Goa University
P.O. Goa University, Taleigao Plateau, Goa 403 206, India

Syllabus for entrance to Ph.D./M.Phil. (Microbiology)

MICROBIAL BIOCHEMISTRY

1.	**Biological Molecules**
1.1	**Proteins**
	Amino acids: features and properties.
	Protein: structure, principles of separation and purification, molecular weight determination; sequencing and synthesis.
	Enzymes: activity, inhibition, mechanism of action; regulatory – allosteric and covalently modulated enzymes and their significance in metabolism.
1.2	**Carbohydrates**
	Monosaccharides: types, characteristics and properties.
	Disaccharides, oligosaccharides, polysaccharides – biological significance.
1.3	**Lipids**
	Fatty acids: saturated and unsaturated, structure and properties.
	Lipids: biological significance; lipid composition of microorganisms.
2.	**Bioenergetics and Carbohydrate Metabolism**
2.1	**Bioenergetics**
	Thermodynamics, exergonic and endergonic reactions, redox potential, high energy compounds, ATP structure and significance.
2.2	**Oxidative Phosphorylation**
	Redox enzymes, aerobic electron transport and oxidative phosphorylation.
2.3	**Carbohydrate metabolism**
A.	Carbohydrates: Central pathways of metabolism – regulatory mechanisms, bioenergetics and significance – EMP, TCA cycle (glucose aerobic and anaerobic metabolism, malate metabolism), Glyoxylate cycle.
B.	Gluconeogenesis from TCA intermediates / amino acids / acetyl-CoA; biosynthesis of polysaccharides and sugar interconversions.
3.	**Lipids, Amino Acids, Nucleotides and other Metabolic Paths**
3.1	**Lipid Metabolism**
A.	Anabolism: Biosynthesis of fatty acids: saturated and unsaturated, triglycerides, phospholipids,
3.2	**Amino Acid and Nucleotide Biosynthesis**
A.	Amino acid biosynthetic pathways and their regulation.
B.	Purine and pyrimidine nucleotides, Deoxyribonucleotides: biosynthesis and regulation.
C.	Biosynthesis of nucleotide coenzymes.

3.3	**Photosynthetic Metabolism**
A.	Organisms and photosynthetic pigments, fundamental processes in Photosynthesis.
B.	Photosynthetic electron transport and photophosphorylation.
3.4	**Chemolithotrophy**
	Organisms, substrates, bioenergetics of metabolism.

MICROBIAL GENETICS

1.	
1.1	**Classical Mendelian genetics and deviation from Mendelian principles:** Origin of mitochondria and plastids – Endosymbiont theory, DNA in Mitochondria and plastids, Mitochondrial and plastid genes inherited by Non-Mendelian mechanism.
1.2	**Microbial genome organization:** 3 Domains of Life based on 16S rRNA and 18S rRNA; Prokaryotic and Eukaryotic; replication, transcription and regulation. Structure of Prokaryotic genes (lac and trp operon) and Eukaryotic Genes (interrupted Genes), Prokaryotic & Eukaryotic genome. Microbial gene transfer (Conjugation, transformation, transduction). **Structural chromosomal aberrations and their significance:** Deletion, duplication, inversion, translocation. Aneuploidy and polyploidy.
1.3	**Viral Genetics :** Genomic organization and Replication of viruses:- T4, Lambda Phage and its strategies - Lytic and Lysogenic cycles, TMV, SV40, Hepatitis B, HIV. Retroviruses and retroposons - introduction and genetic significance. Viroids and plant diseases, virusoids.
2.	
2.1	**Genomic (DNA) Rearrangements:** Mechanism of General and programmed DNA rearrangements, Antigenic and phase variation in bacteria. Transposons: IS elements – Composite transposons (Tn3, Tn10), Ty, Copia and P type, Mechanism of transposition. Role of transposons in DNA rearrangements and microbial genome evolution.
2.2	**Mutagenesis, mutation and mutants**: Somatic and germinal mutation, spontaneous and induced mutations, site specific using PCR/ cassette mutagenesis, and random mutagenesis. **DNA Damage:** Thymine dimer, apyrimidinic site and apurinic site, cross linking, deamination of base, base mismatch. **Types of mutation:** silent mutation, missense mutation, nonsense mutation, Read through mutation, frameshift- insertion and deletion mutation, translocation, Inversion, suppressor mutation. **Mutagenic chemicals and radiations and their mechanism of action**: Base analogues (5-Bromouracil and 2-amino purines), EMS, acridines, NTG, Hydroxylamine; mutagenic radiations- UV, X-rays and gamma rays. Ames test; Auxotrophy.
3.	
3.1	**Fungal Genetics**: Yeast - *Saccharomyces cerevisiae/ S. pombe* and *Neurospora* genomes as model genetic systems; Chromosome replication, yeast artificial chromosomes, tetrad analysis, genetic compatibility and non-compatibility genes, heterokaryosis, Parasexuality, Petite mutants of yeast, Killer yeast.
3.2	**Bacterial plasmids**: Types of plasmids, F plasmids and their use in genetic analysis-$F^{+,}$/Hfr cells/ F'cells, colicin and col plasmids, R plasmids, metal

	resistance, and antibiotic resistance - efflux pump/MDR bacteria, Ti plasmid, 2µ plasmid. Replication in plasmids. Bacterial plasmids as research tools. Integrons and Genomic islands - pathogenicity islands.

MICROBIAL TAXONOMY AND SYSTEMATICS

1.	
1.1	**Microbial taxonomy and systematics** Concepts of taxonomy (characterization, classification and nomenclature) and systematics; classification of microorganisms, three domain, six-kingdom, 8-kingdom systems.
1.2	**Phenotypic characters** - Morphology, Biochemical tests (e.g. API, BIOLOG), Bacteriophage typing, Serotyping.
1.3	**Chemotaxonomic markers** - Cell wall components, lipid composition, cellular fatty acid (FAME analysis), isoprenoid quinones, protein profiles (e.g. MALDI-TOF).
1.4	**Nucleic acid based techniques** – Terminal Restriction Fragment Length Polymorphism (TRFLP); G+C content (T_m and HPLC); pyrosequencing; 16S rRNA gene sequencing; phylogenetic analysis; DNA-DNA hybridization.
1.5	Concepts of species, numerical taxonomy and polyphasic taxonomy.
2.	Salient features of phylum, class and orders with representative examples of the following – Archaea, Eubacteria (bacteria, cyanobacteria, actinomycetes), Mycota, Protista (algae, protozoa, diatoms); and viruses.

BIOSTATISTICS

1.	
1.1	**Characteristics of biological data:** Variables and constants, discrete and continuous variables, relationship and prediction, variables in biology (measurement, ranked, attributes), derived variables (ratio, index, rates), types of measurements of biological data (interval scale, ratio scale, ordinal scale, nominal scale, discrete and continuous data). **Elementary theory of errors:** exact and approximate numbers, source and classification of errors, decimal notation and rounding off numbers, absolute and relative errors, valid significant digits, relationship between number of valid digit and error, the error of sum, difference, product, quotient, power and root, rules of calculating digits.
1.2	**Data handling:** Population and samples, random samples, parameter and statistics, accuracy and precision, accuracy in observations, Tabulation and frequency distribution, relative frequency distribution, cumulative frequency distribution. **Graphical representation:** types of graphs, preparation and their applications.
2.	
2.1	**Measures of central tendency:** characteristics of ideal measure, Arithmetic mean – simple, weighted, combined, and corrected mean, limitations of arithmetic mean; Median – calculation for raw data, for grouped data, for continuous series, limitations

	of median; Mode – computation of mode for individual series, by grouping method, in a continuous frequency distribution, limitations of modes; Relationship between mean, median and mode; mid-range.
2.2	**Measure of dispersion:** variability, Range, mean deviation, coefficient of mean deviation, standard deviation (individual observations, grouped data, continuous series), variance, coefficient of variance, limitation. Skewness – definition, positive, negative, purpose, measure, relative measure, Karl Pearson's Coefficient, Bowley's Coefficient, Kelly's Measure, Moments.
2.3	**Correlation analysis** – Correlation, covariance, correlation coefficient for ungrouped and grouped data, Pearson's Rank Correlation coefficient, scatter and dot diagram (graphical method). **Regression analysis -** Linear and exponential function - examples: DNSA conversion by reducing sugar, survival/growth of bacteria, regression coefficients, properties, standard error of estimates, prediction, regression analysis for linear equation.
3.	
3.1	Probability: Probability, Combinatorial Techniques, Elementary Genetics, Binomial, Poisson, Normal Distributions.
3.2	Hypothesis Testing – parameter and statistics, sampling theory, sampling and non-sampling error, estimation theory, confidence limits, testing of hypothesis, test of significance; Students' T-test, t-distribution, computation, paired t-test.
3.3	Chi-square test, F-test and ANOVA.

TECHNIQUES AND INSTRUMENTATION IN MICROBIOLOGY

1.	
1.1	**Chromatographic techniques:**
	GC, HPLC, detectors, column/s matrix- Ion-exchange, affinity and molecular exclusion. (using examples for separation of microbial lipids, pigments, nucleic acids and proteins/enzymes).
1.2	**Centrifugation:**
	Principles, methodology, application; Density gradient centrifugation; Ultracentrifugation (Separation of ribosomal subunits of bacteria).
1.3	**Spectrophotometry:**
	Atomic Absorption Spectrophotometry (AAS), UV-Visible, fluorimetry, Fourier transformation infra-red spectroscopy (FTIR), NMR, MS.
2.	
2.1	**Microscopy:**
	Epifluorescence filter technique (DEFT), SEM, TEM, Confocal microscopy.
2.2	**Radio-isotope and tracer techniques:**
	Isotope and types of isotopes, Radio-activity counters, Autoradiography,
2.3	**Cell and tissue culture techniques:**
	Primary and secondary/established cell lines, Monolayer and suspension cultures, Fluorescence activated cell sorting (FACS), Biohazards and Biosafety cabinet.
3.	
3.1	**Electrophoretic technique:**
	PAGE, IEF, , PFGE, DGGE, TGGE, Single stranded conformation polymorphism

	(SSCP), Electroporator, Micro-array technique.
3.2	**Isolation of cell organelles:**
	Different methods of cell lysis/ breakage and isolation and purification of various cell organelles - Cell surface structures, cell envelopes, plasma membranes, peptidoglycan, Outer membrane, ribosomes, protoplasts, spheroplast.
3.3	**Others:**
	X-ray diffraction.

INDUSTRIAL MICROBIOLOGY

1.	
1.1	History of Industrial Microbiology, fermentation processes, descriptive layout and components of fermentation process for extracellular and intracellular microbial products.
1.2	Microbial growth kinetics: Batch kinetics – Monod's model (single substrate), deviations from Monod's model, dual substrates – sequential utilization, multiple substrates – simultaneous utilization, substrate inhibition, product synthesis (primary and secondary metabolite), toxic inhibition, death constant.
1.3	Microbial growth kinetics: Fed-batch kinetics – fixed volume, variable volume and cyclic fed-batch, applications and examples of fed-batch systems. Continuous cultivation system – relationship between specific growth rate (μ) and dilution rate, comparison between various cultivation systems.
2.	
2.1	Bioreactor design and operation: classification of reactors; Ideal mixed v/s plug flow reactor; designing parameters for reactors (stirred tank reactor, airlift reactor, plug flow reactor), rheology of fermentation broth.
2.3	Bioreactor design and operation: gas-liquid mass transfer, heat transfer, analysis of dimension less parameters and their application (aeration number, power number and Reynold's number; Scale-up of bioprocesses: parameters used in scale-up and problems associated with scale-up.
3.	
3.1	Solid substrate fermentation (SSF): Principles and application; Surface fermentation Comparison between SSF, Surface fermentation and SmF. Immobilized enzymes and cell systems.
3.2	Fermentation monitor and control: Common measurement and control systems (speed, temperature, gas, pH, Dissolved oxygen, foam, redox, air flow, weight, pressure, biomass), On-line and off-line analysis.
3.3	Industrial scale Down-stream processing and product recovery: principle and general description of instrumentation, Recovery of particulates (cells and solid particles), recovery of intracellular products, primary isolation (extraction, sorption), precipitation, industrial processes for chromatography and fixed bed adsorption, membrane separations; Type Processes - Antibiotic (Penicillin including semi-synthetic).

MOLECULAR BIOLOGY

1.	**Genetic material, bonds, types of DNAs, DNA packaging and model organisms**
1.1	**Nucleic Acids, bonds, types of DNAs, DNA packaging and model organisms**
A.	Structure of DNA and RNA.
B.	Bondings and different types of DNA (B-DNA & Z-DNA).
C.	DNA packaging in bacteria (Nucleoid) and viruses.
D.	Yeast as a minimal model eukaryote.
1.2	**Chromosomes, Genomes and it's evolution**
A.	Fundamental functions of DNA.
B.	Chromosomal DNA and its packaging in the chromatin fibre.
C.	Chromatin structure, structural features (Telomere, Centromere and Repetitive sequences) of chromosomes and their functions.
D.	Gene duplication and mutations.
E.	**DNA Gels:** Agarose gel electrophoresis, RNA denaturing gels, Ethidium Bromide, SYBER GOLD SYBER GREEN II, DNA and RNA ladders, Tracking dyes Methylene blue, Xylene cynol
2.	**DNA Damage, DNA Repair and Recombination**
2.1	**DNA damage elements/factors**
A.	Types of DNA damage (spontaneous and induced DNA damage).
B.	Mechanisms/pathways to remove damaged DNA: Excision repair, mismatch repair, recombination repair in *E. coli* and SOS Repair.
C.	Role of *RecA* in DNA damage repair, Photoreactivation repair in *E. coli* involving photolyase.
2.2	**Mechanisms of Genetic Recombination**
A.	General and site specific recombination.
B.	Heteroduplex DNA formation (Homologous recombination).
C.	Synaptonemal Complex, Bacterial RecBCD system and its stimulation of chi sequences.
D.	Role of RecA protein, homologous recombination, Holliday junctions.
3.	**How cells read the Genome**
3.1	**From DNA to Proteins**
A.	From DNA to RNA.
B.	From RNA to Protein.
C.	The RNA world and origin of life.
3.2	**Gene structure and control of gene expression in Prokaryotes and Eukaryotes**
A.	An overview of Gene expression control, DNA binding motifs in gene regulatory proteins, genetic switches and their role in control of gene expression.
B.	Post-transcriptional controls-transcriptional attenuation, Riboswitches, Alternate splicing, RNA editing, RNA Interference.
C.	Translation of mRNA in Prokaryotes and Eukaryotes.

MYCOLOGY

1.	**Fungal diversity and distribution**
1.1	**Origin and phylogeny**; **classification**
1.2	**Fungi – Terrestrial and Aquatic**
A.	Terrestrial, Fresh water and Marine: Coastal – mangrove; Estuarine; Ocean

B.	Hypersaline waters – Thalassohaline and Athallasohaline: Solar salterns, Salt Lake, Dead Sea.
1.3	**Extremophilic Fungi**
	Oligotrophs, Alkaliphiles, Acidophiles, Barophiles, Psychrophiles, Thermophiles, Halophiles, Osmophiles, Xerophiles.
	Adaptation to extreme environments.
2.	**Physiology and Genetics**
2.1	**Physiology of fungi**
A.	Growth and development.
B.	Fungal hormones- attractants, morphogenesis and differentiation.
C.	Microbial interactions.
D.	Secondary metabolites: antimicrobials, mycotoxin, pigments.
2.2	**Fungal genetics**
	Neurospora and *Saccharomyces*: Life-cycle; Tetrad analysis, gene conversion; Deuteromycotina: parasexuality, cytoplasmic inheritance; Electrophoretic karyotyping.
2.3	**Identification of fungi**
A.	Colonial and morphological characteristics.
B.	Molecular finger printing.
3.	**Pathogenesis - Antifungal Therapy**
3.1	**Pathogenesis**
A. B.	Mycoses - Systemic, sub-cutaneous, cutaneous and superficial, opportunistic Plant pathogens.
3.2	**Antifungal Therapy**
	Drugs acting on cell membrane, protein synthesis inhibitors; fungicides.
4.	**Applications**
A.	Industrially important enzymes.
B.	Bioprospecting of secondary metabolites: Antimicrobials, antitumour agents, nutraceuticals, pigments,.
C.	Biodegradation and bioremediation.
D.	Biocontrol.

MEDICAL VIROLOGY

1.	**Virus: Structure, Cultivation and Assay**
1.1	**Viruses**
A.	Introduction.
B.	Visualization by electron microscopy.
C.	Structure: envelope, capsid, nucleic acid.
D.	Defective viruses.
E.	Classification.
1.2	**Viral genome**
	Genomic diversity - DNA or RNA, segmented or non-segmented.
1.3	**Cultivation and assay of viruses**
A.	Cultivation - *in vitro* using cell cultures: primary, secondary cultures, cell lines.

	- *in ovo* using chick/duck egg embryo. - *in vivo* using experimental animals
B.	Viral multiplication and interference.
C.	Assay by physical methods and by infectivity and cultivation methods Detection by plaque, pock, polykaryocytes, haemadsorption, immunofluorescence, cytopathogenicity, tumor formation.
2.	**Viral Diseases**
2.1	**Viral agents of disease**: structure, mode of replication and pathogenesis Picornavirus: Enteroviruses (polio) and rhinoviruses (upper respiratory tract); Herpes group: Herpes simplex, Herpes zoster, Cytomegalovirus, Epstein Barr virus. Hepatitis (A, B, C, D, E); HIV; Orthomyxoviruses: Influenza. Paramyxoviruses: Mumps and Measles; Arboviruses: Togavirus - Rubella; Rhabdovirus: Rabies; Corona Virus: SARS. Emerging viral agents of disease.
2.2	**Oncogenic viruses** DNA viruses: Papova and Adeno viruses, Herpes EBV and HCV. Retrovirus.
3.	**Antiviral Combat**
3.1	**Virus-Host interactions**. Host specific and nonspecific defense mechanisms; neutralizing antibodies; interferon.
3.2	Viral vaccine development and viral chemotherapy. Traditional vaccine preparations and newer methods - molecular approach

ARCHAEA

1.	
1.1	**Significance of Archaea**: Biotechnology, Biogeochemical cycling, Evolutionary developments.
1.2	**Ecology, physiology and diversity of Archaea** Global econiches: Deep Sea, Hydrothermal vent, Dead Sea, solar salterns, geothermal vents, solfataras, Antarctica, soda lake. Study of archaeal biodiversity; unculturable archaea by metagenomics. Archaeal culture retrieval methods, novel samplers. Preservation and maintainance of archaeal cultures. Nutrition, growth and growth kinetics and physiological versatility, Stress response of Methanogens (*Methanobacterium thermoautotrophicum)*; Halophiles (*H. salinarum)*; Thermophiles (*Thermoplasma acidophilum*); Thermoacidophiles (*Sulfolobus acidocaldarius)*; Psychrophilic archaea (*Methanogenium frigidum, Methanococcoides burtonii*); Methanotrophs.
1.3	**Cell structure and architecture of Archaea:** Cellular organization: cell morphotypes, cell envelopes -archaeal membrane lipids and cell wall, appendages -pili, flagella, cannulae, hami. Novel bio-molecules: Glycerol diether moieties and macrocyclic lipid, novel enzymes, co-enzymes: methanopterin, formaldehyde activation factor, Component B, Coenzyme M, F420, F430, corrinoids.

2.	**Metabolism and energetics of Archaea**
2.1	Modified anabolic pathways of carbohydrates and lipids; methanogenesis and acetoclastic reactions.
2.2	Modified central metabolic pathways: EMP, ED, incomplete TCA; reverse Kreb cycle, carbon dioxide reduction pathways: reductive acetyl-CoA pathway, 3-hydroxypropionate pathway. Chemolithoautotrophy.
2.3	Bioenergetics: ATP synthesis (i) respiration-driven (ii) light-driven, involving bacteriorhodopsin (iii) chloride-driven, involving halorhodopsin
3.	**Genome of Archaea**
3.1	Size of genome, G + C content, associated proteins, archaeal histones and nucleosomes, introns in archaea, archaeal RNA polymerases, reverse DNA gyrase.
3.2	Plasmids, transposons -IS elements. Modifications in tRNA and rRNA structure. Novel 7S rRNA. DNA replication, translation and transcription in archaea.
3.3	Gene organization in Archaea: (i) *his* operon (ii) *bob* operon (iii) *mcr* operon.

MARINE MICROBIOLOGY

1.	
1.1	Introduction to oceanography: the world's oceans and seas, properties of seawater, physico-chemical factors in the marine environment such as temperature, density, nutrients, salinity, dissolved gases, waves, tides, oceanic currents, Ekman transport and upwelling; oceanic phenomena such as Coriolis effect, eddies, gyres, El Nino Southern Oscillation (ENSO).
1.2	Marine microbial habitats: estuaries, mangroves, salt marshes, beach, coastal ecosystems and coral reefs.
2.	**Marine microbes – bacteria, fungi, phytoplankton, zooplankton, viruses: their growth, physiology and contribution to ocean processes**
2.1	Modes of microbial growth: viable but non-culturable (VBNC) microorganisms, biofilms, microbial mats, epibiosis.
2.2	Physiology of marine microbes: metabolic diversity, microbial loop; marine snow; fermentation, aerobic respiration, anaerobic respiration (denitrification, sulphate reduction, methanogenesis); nitrification, annamox, sulphur oxidation, methanotrophy; carbon dioxide fixation in autotrophs; the role of microorganisms in biogeochemical cycling: carbon, nitrogen, phosphorous, sulphur, iron.
3.	**Methods in marine microbiology**
3.1	Sampling equipment: water samplers such as Niskin sampler, Hydro-Bios sampler, Rosette samplers; sediment samplers such as van Veen grabs and corers.
3.2	Analysis of primary productivity: the radiocarbon method
3.3	Analysis of bacterial productivity: the thymidine uptake method
3.4	Measurement of respiration rates: light-dark bottle method
3.5	Tools to study marine microbial diversity: flow cytometry, molecular approaches such as metagenomics and community fingerprinting.

ENVIRONMENTAL MICROBIOLOGY AND BIOREMEDIATION

1.	**Microbial Ecology**

	Microbial community structure, evolution of communities Types of Ecosystems: components and functioning of ecosystem, concept of homeostasis, biotic and abiotic components in the environment and their interaction, characteristics and functions. Energy flow and material cycling. Food webs. Ecological succession. Ecological efficiency. Concepts of microcosms and econiches.
	The expanse of microbial diversity, estimates of total number of species, measures and indices of diversity.
2.	**Biogeochemical processes**
	Biogeochemical cycling of carbon, nitrogen, phosphorous, sulphur, Fe and Mn: physiological and biochemical aspects
3.	**Concepts of sustainable and holistic development**
	Role of microorganisms in environment, Use of microorganisms towards sustainable development and specific pollution abatement programmes, need for environment impact assessment studies.
4.	**Microbes on surface**
	Nature and significance, activity in surface films Biofilm kinetics and its application to waste water treatment
5.	**Microbiological bioremediation**
	Bioremediation technologies. Overview of aerobic / anaerobic biodegradation and biotransformation of aliphatic, aromatic, xenobiotic and recalcitrant hydrocarbons. Methods of environmental monitoring and pollution control using nanotechnology.

GENETIC ENGINEERING

1.	**Introduction to genetic engineering and tools involved in genetic manipulation**
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 kinases, Alkaline phosphatase, S-1 Nuclease, Mung bean nuclease, RNases.
B.	Gene cloning systems/Hosts: Gene cloning in *E. coli* and other organisms such as *Bacillus subtilis, Saccharomyces cerevisiae* and other microbial eukaryotes.
C.	Cloning vectors: plasmid (pUC19, pBR 322), 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.	Expression vectors: Prokaryotic (pET, pGEX-2T and others). Characteristics of expression vectors: strong bacterial and viral promoters (lac, trp, tac, SV 40, T7, T3) for induction of gene expression.
F.	Construction of rDNA molecule and it's transfer to appropriate host (bacteria/yeast/plant cell/animal cell) using a suitable technique: transformation, electroporation, transfection, gene gun.

G.	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, RT-PCR, Real time PCR, Microarray, DNA sequencing using Sanger's Dideoxy chain termination method and automated sequencer; chromosome walking, Hybrid release and hybrid arrest translation to screen clones, site directed mutagenesis.
2.	**Application of Genetic Engineering in Biology, forensics and medicine**
2.1	**Application of genetic engineering in DNA diagnostics and production of recombinant drugs, vaccines and hormones**
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 dispute and criminal cases (DNA finger printing).
2.2	
A.	Manipulation of gene expression in Prokaryotes; , gene expression from strong and regulatable promoters, Developing fusion proteins and separation of cloned protein by protease induced cleavage.
B.	Genetic manipulation to increase recombinant protein stability and secretion using signal sequences.
3.	**Application of Genetic Engineering in Agriculture**
3.1	
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.
4.	**Application of Genetic Engineering in Industry**
4.1	**Genetic engineering of microbes for production of enzymes, biomolecules and fermentation products.**
A.	Genetic manipulation of microbes to over-produce industrially valuable enzymes.
B.	Production of microbial SCPs.
5.	**Application of Genetic engineering in Bioremediation, Biorecovery and Biomonitoring of xenobiotics, metals and organometals.**
5.1	**Genetic engineering of microbes for bioremediation and biomonitoring of toxic environmental pollutants, Biohydrometallurgy**
A.	Microbial bioremediation of xenobiotics by recombinant microbes.
B.	Bioremediation of toxic heavy metals and organometals by recombinant microbes.
C.	Biohydrometallurgy using recombinant microbes for recovery of precious metals.

IMMUNOLOGY

1.	
1.1	Phagocytosis – Cell surface receptors/markers and their role, killing mechanisms; NK cells – Cell to cell recognition for normal and modified cells, receptors, initiation of apoptosis and killing of target cells, malfunctioning of NK cells; role of mast cells in immunity.
1.2	Concept of immunoglobulin domain, distribution of immunoglobulin domain, superfamily member, structure and function of TCR, diversity of antigen binding domain, concept of segmented gene, gene organisation of Ig and TCR, generation of gene during differentiation and development of B and T Cells, expression of Ig and TCR Cistrons, class switch and regulation of expression, B and T Cell ontogeny.
1.3	Major Histocompatibility Cluster – Introduction to MHC I, II and III, structure and function of MHC I and II, distribution and recognition of MHC I and II, gene organisation and concept of polymorphism, expression and its regulation, processing of extracellular antigen by APC, presentation of intracellular antigen by nucleated cells, recognition of MHC I and II by TCR/CD3 complex; Members of MHC III and their roles (in brief).
2.	
2.1	Ontogeny of T- and B-cells, immunocompetent T and B cells, recognition, signalling and activation of T cells by APC, control and regulation of activated T-Cells, B-cell activation – Type 1 thymus-independent antigen, Type 2 thymus-independent antigen, thymus dependent antigen, co-operation with T-cells and activation of resting B-cells, antigen processing by B-cells, stimulation by cross-linking surface Ig.
2.2	Cytokine as messengers, receptor for cytokine – gp130 subfamily, beta-c and gamma-c receptor subfamily, signal transduction and effects, network interactions; TH1 and TH2 responses; Cytokine mediated chronic inflammatory response; Killer T Cell and its regulation; effect of antigen dose and maturation of affinity of antibodies; role of memory cells.
2.3	Antigen as major factor in control, feedback control of antibody production, T cell regulation – T-helper cells, T-cell suppression; Idiotypic networks, influence of genetic factors, immune regulation through hormone; T-cell tolerance.
3.	
3.1	Concept of inflammation, complement fixation, defence against intracellular bacterial pathogen, immunity to viral infection, immunity to fungi, immunity to parasitic infections; Passively acquired immunity, vaccination.
3.2	Immuno-techniques: Antigen antibody interactions in solution, identification and measurement of antigen, epitope mapping, hybridoma technology and monoclonal antibody revolution, catalytic antibodies, engineering antibodies, antigen-antibody based affinity chromatography (revision if done in techniques), isolation of leukocyte and subpopulations, localization of antigen *in cyto* and *in tissue*.

EXTREMOPHILIC MICROORGANISMS

1.	Concept of extremophiles v/s conventional microbial forms
2.	Extreme habitats in universe, extreme communities in following econiches: deserts, rhizospheres, ore deposits/ mining areas (Fe, Mn, Cu), animal systems, deep biosphere (terrestrial and marine), hydrothermal vents.
3.	Significance in biogeochemical cycling, industry, pharma and degradation of

	xenobiotics
4.	Key Molecular components, Unique : physiological features, adaptation strategies and enzymes of various extremophilic types:
A.	Anaerobes: oxygen toxicity and regulation in *Clostridium, Moorella thermoacetica*, Wood Ljungdahl pathway
B.	Barophiles/Peizophiles: mechanism in barophily, alpha proteobacteria
C.	Cryophiles, Psychrophiles: (cold shock proteins and regulation) *Polaromonas*
D.	Thermophiles: heat shock proteins, rho factors and regulation, *Aquifex, Tepidomonas, Rhodothermus*
E.	Alkaliphiles/ basophiles: *Alkalimonas, Nesterenconia*
F.	Acidophiles: *Picrophilus, Ferroplasma*
G.	Halophiles: *Halomonas*
H.	Osmophiles: Osmophilic *Lactobacilli, Schizosaccharomyces pombe*
I.	Oligotrophs: *Pelagibacter*
J.	Xerophiles: *Wallemia*, extreme cyanobacteria
K.	Radiophiles: *Deinococcus radiodurans*
L.	Metallophiles: *Geobacillus*
M.	Xenobiotic users: *Pseudomonas*
N.	Endoliths: *Chroococcidiopsis, Halothece*

MICROBIAL TECHNOLOGY

1.	**Biotechnology and prospecting with microbes.**
A.	Advantages of using microbial technology over chemical and physical technology.
B.	Ethics in the use of GEMs.
C.	Commercialization of Microbial Biotechnology.
D.	Introduction to Nanotechnology.
2.	**Microbial technology in agriculture**
	Production of microbial biofertilizers, biopesticides, soil conditioners to enhance crop yields.
3.	**Microbial technology in mining**
A.	Bioleaching.
B.	Biomining.
C.	Recovery of oil. MEOR
D.	Microbial technology in waste and pollution management in mining: Bioconversions, Bioremediation, Biosedimentation, Bio-beneficiation, Aquifer cleaning.
4.	**Microbial technology for energy production**
A.	Microbial fuel cell.
B.	Biogas.
C.	Microbial cell mass.
5.	**Microbial technology in Human health & aquaculture**
	Pigments, Nutraceuticals, Probiotics, Bioplastics, Microbes as bio-weapons.

FOOD MICROBIOLOGY

1.	**Microbial Food Spoilage and Food Preservation**
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**
2.1	**Fermented and processed foods**
A.	Indian fermented foods.
B.	Oriental fermented foods.
C.	Fermentations: wine
2.2	**Genetically engineered microorganisms in the Food Industry**
A.	Concept and role of genetically engineered microbes in the food industry.
3.	**Food Safety and Quality Assurance**
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.
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.

AGRICULTURE MICROBIOLOGY

1.	**Soil Microbiology**
A.	Terrestrial Ecosystem, Pyramids and Econiches.
B.	Types of Soil, soil Profile, Physico-Chemical Characteristics.
C.	Suitability of soil for agriculture.
D.	Soil Enzymes and significance.
E.	Influence of microbial metabolism on soil chemistry & humus formation and its significance (humic and fulvic acids).
F.	Factors influencing bacterial survival in soils: Biotic & Abiotic.
G.	Establishment of microbial inoculant.
H.	Rhizosphere and Rhizoplane Microflora.
I.	Plant growth promoting Rhizobacteria, nitrogen fixation, phosphate mobilization and biocontrol of plant pathogens.
2.	**Beneficiary Microorganisms to plants**
A.	Mycorrhiza – Ectomycorrhiza, Endomycorrhiza, VAM structure & significance.

B.	Plant growth promoting hormones from microbes viz. bacteria and fungi & their significance.
C.	Nitrogen-fixing microbes - Biochemistry and Genetics of free living and symbiotic nitrogen fixers viz. *Azotobacter vinelandii, Rhizobium*. Significance of *nif* H, D, K, A, L, nod, nodulin and *fix* genes in microbial nitrogen fixation.
D.	Biofertilizers: An Overview.
(i)	free living soil microbes fixing N_2 (*Azotobacter, Azospirillum*).
(ii)	*Rhizobium/Azorhizobium,* in symbiotic association with leguminous plants.
(iii)	Free living cyanobacteria- N*ostoc*.
(iv)	Associative cyanobacteria (symbionts)-*Anabaena azollae*
(v)	*Azolla* as Biofertilizer.
(vi)	Compost as Biofertilizer.
E.	Microbial Pesticides – (Biocontrol agents for agriculturally important crop plants) – Development and their significance; Source Organisms: Bacteria-*Bacillus thuringiensis*, Bt based commercial products, other Bacilli producing pesticides; Fungi—*Beauveria bassiana*, Viruses- Baculoviruses for insect pest control.
3.	
	Plant Pathogens (bacterial, fungal, viral, viroid).
	Virulence in plant pathogens - biochemical and genetic basis of virulence, toxins as virulence factors
	Plant defense responses - anatomical changes, phytoalexins, alkaloids and other biocontrol molecules
	Pathogen control - viral proteins in controlling viral diseases, mycoviruses against fungal plant pathogens, RNA and antisense RNA technology in disease control

MEDICAL MICROBIOLOGY AND EPIDEMIOLOGY

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.
1.2	Pili, flagella, biofilm, quorum-sensing, iron scavenging, aggressins/impedins against host defence.
1.3	Host susceptibility, pre-disposing factor (nutritional, soci-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.
2.	
2.1	Exotoxins – Type III secretion system, AB – type toxins, examples (Tetanospasmin, diphtheria toxin, pertusis toxin). Endotoxin – structure, biosynthesis, assay, pathophysiological effects, excessive inflammatory response, endotoxin neutralizing compound, antagonists of LPS.
2.2	Cystic fibrosis, Spongiform encephalopathy.
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.
3.2	Community acquired infection, infections in immunocompromised 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.

MARINE MICROBIAL INTERACTIONS

1.	**Symbiotic associations**
	Symbiosis of microalgae with animals; Symbiosis of chemoautotrophic prokaryotes with animal; Light organ symbiosis in fish and invertebrates; Microbial symbionts of sponges; Symbiosis and mixotrophy in protists; Metabolic consortia and mutualism between prokaryotes.
2.	**Microbial diseases of fish and invertebrates**
	Diseases of fish, bivalve mollusks, crustaceans, corals in fresh water/ sea water/ aqua culture: Bacterial – vibriosis, furunculosis, bacterial kidney disease, mycobacteriosis, streptococcosis, black band disease, white plague, white pox, Juvenile Oyster Disease (JOD). Viral – Infectious salmon anemia (ISA) virus, viral hemorrhagic septicemia virus (VHSV), lymphocystis virus, birnaviruses, viral nervous necrosis. Protistan – *Paramoeba perurans, Kudoa sp., Loma salmonae, Hematodinium* Diagnostic methods. Control of disease.
3.	**Marine microbes - Beneficial and harmful**
	Beneficial aspects: Biodegradation and bioremediation of marine pollutants such as oil, persistent organics and plastics. Environmental monitoring using indicator microorganisms. Microbial enzymes and polymers. Harmful aspects: Harmful Algal Blooms (HABs). Biodeterioration, biofouling, bio-invasion – ballast waters.

References/ Readings

Adams, M. R. and Moss, M. O., Food Microbiology, New Age International (P) Limited Publishers, New Delhi.
Ahmad, I., Ahmad, F. and Pichtel, J. Microbes and Microbial Technology: Agriculture and Environmental Applications, Springer.
Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K. and Walter, P., Molecular Biology of the Cell, Garland Science.
Alexander, M., Introduction to Soil Microbiology, Wiley.
Alexopoulus, C. J., Mims, C. W. and Blackwell, M., Introductory Mycology, John Wiley & Sons (Asia) Pvt. Ltd.
Arora, P. N. and Malhan, P. K., Biostatistics, Himalaya Publishing House.
Arora, R., Microbial Biotechnology: Energy and Environment, CABI Publishing.
Atkinson, B. and Mavituna, F., Biochemical Engineering and Biotechnology Handbook, Stockton Press.
Barker, D. M., Archaea: Salt-lovers, Methane-makers, Thermophiles and Other Archaeans, Crabtree Publishing Company.
Barlow, A., The prokaryotes: A Handbook on the Biology of Bacteria: Ecophysiology, Isolation, Identification, Applications, Volume 1, Springer-Verlag.
Belkin, S. and Colwell, R. R., Ocean & Health: Pathogens in the Marine Environment, Springer.
Bilgrami K. S. (1987) Plant Microbe Interactions, Proceedings of Focal Theme Symposium, Indian Science Congress Association, Narendra Publishing House.
Birnboim, H. C. and Doly, J., (1979) A rapid alkaline extraction procedure for screening recombinant plasmid DNA. Nucleic Acid Research, 7: 1513-1523.
Blum, P., Archaea: New Models for Prokaryotic Biology, Academic Press.
Bona, C. A. and Bonilla, F. A., Textbook of Immunology, Fine Arts Press
Boone, D. R. and Castenholz, R. W., Bergey's Manual of Systematic Bacteriology: The Archaea and The Deeply Branching and Phototrophic Bacteria, Springer Science and Business Media.
Brock, T. D., Thermophilic Microorganisms and Life at High Temperatures, Springer, New York.
Bull, A. T. and Meadow, P., Companion to Microbiology, Longman Group Limited, New York.
Bull, A. T., Microbial Diversity and Bioprospecting, American Society for Microbiology.
Carr, N. G. and Whitton, B. A., The Biology of Blue-green algae, University of California Press.
Cavicchioli, R., Archaea: Molecular and Cellular Biology, ASM Press.
Chakraborty, P. and Pal, N. K., Manual of Practical Microbiology and Parasitology, New Central Book Agency (P) Ltd, Delhi, India.
Colowick, S. P. and Kaplan, N. O., Methods in Enzymology, Vol. VI, Academic Press, N.Y.
Cooke, R. C. and Whipps, J. M., Ecophysiology of fungi, Blackwell Scientific Publications, Oxford.
Cooper, T. G., The Tools of Biochemistry, Wiley India Pvt. Ltd.
Corcelli, A. and Lobasso, S., (2006) Characterization of Lipids of Halophilic Archaea. Methods in Microbiology, 35: 585-613.

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.
Dadarwal, K. R., Biotechnological Approaches in Soil microorganisms for sustainable crop production, Scientific Publishers.
Dale, J. W. and Park, S. F., Molecular Genetics of Bacteria, John Wiley
Danilina, N.I., Computational Mathematics, Mir Publishers.
Darnell, J. E., Lodish, H. F. and Baltimore, D., Molecular Cell Biology, Scientific American Books, Spektrum Akademischer Verlag.
Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S., Microbiology, Harper and Row.
Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.
Deacon, J. W., Introduction to Modern Mycology, Volume 7 of Basic Microbiology, Blackwell Scientific Publications.
Delves, P., Martin, S., Burton, D. and Roitt, I., Roitt's Essential Immunology. Wiley-Blackwell.
Demain, A. L., Davies, J. E. and Atlas, R. M. Manual of Industrial Microbiology and Biotechnology, ASM Press.
Domsch, K. H., Gams, W. and Anderson, T-H., Compendium of Soil Fungi, IHW-Verlag.
Doyle, M. P. and Buchanan, R. L., Food Microbiology: Fundamentals and Frontiers, ASM Press.
Flickinger, M. C. and Drew S. W., The Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis and Bioseparation, Volumes 1 - 5, John Wiley Publisher.
Frazier, W. C. and Westhoff, D. C., Food Microbiology, M. C. Graw-Hill Companies, Inc., New York.
Gardner, E. J., Simmons, M. J. and Snustad, D. P., Principles of Genetics, John Wiley & Sons.
Garrett, R. A. and Hans-Peter, K., Archaea: Evolution, Physiology and Molecular Biology, John Wiley and Sons.
Gatesoupe, F. J., (1999) The use of probiotics in aquaculture, Aquaculture, 180: 147-165.
Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier.
Gillespie, S.H. and Hawkey, P.M., Principal and Practice of Clinical Bacteriology. Wiley.
Gilman, J. C. and Joseph, C., A Manual of Soil Fungi, Daya Books.
Glick, B. R., Pasternak, J. J. and 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.
Goldsby, R. A., Kindt, T. J. and Osborne, B. A., Kuby Immunology. W.H. Freeman
Goodfellow, M. and Minnikin, D. E., Chemical Methods in Bacterial Systematics, The Society for Applied Bacteriology. Technical Series No. 20, Academic Press.
Goswami, C., Paintal, A. and Narain, R., Handbook of Bioinstrumentation, Wisdom Press, New Delhi.
Grasshoff, K., Ehrhardt, M. and Kremling, K., Methods of Seawater Analysis, Verlag Chem., Weinheim.
Green, M. R. and Sambrook, J., Molecular Cloning: A laboratory manual, Cold Spring Harbour Laboratory Press, New York.
Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring

Harbor Laboratory, New York.
Grinsted, J. and Bennett, P. M., Methods in Microbiology, Vol. 21, Plasmid Technology, Academic Press.
Harrigan, W. F., Laboratory Methods in food Microbiology, CRC Press, Taylor & Francis Group.
Holmes, D. S. and Quigley, M., (1981) A rapid boiling method for the preparation of bacterial plasmids. Anal Biochem., 114(1): 193-197.
Horikoshi, K. and Grant, W. D., Extremophiles-Microbial Life in Extreme Environments, Wiley, New York.
Howland, J. L., The Surprising Archaea: Discovering Another Domain of Life, Oxford University Press.
Hunter-Cevera, J., Karl, D. and Buckley, M., Marine Microbial Diversity: the Key to Earth's Habitability, American Academy of Microbiology.
Janeway, C. A., Travers, P., Walport, M. and Shlomchik, M. J., Immunobiology, Garland Science.
Jay, M. J., Loessner, M. J. and Golden, D. A., Modern Food Microbiology, Springer Science + Business Media Inc., New York.
Jayaraman, J., Laboratory Manual in Biochemistry, John Wiley & Sons, Limited, Australia.
Kendrick, B., The Fifth Kingdom, Focus Publishers.
Kothari, C. R., Quantitative Techniques, Vikas Publishing House.
Krebs J. E., Lewin, B., Goldstein, E. S. and Kilpatrick S.T., LEWIS Genes XI., Jones and Bartlett Publishers.
Kumar, H. D., Modern Concepts of Microbiology, Vikas Publishing House Pvt. Ltd.
Kurtzman, C. P., Fell, J. W. and Boekhout, T., The Yeasts - A Taxonomic Study, Elsevier.
Lehninger, A., Cox, M. and Nelson, D. L., Principles of Biochemistry, W. H. Freeman & Company.
Liu, W-T. and Jansson, J. K., Environmental Molecular Microbiology, Caister Academic Press.
Madigan, M. T., Martinko, J. M., Bender, K. S., Buckley, D. H. and Stahl, D. A., Brock Biology of Microorganisms, Pearson Education Limited.
Mahanta, K. C., Fundamentals of Agricultural Microbiology, Oxford & IBH Publishers.
Maier, R., Pepper, I. and Gerba, C., Environmental Microbiology, Academic Press.
Malacinski, G.M., Freifelder's Essentials of Molecular Biology, Narosa Book Distributors Private Limited.
Maloy, S. R., Cronan, J. E. and Freifelder, D., Microbial Genetics, Jones and Bartlett Publishers.
Mehrotra, R. S. and Aneja, K. R., An Introduction to Mycology, Wiley Eastern Limited.
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.
Moat, A. G., Foster, J. W. and Spector, M. P., Microbial Physiology, A. John Wiley & Sons Inc. Publication.
Munn, C., Marine Microbiology: Ecology and Applications, Garland Science, Taylor and Francis Group, N.Y.
Murray, R. K., Bender, D. A., Botham, K. M., Kennelly, P. J., Rodwell, V. W. and Weil, P. A., Harper's Illustrated Biochemistry, The McGraw-Hill Companies, Inc.
Murugesan, A. G. and Rajakumari, C., Environmental Science and Biotechnology: Theory and Techniques, MUP Publishers.

Norris, J. R. and Ribbons, D. W., Methods in Microbiology, Vol. 5, 18 & 19, Academic Press.
Nybakken, J. W. and Bertness, M. D., Marine Biology: an Ecological Approach, Benjamin Cummings, San Francisco, N.Y.
Old, R. W. and Primrose, S. B., Principles of Gene Manipulation: An introduction to Genetic Engineering, University of California Press.
Onions, A. H. S., Allsop, D. and Eggins, M. O. W., Smith's Introduction to Industrial Mycology, Edward Arnold, London.
Osborn, A. M. and Smith, C. J., Molecular Microbial Ecology, Taylor and Francis.
Parakhia, M. V., Tomar, R. S., Patel, S. and Golakiya, B. A., Molecular Biology and Biotechnology: Microbial Methods, New India, Pitampura.
Parsons, T. R., Maita, Y. and Lalli, C. M., Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, New York.
Peppler, H.J., Microbial Technology: Microbial Processes, Academic Press.
Peter, J. R., iGenetics: A Molecular Approach, Pearson Education.
Plummer, D. T., An Introduction to Practical Biochemistry, Tata McGraw Hill Publishing Company.
Prescott, L. M., Harley, J. P. and Klein, D.A., Microbiology. McGraw Hill, New York.
Rainey, F. A. and Oren, A., Extremophile Microorganisms and The Methods to Handle Them. In: Extremophiles, Methods in Microbiology, Vol. 35, Elsevier, Amsterdam.
Ramesh, K. V., Food Microbiology, MJP Publishers, Chennai.
Reddy, C. A., Methods for General and Molecular Microbiology, ASM Press.
Rothe, O. and Thomm, M., (2000) A simplified method for the cultivation of extreme anaerobic archaea based on the use of sodium sulfite as reducing agent, Extremophiles. 4: 247-252.
Sadasivam, S., Manickam, A., Biochemical Methods, New Age International (P) Limited.
Sambrook, J., Fritsch, E. F. and Maniatis, T., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York.
Scragg, A. H., Environmental Biotechnology, Longman Publishers.
Sharma, P. D., Environmental Microbiology, Alpha Science International.
Sindermann, C. J., Principal Diseases of Marine Fish and Shellfish: Diseases of Marine Fish, Vol. 1, Gulf Professional Publishing.
Sneath, A. H. P., Mair, S. N. and Sharpe, E. M., Bergey's Manual of Systematic Bacteriology Vol. 2. Williams & Wilkins Bacteriology Symposium, Series No 2, Academic Press, London/New York.
Somani, L. L., Biofertilizers in Indian Agriculture, Concept Publishing Company.
Sournia, A., UNESCO Monographs on Oceanographic Methodology, Vol. 6, Phytoplankton Manual, UNESCO Publishing, Paris.
Stanbury, P. F., Whitaker, A. and Hall, S.J., Principles of Fermentation Technology, Butterworth-Heinemann Publishers.
Streips, U. N. and Yasbin, R. E., Modern Microbial Genetics, John Wiley.
Strickberger, M. W., Genetic, The MacMillan Company, New York.
Strickland, J. D. H. and Parsons, T. R., A Manual of Seawater Analysis, Queen's Printer and Controller of Stationery, Ottawa.
Struthers, J.K. and Westran, R.P., Clinical Bacteriology. CRC Press.
Subba Rao, N. S., Advances in Agricultural Microbiology, Oxford & IBH Publishers.
Subba Rao, N. S., Biofertilizers in Agriculture and Forestry, International Science Publishers.

Sukla, L. B., Pradhan, N., Panda, S. and Mishra, B. K. Environmental Microbial Biotechnology, Springer.
Surya, R. K., Biostatistics, Himalaya Publishing House.
Synder, L., Peters, J. E., Henkin, T. M. and Champness, W., Molecular Genetics of Bacteria, ASM Press.
Tamarin, R. H., Principles of Genetics, McGraw-Hill Higher Education.
Tomas, C. R., Identifying Marine Phytoplankton, Academic Press, San Diego, CA.
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.
Trun, N. and Trempy, J., Fundamental Bacterial Genetics, John Wiley & Sons.
Twyman, R. M. and Wisden, W., Advanced Molecular Biology: A Concise Reference, BIOS Scientific Publishers.
Veeresh, G. K. and Rajagopal, D., Applied Soil Biology and Ecology, Oxford & IBH Publishing Company Pvt. Limited.
Ventosa, A., Nieto, J. J. and Oren, A. (1998) Biology of moderately halophilic aerobic bacteria. Microbiology and Molecular Biology Reviews, 62, 504–544.
Voet, D., Voet, J. G. and Pratt, C. W., Principles of Biochemistry, John Wiley and Sons Inc.
Vogel, H. C. and Tadaro, C. M., Fermentation and Biochemical Engineering Handbook: Principles, Process Design and Equipment, William Andrew Publisher.
Watson, J. D., Molecular Biology of the Gene, Pearson/Benjamin Cummings.
Williamson, R., Genetic Engineering, Volumes 4-7, Academic Press.
Wilson, K. and Walker, J., Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press, N.Y., USA.
Woese, C. R., Fox, G. E., (1977) Phylogenetic structure of the prokaryotic domain: the primary kingdoms. Proc Natl Acad Sci USA. 74: 5088–5090.