



Fergusson College (Autonomous) Pune

Learning Outcomes-Based Curriculum

M. Sc. I - Biotechnology

With effect from June 2019

### Program structure

Semester	Course Code	Course Title	No. of Credits
I	BTH4101	Molecular Biology	4
	BTH4102	Cell Biology	4
	BTH4103	Biological Chemistry and Bacteriology	4
	BTH4104	Developmental Biology and Human Population Genetics	4
	BTH4105	Biotechnology Practical - I	4
	BTH4106	Biotechnology Practical - II	4
		<b>Total</b>	<b>24</b>
II	BTH4201	Genetic Engineering and Industrial Biotechnology - I	4
	BTH4202	Animal and Plant Biotechnology	4
	BTH4203	Virology and Immunology	4
	BTH4204	Biotechnology Practical - III	4
	BTH4205	Biotechnology Practical - IV	4
	BTH4206	Critical Reading of Primary Scientific Literature <b>OR</b>	2
	BTH4207	Agricultural Biotechnology <b>OR</b>	
	BTH4208	Environmental Biotechnology <b>OR</b>	
	BTH4209	Microbial Genetics <b>OR</b>	
	BTH4210	MOOCS - I	
	BTH4211	Clinical Research <b>OR</b>	2
	BTH4212	Bioethics and Biosafety <b>OR</b>	
	BTH4213	Research Methodology <b>OR</b>	
	BTH4214	MOOCS - II	
		<b>Total</b>	<b>24</b>

### Programme Outcome

PO1	Identify, analyze and understand problems related to field of biotechnology.
PO2	Gain knowledge and understanding of related norms and practices used in biotechnology product/technique development
PO3	Function as a researcher in laboratory and/or industrial settings.
PO4	Conduct original research in a biological sub-discipline, including the design of experiments with appropriate controls, critical thinking and result analysis.
PO5	Demonstrate awareness about project and financial management when dealing with biotechnology related research.
PO6	Effectively communicate by defending original research in writing and in oral presentation.
PO7	Understand concept and importance of patent laws, intellectual property rights and its implications in biotechnology.
PO8	Combine wet lab and bioinformatics to understand process of biotechnological innovation.
PO9	Develop skills associated with industrially relevant applications.
PO10	Practice professional ethics in the conduct of science.

## BTH4101 Molecular Biology

**Credits: 4**

<p><b>Learning Outcome:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• How different genomes are packaged and organized</li> <li>• Various transposable DNA elements and their mechanism of transposition</li> <li>• Various Molecular Biology processes like replication, transcription, translation</li> <li>• Control and regulation of various processes</li> </ul>	<p><b>Suggested Pedagogical Processes:</b></p> <p>ICT, presentations, blackboard teaching, model making by students, problem solving tutorials, discussions regarding current research trends.</p>
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Sr. No.	Topic	Lecture (Total 60)
<b>1</b>	<b>Genome Structure and Organization:</b> Definition and organization of viral, prokaryotic and eukaryotic genomes: Structure of chromatin, nucleosome, chromatin organization and remodeling, higher order organization-chromosome, centromere, telomere. Histones and their effect on structure and function of chromatin. C value paradox and genome size, Cot curves, repetitive and non-repetitive DNA sequences, satellite DNA, DNA melting and buoyant density. Gene families, clusters, Pseudogenes, super-families, Organelle genomes.	8
<b>2</b>	<b>Mobile DNA elements:</b> Transposable elements in bacteria: IS elements, composite transposons; Types of transposons with examples: replicative and non-replicative transposons, retro-transposons, Transposable elements in eukaryotes: Tc1/marinar as an example, basic structure, mechanism of transposition and its applications.	5
<b>3</b>	<b>DNA damage and Repair:</b> Types of DNA damage; DNA repair mechanisms in (prokaryotes and eukaryotes) against these damages- base excision repair, nucleotide excision repair, double strand break repair, mismatch repair, SOS response, recombination repair, transcriptional coupled repair. Proteins and enzymes associated with DNA repair systems	5
<b>4</b>	<b>Recombination:</b> Homologous recombination process and model for homologous recombination- Holliday junction; site-specific recombination, NHEJ, Proteins involved in recombination- RecA, RuvA, B, C.	5
<b>5</b>	<b>DNA Replication and Regulation:</b> DNA polymerases and mechanisms of DNA replication in prokaryotes and eukaryotes DNA replication models, connection of replication to cell cycle, Gene amplification (rRNA) Reverse Transcriptase	10
<b>6</b>	<b>Gene Expression and Regulation in Prokaryotes and Eukaryotes</b> Transcription: Basic mechanism in prokaryotes and eukaryotes. RNA Polymerases, pseudo-ORFs, Chromatin remodeling in relation to gene expression, DNase hypersensitivity, DNA methylation. Regulation of transcription including transcription factors. Post-transcriptional processing and transport of RNA. Non coding RNAs. Organization and structure-function of ribonucleoproteins (Ribonomeconcept).	17
<b>7</b>	<b>Protein Synthesis and Regulation:</b> Components of protein synthesis, Mechanism of protein synthesis, Genetic code, codon usage, Regulation of protein synthesis	10
	<b>Seminars/ group discussion for various current and relevant topics</b>	

**Reference Books:**

1. Genes XI, 11th edition (2012), Benjamin Lewin, Publisher - Jones and Barlett Inc. USA
2. Molecular Biology of the Gene, 6th Edition (2008), James D. Watson, Tania Baker, Stephen P. Bell, Alexander Gann, Michael Levine, Richard Lodwick. Pearson Education, Inc. and Dorling Kindersley Publishing, Inc. USA
3. Molecular Biology, 5th Edition (2011), Weaver R., McGraw Hill Science. USA
4. Fundamentals of Molecular Biology, (2009), Pal J.K. and Saroj Ghaskadbi, Oxford University Press. India
5. Molecular Biology: genes to proteins, 4th edition (2011), Burton E Tropp, Jones & Bartlett Learning, USA
6. Muñoz-López M, García-Pérez JL. DNA transposons: nature and applications in genomics. *Curr Genomics*. 2010;11(2):115-28.

## BTH4102 Cell Biology

**Credits: 4**

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Structure and function of organelles in a cell.</li> <li>• Cellular transport and protein trafficking.</li> <li>• Cell signaling and cancer pathways.</li> <li>• Techniques in cell biology.</li> </ul>	<p><b>Suggested Pedagogical Processes:</b></p> <p>ICT, presentations, brainstorming, research article analysis, story boarding, co-operative learning, practical based unit of enquiry.</p>
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Sr. No.	Topic	Lecture (Total 60)
1	<p><b>Introduction to different types of cells:</b></p> <ul style="list-style-type: none"> <li>• Concept of different cell types: bacteria, archaea, eukaryotes</li> <li>• Discuss specialized eukaryotic cells – eg: photoreceptors, auditory hair cells, egg/sperm, nematocyte (stinging cell), plant cells (velamen, pollen)</li> </ul>	3
2	<p><b>Cell structure and function: Biomembranes and Cell Architecture</b></p> <ul style="list-style-type: none"> <li>• Biomembrane structure and properties: Membrane lipids and membrane proteins</li> <li>• Structure and function of organelles of the eukaryotic cell: Overview of plasma membrane, ER, golgi, mitochondria, chloroplast, vacuoles, peroxisomes, lysosomes, nucleus.</li> </ul>	7
3	<p><b>Cell communication</b></p> <ul style="list-style-type: none"> <li>• Cellular interaction</li> <li>• Cell-cell adhesion</li> <li>• Cell- matrix adhesion</li> <li>• Plant cell communication</li> </ul>	6
4	<p><b>Transport across Cell Membranes:</b> Overview of Membrane Transport :                      Passive , active and co-transport</p> <ul style="list-style-type: none"> <li>• Transporters and channels</li> <li>• ATP-Powered Pumps</li> <li>• Gated and Non-gated Ion Channels</li> <li>• Co-transport by Symporters and Antiporters</li> <li>• Movement of Water</li> </ul>	6
5	<p><b>Protein trafficking</b></p> <p>Intracellular Compartments and Protein Sorting</p> <ul style="list-style-type: none"> <li>• Translocation of secretory proteins across the ER Membrane</li> <li>• Insertion of proteins into the ER Membrane</li> <li>• Protein modifications, folding, and quality control in the ER</li> <li>• Sorting of Proteins to nucleus, mitochondria, chloroplasts and peroxisomes</li> </ul> <p>Intracellular Vesicular Traffic</p> <ul style="list-style-type: none"> <li>• Molecular Mechanisms of Vesicular Traffic</li> <li>• Transport from the ER through the golgi</li> <li>• Endocytosis and exocytosis</li> </ul>	8
6	<p><b>Cell Signalling pathways:</b> Signaling Molecules and Cell-Surface Receptors</p> <ul style="list-style-type: none"> <li>• GPCRs</li> <li>• TGF Receptors</li> <li>• JAK-STAT Pathway</li> <li>• Receptor Tyrosine Kinases and Activation of Ras</li> <li>• MAP Kinase Pathways</li> </ul>	8

	<ul style="list-style-type: none"> <li>• Electrical and synaptic signalling</li> <li>• Synaptic Vesicle Function and Formation</li> </ul>	
7	<b>The Cytoskeleton :</b> <ul style="list-style-type: none"> <li>• The dynamic network</li> <li>• Microfilaments, intermediate filaments and microtubules</li> </ul>	5
8	<b>The Cell Cycle and Cancer:</b> <ul style="list-style-type: none"> <li>• Cell cycle and cell-cycle check points</li> <li>• Apoptosis</li> <li>• Tumor suppressors and oncogenes</li> </ul>	8
9	<b>Techniques in cell biology:</b> <ul style="list-style-type: none"> <li>• Imaging of cells using different microscopy techniques (light, electron, scanning electron, phase-contrast, time-lapse and confocal microscopy). Patch-clamping technique, Fractionation of subcellular components, immuno-fluorescence technique, cell-sorting (FACS), FRET and FRAP.</li> </ul>	9
	<b>Seminars/ group discussion for various current and relevant topics</b>	

### Reference Books:

1. Molecular Cell Biology. 7th Edition, (2012) Lodish H., Berk A, Kaiser C., K Reiger M., Bretscher A., Ploegh H., Angelika Amon A., Matthew P. Scott M.P., W.H. Freeman and Co., USA
2. Molecular Biology of the Cell, 5th Edition (2007) Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter. Garland Science, USA
3. Cell Biology, 6th edition, (2010) Gerald Karp. John Wiley & Sons., USA
4. The Cell: A Molecular Approach, 6th edition (2013), Geoffrey M. Cooper, Robert E. Hausman, Sinauer Associates, Inc. USA.

## BTH4103 Biological Chemistry and Bacteriology

Credits:4

<b>Learning Outcomes:</b> <b>The students will be able to understand:</b> <ul style="list-style-type: none"><li>• Fundamentals of structure and function of proteins</li><li>• Techniques to study protein structure and interactions</li><li>• Enzyme kinetics and the complexity of metabolic reactions</li></ul>	<b>Suggested Pedagogical Processes:</b> ICT, presentations, blackboard teaching, model making by students, problem solving tutorials, discussions regarding current research trends, designing and planning biochemistry practicals.
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### Section I - Biological Chemistry

Sr. No.	Topic	Lecture (Total 30)
1	<b>Protein Biochemistry:</b> Primary, Secondary, Tertiary, quaternary Structure of Proteins. Protein folding mechanisms - Molten globule, energy funnel, chaperon, Protein Misfolding and misfolding diseases. Protein Processing- Proteolytic cleavage (Pre, Pro, removal). Protein Modifications – Glycosylation, Phosphorylation, Lipids attachment, Glycolipids. Protein degradation – Lysosomal & proteosomal ubiquitination	5
2	<b>Protein Structure and interactions:</b> Structure determination: Databases, various structure determination techniques. Structure-function relationship Techniques to study protein-protein and protein-small molecule interactions Spectroscopic techniques	10
3	<b>Bioenergetics &amp; Metabolism:</b> Free energy, Coupled reactions, Chemical equilibrium. Interaction networks of biomolecules in a cell. How signaling and metabolic pathways interact. Study of key molecules which play a role as multiple regulators. Understanding complex disorders	5
4	<b>Enzymology:</b> Enzymes–Activity, Regulation, Kinetics, Action of inhibitors and cofactors. Techniques for studying activity, kinetics, regulation	10
	<b>Seminars/ group discussion for various current and relevant topics</b>	

#### Reference Books:

1. Biochemistry: 4<sup>th</sup> Edition, (2011), Voet and Voet, John Wiley and Sons, Inc.
2. Principles of Biochemistry, 7<sup>th</sup> edition (2017), Lehninger, Freeman W.H. and Company
3. Biochemistry, Berg J., Tymoczko J., Stryer L., 8<sup>th</sup> edition (2015), Freeman W. H. and Company
4. Biochemical Calculations, 2<sup>nd</sup> Ed., (1997) Segel Irvin H., John Wiley and Sons, New York

## Section II - Bacteriology

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Molecular techniques for characterization of Bacteria.</li> <li>• Molecular basis of binary fission, bacterial cell structure, endospore formation</li> <li>• Metabolic diversity, molecular adaptations of extremophiles, quorum sensing and biofilm formation, Mathematical problems on generation time and growth rate, Microbial growth kinetics, Bacterial pathogenesis, antibacterial agents, multidrug resistance and plasmid curing.</li> <li>• Current trends in bacteriology</li> </ul>	<p><b>Suggested Pedagogical Processes:</b>            ICT, presentations, blackboard teaching.</p>
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Sr. No.	Topic	Lectures (Total 30)
1	<p><b>Bacterial Taxonomy:</b>            Overview of Classical methods, polyphasic approach, Molecular techniques for characterization of bacterial genotype (Pattern and Sequence Based).</p>	4
2	<p><b>Binary Fission and Cell Structure (Molecular basis)</b> –Cytoskeleton in prokaryotes, Genetic mechanism determining bacterial shapes, Proteins involved in process of binary fission.</p> <p><b>Cell Structure:</b>            Fimbriae, pili, axial filament, S layer, Glycocalyx (structure and significance)            Structure and Assembly of Flagella, Motility and Chemotaxes(molecular mechanism)            Cell wall and Cell membrane (Gram Positive, Negative and Archaeobacterial), Protoplast, Spheroplast, Lforms, Mycoplasma (taxonomic significance).            Endospore formation (mechanism describing role of sensor kinases) and Germination Inclusion bodies</p>	5
3	<p><b>Metabolic diversity of bacteria</b>            Nutritional Classification and Metabolic diversity of bacteria with specific examples, Quorum Sensing in Bacteria, Biofilms: Significance in bacterial Virulence and antibiotic resistance (one example each).</p>	5
4	<p><b>Microbial Growth:</b>            Generation time, Growth rate, Concept of Batch, fed batch and Continuous Culture, Synchronous growth, Diauxic growth.            Environmental effects on bacterial growth, Extremophiles their molecular adaptations and significance.</p>	5
5	<p><b>Bacterial Pathogenesis:</b> Entry of Pathogen in the host, colonization, Virulence factors, host factors, Molecular mechanism of pathogenesis of: <i>Mycobacterium tuberculosis</i>, Pathogenic <i>E. coli</i>, <i>Staphylococcus aureus</i>            Pathogenicity Islands – Concept with example            Molecular and immunological methods for disease diagnosis (of above mentioned pathogens)            Antibacterial agents with mode of action (Natural and synthetic)            Multidrug resistance in bacteria (cause and effect), Mechanisms of development of drug resistance of Methicillin Resistant <i>Staphylococcus aureus</i> (MRSA), case</p>	10



	studies. Plasmid curing a possible approach for overcoming drug resistance.	
6	Current trends in Bacteriology, Threats of Bioterrorism	1

### Reference Books:

1. Introduction to Microbiology. 3rd Edition, (2004), Ingraham JL and Ingraham CA. Thomson Brooks / Cole.
2. Brock's Biology of Microorganisms. 11th Edition, (2006). Madigan MT, Martinko JM. Pearson Education Inc. , USA
3. Pearson Education Inc. , USA
4. Fundamental Principles of Bacteriology. 7th Edition, (1971) Salle AJ. Tata MacGraw Publishing Co. India
5. Microbiology: An introduction, 5th edition,(1992), Tortora, G.J., Funke B.R., Case C.L, Benjamin Pub.Co. NY
6. Microbiology, 4th edition (1990), Davis B.D. ,DeBacco, J.B. Lippincott Co. NY
7. Zinsser, W , 1976, Microbiology Edition, W .K Joklik, NY
8. Medical Bacteriology, 14th edition, (1988), Dey, N.C and Dey, TK., Allied Agency, India
9. Text book of microbiology 5th edition (1996), Ananthnarayana, R. and C.E, Jayaram Panakar, Orient Longman.
10. General Microbiology, 5th edition (1987), Stanier R.Y., Adelberg E.A. and Ingraham J.L..Macmillan Press Ltd.
11. Prescott L.M., Harley J.P., and Klein D.A. (2005). Microbiology, 6th Edition. MacGrawHillCompanies Inc.
12. Principles of Virology 3<sup>rd</sup> edition, (1999), Flint Jane. S., ASM (American Society of Microbiology) Press Publisher, USA.
13. Field's Virology - 2 volumes, 5<sup>th</sup> edition, (2006), Bernard.N. Fields, Lippincott and Williams Wilkins, USA
14. Microbiology: An introduction, 5th edition,(1992), Tortora, G.J., Funke B.R., Case C.L, Benjamin Pub.Co. NY

**BTH4104 Developmental Biology and Human Population Genetics**  
**Credits: 4**  
**Section I-Developmental Biology**

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• The key events related to early embryogenesis including fertilization, cleavage, compaction. implantation, gastrulation and formation of body plan.</li> <li>• The basis of organogenesis.</li> <li>• Relate defects in prenatal development to congenital anomalies.</li> </ul>	<p><b>Suggested Pedagogical Processes:</b></p> <ul style="list-style-type: none"> <li>• ICT, presentations, blackboard teaching</li> </ul>
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Sr. No.	Topic	Lecture (Total 30)
1	<p><b>Gametogenesis and Early Development:</b></p> <ul style="list-style-type: none"> <li>• Oogenesis and Spermatogenesis:</li> <li>• Human Embryonic development till first eight weeks</li> <li>• Hormonal Regulation and Molecular Factors involved.</li> <li>• Cleavage, Embryo Implantation, Gastrulation</li> <li>• Discussion on abnormalities in early development</li> <li>• Emphasis on Human Development</li> </ul>	10
2	<p><b>Late Development:</b></p> <ul style="list-style-type: none"> <li>• Organogenesis,</li> <li>• Extra Embryonic Membranes</li> <li>• Birth</li> </ul>	8
3	<p><b>Techniques to study Developmental Biology:</b></p> <ul style="list-style-type: none"> <li>• Genetic analysis of developmental processes</li> <li>• Techniques of fluorescence microscopy</li> <li>• Cell transplantations</li> <li>• Transgenic techniques</li> <li>• RNAi and knock-down of developmental genes</li> <li>• Life-imaging of morphogenetic processes</li> <li>• Cell migration and intracellular transport of mRNAs and proteins</li> <li>• Basic techniques of molecular cloning and protein techniques</li> </ul>	8
4	<p><b>Applications and Clinical Significance:</b> prenatal testing to determine developmental abnormalities in embryo and foetal development. Biomedical applications like IVF, toxicity testing etc.</p>	4
	<b>Seminars/ group discussion for various current and relevant topics</b>	

### **Reference Books:**

1. Developmental Biology, Tenth Edition. Scott F. Gilbert; ISBN 10: 0878939784 ISBN 13: 9780878939787; Publisher: Sinauer Associates, Inc., 2013
2. Langman's Medical Embryology, Twelfth edition. Thomas W Sadler; Langman, Jan; ISBN: 9781451113426/1451113420; Publisher: Philadelphia : Wolters Kluwer Health/Lippincott Williams & Wilkins, c2012.
3. Principles of development, Third edition. Lewis Wolpert; ISBN: 9780199275373 (alk. paper); Publisher: Oxford ; New York : Oxford University Press, c2007.

## Section-II Human Population Genetics

<b>Learning outcome:</b> <b>The students will be able to understand:</b> <ul style="list-style-type: none"> <li>• Concepts in human genetics and its applications.</li> </ul>	<b>Suggested Pedagogical Processes:</b> ICT, presentations, blackboard teaching.
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Sr. No.	Topic	Lecture (Total 30)
1	<b>Pedigree analysis in humans:</b> Symbols, construction of pedigree, molecular genetic data.	3
2	<b>Genetic traits:</b> Monogenic traits and inheritance patterns (autosomal, sex-linked inheritance, sex limited and mitochondrial inheritance) <b>Quantitative Genetics:</b> Polygenic traits and mode of inheritance, analysis of variation: genetic and environmental factors, heritability, inbreeding and consequences, co-efficient of inbreeding and consanguinity	5
3	<b>Cytogenetics:</b> Karyotyping, Classical karyotyping (banding techniques). Molecular karyotyping (FISH, M-FISH, SKY, QF-PCR and mBAND). Various karyotyping symbols used in human genetics.	4
4	<b>Chromosomal aberrations and syndromes:</b> Changes in chromosomal number: euploidy, aneuploidy, polyploidy, mosaics, trisomy and monosomy. Changes in chromosomal structure: translocation, inversion, duplication, deletion. Autosomal and sex-linked disorders. Abnormal karyotype and its implications. Chromosomal abnormalities in cancer.	6
5	<b>Environment and the genome:</b> Imprinting and epigenetics, Genetics of cancer (Oncogenes and tumor suppressor genes), Genetics of aging (gerontology)	3
6	<b>Clinical detection of chromosomal abnormalities and molecular genetic analysis approaches:</b> Clinical tests to detect genetic disorders, amniocentesis, CVS, ultrasound, detection of alpha-fetoprotein. Application of molecular methodologies in genetic analysis, gene-based therapeutic approaches, mapping human genome, polymorphism and population analysis-SNPs and genotyping using sequence analysis and microarrays. Ethics and limitations.	5
7	<b>Mendelian genetics in random mating populations and discrepancies in human population:</b> Human population and gene pool concepts, modes of speciation, genotype and allele frequencies, variation, Hardy-Weinberg's laws, genetic equilibrium, X-linked loci, departure from equilibrium.	4
	<b>Seminars / group discussion for various current and relevant topics</b>	

### Reference Books:

1. Pasternak, An Introduction to Molecular Human Genetics, Fitzgerald, 2000
2. Gersen & Keagle, The Principles of Clinical Cytogenetics, Humana, 1999
3. Strachan & Read, Human Molecular Genetics, Wiley, 1999
4. Strickberger MW, Genetics, Prentice Hall-India, 2006
5. Hartl DL, Jones EW, Genetics: analysis of genes and genomes, Jones and Bartlett, Massachusetts)

**BTH4105 Biotechnology Practical - I**  
**(Molecular and Cell Biology)**  
**Credits: 4**

**Learning Outcome:**

**The students will be able to understand:**

- How nucleosomes are organized
- Isolation and separation of chromatin and RNA
- The functions and features of major organelle systems in eukaryotic cells.
- Apoptosis
- Basic cell biology lab techniques
- Enzyme activity assays

<b>Sr. No.</b>	<b>Topic</b>	<b>Practical (15Px4H)</b>
1	Isolation of nuclei and chromatin Mononucleosome size determination by agarose gel electrophoresis	3
2	Extraction and Analysis of Histones	3
3	RNA isolation from prokaryotes / eukaryotes	3
5	Isolation of mitochondria and lysosomes by sucrose gradient centrifugation and analysis of fractions by assay of SDH and acid phosphatase activity	3
6	Programmed cell death during limb development In Chick	2
7	Visualization of different cell junctions / Permanent slide preparation	1

**BTH4106 Biotechnology Practical - II**  
**(Biochemistry, Bacteriology, Developmental Biology and Human Population Genetics)**  
**Credits: 4**

**Learning Outcome:**

**The students will be able to understand:**

- Protein quantification, Extraction and purification of proteins
- Enzyme activity by performing assays
- Study growth curve pattern under different environmental conditions
- Techniques of isolation and identification of an organism
- Extract bioactive component from given sample
- Stage-specific developmental changes in the given system and correlate it with human development.
- Modern techniques and biomedical applications of Developmental Biology after their visit to a genetics lab.
- Inheritance patterns in a given population.
- Reasons behind manifestations of various genetic disorders which might help them in thinking about possible strategies for devising cures for them.

Sr. No.	Topic	Practical (7.5Px4H)
1	Extraction, purification and characterization of protein <ul style="list-style-type: none"> <li>• Ammonium sulphate precipitation</li> <li>• Dialysis</li> <li>• Column Chromatography- Gel filtration, Ion exchange</li> <li>• SDS PAGE</li> <li>• Protein Quantification by UV-Vis Spectroscopy</li> </ul>	2
2	Enzyme Assay : Beta- galactosidase/ LDH/ Invertase Effect of pH, Temperature, time, varying Substrate concentration	2
4	Isolation, identification of following organisms by morphology, cultural characteristics and biochemical tests: <ul style="list-style-type: none"> <li>• <i>E.coli</i>, <i>Staphylococcus spp</i>, <i>Mycobacterium spp</i>.(for identification use of keys as well as Bergey's Manual is recommended)</li> <li>• Antibiotic sensitivity testing of the isolates (for Gram negative and Gram Positive)</li> <li>• Study of growth characters of isolated pathogens on following media: Mannitol Salt Agar, MacConkey's agar, EMB agar and TSI agar.</li> </ul>	1.5
5	Extraction of bioactive principles from plant and estimation of its antimicrobial activity using standard guidelines (CLSI)	1
6	Effect of environmental parameters on bacterial growth curve and generation time.	1
7	Tracking and study of developmental stages of Chick/ Drosophila	1.5
8	Isolation of Imaginal disc	1
9	Chick embryo culture	1

10	Problems in human genetics- Allele frequencies, Hardy-Weinberg equilibrium, study of gene and genotype frequencies.	1
11	Inheritance patterns: Case studies and pedigree analysis, population survey of a genetic disorder	1
12	Staining of Barr body from buccal epithelial cells.	1
13	Lab visit	1

**BTH4201 Genetic Engineering and Industrial Biotechnology - I**  
Credits: 4

**Section I- Genetic Engineering**

<p><b>Learning Outcomes:</b> The students will be able to understand:</p> <ul style="list-style-type: none"> <li>• Various natural and laboratory based modifications of DNA.</li> <li>• How damage is repaired.</li> <li>• Tools creating DNA constructs.</li> <li>• Various protein expression strategies.</li> </ul>	<p><b>Suggested Pedagogical Processes:</b></p> <p>ICT, presentations, blackboard teaching, problem solving tutorials, discussions regarding current research trends, designing and planning practical lab.</p>
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Sr. No.	Topic	Lecture (Total 30)
<b>1</b>	<p><b>Tools in genetic engineering:</b> DNA modifying enzymes and restriction enzymes for Genetic engineering , Vectors in gene cloning-Plasmid, Cosmid, Phages, Phasmids, Advanced cloning vectors-BAC, YAC, PAC Host types and specificity for recombinant molecule production cDNA and genomic DNA library, screening of gene libraries</p>	6
<b>2</b>	<p><b>Expression strategies and methods for producing industrially important molecules (with examples):</b> Techniques for analyzing genes and gene expression Various expression vectors in bacteria and eukaryotes- (Yeast/Mammalian/Shuttle vectors). Induced expression strategies and protocols. Expression of industrially important products. Applications and current research focus</p>	8
<b>3</b>	<p><b>DNA Sequencing</b> Sanger Sequencing, Next-generation sequencing platforms: Sequencing by synthesis, Sequencing by ligation methods</p>	4
<b>4</b>	<p><b>Advanced Tools in genetic engineering:</b> CRISPR, Genome re-coding, lentivirus and Cre/loxP system, phiC31 integrase, PiggyBac transposase and zinc finger nucleases, TALENs Gene editing Applications and current research focus</p>	10
<b>5</b>	<p><b>GMOs:</b> databases, regulations, ethics</p>	2
	<b>Seminars/ group discussion for various current and relevant topics</b>	

**References Books:**

1. From Genes to Genomes, 2nd edition, (2008), J.Dale and M.Schantz, John Wiley & Son Ltd.USA
2. Gene Cloning and DNA Analysis: an introduction, 6th edition, (2010) T. A. Brown, Wiley-Blackwell Publisher, UK
3. From Gene to Clones ; Introduction to gene technology, 4th edition, (2003), E. Winnacker, Panima Publisher, India
4. Molecular Biology Problem solver: A laboratory guide (2004), A. Gerstein, A John



- Wiley & Sons, Inc., Publication, USA.
5. Molecular Biology of the Gene, 6th Edition (2008), James D. Watson, Tania Baker, Stephen P. Bell, Alexander Gann, Michael Levine, Richard Lodwick, Pearson Education, Inc. and Dorling Kindersley Publishing, Inc. USA
  6. Molecular Biotechnology: 4th edition. (2010), Glick B.R., Pasternak J.J., Patten C. L., ASM press, USA.
  7. Principles of Gene Manipulation & Genomics, 7th Edition (2006), Primrose and Twyman, Blackwell Publishing, USA.
  8. Molecular cloning – a laboratory manual – (Vol. 1-3), 4rd edition, (2012), Green and Sambrook, Cold Spring Harbor Laboratory Press, USA
  9. Sambrook, Cold Spring Harbor Laboratory Press, USA

**Section II**  
**Industrial Biotechnology - I**

<p><b>Learning Outcomes:</b> <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Design of Fermenter/ bioreactors</li> <li>• Mass transfer, KLa concept and significance in bioprocess.</li> <li>• Designing of media Sterilization and monitoring of process variables</li> <li>• Strain Improvement and importance.</li> <li>• Downstream processing methods</li> </ul>	<p><b>Suggested Pedagogical Processes:</b> ICT, presentations, blackboard teachin</p>
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Sr. No.	Topic	Lecture (Total 30)
1	<p><b>Introduction to fermentation and Basic aspects of bioengineering:</b> Introduction to fermentation and Bioprocess engineering, Biotechnology and Bioengineering, Fermentation, types</p> <p><b>Overview of bioreactor design:</b> Design of Fermenter/Bioreactors – Design aspects of Stirred tank reactor and non- mechanically agitated bioreactors, Animal and Plant Cell Bioreactor, immobilized cell reactors. New designs of Bioreactors.</p> <p><b>Kinetics of operation of bioreactors:</b> Batch, Fed Batch and Continuous Processes.</p> <p><b>Aeration and agitation of fermentation broth:</b></p> <p><b>Mass transfer:</b> Concept of mass transfer, Molecular diffusion and role in bioprocess, Two – film theory, Convective mass transfer, volumetric mass transfer (<i>KLa</i>), Liquid-Solid, Liquid-liquid and Gas- liquid mass transfer equations and significance in bioprocess.</p> <p><b>Aeration:</b> Oxygen Uptake in cell cultures, Oxygen transfer from Gas bubble to Cell. Gas hold up, <i>KLa</i> importance, Factors affecting <i>KLa</i>.</p> <p><b>Fermentation Broth rheology</b> – Newtonian and Non -Newtonian fluids, Factors affecting broth rheology, Power requirement for mixing Power number, Reynolds number, Flow regimes in fermentation tank (Laminar, turbulent and transition), Correlation between mass transfer coefficient and operating variables. Mass and Energy balances</p>	10
2	<p><b>Media Sterilization:</b> Kinetics of thermal death of cells and spores, Design of Batch and continuous thermal sterilization, Filter Sterilization</p>	5
3	<p>Overview of methods for online and off line monitoring of Bioreactors, P.I.D. control, Role of computers in Bioprocess monitoring, Scale Up and Scale Down</p>	5
4	<p><b>Molecular Engineering:</b> Important strains and pathways –Mutation, Protoplast fusion, parasexual cycle and genetic engineering for strain improvements, product formation and inhibition pathways and their regulations; Industrially important microorganisms, Culture collection centers</p>	5

5	<p><b>Downstream Processing:</b>  <b>Removal of insoluble:</b> Centrifugation, Sedimentation, Filtration, Electro precipitation</p> <p><b>Product Isolation:</b>  Cell Lysis methods for intracellular products, Solvent extraction, Aqueous two phase, Supercritical fluid extraction, Adsorption, precipitation</p> <p><b>Product Purification:</b>  Chromatography, Crystallization, drying, product formulation  New techniques used for recovery of specific products (recent papers may be discussed)</p>	5
	<b>Seminars/ group discussion for various current and relevant topics.</b>	

#### References Books:

1. E. M. T. El-Mansi, Jens Nielsen, David Mousdale, Ross P. Carlson(2019), Fermentation Microbiology and Biotechnology, 4th Edition, CRC press
2. Bioreactor Design and Product Yield (1992), BIOTOL series, Butterworths Heinemann.
3. Casida, L. E., (1984), Industrial Microbiology, Wiley Easterbs, New Delhi
4. Aiba, S., Humphrey A. L. and Miles, N.F. Biochemical Engineering, 2nd Edition (1973), Academic Press, New York.
5. Indian Pharmacopia and British Pharmacopia (Latest Edn).
7. Lydersen B., N. a. D' Elia and K. M. Nelson (Eds.) (1993)Bioprocess Engineering: Systems, Equipment and Facilities, John Wiley and Sons Inc.
8. Operational Modes of Bioreactors, (1992) BIOTOL series, Butterworths Heinemann.
9. Pepler, H. L (1979), Microbial Technology, Vol I and II, Academic Press, New York.
10. Peter F. Stanbury. Principles Of Fermentation Technology, 2E, Elsevier (A Division of Reed Elsevier India Pvt. Limited), 2009
12. Prescott, S.C. and Dunn, C. G., (1983) Industrial Microbiology, Reed G. AVI tech books.
13. Reed G. Ed. Prescott and Dunn's Industrial Microbiology. 4thEd., CBS Pub. New Delhi.
14. Crueger, W. and Crueger, A.; A Text Book of Industrial Biotechnology, (2005) Panima, New Delhi.
15. Schuler, M. and Kargi, F. Bioprocess Engineering - Basic Concepts, 2nd edition, (2002), Prentice Hall
16. Stanbury, P. F. and Whittaker, A. (1984) Principles of Fermentation technology, Pergamon press.
17. Van Damme E. J. (1984) Biotechnology of Industrial Antibiotics, Marcel Dekker Inc. New York.
18. Wiseman A.(1985) Topics in Enzyme and Fermentation - Biotechnology, Vol. 1 and 2, John Wiley and Sons, New York
19. A. H. Patel. (1985), Industrial Microbiology, Macmillan India Ltd.

**BTH4202 Animal and Plant Biotechnology**

**Credits: 4**

**Section I- Animal Biotechnology**

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Concept and different types in Animal Cell Culture.</li> <li>• Use of molecular biology techniques genetically engineer the animals to improve sustainability, productivity and suitability for pharmaceutical, agricultural and industrial applications.</li> </ul>	<p><b>Suggested Pedagogical Processes:</b>                  ICT, presentations, blackboard teaching.</p>
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Sr. No.	Topic	Lecture (Total 30)
1	<p><b>Concept of Tissue culture.</b>                      Factors affecting the success of <i>in vitro</i> culture; Physico chemical requirements                      Buffers, Balanced salt solutions and Growth Media types and formulation:                      natural, synthetic, sera and substitutes                      Maintenance of asepsis, Sterilization of media, reagents and labware                      Contamination: Types, Detection methods, Prevention methods                      Storage and transport of cell cultures                      Equipment required for ATC</p>	8
2	<p><b>Evolution of Cell line:</b> Concept, properties of cell lines and types; Cell Culture                      Systems: Monolayer, Suspension Organ Culture, Histotypic Organotypic Culture</p>	7
3	<p>Overview-livestock breed and their productivity, artificial breeding methods and hazards, marker assisted breeding of livestock. artificial breeding – <i>in vitro</i> fertilization and embryo transfer technology, artificial insemination ,germ cell storage, Introduction to animal genomics, different methods for characterization of animal genomes, SNP, STR, QTL, RFLP, RAPD, genetic basis for disease resistance</p>	7
4	<p><b>Applications:</b> Application of animal cell culture for <i>in vitro</i> testing of drugs, in production of human and animal viral vaccines and pharmaceutical proteins.                      Culture Scale up and mass production of biologically important compounds.                      Harvesting of products, purification and assays.                      Hybridoma Technology, Virus propagation</p>	8
	<b>Seminars/ group discussion for various current and relevant topics</b>	

**Reference books:**

1. R. Ian Freshney. Culture of Animal cells, 5rd Edition, 2010. A John Wiley & Sons, Inc., Publications, USA
2. R.W.Masters. Animal Cell Culture- Practical Approach, 3rd Edithion,2000, Oxford University Press. USA
3. Robert Lanza et al. Essentials of Stem Cell Biology”, Academic Press, 2nd edition, 2006.USA
4. Text book of Animal Husbandary, 8th edition, ( 1998 ) G.C. Banerjee,Oxford and IBH Publishin co.Pvt. Ltd. India
5. Molecular Biotechnology: 4th edition. (2010), Glick B.R., Pasternak J.J., Patten C. L., ASM press, USA
6. Gene Transfer to Animal Cells, 1st edition (2005), R. M. Twyman, Taylor & Francis USA.

## Section II Plant Biotechnology

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Methods for developing transgenic plants</li> <li>• Transgenic methods to improve algal, fungal and plant productivity</li> <li>• Importance of secondary metabolites and production in plants</li> <li>• Molecular approaches used for plant breeding and trait selection</li> <li>• Concept of molecular farming and the derived products</li> </ul>	<p><b>Suggested Pedagogical Processes:</b>            ICT, presentations, blackboard teaching, model making by students, problem solving tutorials, discussions regarding current research trends, designing and planning simple biochemistry practicals</p>
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Sr. No.	Topic	Lectures (Total 30)
1	<p><b>Algal and fungal Biotechnology-</b></p> <ul style="list-style-type: none"> <li>• Quantitative improvement in economically important Algae with one example</li> <li>• Applications- Biofuels, Pigments, Single cell proteins</li> <li>• Algal transgenics</li> <li>• Quantitative improvement in economically important Fungi like Mushrooms with one example</li> </ul>	6
2	<p><b>Secondary metabolites in plants-</b></p> <ul style="list-style-type: none"> <li>• Introduction and concept:</li> <li>• Phytochemicals- Glycosides and Flavonoids; Anthocyanins and Coumarins Lignans, Terpenes, Volatile oils and Saponins; Carotenoids and Alkaloids: biogenesis, therapeutic applications</li> <li>• physiology and ecological functions of secondary metabolites</li> <li>• Biotechnology for the production of plant secondary metabolites,</li> <li>• Secondary metabolites in plant defence mechanisms,</li> </ul>	9
3	<p><b>Transgenic Technology-</b></p> <ul style="list-style-type: none"> <li>• Introduction, Methods of Transgenesis (Vector mediated and non vector based gene transfer)</li> <li>• Transgenic plants for biotic stress tolerance (Fungi, bacteria, viruses, Insects, weeds)</li> <li>• Transgenic plants for abiotic stress tolerance (Drought, Salt, Temperature)</li> <li>• Molecular Farming- Improvement in Carbohydrates, Proteins, Lipids, Plantibodies, Edible vaccines</li> </ul>	15
	<b>Seminars / group discussion for various current and relevant topics</b>	

### Reference Books:

1. Chawla, H. C. (2004) Introduction to Plant Biotechnology
2. Davies k (2004) –Plant Pigments and their manipulation-Annual plat reviews-Vol 14
3. Altman,A and Hasegawa P M (2012) – Plant Biotechnology and Agriculture Prospects for the 21<sup>st</sup> century
4. Bhojwani,S S and Razdan M.K.(1996) plant Tissue Culture: Theory and Practices
5. Slater A, Scott,N W, Fowler, M R (2008) –Plant Biotechnology: Genetic manipulation of plants
6. Rai, M (2009) Fungal Biotechnology (IK International)
7. Vasil K., Thorpe T A.(1994) plant cell and Tissue Culture

**BTH4203 Virology and Immunology****Credits: 4****Section I - Virology**

<b>Learning Outcomes:</b> <b>The students will be able to understand:</b> <ul style="list-style-type: none"> <li>• Properties of viruses and their replication cycle.</li> <li>• Mode of action of antiviral drugs and viral vaccines.</li> <li>• Contribution of epidemiology in relation to public health.</li> <li>• Concept of oncogenic virus and cancer immunology.</li> </ul>	<b>Suggested Pedagogical Processes:</b>  ICT, presentations, conduct survey, brainstorming, research article analysis , story boarding, co-operative learning, practical based unit of enquiry.
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Sr. No	Topic	Lectures (Total 30)
1	<b>Introduction to viruses:</b> <ul style="list-style-type: none"> <li>• General properties of viruses, Morphology, Symmetry and Ultra structure of Viruses</li> </ul>	3
2	<b>Classification of viruses:</b> <ul style="list-style-type: none"> <li>• Classification and Characterization of DNA and RNA viruses, ICTV system and Baltimore system.</li> </ul>	3
3	<b>Replication of viruses:</b> <ul style="list-style-type: none"> <li>• DNA (ds) - Poxvirus ,</li> <li>• RNA( ss+ve)- Poliovirus,</li> <li>• RNA (ss -ve ) - Influenza virus</li> <li>• RNA with RT- HIV .</li> </ul>	7
4	<b>Bacteriophages:</b> <ul style="list-style-type: none"> <li>• Virulent and temperate phages, lytic and lysogenic life cycles.</li> </ul>	2
5	<b>Antiviral :</b> <ul style="list-style-type: none"> <li>• Mode of Action of various antiviral drugs with examples and Viral Vaccines.</li> </ul>	3
6	<b>Types of Infections:</b> <ul style="list-style-type: none"> <li>• Acute and persistent infections with example. Case study, Immunopathogenesis of HIV and Herpes.</li> </ul>	4
7	<b>Epidemiology:</b> <ul style="list-style-type: none"> <li>• Emerging viruses. Principles and related terminologies, Current National and Global epidemiology of viral infections (with suitable examples).</li> </ul>	3
8	<b>Oncogenic virus:</b> <ul style="list-style-type: none"> <li>• Cancer Immunology, Immunotherapy, Immunodeficiency (Primary and secondary) .</li> </ul>	5
	<b>Seminars/ group discussion/journal club for various current and relevant topics.</b>	

**Reference Books:**

1. Principles of Virology-2 volumes 4<sup>th</sup> edition, (2015), Flint Jane *etal* ASM (American Society of Microbiology) Press Publisher, USA.
2. Field's Virology - 2 volumes, 6<sup>th</sup> edition, (2014), Bernard.N. Fields, Lippincott and Williams Wilkins, USA

3. Clinical Virology, 4th edition,(2017), Douglas D. Richman, Richard J. Whitley, Frederick G. Hayden ASM (American Society of Microbiology) Press Publisher, USA.
4. Origin of AIDS Dr. Jacques Pepin (2011) Cambridge University Press, Cambridge, UK,

## Section II - Immunology

<p><b>Learning Outcomes:</b></p> <p><b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Cellular and molecular basis of immune responsiveness.</li> <li>• Antigen antibody reaction and autoimmunity</li> <li>• Animal models in immunology</li> </ul>	<p><b>Suggested Pedagogical Processes:</b></p> <p>ICT, presentations, brainstorming, research article analysis , story boarding, co-operative learning, practical based unit of enquiry.</p>
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Sr. No.	Topic	Lecture (Total 30)
1	<p><b>Overview of the immune system:</b></p> <ul style="list-style-type: none"> <li>• Introduction to Immune system. Immune system cells, tissues and organs.</li> </ul>	3
2	<p><b>Innate immunity:</b></p> <ul style="list-style-type: none"> <li>• Understanding the physical and chemical barriers,</li> <li>• Cells of the innate immune system.</li> <li>• Process of inflammation.</li> </ul>	4
3	<p><b>Adaptive immunity:</b></p> <ul style="list-style-type: none"> <li>• Structure and function of MHC molecules.</li> <li>• Antigen presentation and processing.</li> <li>• Cells of the adaptive immune system.</li> <li>• T cell maturation and TCR structure</li> <li>• B cell maturation and BCR structure</li> <li>• VDJ recombination</li> <li>• Functions of immunoglobulins</li> <li>• Humoral and Cellular Immune responses.</li> </ul>	9
4	<p><b>Complement system:</b></p> <ul style="list-style-type: none"> <li>• Three pathways of complement activation.</li> <li>• Regulation and Function of Complement.</li> </ul>	2
5	<p><b>Hypersensitivity Reactions</b></p> <ul style="list-style-type: none"> <li>• Understand hypersensitivity reactions -I, II , III, IV with examples.</li> </ul>	2
6	<p><b>Autoimmunity:</b></p> <ul style="list-style-type: none"> <li>• Autoimmune diseases</li> <li>• Molecular mimicry,</li> <li>• Autoimmune therapy.</li> </ul>	2
7	<p><b>Transplant immunology:</b></p> <ul style="list-style-type: none"> <li>• Classification of Grafts,</li> <li>• Immunological basis of acceptance of autografts and rejection of allografts,</li> <li>• Acute, Hyperacute and Chronic rejections of transplant,</li> <li>• GVHD and Immunosuppressive therapy.</li> </ul>	3
8	<p><b>Molecular immunology:</b></p> <ul style="list-style-type: none"> <li>• Antibody engineering and Chimeric antibodies.</li> </ul>	2
9	<p><b>Animal Models :</b></p> <ul style="list-style-type: none"> <li>• Nude mouse, SCID mouse, NOD mouse, Obese-strain chicken, NZB and NZW mice, Knock – out, animal models for autoimmunity (EAE)</li> </ul>	3
	<p><b>Seminars/ group discussion/journal club for various current and relevant topics.</b></p>	



### **Reference Books:**

1. Kuby Immunology, Judy Owen , Jenni Punt , Sharon Stranford., 7<sup>th</sup> edition (2012), Freeman and Co., NY
2. Cellular and Molecular Immunology, Abul Abbas, Andrew H. Lichtman, Shiv Pillai 9<sup>th</sup> Edition 2017 Elsevier.
3. Janeway's Immunobiology, Kenneth M. Murphy, Casey Weaver 8<sup>th</sup> Edition 2011 W. W. Norton & Company
4. Immunology, 7<sup>th</sup> edition (2006), David Male, Jonathan Brostoff, David Roth Roittand Mosby, USA. Roitt's Essential Immunology (2011), 12<sup>th</sup> edition, Wiley and Black Well.
5. The Elements of Immunology, F.H. Khan (2009), Pearson Education.
6. Textbook of Basic and Clinical Immunology, 1<sup>st</sup> edition (2013), Sudha Gangal and Shubhangi Sontakke, University Press, India.

**BTH4204 Biotechnology Practical - III**  
**(Genetic Engineering, Animal Biotechnology and Plant Biotechnology)**  
**Credits:4**

**Learning Outcome:**

**The students will be able to understand:**

- How cells become competent for transformation and their selection methods
- Isolation of the plasmid DNA
- Designing primers, strategy for cloning and expression
- Initiate primary culture and passage it without contamination
- Analyze effect of different factors on growth of cell line
- Initiation and maintenance of callus culture and harvesting secondary metabolites.
- Mushroom cultivation
- Initiate hairy root culture for secondary metabolites
- Initiate anther culture to get haploid plants

Sr. No.	Practical	Practicals (7.5Px4H)
1	Preparation of competent cells and transformation Selection of transformants	3
2	Isolation of plasmid DNA and quantification	1.5
3	Designing a strategy for producing a recombinant product & expression of gene product and its analysis	2
4	Primer designing and PCR of gene product	1
<b>Plant Biotechnology</b>		
1	Spirulina culture or Pleurotus cultivation and biochemical analysis	1
2	Protoplast isolation	1
3	<i>In vitro</i> production of secondary metabolites	1
4	Initiation of hairy root culture/ anther culture	1
<b>Animal Biotechnology</b>		
6	Initiation of cell culture from chick embryo	2
7	Subculture and maintenance of cell line established in laboratory	1.5

**BTH4205 Biotechnology Practical - IV**  
**(Industrial Biotechnology, Virology and Immunology)**  
**Credits:4**

**Learning Outcome**

**The students will be able to understand:**

- Screening and identification of a production strain
- Optimization of different parameters and sterilization cycle designing of the isolated organism
- Working of lab bench Fermenter and downstream processing.
- Various inoculation routes in embryonated eggs.
- Isolation and enumeration of bacteriophages.
- Basic Immunology techniques
- Antibody-Antigen Reactions
- Microscopical analysis of immune system cells

Sr. No.	Practical	Practical (15Px4H)
1	Screening and identification (Genus Level) of a production strain (enzyme /antibiotic / or any other) from soil samples.	1
2	.Optimization of different parameters of the isolated organism (conventional and Statistical design).	1
3	Calculation of Del factor for the fermentation medium sterilization	1
4	a.Inoculum build up of the isolated organism for use in bench top fermentation b.Study of Working of lab bench fermenter ( with production of enzyme or antibiotic using screened organism ), Study of different parts and assembly of the bench top fermenter c.Assay of product formed (Bioassay or Enzyme assay).	1
4	Routes of virus inoculation in embryonated eggs.	1.5
5	Phage Assay.	1
6	Visit to National Institute of Virology/Virology Lab	1
7	Radial Immuno Assay/ELISA	1
8	Western blotting	2
9	Widal Test	1.5
10	Study of immune cells from blood smear	1
11	Isolation of Lymphocytes: Ficoll-hypaque density gradient separation	2

## BTH4206 Critical Reading of Primary Scientific Literature

Credits: 4

(Departmental Elective)

<b>Learning Outcomes:</b> <b>The students will be able to understand:</b> <ul style="list-style-type: none"><li>critical reading and analysis of primary scientific literature</li><li>how to present data and write scientific text.</li><li>how to communicate research clearly.</li><li>new techniques, cutting-edge research and application.</li></ul>	<b>Suggested Pedagogical Processes:</b> ICT, presentations, discussions regarding current research trends.
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Sr. No.	Topic	Lecture (Total 30)
1	<b>Presentations to the students:</b> Initially, responsible faculty will present few classical and recent research publications for the students to understand how to assess strengths and weaknesses of each experiment from the selected papers, identify how the authors' have interpreted the data and scrutinize the discussion presented.	10
2	<b>Presentations by the students:</b> The students will choose appropriate research publications, critically analyze the publication on their own and present it as a seminar. These presentations will be followed by questions from the faculty and other students.	20

**BTH4207 Agricultural Biotechnology**

**Credits: 2**

**(Departmental Elective)**

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Different types of molecular markers</li> <li>• Application of molecular markers in identification and improvement of crop traits</li> <li>• Functional analysis of genes for crop improvement</li> <li>• Plant pathology and genetics of disease resistance</li> </ul>	<p><b>Suggested Pedagogical Processes:</b>                  ICT, presentations, blackboard teaching.</p>
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Sr. No.	Topic	Lectures (Total 30)
1	Fundamental biotechnology: gene cloning, PCR: types and applications Introduction to DNA fingerprinting and profiling techniques: biochemical markers and DNA based (genic and random) markers; repertoire of DNA fingerprinting techniques Molecular markers: Molecular basis of dominant and co-dominant markers, RFLP, MAAP (Multiple Arbitrary Amplicon Profiling) and other PCR based markers (DNA Amplification Fingerprinting, Arbitrarily Primed PCR, RAPD, SSRs, STMS, SCARs, Inter-SSRs, AFLP, Intron spanning markers SNP based marker assays (CAPs, dCAPs, dHPLC, molecular beacons, 5' nuclease assay/Taqman assays)	7
2	Other applications of molecular markers: Genotyping tools as plant variety protection, DNA bar-coding technology, establishing clonal fidelity	3
3	Functional analysis of genes:, RNA-mediated interference; gene knockoffs; site directed mutagenesis, insertional mutagenesis; Gene traps/ T-DNA insertion lines Gene expression: microarray profiling; SAGE; SNPs/variation; gene expression and transcript profiling; EST contigs;, allele/gene mining; synteny and comparative genomics Eco-TILLING (Targeting induced local lesions in the genome), high-throughput genotyping techniques: Diversity Array Technology (DArTs), SNP and tiling arrays	5
4	Plant pathology: Importance, definitions and concepts of plant diseases, Host pathogen interaction, recognition concept and infection, disease development- role of enzymes, toxins, growth regulators; defense strategies- oxidative burst; Phenolics, Phytoalexins, PR proteins, Elicitors. Genetics of resistance; 'R' genes; mechanism of genetic variation in pathogens; molecular basis for resistance; marker-assisted selection; genetic engineering for disease resistance.	5

## Reference Books:

1. Till, Bradley J., Troy Zerr, Luca Comai, and Steven Henikoff. "A protocol for TILLING and EcoTilling in plants and animals." *Nature protocols* 1, no. 5 (2006): 2465-2477.
2. Barkley, N. A., and M. L. Wang. "Application of TILLING and EcoTILLING as reverse genetic approaches to elucidate the function of genes in plants and animals." *Current genomics* 9.4 (2008): 212-226.
3. Varshney, Rajeev K., Kailash C. Bansal, Pramod K. Aggarwal, Swapan K. Datta, and Peter Q. Craufurd. "Agricultural biotechnology for crop improvement in a variable climate: hope or hype?" *Trends in plant science* 16, no. 7 (2011): 363-371.
4. Collard, B. C. Y., M. Z. Z. Jahufer, J. B. Brouwer, and E. C. K. Pang. "An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: the basic concepts." *Euphytica* 142, no. 1-2 (2005): 169-196.
5. Madesis, Panagiotis, Ioannis Ganopoulos, Argiriou Anagnostis, and Athanasios Tsiftaris. "The application of Bar-HRM (Barcode DNA-High Resolution Melting) analysis for authenticity testing and quantitative detection of bean crops (Leguminosae) without prior DNA purification." *Food Control* 25, no. 2 (2012): 576-582.
6. Kane, Nolan C., and Quentin Cronk. "Botany without borders: barcoding in focus." *Molecular Ecology* 17, no. 24 (2008): 5175-5176.
7. Talbot, Nicholas J. *Plant-pathogen interactions*, Vol. 11, 2004. Taylor and Francis, CRC Press, USA.

**BTH4208 Environmental Biotechnology**  
**Credits: 2**  
**(General Elective)**

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Global and regional threats to the environment</li> <li>• Role of Biotechnology in analysis and treatment of pollutants</li> <li>• Concept of EMP, EIA and environmental laws.</li> <li>• Concept of GIS and RS</li> </ul>	<p><b>Suggested Pedagogical Processes:</b>            ICT, presentations, blackboard teaching.</p>
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Sr. No.	Topic	Lectures (Total 30)
1	<p><b>Global and regional threats to the environment: pollution</b></p> <ul style="list-style-type: none"> <li>• Concept, Sources, impacts and measurement of :</li> <li>• Air, water, noise, soil, solid waste and radiation pollutants.</li> <li>• Industrial pollution and safe disposal of effluents with case study and field visit.</li> <li>• Recycle, Reuse and Recovery.</li> <li>• Biomedical waste and its management.</li> </ul>	5
2	<p><b>Bioremediation, Biotransformation and Biodegradation:</b></p> <ul style="list-style-type: none"> <li>• Bioremediation; In situ and Ex situ bioremediation;</li> <li>• Constrains and priorities of bioremediation; Evaluating Bioremediation;</li> <li>• Bioremediation of VOCs.</li> <li>• Biodegradation; Factors affecting process of biodegradation; Methods in determining biodegradability; Contaminant availability for biodegradation.</li> <li>• Xenobiotics; Persistence and biomagnification of xenobiotic molecules; Microbial interactions with xenobiotics;</li> <li>• Phase I and Phase II reactions; Cyt P 450 mediated reactions; Use of microbes (bacteria and fungi) and plants in biodegradation and Biotransformation.</li> </ul> <p><b>Environmental monitoring and sample analysis:</b></p> <ul style="list-style-type: none"> <li>• Sampling of air and water pollutants; Monitoring techniques and methodology, pH, Dissolved Oxygen(DO); Chemical oxygen demand (COD); Biological Oxygen Demand (BOD); Speculation of metals, monitoring&amp; analysis of CO, NO<sub>2</sub>, CO<sub>2</sub>,SO<sub>2</sub>; Pesticide residue; Phenols and petrochemicals.</li> </ul>	10
3	<p><b>Principles of Remote sensing, its applications in Environmental Monitoring:</b></p> <ul style="list-style-type: none"> <li>• Concept of Remote sensing; EMR &amp; its interaction with matter; Aerial Photography: Types, Camera, Elements of photo interpretation (Aerial Photography/image recognition);</li> <li>• Sensors &amp; platforms; IRS satellites &amp; their sensors; Application of remote sensing in environmental studies.</li> </ul> <p><b>Geographical Information System (GIS) Concept of GIS</b></p> <ul style="list-style-type: none"> <li>• Types of Geographical Data; Data Structure; Vector and Raster data: their</li> </ul>	5

	Advantages and Disadvantages; Input, verification, storage and output of geographical data; Importance of Geographical Information System in environmental studies	
4	<p><b>Environmental management:</b></p> <ul style="list-style-type: none"> <li>• Environmental management Plan: scope, EMP preparation , Need of EMP</li> </ul> <p><b>Environmental Impact Assessment:</b></p> <ul style="list-style-type: none"> <li>• (EIA):Need of EIA; Scope and objectives; Types of environmental impacts; Steps involved in conducting the EIA Studies; Environmental Impact Assessment techniques-Ad-hoc method, checklist method, overlay mapping method, network method, simulation and modeling technique, matrix method, and system diagram technique; Merits and Demerits of EIA studies.</li> </ul> <p><b>Environmental Quality Assessment and Monitoring:</b></p> <ul style="list-style-type: none"> <li>• What is environmental quality? Quality of environment for life on earth and man; Deterioration of environmental quality with reference to anthropogenic impact; Methods of assessment of environmental quality; Short term studies/surveys; Rapid assessment; Continuous short and long term monitoring</li> </ul> <p><b>ISO 14000, Environmental audits and ethics</b></p> <p><b>Environmental Laws and Policies.</b></p>	10

#### Reference Books:

1. Bruce Rittman, Perry L. McCarty, Environmental Biotechnology: Principles and Applications, 2nd edition, McGraw-Hill, 2000.
2. Indu Shekhar Thakur (2006) Environmental Biotechnology: Basic Concepts and Applications, I. K. International Pvt Ltd, 2006.
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4. Alan H. Scragg (2006) Environmental Biotechnology , 1st edition , Oxford University Press
5. S.K. Agarwal (2007) Environmental Biotechnology , APH Publishing Co-operation , New Delhi
6. Alexander N. Glazer and Hiroshi Nikaido (2010) Microbial Biotechnology, 2nd edition, Cambridge University press.
7. An Introduction To Geographic Information Technology (2009) Suchandra Choudhury I K International Pvt Ltd., New Delhi
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9. Biotreatment of Industrial & Hazardous Waste (1993) M. V. Levin and Gealt, M.A. McGraw Hill. Inc, New York.
10. Concepts and Techniques of Geographic Information Systems (2009) C.P.Lo.Albert and K.W.Yeung 2nd edition, Prentice Hall, Inc., New Jersey.
11. Ecology and environmental biology (2011) Saha T K Books & Allied (p) Ltd, Delhi.
12. Environment Problems & Solutions (2001) Asthana & Asthana S. Chand Limited, New Delhi.
13. S.C. Santra Environmental Science (2014), New central book agency Pvt. Ltd. Kolkata.



**BTH4209 Microbial Genetics**  
**Credits: 2**  
**(Departmental Elective)**

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• Gene transfer mechanisms in bacteria and gene mapping.</li> <li>• Molecular basis of phage life cycles and significance</li> <li>• Yeast as a eukaryotic model to understand fundamentals of genetics.</li> <li>• Role of fungi in understanding genetics and its significance.</li> </ul>	<p><b>Suggested Pedagogical Processes:</b>            ICT, presentations, blackboard teaching.</p>
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Sr. No.	Topic	Lecture (Total 30)
1	<p><b>Overview of basics of genetics:</b> Bacterial Chromosome, Plasmids, Mutations types, DNA damage and repair, operon concept, transposable elements in prokaryotes and eukaryotes. (The knowledge of these topics is a prerequisite for this course and therefore a brief overview of these topics can be taken)</p>	2
2	<p><b>Bacterial Genetics:</b>  <b>Bacterial plasmids:</b> Types, F, R, Col, broad host range and other plasmids, structure, properties and significance (including evolutionary significance), Episomes  <b>DNA transfer mechanisms:</b>  <b>Bacterial Conjugation-</b>Ffactor, mechanism of conjugation (F<sup>+</sup>X F<sup>-</sup>), Hfr strain formation and its transfer, recombination in recipient cells, F prime, sexduction, interrupted mating and temporal mapping, Gene mapping using conjugation data.  <b>Bacterial transformation,</b>  <b>Natural transformation:</b> Competence, Molecular mechanism of Transformation in <i>Streptococcus</i> and <i>Haemophilus influenzae</i>, gene mapping by transformation</p>	10
3	<p><b>Phage Genetics:</b>            Virulent and temperate phages, lytic and lysogenic life cycles, Generalized and specialized transduction, Specificity in phage infection, abortive transduction, co-transduction.            Molecular basis of decision between lytic and lysogenic cycles in lambda phage, Lysogenic conversion and Bacterial Pathogenesis, genemapping by specialized transduction  <b>Genetics of Phage T4:</b> phage mutants, Benzer's fine structure of gene in bacteriophage T4 : Plaque Formation and Phage Mutants, Transposable phage (phage Mu): Genetic organization, and transposition, Mu as a genetic tool</p>	10

4	<b>Yeast Genetics:</b> Yeast as a model eukaryotic cell for the study of biological processes: Life cycle, organization of nuclear and organellar genomes, making mutants and analyzing genetic interactions, Meiotic crosses, tetrad analyses, yeast mating type switch; dominant and recessive genes/mutations, genetic nomenclature and genome manipulation strategies, random spore analysis, complementation, heterothallism disruption plasmids in <i>S. cerevisiae</i> and <i>S. pombe</i>	5
5	<b>Fungal Genetics:</b> Lifecycle of <i>Neurospora crassa</i> , mapping by tetrad analysis. Parasexual cycle in <i>Aspergillus</i> and its significance	3

### Reference Books:

1. Maloy, S.R.; Cronan, Jr., Freifelder D.; Microbial Genetics, 2nd edition (2009), Narosa book distributors Pvt. Ltd., New Delhi.
2. Stanier, R. Y., Adelberg, E. A. and Ingraham, J. L.; General Microbiology; 5<sup>th</sup> Edition (1987), Macmillan Press Ltd.
3. Snustad, Simmons, Principles of genetics, 6th Edition (2011), John Wiley & Sons, Inc.
4. Hartl, D. L., Jones, E. W., Genetics-Analysis of genes and genomes, 8<sup>th</sup> Edition, (2011), Jones and Bartlett learning
5. Snyder, L. and Champness, W. Molecular Genetics of Bacteria, 3<sup>rd</sup> Edition (2007), ASM press.
6. Gardner, Simmons, Snustad. (2006), Principles of Genetics, 8th Edn. John Wiley & Sons. Inc. New York.
7. Gunther S. Stent, (1978), Molecular Genetics: An Introductory Narrative, 2nd Edn. W.H. Freeman & Co.
8. Strickberger, M.W. (1985), Genetics, 3rd Edition Macmillan Pub. Co. NY.
9. Hayes, W. (1964), The Genetics of Bacteria and their Viruses, CBS Pub. New Delhi.
10. Smith Gerald R. , Genetic Analysis of Meiotic Recombination in *Schizosaccharomyces pombe*, 2009, Methods Mol Biol.; 557: 65–76.
11. Neurospora crassa: Looking back and looking forward at a model microbe *Am. J. Bot. December 1, 2014;101:2022-2035*

**BTH4211 Clinical Research**  
**Credits: 2**  
**(Departmental Elective)**

<b>Learning Outcomes:</b> <b>The students will be able to understand:</b> <ul style="list-style-type: none"> <li>• Concept of Drug Development, protocol designing and clinical trials</li> </ul>	<b>Suggested Pedagogical Processes:</b> ICT, presentations, blackboard teaching.
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Sr. No.	Topic	Lecture (Total 30)
1.	<b>Introduction to clinical research</b> <b>Drug Development Process</b> <ul style="list-style-type: none"> <li>• Overview of Drug Development Process including clinical trials phases</li> </ul>	1
2	<b>Protocol Designing:</b> <ul style="list-style-type: none"> <li>• Definition of protocol, its importance and purpose</li> <li>• Protocol format: Chapters (Headings) and broad contents of protocol</li> <li>• Important scientific and administrative aspect included in protocol</li> <li>• Introduction to Research Methodology</li> <li>• Protocol writing team and role of each member</li> <li>• Clinical trial design: Types of study designs</li> <li>• Sampling, sample size, randomization, Inclusion &amp; Exclusion criteria</li> <li>• Phases of clinical trial &amp; Types of trials</li> </ul>	6
3	<b>Good Clinical Practice (GCP)-ICH E6:</b> <ul style="list-style-type: none"> <li>• Ethical Principles and their origin</li> <li>• Ethics in clinical research: As per ICMR &amp; GCP</li> <li>• Ethics committees: Roles &amp; responsibility of IEC and IRB</li> <li>• Ethics in relation to vulnerable groups &amp; special situations</li> <li>• Responsibilities of Sponsors, Investigators &amp; Regulators</li> <li>• ICH: Purpose, regulations &amp; guidelines</li> <li>• Informed consent and Informed consent form</li> <li>• Essential Documents</li> </ul>	6
4	<b>Drug Regulatory Affairs (Clinical Trial)</b> <ul style="list-style-type: none"> <li>• Regulatory Authority in India (DCGI &amp; CDSCO)</li> <li>• Schedule Y of Drugs &amp; Cosmetics Act</li> <li>• International Scenario of Regulatory Aspects: FDA, CFR,</li> </ul>	3
5	<b>Clinical Safety &amp; Pharmacovigilance:</b> <ul style="list-style-type: none"> <li>• Definitions of AE, ADR, SAE,</li> <li>• Recording &amp; reporting: Objectives &amp; Importance</li> <li>• Pharmacovigilance: International procedures</li> <li>• Pharmacovigilance in India</li> </ul>	5
6	<b>Monitoring of Clinical Trials</b> <ul style="list-style-type: none"> <li>• Monitoring and its role in clinical trials</li> <li>• CRF and other source documents relevant to monitoring</li> </ul>	2
7	<b>Clinical Data Management</b>	1
8	<b>Practical for Protocol Design, CRF Design and source documentation</b>	6

## Reference Books:

1. Maloy,S.R.;Cronan, Jr.,Freifelder D.; Microbial Genetics, 2ndedition (2009), Narosa book distributors Pvt. Ltd., New Delhi.
2. Stanier,R. Y., Adelberg,E. A.and Ingraham,J. L.; General Microbiology; 5<sup>th</sup> Edition (1987), Macmillan Press Ltd.
3. Snustad, Simmons, Principles of genetics, 6th Edition(2011),John Wiley & Sons, Inc.
4. Hartl,D. L., Jones,E. W., Genetics-Analysis of genes and genomes,8<sup>th</sup> Edition,(2011),Jones and Bartlett learning
5. Snyder,L.and Champness, W.Molecular Genetics of Bacteria,3<sup>rd</sup> Edition (2007), ASM press.
6. Gardner, Simmons, Snustad. (2006), Principles of Genetics, 8th Edn.John Wiley & Sons. Inc. New York.
7. Gunther S. Stent, (1978), Molecular Genetics: An Introductory Narrative, 2nd Edn. W.H. Freeman & Co.
8. Strickberger, M.W. (1985), Genetics, 3rd Edition Macmillan Pub. Co. NY.
9. Hayes, W. (1964), The Genetics of Bacteria and their Viruses, CBS Pub. New Delhi.
10. Smith Gerald R. ,Genetic Analysis of Meiotic Recombination in *Schizosaccharomyces pombe*,2009,Methods Mol Biol.; 557: 65–76.
11. Neurospora crassa: Looking back and looking forward at a model microbe *Am. J. Bot. December 1, 2014;101:2022-2035*

**BTH4212 Bioethics and Biosafety**  
**Credits: 2**  
**Departmental Elective**

<p><b>Learning Outcomes:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products.</li> <li>• To become familiar with ethical issues in biological research.</li> <li>• To understand ethical aspects related to biological, biomedical, health care and biotechnology research.</li> </ul>	<p><b>Suggested Pedagogical Processes:</b>  ICT, presentations, blackboard teaching.</p>
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Sr. No.	Topic	Lecture (Total 30)
1	Introduction, bioethics in health care patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research cloning and stem cell research, Agricultural biotechnology - Genetically engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – biopiracy	10
2	Regulation (International /national) for animal and biomedical research. Human and animal experimentation, animal rights/welfare, Animal and Human ethical committees And their working. Animal welfare rights EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies	6
3	Accreditation for healthcare Purpose and process Introduction and background of NCS-TCP for biotechnology	4
4	Good Lab Practices, Biosafety Introduction; Historical Background; Introduction to Biological Safety Cabinets; Primary Containment for Biohazards; Biosafety Levels; Biosafety Levels of Specific Microorganisms; Recommended Biosafety Levels for Infectious Agents and Infected Animals MSDS	10

**Reference Books:**

1. Kuhse, H. (2010). Bioethics: an Anthology. Malden, MA: Blackwell.
2. National certification system for tissue culture raised plants (NCS-TCP) (Department of Biotechnology Ministry of Science & Technology Government of India)
3. National ethical guidelines for biomedical and health research involving human participants (ICMR 2017)
4. Wolt, J. D., Keese, P., Raybould, A., Fitzpatrick, J. W., Burachik, M., Gray, A., Wu, F. (2009). Problem Formulation in the Environmental Risk Assessment for Genetically Modified Plants. *Transgenic Research*, 19(3), 425-436. doi:10.1007/s11248-009-9321-9
5. NABH guidelines.

**BTH4213 Research Methodology**  
**Credits: 2**  
**(General Elective)**

<p><b>Learning Outcome:</b>  <b>The students will be able to understand:</b></p> <ul style="list-style-type: none"> <li>• How research is designed, planned and executed</li> <li>• How data is analyzed and presented</li> <li>• Presentation and research communication skills.</li> </ul>	<p><b>Suggested Pedagogical Processes:</b>            ICT, presentations, blackboard teaching.</p>
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Sr. No.	Topic	Lecture (Total 30)
1	<p><b>Introduction to Research Methods</b>            Phases of Scientific Enquiry            Problem identification/ beginning of scientific approach            Asking the right question, review of literature and referencing            Choosing an appropriate system/s,            Design of a study,            Observational Studies,            Experimental Studies            Data Collection,            Data Analysis</p>	2
2	<p><b>Designing Research</b>            Formation of a query-hypothesis design            Data collection methods            Advantages &amp; shortcomings and - explanation with examples            Importance of controls in designing an experiment            Different types of controls (Positive, negative and internal)</p>	5
3	<p><b>Research Methods</b>            Quantitative and Qualitative            Quantitative Research Designs:            Formation of a query-hypothesis design            Data collection methods, Sampling and Sample Design            Advantages &amp; shortcomings and - explanation with examples            Importance of controls in designing an experiment            Different types of controls (Positive, negative and internal)</p>	11
4	<p><b>Analyzing and plotting Research Data</b>            Data distributions,            Statistical tests for comparison of sample means and sample variance- t-test, non parametric tests,            Correlation and Regression,            Introduction to multivariate analysis            Mathematical models            Simulation as a tool to test these models</p>	12

## Reference Books:

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2. Barass Robert, Scientists Must Write: A Guide to Better Writing for Scientists, Engineers and Students (2002), Routledge Publication, UK
3. Barrow And Tipler, The Anthropic Principle (1988), Oxford University Press, Oxford
4. David B. Resnik, The Ethics of Science: An Introduction (1998), Routledge Publication, UK
5. Fisher R A, The Design of Scientific Experiment (1971) 9th edition, Collier Macmillan Publishers, London
6. Ganguli Prabuddh, Intellectual Property Rights (2001), Tata McGraw-Hill Publishing Company Ltd., Delhi
7. Jacob Bronowski And Bruce Mazlish, The Western Intellectual Tradition (1960), Harper & Row, New York
8. John D'Angelo, Ethics in Science: Ethical Misconduct in Scientific Research (2012), CRC Press, USA
9. Kuhn Thomas, The Structure of Scientific Revolution (2012) 50th anniversary edition, Chicago University Press, USA
10. Martha Davis, Scientific Papers And Presentations 2nd edition (2004), Academic Press Maynard Smith, J. The Problems Of Biology (1986), Oxford University Press, Oxford
11. Maynard Smith, J., Current Controversies in Evolutionary Biology (1983), Cambridge University Press, USA
12. Medawar, P. B. And Medawar, J. S., The Life Science: Current Ideas Of Biology (1977), Wildwood House, London
13. Peter Raven et al, Biology 9th edition (2010), McGraw-Hill Education, Singapore Popper Karl, The Logic of Scientific Discovery (2004), Routledge Publication, UK
14. Richard P. Feynman, The Meaning Of It All: Thoughts Of A Citizen-Scientist (2005), Basic Books, New York
15. Richard P. Feynman, The Pleasure Of Finding Things Out: The Best Short Works Of Richard P. Feynman (1999), Edited By Jeffrey Robbins, Perseus Books, USA
16. Robert A. Day, Barbara Gastel, How to Write and Publish a Scientific Paper 7th edition (2011), ABC-CLIO, USA
17. Robert R. Sokal and F. James Rohlf, Introduction to Biostatistics 2nd edition (2009), Dover Publication, New York
18. Scott, E. C. Evolution Vs. Creationism: An Introduction. (2004), University of California press, USA
19. Smith, Roger, The Norton History Of The Human Sciences, New York: W.W. Norton, 1997. Strunk, Jr., W. And White, E.B., The Elements of Style 5th Edition (2003), Pearson Publication, Delhi
20. Wolpert, L., The Unnatural Nature of Science (1992), Faber & Faber, London