microbiological Examination Methods of Food and Water: A Laboratory Manual, CRC Press, Taylor & Francis Group, U.K.	
	• Department of Food and Public Distribution, Ministry of Consumer Affairs, Food & Public Distributin, GOI https://dfpd.gov.in/index.htm	
	• Doyle, M. P. and Buchanan, R. L., Food Microbiology: Fundamentals and Frontiers, ASM Press.	
	• Food Safety and Standards Authority of India, Ministry of Healthand Family Welfare, GOI https://fssai.gov.in/cms/food-safety-and-standards-act-2006.php#:~:text=The%20Food%20Safety%20and%20Standards,34%20OF%202006.	
	• Frazier, W. C. and Westhoff, D. C., Food Microbiology, M. C. Graw-Hill Companies, Inc., New York.	
	• Harrigan, W. F., Laboratory Methods in food Microbiology, CRC Press, Taylor & Francis Group.	
	• Jay, MJ, Loessner, M.J. & Golden, D.A., Modern Food Microbiology, Springer Science + Business Media Inc., NY.	
	• Ramesh, K. V., Food Microbiology, MJP Publishers, Chennai.	
Learning Outcomes	• To understand the beneficial and harmful association of microorganisms with the food. • To appraise the prospective applications of the microorganisms in food industry. • To select the different methods of controlling the type and number of microorganisms in the food for its preservation. • To integrate the knowledge about the role of food regulatory bodies and measures of food safety, quality control and validation.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPG-504
Title of the Course: FOOD MICROBIOLOGY [P]
Number of Credits: 1, Practical

Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that the student should have knowledge about handling of microorganisms.	
Objective:	● Students will be assessing the microbiological quality of food. ● Students will learn the role of microorganisms in food fermentations.	
Content:		**(30)**
1.	Determination of the D value in heat treatment of foods.	
2.	Fermentation: Production of wine, monitoring of sugar reduction and alcohol production.	
3.	Assessment of sanitary status of an eatery – Examination of microflora from table surface; utensils; drinking water.	
4.	Isolation of probiotic culture (*Lactobacillus*).	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course **MITG-504**	
Learning Outcomes	● To analyse food samples produced in food industry. ● To connect the different methods of food treatments used to control the microorganisms with food preservation. ● To evaluate foods in terms of microbial quality for food safety and quality control. ● To design the value added food products using beneficial microorganisms.	

Programme: M.Sc. (Microbiology)
Course Code: MITG-505
Title of the Course: MEDICAL MICROBIOLOGY AND EPIDEMIOLOGY [T]
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	Knowledge of microorganisms, pathogens and various infectious diseases.	
Objective:	● To understand the mechanism of pathogenesis leading to development of disease in the host. ● To relate the pathogen, host and environment in terms of its varied existence and interactions, leading to various epidemiological events.	
Content:		
1.		

1.1	Pathogenicity, virulence and virulence factor – historical perspective and definitions, course of infectious diseases, damage-response curve and classes of pathogen, growth of pathogen in host.	**(05)**
1.2	Pili, flagella, biofilm, quorum-sensing, iron scavenging, aggressins/impedins against host defence.	**(03)**
1.3	Host susceptibility, pre-disposing factor (nutritional, socio-economical, occupational, therapy, genetical), factors affecting immune systems; Receptors for pathogen – GalNacbeta1-4 gal moiety exposed on asialylated glycolipids, TLRs, regulation of host cell apoptosis; establishment of latent infection; TB, Streptococcal Pneumonia, Amoebic and Bacillary dysentery.	**(07)**
2.		
2.1	Exotoxins – Type III secretion system, AB – type toxins, examples (Tetanospasmin, diphtheria toxin, pertusis toxin), bifunctional toxins, cytotoxins and cytolysins. Endotoxin – structure, biosynthesis, assay, pathophysiological effects, excessive inflammatory response, endotoxin neutralizing compound, antagonists of LPS.	**(08)**
2.2	Diagnostics – Sample type and handling of samples, selective enrichment, classical methods (review) of culturing and identification of pathogens, staining methods for demonstration of pathogen in situ (direct staining, fluorescent antibody staining), Applications of Molecular diagnosis and Typing: LPS (chemotyping), phage, pyocin, antimicrobial, serotyping, Restriction mapping, RFLP, PFGE, PCR.	**(03)**
2.3	Cystic fibrosis, Spongiform encephalopathy.	**(04)**
3.		
3.1	Spatial, temporal and social distributions of communicable diseases, transmissibility of infections, cross-sectional studies, case-control studies, cohort studies, Models for Developing Epidemiological Theory, modeling tools, Rates and risks, Population dynamics, Epidemiological Statistics Relating Exposure and Disease, Simple Epidemic Processes, Vaccine effect measures, Multistage chronic diseases, Joint effects of multiple exposure variables.	**(09)**
3.2	Community acquired infection, infections in immuno-compromised patients, Nosocomial infections, catheter associated infections, infections in patients with debilitating diseases, neo-natal infections; Vector borne diseases – vectors for transmission of infectious diseases, epidemiological cycles of vector borne diseases, control measures.	**(06)**
Pedagogy:	Lectures/tutorials/assignments/Moodle/videos/web resources	
References/ Readings (Latest editions)	● Carroll, KC, Butel, J and Morse, S. Jawetz melnick and adelbergs medical microbiology. McGraw-Hill Education. ● Centers for Disease Control and Prevention, Department of Health & Human Services, USA https://www.cdc.gov/	

	• Chakraborty, P. and Pal, N.K., Manual of Practical Microbiology and Parasitology. New Central Book Agency, India. • Chakraborty, P. Textbook of Medical Parasitology. New Central Book Agency, India • Davis, B.D. et al., Microbiology. Harper and Row. • Gillespie, S.H. and Hawkey, P.M., Principal and Practice of Clinical Bacteriology. Wiley. • National Centre for Disease Control, Ministry of Health & Family welfare, GOI https://ncdc.gov.in/ • Online Tuberculosis Information System (OTIS) Data, Centers for Disease Control and Prevention, Department of Health & Human Services, USA https://wonder.cdc.gov/tb.html • Parija, SC, Textbook of Microbiology & Immunology. Elsevier Health Sciences. • Rafi, MD, Textbook of biochemistry for Medical Students, Universities Press, India • Struthers, J.K. and Westran, R.P., Clinical Bacteriology. CRC Press. • Topley, W.W.C., Wilson, G.S., Parker, M.T., & Collier, L.H. , Topley and Wilson's Principles of Bacteriology, Virology and Immunity: v. 1-4, Hodder Arnold • World Health organization, South-East Asia https://www.who.int/southeastasia	
Learning Outcomes	• To identify the various virulence and pathogenicity factors of microbial pathogens. • To correlate the various pathological events during the progression of an infectious disease. • To apply the various diagnostics techniques involved in identification of pathogenic agent. • To categorize the strategies/methods required to combat the spread of pathogens under various circumstances.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPG-505
Title of the Course: MEDICAL MICROBIOLOGY AND EPIDEMIOLOGY [P]
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	Ability to handle microorganisms in the laboratory.	
Objective:	• Student will learn in handling, characterization and identification of pathogens. • Student will able to do analysis of epidemiological data.	
Content:		**(30)**
1.	Demonstration of malaria parasite in blood film.	
2.	Determination of sensitivity of bacteria to antibiotics (Disc method).	

3.	Enrichment, isolation and identification of Enteric pathogen.	
4.	Analysis of disease incidence using CDC/epidemiological data.	
Pedagogy:	Experiments in the laboratory, web resources	
References/ Readings	As given under Theory Course **MITG-505**	
Learning Outcomes	● To identify and distinguish between various human pathogens. ● To apply the microbiology tools and techniques in specific need for clinical cases. ● To estimate the resistance of bacteria against commercially available antibiotics. ● To apply the principles of statistics in processing of epidemiological data.	

Programme: M.Sc. (Microbiology)
Course Code: MITG-506
Title of the Course: MARINE MICROBIOLOGY [T]
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-23

Prerequisites	Basic understanding of the unique properties of water, features of marine environments and microorganisms.	
Objective:	● Students will learn microbial diversity in context of various characteristics of marine and coastal environments. ● Students will understand specialized tools and techniques used in study of microorganisms present marine and coastal ecosystems.	
Content:		
1.		**(15)**
1.1	Introduction to oceanography: the world's oceans and seas and its demarcations, zonation of the water column with respect to depth and light. Impact of water column zonation on biology. Properties of seawater, physico-chemical factors in the marine environment such as temperature, density, nutrients, salinity, dissolved gases. Ocean phenomena: waves, tides, oceanic currents, Ekman transport and upwelling- its significance and impact on biology in coastal regions and open ocean, Coriolis effect, eddies, gyres, El Nino- Southern Oscillation (ENSO), and its significance.	
1.2	Marine microbial habitats: water column, sediments, estuaries, mangroves, salt marshes, beach ecosystems, coral reefs, deep sea hydrothermal vents, cold seeps.	
2.	**Marine Microorganisms**	**(15)**
2.1	Marine microbes – viruses, bacteria, fungi, phytoplankton, zooplankton: their growth, physiology and contribution to ocean processes. Modes of	

	microbial growth: viable but non-culturable (VBNC) microorganisms, biofilms, microbial mats, epibiosis.	
2.2	Physiology of marine microbes: metabolic diversity and energy-yielding processes: Microbial carbon pump, microbial loop; marine snow; phototrophy and primary productivity, aerobic respiration, anaerobic respiration (denitrification, sulphate reduction, methanogenesis); nitrification, annamox, sulphur oxidation, methanotrophy; fermentation. Carbon dioxide fixation in autotrophs; the role of microorganisms in biogeochemical cycling: carbon, nitrogen, phosphorous, sulphur, iron, manganese.	
2.3	Role of microbes in climate change and global warming. Microbes - a tool of carbon sequestration.	
2.4	Mesocosm- quantification of global warming impact- species composition and turnover, distribution of functional traits, ecological processes; Microcosm- Quantification of global warming on bacterial metabolic rates, productivity.	
3.	**Methods in marine microbiology**	**(15)**
3.1	Sampling equipment: water samplers such as CTD rosette- Niskin sampler, sediment samplers -different types of grabs such as Van Veen grabs, Shipek grabs, Eckman grab and different types of corers- Piston corer, box corer, gravity corer.	
3.2	Analysis of primary productivity: the radiocarbon method; Analysis of bacterial productivity: the thymidine uptake method; Analysis of bacterial productivity: the thymidine uptake method; Measurement of respiration rates: light-dark bottle method	
3.3	Tools to study marine microbial diversity: flow cytometry (bacteria, picoplankton, picoeukaryotes, viruses); molecular approaches such as metagenomics, community fingerprinting and Fluorescence *in situ* hybridization (FISH), Microsensor, Biosensors**.**	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	● Belkin, S. and Colwell, R. R., Ocean & Health: Pathogens in the Marine Environment, Springer.	
	● Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim.	
	● Hunter-Cevera, J., Karl, D. and Buckley, M., Marine Microbial Diversity: the Key to Earth's Habitability, American Academy of Microbiology.	
	● Intergovernmental Oceanographic Commission (1994) Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. DOI: https://doi.org/10.25607/OBP-1409 Intergovernmental Oceanographic Commission Manuals and Guides : 29 -JGOFS Report; 19	
	● Meller, C. B., Wheeler, P. A., Biological Oceanography, Wiley-Blackwell Publishers.	

	• *Mitchell, R. and Kirchman, D. L., Microbial Ecology of the Oceans, Wiley- Blackwell Publishers.*	
	• Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y.	
	• Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco.	
	• Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York.	
	• Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa.	
	• Sournia, A., UNESCO Monographs on Oceanographic Methodology, Vol. 6, Phytoplankton Manual, UNESCO Publishing, Paris.	
	• Tomas, C. R., Identifying Marine Phytoplankton, Academic Press, San Diego, CA.	
Learning Outcomes	• To integrate microbial diversity in context of various characteristics of marine and coastal environments • To connect the microbes and their role in marine and coastal habitats. • To categorize and select different methods and tools to study microorganisms in marine and coastal ecosystems. • To illustrate the various biogeochemical cycles in context of microorganisms.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPG-506
Title of the Course: MARINE MICROBIOLOGY [P]
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	It is assumed that students should have a basic understanding of the unique physico-chemical characteristics of seawater and the different microbial groups in marine environments.	
Objective:	• Students will learn different methods of sampling and analysis of physico-chemical parameters of estuarine and coastal environments. • Students will analyze the marine samples for isolation and enumeration of microorganisms. • Students will understand the different biochemical processes in marine microorganisms.	
Content:		**(30)**

1.	Sampling methods for collection of water and sediment samples from estuarine and coastal environments.	
2.	Analysis of physico-chemical parameters of seawater- Temperature, Salinity, Dissolved Oxygen, pH, Suspended matter, Nutrients; Nitrate, Nitrite, Phosphate, Silicate.	
3.	Isolation and enumeration of microbes from estuarine and coastal environments - Microscopic count of water column bacteria, Total count (epifluorescence method-DAPI), Bacterial respiration, community respiration and net production	
4.	Assessment of salt requirement of marine isolates from different ecosystems.	
5.	Denitrification by marine bacterial isolates.	
6.	Study of biofilm formation by microorganisms.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course **MITG-505**	
Learning Outcomes	● To explain sampling and analysis of physico-chemical parameters of estuarine habitat ● To analyse samples from marine and coastal habitat for isolation and enumeration. ● To connect microorganisms with marine and coastal habitats. ● To asses metabolic rates in marine bacterial isolates.	

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Programme: M.Sc. (Microbiology)
Course Code: MITG 507
Title of the Course: ENTREPRENEURSHIP IN MICROBIOLOGY [T]
Number of Credits: 4
Contact hours: 60
Effective from Academic Year: 2022-2023

Prerequisites	Basics of microbiology, microbial physiology and industrial microbiology	
Objective:	● Students will able to recognize and acquire skills for entrepreneurship in microbiology. ● Students will able to discuss the possibilities of developing wealth derived from application of microbiology. ● Students will able to state various schemes and opportunities in taking up entrepreneurship in microbiology as career growth.	
Content:		
1	Scope of entrepreneurship in microbiology, process of entrepreneurship, type and competencies of entrepreneur, self-assessment of abilities and skills for entrepreneurship in microbiology, advantages and disadvantages of entrepreneurship in microbiology,	4

	motivational stories and sharing of experience of entrepreneurs in microbiology.	
2	Characteristics of industries based on Microbiology, Context of entrepreneurship in microbiology and comparison with entrepreneurship in other fields, Bioentrepreneurial opportunities - spotting problems and needs, online-tools for searching databases for problems and needs, opportunities for solutions using microbiology, creativity and developing innovative ideas. Identifying limitation of product, process and design in implementation. Innovative steps in developing product or process in microbiology, use of mind-maps, proof of concept, identifying market and business possibility.	7
3	Entrepreneurial planning: MSME - definition, type; Five basic forms of legal organization - sole proprietorship, partnership, joint stock companies; company - types and salient features of companies; story of start-up and company of microbiology, regulations associated for company based on microbiology, economics of microbiology based industry including taxes	6
4	Stages-Types of microbiological products/process - microorganisms as product, metabolites, proteins and small molecules from microorganisms, microorganism based processes, genetically modified microorganisms for product and process, scale-up of process, stability and shelf life, ethical issues, Technological Readiness Levels (TRL), Marketable Readiness levels (MRL) and Business Readiness Level (BRL); technology versus business model; stages and strategies for commercialization and market, role of bioincubators and Government support system, Business models - Research Intensive pharmaceutical companies (RIPCO), fully integrated drug discovery and development organization (FIDDO), No research-development only (NRDO), fully integrated pharmaceutical/ biopharmaceutical company (FIPCO/FIBCO), Fully integrated pharmaceutical network (FIPNET/VIPCO)	14
5	Intellectual Property Rights - Patents, Trademarks, Copyrights, Industrial Designs, Geographical Indications and Traditional knowledge, Integrated Circuits, Plant Varieties & Farmers Rights, Trade Secrets; Acts associated with: patents, copyrights and trademarks. Non-disclosure agreements, overview of patent registration in India, National and International IPR laws pertaining to microorganisms and product/process thereof , Budapest treaty, National and International Repositories for Microorganisms, comparison of Indian and International patent laws, Description and requirement for Indian Patent, search and filing of patent, microbiology based examples of patents (product/process/design), Role and importance of trademarks and brand name, search of trademarks, example of trademarks in Microbiology, management of innovation and IPR, IP portfolio, selling	12

	and licensing of IPR - examples from product and technologies in microbiology	
6	Financial and economics of microbiology based industry - consideration and approaches for managing capital, determining capital cost, cost of equity and risks, working capital, working capital cycle, operating cycle and cash cycle, working capital management, cash flow management, financial planning and budget, Financial statements, Case study	5
7	Regulatory requirement and management - Food Act, FSSAI, Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/Genetically Engineered Organisms or Cells 1989 (Rules, 1989) [first notified under the Environment (Protection) Act, 1986], Drugs and Cosmetic Act, Guidelines on Similar Biologics, Insecticides Act, Biofertilizers and Organic Fertilizers (Fertilizer (Control) Order), Solid Waste Management Act	8
8	Funding opportunities and management: Funding Opportunities for Startups - Bootstrap, crowdfunding, angel investment, venture capital, bank loans, business loans from microfinance provider, friends and family, government grants, Schemes of the Government for start-up in microbiology, Incentives for Startups, Special Royalty Tax for Patents.	4
Pedagogy:	Lectures/tutorials/assignments/Group-discussion	
References/ Readings	● Amaresan, N, Dharumadurai, D, & Babalola, OO, Agricultural Microbiology Based Entrepreneurship, Making Money from Microbes, Microorganisms for Sustainability (MICRO, volume 39), Springer Nature Singapore Pte Ltd.	
(Latest edition)	● Amaresan, N, Dharumadurai, D, & Babalola, OO, Food Microbiology Based Entrepreneurship: Making Money From Microbes, Microorganisms for Sustainability (MICRO, volume XX), Springer Nature Singapore Pte Ltd.	
	● Amaresan, N, Dharumadurai, D, & Cundell, DR, Industrial Microbiology Based Entrepreneurship, Making Money from Microbes, Microorganisms for Sustainability (MICRO, volume 42), Springer Nature Singapore Pte Ltd.	
	● Casida, LE, Industrial Microbiology, New Age International Limited, New Delhi	
	● Central pollution Control Board, Ministry of Environment, forest and Climate Change, GOI, https://cpcb.nic.in/env-protection-act/	
	● Cntral Drugs Standard Control Organization, DGHS, MHFW, GOI https://cdsco.gov.in/opencms/opencms/en/Acts-Rules/	
	● Department of Biotechnology, Ministry of Science and Technology, GOI, https://dbtindia.gov.in/	
	● El-Mansi, EMT, Bryce, CFA, Demain, AL and Allman, AR (Editors), Fermentation Microbiology and Biotechnology, Taylor & Francis, FL	

	• Food Safety and Standards Authority of India, Ministry of Healthand Family Welfare, GOI https://fssai.gov.in/cms/food-safety-and-standards-act-2006.php#:~:text=The%20Food%20Safety%20and%20Standards,34%20OF%202006.	
	• Genetic Engineering Appraisal Committee, Ministry of Environment, Forest & Climate Change, GOI, https://geacindia.gov.in/acts-and-rules.aspx	
	• Malik, S.S. & Shukla, S.S. Bioentrepreneurship development, Biotech Consortium India Limited, New Delhi	
	• Office of the Controller General of Patents, Design & Trade Marks, Department for Promotion of Industry and Internal Trade, Ministry of Commerece & Industry, MOI https://ipindia.gov.in/	
	• Stanbury, PF, Whitaker, A & Hall, SJ. Principles of Fermentation Technology, Elsevier	
	• United States Patent & Trademark Office, USA, https://www.uspto.gov/	
	• World Intellectual Property Organization, Switzerland, https://www.wipo.int/portal/en/index.html	
	• Various acts and rules listed in the content section.	
	• Biochemical Engineering and Biotechnology.	
	• Journal of Industrial Microbiology and Biotechnology.	
Learning Outcomes	• To develop product and/or process based solution using microbiological concepts. • To differentiate IPR potentials of microbial process and product. • To connect with the funding and marketing opportunities available in bioentrepreneurship. • To appraise the process for developing and manufacturing product using microorganisms or their produce. • To formulate strategies for establishing a start-up.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPG-508
Title of the Course: Field Trip to industries/institutions in Goa
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	The student should have knowledge of microbiology.	
Objective:	• To recognize various industries and institutions in Goa providing employment in the area of Microbiology. • To understand the scope of microbiology and role of microbiologists in various institutions and industries in Goa.	

Content:		
1.	**Visit to National Research Institutes:** National Centre for Polar and Ocean Research [NCPOR] / Council of Scientific and Industrial Research-National Institute of Oceanography [CSIR-NIO] / Indian Council of Agricultural Research – Central Coastal Agricultural Research Institute (ICAR - CCARI) / Indian Council of Medical Research- National Institute of Malarial Research (ICMR-NIMR) / Goa Medical College / Birla Institute of Technology and Sciences (BITS) Pilani, Goa Campus / Don Bosco College of Agriculture.	**(15)**
2.	**Visits to Industries:** Pharmaceutical industry, Agricultural farming, Food and Beverage industry, Waste Management Plant, CIBA	**(15)**
3.	**Report writing**	
4.	**Presentation and group discussion**	
Pedagogy:	Field visits/Presentation	
References/ Readings (Latest version)	Reading material provided by the institutions/industries. Websites of the institutions/industries.	
Learning Outcomes	• To appraise the different instruments used in industries and institutions for microbiological analysis and research. • To connect with the recent advancements in Microbiology taking place in different industries and institutions. • To choose between the career in industry or research in Goa. • To categorize the various opportunities available in microbiological industries in Goa.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPG-509
Title of the Course: Field Trip to industries/institutions across India
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	The student should have knowledge of microbiology.	
Objective:	• To recognize various industries and institutions in India providing employment in the area of Microbiology. • To understand the scope of microbiology and role of microbiologists in various institutions and industries in India.	
Content:		**(30)**
1.	**Visit to Institutes/Industries:** National/State research institutes/ Universities/ Industries outside Goa will be identified and the study tour will be arranged for the students.	
2.	**Report writing**	
3.	**Presentation and group discussion**	

Pedagogy:	Field visits/Presentation	
References/ Readings (Latest Edition)	Reading material provided by the institutions/industries. Websites of the institutions/industries.	
Learning Outcomes	● To appraise the different instruments used in industries and institutions for microbiological analysis and research. ● To connect with the recent advancements in Microbiology taking place in different industries and institutions. ● To choose between the career in industry or research in India. ● To categorize the various opportunities available in microbiological industries in India.	

Programme: M.Sc. (Microbiology)
Course Code: MIPG-510
Title of the Course: Field Trip to coastal ecosystems and allied industries
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-23

Prerequisites	The student should have knowledge of microbiology.	
Objective:	● To apply various techniques and instruments used for collection of samples from marine and coastal ecosystem. ● To understand the processing of marine and coastal samples.	
Content:		
1.	**Sample collection from coastal regions:** **a) Estuarine sampling** Collection of samples using various water samplers and sediment grabs; recording of lat-long (net GIS), temperature and salinity; samples for BOD, COD; maintenance and transfer of samples. Processing the samples for isolation of microorganisms **b) Intertidal regions** Sampling and culturing of microorganisms associated with marine flora and fauna.	**(22)**
3.	**Visit to marine industries:** Aquaculture / Marine farming / Seafood processing industry.	**(08)**
4.	**Report writing**	
5.	**Presentation and group discussion**	
Pedagogy:	Field visit/Laboratory analysis/Presentation	
References/ Readings (Latest Edition)	● Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y. ● Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New	

	York. ● Przeslawski, R., Berents, P., Clark, M., Edgar, G., Frid, C., Hughes, L., & Smith, J. (2018). Marine sampling field manual for grabs and box corers. *Field Manuals for Marine Sampling to Monitor Australian Waters*, 172-195. ● Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa. ● Suter, E. A., Scranton, M. I., Chow, S., Stinton, D., Medina Faull, L., & Taylor, G. T. (2017). Niskin bottle sample collection aliases microbial community composition and biogeochemical interpretation. *Limnology and Oceanography*, *62*(2), 606-617. ● Reading material provided by the industries. ● Websites of the industries.	
Learning Outcomes	● To experiment with marine and coastal samples. ● To plan isolation of marine microorganisms. ● To analyse the marine microorganism for their potential applications. ● To categorize the various opportunities available in marine industries in Goa.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPG-511
Title of the Course: Internship in Industry/Institution
Number of Credits: 2, Practical
Contact hours: 60
Effective from Academic Year: 2022-23

Prerequisites	The student should have knowledge of microbiology.	
Objective:	● To apply the use of instruments and techniques used in industries and institutions through hands-on training. ● To associate with recent trends in research/economic activities in institutes/industries.	
Content:		
1.	**Training in an Institute/Industry** The student shall be required to undertake training in Research Institute/Industry for a minimum period of 2 weeks or its equivalent and submit a certificate of attendance signed by the Training Coordinator of the respective Institute/ Industry. *Students may opt to undertake a summer training Course in an Institute/ Industry of their choice. A student shall be required to make the necessary inquiries to seek the possibility of doing such a training; faculty*	**(60)**

	will be assigned to assist them in their preparations. An official letter will then be issued.	
2.	**Report writing**	
3.	**Presentation and group discussion**	
Pedagogy:	Hands-on-training/literature review	
References/ Readings (Latest Edition)	Reading material provided by the institution/industry Websites of the institutions/industries.	
Learning Outcomes	• To evaluate the use of specialized instruments for application in microbiological analysis. • To plan the experiments based on recent trends in microbiology. • To appraise the future prospects in microbiological research and industry. • To compile analysis reports.	

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Programme: M.Sc. (Microbiology)
Course Code: MITR 501
Title of the Course: Research Methodology and Advanced Biostatistics
Number of Credits: 4
Contact hours: 60
Effective from Academic Year: 2022-2023

Prerequisites	Student should have knowledge about microbiology and bassic biostatistics.	
Objective:	• To understand the basic concepts and methodologies involved in research. • To develop the understanding of various advanced biostatistical tools involved in data analysis and interpretation.	
Content:		
1	**Introduction to research methodology**	**(20)**
1.1	Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical, concept of applied and basic research process, criteria of good research	
1.2	Defining the problem, setting of working hypothesis, Defining the Aims and Objectives, Literature survey: sources of literature, gathering of literature, understanding the flow for literature review, identification of gap areas, Databases and Research Metrics: Indexing databases, citation databases, Web of Sciences, Scopus, Pubmed, *etc*, Impact factor of journals, Citation of bibliography, Work Plan – Time-bound Frame, GANTT chart, technical writing: Research manuscript writing, thesis writing	

1.3	Establishment of ethics in science and research; examples of unethical work done in past, Ethical use of animal subjects, human subjects, Stem cell ethics, plant use and transgenic crops	
1.4	Plagiarism in research: Scientific misconduct, Falsification, fabrication, misinterpretation of data. Anti-plagiarism tools like Ouriginal / iThenticate / Turnitin and other open source software tools	
1.5	Hazards: Types of Hazards: radioactive, chemical and biohazard, waste management and disposal. Safety in laboratory: first-aid, fire safety, biosafety in laboratory, Good Laboratory Practices	
2	**Advanced biostatistics**	**(40)**
2.1	**Curve fitting**- fitting of a second degree parabola, power curve, exponential curve	
2.2	**Multiple Regression Analysis**- Two-variable linear model, significance test for parameter estimates, goodness of fit, three variable linear model, coefficient and adjusted coefficient of multiple determination, test of overall significance of regression (F test), correlation coefficient- partial, zero order, first order, second order, Multiple correlation, generalized linear model, matrix approach for analysis, Regression analysis for qualitative variable/s and role of dummy variable	
2.3	**Non-parametric tests** – Concept of non-parametric test, advantages, disadvantages, sign test for one sample and two samples, Wilcoxon signed rank test, Median test, Run test, Mann-Whitney 'U' test, Kruskal-Wallis 'H' test	
2.4	**ANOVA-Two way classification** with one observation and multiple observations per cell- concept, procedure and examples	
2.5	**Designs of experiment**- Use and reasons for Design of experiments, definitions, concepts and terminology, Principles of experimental designs – replication, randomization and controls, Completely randomized design (CRD), Randomized complete block design (RCBD), Repeated measures design (RMD) – Single factor repeated measure design (SFRMD), handling of missing observations in RCBD, Latin square design (LSD), 2^2 Factorial experiments, Yates' Method, Confounding in factorial design, partial confounding, advantages and disadvantages	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	● Alley, M, The Craft of Scientific Writing, Springer Science and Business Media.	
(Latest edition)	● Biological Safety Cabinets And Other Primary Containment Devices, Laboratory safety manual, WHO	
	● Biosafety in Microbiological and Biomedical Laboratories, U.S. Department of Health and Human Services	
	● Cochran, WG and Snedecor, GW Statistical Methods. Iowa State University Press.	
	● Cooray P.G. Guide to Scientific and Technical Writing, Hindagala	

	• Day R.A. How to write and publish a scientific paper, Part 274, Volume 994, Oryx Press.	
	• Good C V, Scates, DE, Methods of Research, Appleton-Century-Crofts.	
	• Haaland, P.D., 2020. *Experimental design in biotechnology*. CRC press.	
	• Indian Statistical Institute (https://www.isical.ac.in/)	
	• Kothari CR, Research Methodology Methods and Techniques, New Age International	
	• Kumar, RC, Research Methodology. APH Publ Corporation, New Delhi.	
	• Mourya, DT, Yadav, PD, Majumdar, TD, Chauhan, DS and Katoch, VM, 2014. Establishment of Biosafety Level-3 (BSL-3) laboratory: Important criteria to consider while designing, constructing, commissioning & operating the facility in Indian setting. *The Indian Journal of Medical Research*, *140*(2), p.171.	
	• Rao, KS, Biostatistics for Health and Life sciences, Himalaya Publishing House.	
	• Rao, PSSS & Richard, J, An introduction to biostatistics - A manual for students in health sciences, Prentice-Hall of India pvt. Ltd., New Delhi	
Learning Outcomes	To sketch the procedures and methodologies for performing a research experiment. To predict the required experimental designs. To analyze the experimental data using various biostatistical tools. To create a scientific report/ manuscript/ thesis.	

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Programme: M.Sc. (Microbiology)
Course Code: MITR 502
Title of the Course: MICROBIAL TECHNOLOGY [T]
Number of Credits: 3
Contact hours: 45
Effective from Academic Year: 2022-2023

Prerequisites	Students should have basic knowledge of different techniques and instruments, their principle and applications.	
Objective:	• The course develops an understanding on the potential of microorganisms in sustainable development. • The course summarizes the microbial technologies for energy production. • The course discuss microbial technologies in aquaclture and for human health. • The course describe potential of genetically engineered microorganisms and nanobiotechnology.	

Content:		
1.	**Biotechnology and prospecting with microbes.**	**(06)**
	Advantages of using microbial technology over chemical and physical technology. Increasing relevance of microbiology in all biotechnologies. Ethics in the use of Genetically Engineered Microorganisms (GEMs). Commercialization of Microbial Biotechnology. Introduction and applications of Nanobiotechnology.	
2.	**Microbial technology in agriculture**	**(09)**
	Production of microbial biofertilizers, biopesticides, soil conditioners to enhance crop yields.	
3.	**Microbial technology in mining**	**(15)**
	Bioleaching, Biomining, Microbial Enhanced Oil Recovery (MEOR), Microbial technology in waste and pollution management in mining: Bioconversions, Bioremediation, Bio-sedimentation, Bio-beneficiation, Aquifer cleaning.	
4.	**Microbial technology for energy production**	**(07)**
	Microbial fuel cell; Biogas; Biodiesel; Microbial cell mass	
5.	**Microbial technology in Human health & aquaculture**	**(08)**
	Pigments, Nutraceuticals, Probiotics, Bio-actives, Bioplastics, Microbes as bio-weapons.	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings (Latest edition)	● Ahmad, I., Ahmad, F. and Pichtel, J. Microbes and Microbial Technology: Agriculture and Environmental Applications, Springer. ● Arora, R., Microbial Biotechnology: Energy and Environment, CABI Publishing. ● Bull, A. T., Microbial Diversity and Bioprospecting, American Society for Microbiology. ● Peppler, H.J., Microbial Technology: Microbial Processes, Academic Press. ● Sukla, L. B., Pradhan, N., Panda, S. and Mishra, B. K. Environmental Microbial Biotechnology, Springer.	
Learning Outcomes	● To understand the key potential of microorganism in environmental remediation. ● To appraise and evaluate the microbial products for their potential application. ● To apply the knowledge of various microorganisms in developing technology. ● To create a microbial technology towards achieving the sustainable development goals.	

Programme: M.Sc. (Microbiology)
Course Code: MIPR 502
Title of the Course: MICROBIAL TECHNOLOGY [P]

Number of Credits: 1, PRACTICAL
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students should have a basic knowledge of different techniques in instrumentation- their principle, working and applications.	
Objective:	● This course gives hands-on experience to connect microbial potential with technology to produce the product.	
Content:		**(30)**
1.	Determination of stability of microbial fertilizer.	
2.	Effect of microbes on sedimentation and clarification of water.	
3.	Screening of isolates for production of (a) Pigments as bioactives and (b) Probiotics: Isolation of LABs and their characterization- Morphology, lactose fermentation, Bile tolerance test.	
4.	Demonstration of Microbial Bioplastics.	
5.	Biosynthesis of nanoparticles	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course **MITR-502**	
Learning Outcomes	● To evaluate the procedures for formulation of biofertilizers and probiotics. ● To analyse the role of microorganisms in biremediation of contaminated water. ● To understand and analyse the role of microbial synthesis of bioplastics. ● To design and produce technologies for biosynthesis of nanoparticles using microorganisms.	

Programme: M.Sc. (Microbiology)
Course Code: MITR 503
Title of the Course: EXTREMOPHILIC MICROORGANISMS [T]
Number of Credits: 3
Contact hours: 45
Effective from Academic Year: 2022-2023

Prerequisites	The student should have knowledge of microorganisms and their diversity.	
Objective:	● To discuss about the extreme habitats, extremophilic microorganisms, their adaptations and biotechnological potentials.	
Content:		
1.		**(15)**
1.1	Concepts of extremophilic and polyextremophilic microorganisms	**1**
1.2	Extreme habitats and extreme microbial communities: deserts, ore deposits/ mining areas (Fe, Mn, Cu), Yellow stone national park, Ring of	**10**

	fire, deep biosphere (terrestrial and marine), hydrothermal vents, cold seeps, soda lake, Dead Sea, solar salterns, polar environments. Astrobiology / exobiology (Mars, Europa and asteroids). Conventional culture techniques, high throughput techniques for culturing and culture independent (metagenomics) approach to study extremophiles.	
1.3	Significance of extremophiles in biogeochemical cycling, industry, pharma and bioremediation.	**4**
2	**Key molecular components, unique physiological features, adaptation strategies and enzymes of various extremophilic types:**	**(30)**
2.1	Anaerobes- oxygen toxicity and regulation in *Clostridium, Moorella thermoacetica,* Wood Ljungdahl pathway; barophiles / piezophiles- mechanism in barophily, *Photobacterium profundum, Shewanella*; cryophiles / psychrophiles - (cold shock proteins and regulation) *Polaromonas, Pseudomonas, Methanococcoides burtonii*; thermophiles & hyperthermophiles: heat shock proteins and regulation, *Aquifex, Tepidomonas, Rhodothermus, Pyrococcus*; metallophiles - *Geobacter*; stromatolites; microbial mat and biofilms.	**(15)**
2.2	Alkaliphiles / basophiles - *Alkalimonas, Nesterenconia*; acidophiles - *Picrophilus, Ferroplasma, Thiobacillus ferrooxidans*; halophiles - *Halomonas, Haloferax, Dunaliella salina, Hortaea werneckii*; osmophiles - osmophilic *Lactobacilli, Schizosaccharomyces pombe*; oligotrophs - *Pelagibacter, Caulobacter*; xerophiles - *Wallemia*; extreme cyanobacteria (*Phormidium; Synechococcus lividus, Mastigocladus laminosus*); radiophiles - *Deinococcus radiodurans*; xenobiotic degraders - *Pseudomonas*; endoliths - *Chroococcidiopsis, Halothece*	**(15)**
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	● Blum, P., Archaea: New models for prokaryotic biology. Academic press.	
(Latest readings)	● Brock, T. D. Thermophilic microorganisms and life at high temperatures. Springer.	
	● Cavicchioli, R., Archaea: Molecular and cellular biology. ASM Press.	
	● Durvasula, R.V., Subba Rao, D.B. Extremophiles from biology to biotechnology. CRC Press.	
	● Gerday, C., Glansdorff, N., Physiology and biochemistry of extremophiles. ASM Press.	
	● Horikoshi, K. and Grant, W.D. Extremophiles-microbial life in Extreme Environments, Wiley. New York.	
	● Kannan, P., Ignacimuthu, S., Paulraj, MG.Buffering capacity and membrane H^+ conductance of protease producing facultative alkaliphilic bacterium *Bacillus flexus* from mangrove soil. Indian J of Biochemistry and Biophysics. 46:261-265.	
	● Medigan, M.T., Bender, K. S., Bukley, D.H., Sattley, W. M., & Stahl, D.A. Brock biology of microorganisms. Pearson.	
	● Munn, C. Marine microbiology: Ecology and applications. Garland	

	Science, Taylor and Francis Group.	
	• Rainey, F.A. and Oren, A. Extremophile microorganisms and the methods to handle them. In: Extremophiles, methods in microbiology. Elsevier.	
	• Satyanarayana, T., Raghukumar, C., Shivaji, S. Extremophilic microbes: diversity and perspectives. Current Science, 89(1): 78-90.	
	• Ventosa, A., Nieto, J.J. and Oren, A. Biology of moderately halophilic aerobic bacteria. Microbiology and molecular biology Reviews, 62, 504–544.	
	• Willey, J.M., Sherwood, L.M., and Woolverton, C.J. Prescott's Microbiology. McGraw-hill education.	
Learning Outcomes	• To identify and compare different groups of extremophiles. • To analyse physiological features and adaptation strategies employed by different groups of extremophiles. • To develop extremophilic microbially derived product for industrial applications. • To apply high throughput techniques and culture independent approach to explore extremophiles from diverse econiches and their unique properties.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPR 503
Title of the Course: EXTREMOPHILIC MICROORGANISMS [P]
Number of Credits: 1
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	The student should be familiar with handling of microorganisms in the laboratory.	
Objective:	• To develop skills involved in handling extremophilic microorganisms. • To illustrate adaptations strategies of extremophilic microorganisms and their biotechnological potentials.	
Content:		**(30)**
1.	Isolation of halophiles, alkaliphiles, and anaerobes.	
2.	Tolerance of bacterial culture to temperature, pH and salinity.	
3.	Buffering capacity of alkaliphiles.	
4.	Study extremozymes and pigments from extremophilic microorganisms.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MITR 503	

Learning Outcomes	● To identify the extremophilic microorganisms from different econiches. ● To select novel industrially useful biomolecules from extremophilic microorganisms. ● To analyse adaptation strategies of extremophiles in different physiological conditions. ● To produce various biomolecules from extremophiles and study their unique properties.	

Programme: M.Sc. (Microbiology)
Course Code: MITR 504
Title of the Course: AQUATIC VIROLOGY [T]
Number of Credits: 2
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students should have an understanding of basic concepts in microbiology and molecular biology.	
Objective:	Develops the concept of viruses as key determinants of aquatic ecology. It introduces the traditional, modern and emerging techniques used in the study of aquatic viruses.	
Content:		
1.	**Aquatic viruses and their significance**	**15**
	Introduction to viruses, their structure and classification	
	Abundance and distribution of virioplankton in various aquatic environments	
	Diversity of aquatic viruses in terms of morphology, life cycle and host range; giant viruses and virophages	
	Viruses as agents of microbial mortality; effects of viral infection on microbial community composition; viruses as an active component of aquatic microbial communities	
	The role of viruses in biogeochemical cycles and the aquatic food web; Aquatic viruses and climate change	
	Horizontal gene transfer and evolutionary contributions of viruses.	
	Aquatic viruses pathogenic to humans and animals of economic importance	
2.	**Cultivation, enumeration and molecular studies of aquatic viruses**	**15**
	Methods for isolation of aquatic viruses – concentration and purification of viruses from water, cultivation and assay of microbial viruses in liquid and solid media	
	Methods for enumeration and ultrastructural observation of viruses – epifluorescence microscopy, transmission electron microscopy, flow cytometry	

	Molecular techniques for detection of aquatic viruses – PCR-amplification of marker genes such as *g20, psbA, polB*; whole genome sequencing of cultured isolates; metagenomics of viral communities from diverse aquatic ecosystems	
	Significance of culture-based and culture-independent methods for studying aquatic viruses	
	Novel approaches in aquatic virus research and detection: single virus genomics, viral cross-linking and solid-phase purification, optical trapping, integrated approaches	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings (Latest Editions)	● Abedon, S. (Ed.), *Bacteriophage Ecology: Population Growth, Evolution, and Impact of Bacterial Viruses* - Advances in Molecular and Cellular Microbiology, Cambridge: Cambridge University Press. ● Adriaenssens, E. M., & Cowan, D. A. (2014). Using signature genes as tools to assess environmental viral ecology and diversity. *Applied and Environmental Microbiology*, 80(15), 4470-4480. ● Clokie, M.R.J., and Andrew M.K. *Bateriophages Methods and Protocols, Volume 1: Isolation, Characterization, and Interactions*. Springer International Publishing. ● Hyman, P. & Abedon, S.T., *Viruses of Microorganisms*. Caister Academic Press. ● Malmstrom, C., *Environmental Virology and Virus Ecology*. Elsevier Academic Press. ● Moon, K., & Cho, J. C. (2021). Metaviromics coupled with phage-host identification to open the viral 'black box'. *Journal of Microbiology*, 59(3), 311-323. ● Weitz, J. S., & Wilhelm, S. W. (2012). Ocean viruses and their effects on microbial communities and biogeochemical cycles. *F1000 Biology Reports*, 4:17. ● Wilhelm, S.W., Weinbauer, M.G., & Suttle, C.A., *Manual of Aquatic Viral Ecology*. American Society of Limnology and Oceanography, USA. ● Wommack, K. E., & Colwell, R. R. (2000). Virioplankton: viruses in aquatic ecosystems. *Microbiology and Molecular Biology Reviews*, 64(1), 69-114. ● Zhang, Q. Y., Ke, F., Gui, L., & Zhao, Z. (2022). Recent insights into aquatic viruses: Emerging and reemerging pathogens, molecular features, biological effects, and novel investigative approaches. *Water Biology and Security*, 100062. Zhang, R., Weinbauer, M. G., & Peduzzi, P. (2021). Aquatic viruses and climate change. *Current Issues in Molecular Biology*, 41(1), 357-380.	
Learning outcome	● Summarize the roles of viruses in aquatic ecosystems.	

	• Apply the traditional and modern techniques to isolate and characterize aquatic viruses • Integrate the knowledge of viruses into an existing framework of aquatic microbiology • Frame relevant research objectives in the field of aquatic virology.	

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Programme: M.Sc. (Microbiology)
Course Code: MITR 505
Title of the Course: INTRODUCTION TO BIOINFORMATICS [T]
Number of Credits: 2
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students should have an understanding of basic concepts in molecular biology.	
Objective:	Develops concepts of informatics analysis for biological data, such as nucleic acid and protein sequence data	
Content:		
1.		**(15)**
1.1	**Introduction to Bioinformatics, Sequencing and Databases**	**8**
	Introduction to bioinformatics, the necessity for computation in modern life sciences research	
	The central dogma of molecular biology (overview), Types of bioinformatics databases	
	DNA sequencing, RNA sequencing; Nucleotide sequence databases – GenBank, EMBL, DDBJ; Cloning vectors used in sequencing; primer designing	
	Protein sequencing – Edman degradation, mass spectrometry; Protein sequence databases – SwissProt, UniProt	
	Protein structural and functional databases – PDB, Pfam, GO, KEGG, Subsystems	
	Molecular docking – applications and tools – Autodock, DOCK	
1.2	**Sequence Alignment**	**7**
	Rationale: why does sequence alignment matter? Evolutionary basis of sequence alignment; Pairwise and multiple alignment	
	Scoring matrices – PAM, BLOSUM, optimal alignment methods, gap penalties	
	Dynamic programming algorithms – Smith-Waterman, Needleman-Wunsch, k-mer, k-tuple	
	FASTA; BLAST; understanding of BLAST parameters including statistical scores	
2.		**(15)**
2.1	**Multiple Sequence Alignment Methods**	**4**

	Progressive methods – ClustalW, Iterative methods – MUSCLE, Short-read alignment – Bowtie, Motif-based alignment – MEME	
	Use of BioEdit for nucleotide sequence editing and alignment	
2.2	**Phylogenetic tree building and evaluation**	**5**
	Introduction to phylogeny and applications of phylogenetic analysis	
	Methods for tree building – UPGMA, NJ, MP and ML	
	Generation of phylogenetic trees in MEGA	
2.3	**Principles of Whole Genome and Metagenome Analysis by Bioinformatics**	**6**
	Quality control, reference databases – NCBI nr, Kraken	
	Assembly – reference-based, *de novo*	
	Annotation – taxonomic annotation, functional annotation	
	Use of Unix / Linux-based operating systems for bioinformatics analysis of sequence data	
Pedagogy:	Lectures/tutorials/assignments/online hands-on	
References/ Readings (Latest editions)	• Antao, T, Bioinformatics with Python Cookbook 2nd Edition. • Christensen, H, Introduction to Bioinformatics in Microbiology. Vol. 39. • Lesk, AM, Introduction to Bioinformatics. Vol. 66. Oxford University Press. • Ramsden, J, Bioinformatics: An Introduction. Springer-Verlag London. • Note: Latest versions of software tools and databases should be used for instruction.	
Learning Outcomes	• Explain the principles behind bioinformatics tools and techniques. • Apply the principles in the analysis of biological sequence data. • Compare the various methods for sequence alignment and phylogenetic analysis. • Design an analysis pipeline for specific types of biological data.	

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Programme: M.Sc. (Microbiology)
Course Code: MITR 506
Title of the Course: MARINE MICROBIAL INTERACTIONS [T]
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-2023

Prerequisites	Students must have a background about the basic concepts of Marine Microbiology, including properties of seawater, marine microorganisms.	
Objective:	• Students will learn advances in marine microbiology with special emphasis on the intricate associations between microorganisms and marine organisms, diseases of microbial origin in fish and	

	invertebrates, and other beneficial and harmful aspects like bioremediation and HABs respectively.	
Content:		
1.	**Symbiotic associations**	**(15)**
1.1	Symbiosis of microalgae with animals, Symbiosis of chemoautotrophic prokaryotes with marine animals; Light organ symbiosis in fish and invertebrates; Microbial symbionts of sponges-significance and advantages; Symbiosis and mixotrophy in protists; Metabolic consortia and mutualism between prokaryotes.	
1.2	Ecological significance and advantages of various symbiotic associations - Bacterial, Algal, Sponges, Protists, Planktons. Applications of symbiotic associations.	
2.	**Microbial diseases of fish and invertebrates**	**(15)**
	Diseases of fish, bivalve mollusks, crustaceans, corals in fresh water/ sea water/ aqua culture: Bacterial – vibriosis, pasteurellosis, furunculosis, marine, bacterial kidney disease, mycobacteriosis, streptococcosis, black band disease, white plague, white pox, Juvenile Oyster Disease (JOD), bacterial shell disease, Coral Bleaching and methods of restoration; Symptoms and diagnosis; Control of the disease Viral – Infectious salmon anemia (ISA) virus, viral hemorrhagic septicemia virus (VHSV), lymphocystis virus, birnaviruses, viral nervous necrosis. Symptoms and possible diagnosis; Control of the disease Protistan – *Paramoeba perurans, Kudoa sp., Loma salmonae, Hematodinium* Symptoms, Diagnostic methods, Control of disease.	
	Human diseases- toxic dinoflagellates and diatoms Red tides, shell fish poisoning, ciguatera fish poisoning	
3.	**Marine microbes - Beneficial and harmful aspects**	**(15)**
	Beneficial aspects: Biodegradation and bioremediation of marine pollutants such as oil, persistent organics and plastics. Environmental monitoring using indicator microorganisms. Microbial enzymes and polymers; biomedical and health products. Harmful aspects: Harmful Algal Blooms (HABs)- effect on biota. Biodeterioration, biofouling, bio-invasion – ballast waters. Environmental monitoring – Microbiology of fish and sea food products, microbial enzymes, Secondary products from fish waste, application of microbial enzymes	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	• Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim.	

	• Gatesoupe, F. J., (1999) The use of probiotics in aquaculture, Aquaculture, 180: 147-165.	
	• Maier, R., Pepper, I. and Gerba, C., Environmental Microbiology, Academic Press.	
	• Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis, N.Y.	
	• Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco, N.Y.	
	• Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York.	
	• Sharma, P. D., Environmental Microbiology, Alpha Science.	
	• Sindermann, C. J., Principal Diseases of Marine Fish and Shellfish: Diseases of Marine Fish, Vol. 1, Gulf Professional Publishing.	
	• Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa.	
	• Toranzo, A. E., Magarinos, B. and Romalde, J. L., (2005) A review of the main bacterial fish diseases in mariculture systems, Aquaculture, 246(1): 37-61.	
	• Intergovernmental Oceanographic Commission (1994) Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. DOI: https://doi.org/10.25607/OBP-1409 Intergovernmental Oceanographic Commission Manuals and Guides : 29 -JGOFS Report; 19	
Learning Outcomes	• Different kinds of interactions of microbes and marine organisms • Ecological significance of microbial associations • Understanding the various microbial diseases of marine organisms • Bioprospecting and applications of microbial associations.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPR 506
Title of the Course: MARINE MICROBIAL INTERACTIONS [P]
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students must have a background about the basic concepts of Marine Microbiology, and the techniques involved for sampling and processing of water, sediment, flora and fauna from the marine environment.	

Objective:	This Course emphasizes the techniques used to study the interactions between microorganisms and marine organisms, and also screening of enzymes for degradation of litter.	
Content:		**(30)**
1.	Determining *E. coli* in shellfish –MPN/ EC-MUG medium.	
2.	Isolation of luminescent bacteria from fish/shellfish.	
3.	Assessment of the microbiological quality of marine water in aquaculture: – physicochemical parameters. – potential pathogens.	
4.	Screening of enzymes involved in deterioration of wood/litter in marine environments.	
5.	Examine the beneficial effect of microbial association- Macro algae - Bacteria Isolation and identification of marine algae associated bacteria Isolation and identification of Zooplankton associated bacteria Associated bacterial efficiency for chitin degradation	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course **MITR 506**	
Learning Outcomes	● To isolation of marine organisms associated bacteria ● To analyse the bacterial diseases of fish ● To evaluate the marine organism associated bacteria for beneficial biomolecules	

Programme: M.Sc. (Microbiology)
Course Code: MITR 507
Title of the Course: MEDICAL VIROLOGY [T]
Number of Credits: 3, Theory
Contact hours: 45
Effective from Academic Year: 2022-2023

Prerequisites	The student should have a basic understanding of viruses.	
Objective:	● Develops concepts in structure, classification, cultivation, assay, pathogenesis and treatment of disease-causing viruses.	
Content:		
1.	**Viral Diversity and the Study of Viruses**	**(15)**
1.1	**Viruses**	
	Structure, genomic diversity, classification according to Baltimore's system and the ICTV	
	Viral replication and interference	
1.2	**Methods to study and detect viruses**	
	Ultrastructure visualization by electron microscopy	

	Cultivation *in vitro*, *in ovo* and *in vivo*	
	Monitoring of clinical manifestations of *in vivo* viral inoculation: fever, neurological symptoms, pruritis	
	Detection by cytological and histological techniques: plaque, pock, polykaryocytes, hemadsorption, cytopathogenicity, tumor formation.	
	Detection by quantitative and serological techniques: hemagglutination assay, virus neutralization, ELISA, immunofluorescence, immunohistochemistry	
	Detection by nucleic acid-based techniques: PCR, RT-PCR, nucleic acid hybridization, high-throughput sequencing	
2.	**Viral Diseases**	**(15)**
	Viral agents of disease: structure, mode of replication, symptoms, pathogenesis and diagnosis Family Picornaviridae: Polio virus Family Herpesviridae: Herpes simplex virus Family Coronaviridae: SARS-CoV-2 Family Hepadnaviridae: Hepatitis B virus Family Orthomyxoviridae: Influenza A virus Family Retroviridae: HIV	
3.	**Oncogenic and Emerging Viruses and Antiviral Combat**	**(15)**
3.1	Oncogenic viruses: Family Papovaviridae – Human papillomavirus 16 and 18, cervical cancer development Role of viral oncogenes in causing cancer, retroviral oncogenes such as growth factors, transcription regulators and kinases Role of the Human Genome Project in identification of viral oncogenes	
3.2	Emerging viral agents of disease, such as Ebola, Nipah and Zika viruses	
3.3	Virus-host interactions: Host specific and nonspecific defense mechanisms; neutralizing antibodies; the role of interferon.	
3.4	Viral vaccine development: Traditional vaccine preparations and modern molecular approaches (adenoviral vector-based vaccines, mRNA vaccines), vaccines against oncoviruses. Antiviral drugs: nucleoside analogs, entry inhibitors, viral enzyme inhibitors, immunotherapy, combination therapy	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	● Cohen, A., *Medical Virology*, John Wiley & Sons, Incorporated.	
(Latest editions)	● Davis, B.D., Dulbecco, R., Eisen, H.N. and Ginsberg, H.S., *Microbiology*, Harper and Row Publishers.	
	● De La Maza, L.M., Peterson, E.M., *Medical Virology*, Springer Science & Business Media.	
	● Dimmock, N.J., Easton, A.L. Leppard, K.N., *Introduction to Modern Virology*, Blackwell Publishing Ltd.	

	• Evans, B., *Perspectives in Medical Virology*, Volume 1, Elsevier.	
	• Flint, S. J., Racaniello, V. R., Rall, G. F., Hatziioannou, T., & Skalka, A. M., *Principles of Virology*, John Wiley & Sons.	
	• Harper, D.R., *Viruses: Biology, Applications, Control*, Garland Science	
	• Payne, S., *Viruses: From Understanding to Investigation*, Elsevier,	
	• Ryu, W., *Molecular Virology of Human Pathogenic Viruses*, Elsevier.	
	• White, D.O., Fenner, F., *Medical Virology*, Gulf Professional Publishing.	
	• https://www.cdc.gov/ncird/dvd.html	
	• https://www.who.int/southeastasia	
	• https://viralzone.expasy.org	
Learning Outcomes	• To explain morphology, mode of infection and multiplication of medically important viruses and their treatment. • To apply traditional and modern techniques for the study and detection of viruses • To analyze the roles of viral pathogen and host in the development of disease • To devise strategies to combat emerging viral pathogens.	

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Programme: M.Sc. (Microbiology)
Course Code: MIPR 507
Title of the Course: MEDICAL VIROLOGY [P]
Number of Credits: 1, Practical
Contact hours: 30
Effective from Academic Year: 2022-2023

Prerequisites	Students should have basic knowledge of viruses and microbiological techniques.	
Objective:	Develop skills in handling, detecting and identifying viruses of medical importance	
Content:		**(30)**
1.	Electron micrographs representative of all the Baltimore classes of viruses	
2.	Real-time PCR detection of RNA viruses	
3.	Rapid antigen / antibody detection test for: i) HIV (retrovirus) ii) SARS-CoV-2 (coronavirus) iii) Dengue (picornavirus) iv) Hepatitis B (hepadnavirus)	
4.	ELISA test for detection of any one virus	
Pedagogy:	Experiments in the laboratory	

References/ Readings	As given under Theory Course MITR 507	
Learning Outcomes	● Identify viruses of medical importance based on their structural characteristics. ● Distinguish between the morphologies and tropism of various pathogenic viruses. ● Acquire skills in laboratory handling of viral material ● Apply modern techniques for the detection of viruses	

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Annexure III

Question paper formats for SEA of M.Sc. Microbiology Examination (OA-35)
Semester End Assessment
Effective from Academic year 2022-23

A. Question Paper Format for M.Sc. Part I Microbiology SEA Theory (Core Course - Credit 3)

Date: **Duration: 2 Hours** **Total Marks: 30**

Instructions:
1. Section I consists of Q1 to Q6. Answer any FOUR questions from Section I. Each question carries 2 marks.
2. Section II consists of Q7 to Q12. Answer any FOUR questions from Section II. Each question carries 2.5 marks.
3. Section III consists of Q13 to Q16. Answer any THREE questions from section III. Each question carries 4 marks.

Section I **Answer ANY FOUR (2 marks each)** **(08)**
Q1
Q2
Q3
Q4
Q5
Q6

Section II **Answer ANY FOUR (2.5 marks each)** **(10)**
Q7
Q8
Q9
Q10
Q11
Q12

Section III **Answer ANY THREE (4 marks each)** **(12)**
Q13
Q14
Q15
Q16

B. Question Paper Format for M.Sc. Part I Microbiology SEA Practical (Core Course - Credit 1)

Date: **Duration: 2 Hours** **Total Marks: 10**
Instructions:

Q1 Practical 1 (Marks 04)
Q2 Practical 2 (Marks 02)
Q3 Spots (Marks 02)
Q4 Journal and Viva (Marks 02)

C. Format specified in Section A above should be followed for SEA of optional theory papers having 3 credits. Format for optional theory paper having credit/s 1, 2 and 4 can be decided by the respective Teacher/s teaching the paper.

D. Format specified in Section B above should be followed for SEA of optional practical papers having 1 credit.

E. Question Paper Format for SEA Practical - Field Trip (Optional Course - Credit 1)

Date: **Duration: 2 Hours** **Total Marks: 10**
Instructions:

Q1 Marks 03
Q2 Spots (Marks 02)
Q3 Presentation and Viva (Marks 05)

F. Question Paper Format for SEA for course "Internship in Industry/Institution" (Credit: 2):

Date: **Duration: 2 Hours** **Total Marks: 20**
Instructions:

Q1 Marks 04
Q2 Marks 04
Q3 Marks 04
Q4 Presentation and Viva (Marks 08)

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Annexure IV

Goa University
School of Biological Sciences and Biotechnology

Programme: Ph.D. Microbiology
Paper-I Syllabus
Title of the course: Research Methodology
Number of Credits: 04
Contact Hours: 60
Effective from AY: 2022-23

Prerequisites	Provisional registration for Ph.D. in Microbiology	
Objective:	To introduce aspects of research methodology pertaining to microbiology To sensitize about the hazards and norms of safety in microbiology laboratory To expose the students to biological data handling and statistical tools used for analysis To familiarize the students with various tools and techniques required in conduct of microbiological research –for isolation, characterization, purification, etc of microorganisms and biomolecules	
Content:		
1.	**Safety in Microbiology laboratory**	**(4)**
	Introduction and importance of safety in laboratory, Classification and types of hazards and safety measures, fire hazard and safety procedures, handling of hazardous chemicals, and solvents and hazards associated with instruments. First-Aid and its role in life saving during accident. Classification of biohazard, biosafety levels and procedures of handling biohazardous materials, Roles and types of personal safety equipment.	
2.	**Data handling and statistical analysis**	**(8)**
	Statistical analysis of any replicative measurements, Accuracy, precision, population and sample, true value, mean, standard deviation, standard error, Gaussian distribution, confidence limits and its estimates, Hypothesis testing (Z-test, t-test), Experimental designing (Factorial Design), Chi-square, F-test, ANOVA analysis. Use of computation software for statistical analysis. Mathematical modelling, Response surface methodology for 2 and 3 factors, and other advance statistics.	
3.	**Methods for handling microorganisms**	**(6)**
	Culture media and Growth system, Assay/monitoring methods for growth (Absorbance/packed volume/dry and wet weight/protein/ pigment content); colony forming units (cfu), plaque forming unit (pfu). Maintenance of cultures and taxonomic placement including keys of classification.Assay for Toxicity: LD50, MIC; Assay of Lethality: TDT, TDP, D_{10} ; Assay for enzymes and other biochemical reactions, including kinetics, Methods and evaluation of cell disruptions, Common reference	

	biomolecules (proteins, lipids, nucleic acids, carbohydrates), SI units, Molarity, Molar, Moles, Buffers, Buffering capacity, Molecular weights, Nomograms, Common detergents used in microbiology	
4	**Microscopic techniques**	**(4)**
	Microscopy and Micrometry, Stains and staining procedures, Photomicrometry, optical systems resolution, Phase Contrast microscopy, fluorescence microscopy, SEM	
5	**Molecular Techniques**	
	Isolation, detection, characterisation of genomic and plasmid DNA. Endonucleases and restriction mapping. Common vectors, protocols for scoring recombinants, transformants and transconjugants. Isolation of RNA and their types. Thermal denaturation curve and calculation of G+C%. Use of X-gal, IPTG, PCR amplification of DNA, Nucleic acid hybridization (Southern and Northern blot techniques).	**(6)**
6	**Microbial cells and physiology**	**(8)**
	Fungi, Yeast, Algae, Cyanobacteria, Viruses, Eubacteria and Archaea. Biochemical activities of microorganisms-photosynthesis, respiration, fermentation. Energy acquisition pathways: EMP, HMP, ED, TCA Physiological and Nutritional characteristics of Microbial types. Genome organisation in microorganisms.	
7	**Extraction, Separation and purification of biomolecules**	**(10)**
	Electrolyte / Solvent separation / Extractions, Centrifugation, Chromatography: adsorption, Ion exchange, affinity and Size exclusion, HPLC; Electrophoresis, ion-selective electrode, pH, pKa, pI, ampholyte, LC-Mass.	
8	**Characterization of biomolecules**	**(14)**
	GC-Mass, AAS, Flame Photometer, NMR & ESR, CD, IR, UV-Visible, Fluorimetry, Luminometry, Radioisotopy (Counter decay, safety of isotopes and usage)	
Pedagogy:	Lectures/tutorials/assignments	
References/ Readings	Arora, PN and Malhan, PK, Biostatistics, Himalaya Publishing House	
(Latest edition)	Davis, BD., Dulbecco, R, Eisen, HN & Ginsberg, HS, Microbiology, Harper and Row Publishers.	
	Haaland, PD, Experimental design in biotechnology. CRC press.	
	Moat, AG, Foster, JW and Spector, MP eds., Microbial Physiology. John Wiley & Sons.	
	Plummer, DT, An introduction to practical biochemistry, Tata McGraw Hill	
	Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA.	
	Rao, KS, Biostatistics for Health and Life Sciences. Himalaya Publishing House, India	

	Sadasivam, S, Manickam, A, Biochemical methods. New Age (P) International.	
	Sambrook, J, Fritsch, EF, andManiatis, T, Molecular cloning: a laboratory manual, Cold Spring Harbor Laboratory Press, New York	
	Singh, Y.K., Fundamentals of Research Methodology and Statistics, New Age International Pvt. Ltd., India	
	Silverstein, RM, Bassler, GC & Morrill, TC, Spectrometric Identification of Organic Compounds, John Wiley, Singapore.	
	Skoog, DA, Holler, FJ, & Crouch, SR, Principles of Instrumental Analysis, Cengage Learning.	
	Voet, D, Voet, JG and Pratt, CW, Fundamentals of biochemistry: life at the molecular level. John Wiley & Sons.	
	Wilson, K, &Walker J., Principles and Techniques of Practical Biochemistry, Cambridge University Press	
Learning Outcomes	To execute safe laboratory practices in research. To apply the knowledge of research methodology to plan and execute the experiments independently. To analyse the microbiological data and perform statistical analysis. To demonstrate the use of various equipment and techniques for microbiological research pertaining to isolation, characterization and identification of microorganisms and their biomolecules.	

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