SCHEME OF EXAMINATION

&

SYLLABI

For

Master of Technology

In Industrial Biotechnology

Offered by

University School of Biotechnology
(2023 onwards)

GURU GOBIND SINGH
INDRAPRASTHA
UNIVERSITY

Guru Gobind Singh Indraprastha University
Sector 16C, Dwarka, Delhi – 110 078 [INDIA]

M.Tech. Industrial Biotechnology

Program Outcomes (POs)

PO1: Identify, formulate, use research literature, and analyze industrial engineering problems to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.

PO2: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions to aid in the understanding of industrial biotechnology and translational industrial research practices.

PO3: Apply reasoning generated by the contextual knowledge of industrial biotechnology to assess societal, health, safety, legal and cultural issues towards sustainable development and the consequent responsibilities relevant to the professional engineering practice.

PO4: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice used in the industries for development of green and lean processes

PO5: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions in multidisciplinary environments.

PO6: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change useful for modern industries for achieving sustainable goals.

PO7: Demonstrate knowledge for in-depth analytical and critical thinking to identify, formulate and solve the issues related to Biotechnology Industry, Pharma industry, Medical or hospital related organizations, Regulatory Agencies, & Academia.

PO8: Demonstrate skills to use modern analytical tools/software/equipment and analyze and solve problems in various courses of biotechnology in general and industrial biotechnology in particular.

PO9: Develop skills, attitude and values required for self-directed, lifelong learning and professional development in multidiciplinary industries, academic and entrepreneurial environments.

Program Specific Outcomes (PSOs)

PSO1: Students will acquire knowledge in domain of industrial biotechnology enabling their applications in industry and research.

PSO2: Students will be able to demonstrate and apply their knowledge of cell biology, biochemistry, microbiology and molecular biology to solve the problems related to the field of industrial biotechnology.

PSO3: Students will be able to understand and apply the principles of bioprocess and metabolic engineering in the design, analysis, optimization and simulation of bioprocess operations and scale up in bioprocesses including reactor configurations and design and understand the application of membranes in various process industries

PSO4: Student will be able to get in-depth understanding of industrial microbiology including the knowledge for improvement of industrially important strains and understand the role of microorganisms in the production of industrially important products

PSO5: Students will be able to understand advanced fermentation technologies and principles and practices of biomanufacturing employed in biopharmaceuticals, diagnostics and food industries

PSO6: Students will be able to understand various facets of genomics, recombinant DNA technology, industrial enzymology, virology and clinical immunology, Environmental Biotechnology and Bioremediations, Process Design for Wastewater Treatment and nanobiotechnology that could be employed in modern industries.

M.Tech -Industrial Biotechnology

Semester I

Course Code	Course Name	No. of contact Periods/week			Credits
		L	T	P	
IBT-501	Bioprocess Engineering	3	0	0	3
IBT-503	Industrial Microbiology	3	0	0	3
BT-517	Research Methodology & IPR	2	0	0	2
IBT-Professional core elective 1 (select any one)		3	0	0	3
IBT-507	Genome Science and Biotechnology	3	0	0	3
CT-637	Application of membranes in bioprocessing	3	0	0	3
IBT-511	Biologics & Biosimilars	3	0	0	3
IBT-Professional core elective 2 (select any one)		3	0	0	3
IBT-515	Bioinformatics	3	0	0	3
IBT-517	Advanced Fermentation Technology	3	0	0	3
IBT-Open Area elective 1 (select any one)		3	1	0	4
IBT-519	Metabolic Engineering	3	1	0	4
IBT-521	Biomanufacturing Principles and Practice	3	1	0	4
PES-903	Environmental Biotechnology and Bioremediation	3	1	0	4
Lab					
IBT-551	Industrial Microbiology Lab	0	0	4	2
IBT-553	Fermentation Process Lab	0	0	4	2
Total		12	6	4	22

Semester II

Course Code	Course Name	No. of contact Periods/week			Credits
		L	T	P	
CT-514	Design and Analysis of Biological reactors	3	0	0	3
IBT-504	Advanced Downstream processing	3	0	0	3
IBT-Professional core elective 3 (select any one)		3	0	0	3
BT-510	Biophysics and structural Biology	3	0	0	3
IBT-508	Recombinant DNA Technology	3	0	0	3
IBT-510	Industrial Enzymology	3	0	0	3
CT-534	Bioprocess Instrumentation & Control	3	0	0	3
IBT-Professional core elective 4 (select any one)		3	0	0	3
BT-512	Virology	3	0	0	3
BT-506	Clinical Immunology and & Immuno technology	3	0	0	3
CT-512	Process design for waste water treatment	3	0	0	3
CT-510	Membrane Science and Technology	3	0	0	3
IBT-Open Area elective 2 (select any one)		3	1	0	4
IBT-520	Continuum Analysis of Biological Processes	3	1	0	4
IBT-522	Multivariate Statistics and Design of Experiments	3	1	0	4
IBT-524	Bioprocess Modelling & Control	3	1	0	4
IBT-526	Advanced Instrumentation in Industrial Analytical Techniques	3	1	0	4
Lab					
IBT-552	Recombinant DNA technology Lab	0	0	4	2
IBT-554	Downstream process Lab	0	0	4	2
IBT-556	Mini Project	0	0	4	2
IBT-558	Seminar	2	0	0	2
Total					24

Semester III

Course Code	Course Name	No. of contact Periods/week			Credits
		L	T	P	
IBT-Professional core elective 5 (select any one)		3	0		3
IBT-601	Bioproduct development and Bioentrepreneurship	3	0		3
IBT-603	Applied Animal Tissue Culture	3	0		3
CT-603	Membrane Technology for Water and Waste Water Treatment	3	0		3
IBT-607	Plant Metabolomics	3	0		3
IBT-Open Area elective 3 (any one)		3	1		4
IBT-609	Advanced Biochemistry	3	1		4
IBT-611	Clinical trials and Bioethics	3	1		4
IBT-613	Nanobiotechnology	3	1		4
Lab					
IBT-651	Animal Tissue culture Lab	0	0	4	2
Dissertation					
IBT-653	Dissertation (Phase-1)	0	0	20	10
IBT 655	Industrial Visit	0	0		0
Total					19

Semester IV

Course Code	Course Name	No. of contact Periods/week			Credits
		L	T	P	
IBT-652	Dissertation (Phase-2)*	0	0	32	16
Total					16

%*By default every student shall do a dissertation work under the supervision of USBT/USCT/USEM faculty.

Evaluation shall be conducted of 40 marks (Teachers' continuous evaluation/internal assessment) by the supervisor and 60 marks by an external examiner deputed by examinations division (COE) for a total of 100 marks.

**Evaluation shall be conducted for 40 marks (Teachers' continuous evaluation / internal assessment) by appointed teacher and for 60 marks by a bench comprising of all faculty and an external examiner deputed by examinations division (COE) for a total of 100 marks.

In the absence of any supervisor/faculty, Dean of the school can assign responsibility of the supervisor (for purpose of examinations) to any faculty of the School/ collaborating schools.

Note:

The programme of study shall be governed by DBT norms.

Total credits for M.Tech. Industrial Biotechnology (1-4 semesters): 81

Minimum credits required: 75

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Code	Title	Lectures	Credits	Hrs/ Sem
IBT-501	Bioprocess Engineering	3	3	30

Course Outcomes:

After successful completion of this course, the students should be able to:

CO1. Understand the basic reaction theory and calculate the kinetic parameters of enzymatic reactions.
CO2. Calculate and analyze the kinetic parameters for microbial growth.
CO3. Analyze bioprocess design, operation and select suitable bioreactor.

1. Stoichiometry Of Microbial Growth and Product Formation: Introduction, Stoichiometric Calculations, Elemental Balances, Degree of Reduction, Theoretical Predictions of Yield Coefficients. (4)

2. Homogeneous Reaction Engineering: Basic reaction theory, calculation of reaction rates, general reaction kinetics for biological systems, yields in cell culture, cell growth kinetics, production kinetics, kinetics of cell death. Kinetics of substrate uptake, Determining cell Kinetics Parameters from batch data. (5)

3. Heterogeneous Reaction Engineering: Concentration gradients and reaction rates in solid catalysts, internal mass transfer and reaction, the Thiele modulus and effectiveness factor, external mass transfer. Liquid-solid Mass transfer effects. (4)

4. Process Initialization: Types of sterilization, thermal death kinetics of microorganism. Heat sterilization of liquid medium in batch and continuous mode. Air sterilization. Inoculum development. Various types of Fermentation, submerged fermentation, aerobic and anaerobic fermentation. Overview of biosynthetic mechanisms. (4)

5. Reactor Engineering: Bioreactor configurations, practical considerations for bioreactor construction, monitoring and control of bioreactors, ideal reactor operations including batch, fed batch and continuous including recycle stream, batch operation of a mixed reactor. (5)

6. Bioprocess Scale up: Scale up with constant parameters like OTR, mixing, shear stress, flow regime, Reactor volume, etc. Scale-up methods by currently used rules-of-thumb viz. constant P/V, kLa, Various approaches to scale-up including regime analysis and scale-down.

7. Analysis of alternate bioreactor configurations including cell-recycle, air-lift and immobilized-cell bioreactors, Problems on scale-up methods. (5)

8. Biosafety & Biosecurity: Biological Risk Assessment, Laboratory Biosafety Level 1 to 4, Animal Biosafety biosafety for research with recombinants, Biosecurity, development of biosecurity program, Containment for biohazards. (3)

Text / Reference Books:

Bioprocess Engineering - Basic concepts by Schuler ML, Kargi F &DeLisa M, 3rd Edition, Prentice Hall, 2017.

Bioprocess Engineering Principles by Doran PM, 2nd Edition Academic Press 2012.

Basic Biotechnology by Ratledge C & Kristiansen B, "3rd Edn. Cambridge University Press, 2008.

Principles of Fermentation Technology by Stanbury PF, Hall SJ & Whitaker A, Â Elsevier India Pvt Ltd, 2007.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	1	3	3	2	1	1	2	1
CO2	2	1	3	3	2	1	1	2	1
CO3	2	1	3	3	2	1	1	2	1

MK.

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-503	Industrial Microbiology	3	3	30

Course Outcomes:

After successful completion of this course, the students should be able to:

CO1. Understand the basic concept of prokaryotes, structure and their growth.
CO2. Demonstrate knowledge for improvement of industrial important strains.
CO3. Understand the media requirement in industry for the growth of microorganism.
CO4. Understand the role of microorganisms in the production of industrially important products.

1. Introduction of microorganisms: Prokaryotic cell, Structure of Bacterial cell, Archaebacteria and Eubacteria, Structure and function of Plasma membrane, cell wall, capsule, flagella, nucleoid, plasmid, Gram-positive and Gram-negative bacteria. (3)

2. Microbial growth and nutrition: Microbial nutrition- Macronutrients, Minor elements, Trace elements, Microbial growth kinetics - Batch growth, Continuous growth kinetics, Monitoring microbial growth in culture, Effects of environmental conditions on microbial growth, Control of microbial growth. (3)

3. Industrial microorganisms: Isolation of Industrial strains, Strain improvement - Conventional and Genetic engineering approaches, Prokaryotic and Eukaryotic hosts, Limitations of hosts (3)

4. Fermentation media: Fermentation system, Media formulation, Carbon sources – Molasses, Malt extract, Starch and Dextrins, Nitrogen sources - Corn Steep Liquor, Yeast Extracts, Peptones, Soya Bean Meal, Vitamins and growth factors, Precursors, Inducers and elicitors, Inhibitors, Oxygen. Antifoams. (5)

5. Microbial enzymes production: Detergent enzymes, Starch processing enzymes and related carbohydrases, Enzymes in cheese production, Enzymes in textile manufacture, Enzymes in leather manufacture, Enzymes used in the treatment of wood pulps. (5)

6. Fuels and industrial chemicals: Production of Butanol, Production of Ethanol, Amino acids Production, Citric acid Production, Xanthan gum production. (4)

7. Health-care products: Antibiotics – Penicillin, Recombinant therapeutic peptides and proteins - Insulin, Interferon, Interleukins, Tissue plasminogen activator. (4)

8. Microbial biomass production: Baker's yeast production, Single cell protein production, mushroom production. (3)

Text / Reference Books:

1. Prescott and Dunns. Industrial Microbiology (2004) Publisher CBS; 4th edition.
2. Whitaker & Stanbury. Principles of Fermentation Technology. (2016). Publisher: Butterworth- Heinemann; 3rd edition.

3. Okafor, N & Okeke, BC. Modern Industrial Microbiology and Biotechnology. (2017). Publisher CRC Press; 2th edition.
4. Casida, L.E.J.R.. Industrial Microbiology. (2019) Publisher: New Age International Private Limited.
5. Patel, AH. Industrial Microbiology. (2022). Publisher: Laxmi Publications; Second edition.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	1	1	2	1	3	2	1	2
CO2	2	2	2	1	1	3	3	3	2
CO3	1	3	2	1	1	2	1	3	1
CO4	2	2	2	2	1	1	1	2	1

Code	Title	Lectures	Credits	Hrs/ Sem
BT-517	Research Methodology and IPR	2	2	20

Course Outcomes:
After successful completion of this course, the students should be able to:

CO1. Understand research problem formulation
CO2. Analyze research related information
CO3. Follow research ethics

1. Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations. (4)

2. Effective literature studies approaches, analysis Plagiarism, Research ethics, Effective technical writing, how to write report, Paper Developing a Research Proposal, Form at of research proposal, a presentation and assessment by a review committee. (4)

3. Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. (4)

4. Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indication. (4)

5. Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and Indian Institutes. (4)

Text BooksIReferences:
I. Stuart Melville and Wayne Goddard,"Research methodology: an introduction for science & engineering students"
Wayne Goddard and Stuart Melville,"Research Methodology: An Introduction"
Ranjit Kumar, 2nd Edition,"Research Methodology: A Step by Step Guide for beginners"
Halbert,"Resisting Intellectual Property",Taylor & Francis Ltd, 2007.
Mayall,"Industrial Design",McGraw Hill, 1992.
Niebel,"Product Design",McGraw Hill, 1974.
Asimov,"Introduction to Design", Prentice Hall, 1962.
Robert P. Merges, Peter S. Mcnell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
T.Ramappa,"Intellectual Property Rights Under WTO", S.Chand, 2008

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	1	1	2	3	3	2	2	1
CO2	1	1	2	2	3	2	2	3	3
CO3	3	3	2	3	2	2	3	3	3

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-507	Genome Science and Biotechnology	3	3	30

Course Outcomes:

After successful completion of this course, the students should be able to:

CO1. Learn genome sciences and high-throughput technologies.
CO2. Understand basic research mechanisms incorporating photosynthesis, plant-tissue culture-based methods and plant-microbe interactions.
CO3. Acquire theoretical and practical knowledge of biotechnological techniques and bio-organisms and ways to harness them for better health, agriculture produce and industrial products.
CO4. Develop a culture of innovation and discovery by allowing science graduates to acquire new knowledge and update their understanding of modern biotechnology.

1. Macromolecular Structure: Protein and nucleic acids structure and function, Chromosome structure and organisation (prokaryotes and eukaryotes), Methods to study macromolecules. (2)
2. Macromolecular synthesis and Regulation: DNA replication, Transcription, RNA processing and translation. Key concepts, Techniques to study these mechanisms, Regulation of cellular processes, Signal transduction, Protein trafficking, sorting and secretion. (4)
3. Functional Genomics: Introduction to experimental technologies to study genomics, DNA sequencing (targeted approaches, whole exome and whole genome sequencing), RNA sequencing, Basic bioinformatics, Current technologies used for investigating genomic variation. (4)
4. Epigenomics: Epigenetic modifications at DNA and histone protein levels, RNA-based and chromatin-organisation based epigenetic mechanisms, Mechanisms of epigenetic control of gene expression, Gene and transposon silencing mechanisms, X-chromosome inactivation and its mechanism. (4)
5. Molecular engineering: Mechanisms of nucleic acids and protein engineering, Gene delivery mechanisms, Expression and purification of recombinant proteins using *E.coli*, and other expression systems, genome editing tools (ZFNs, TALENs and CRISPR-Cas9). (4).
6. Genomic medicine: Use/application of genomics in precision medicine, Genomics-guided treatments, Introduction to different cellular and molecular actions of treatments, Interpretation of genomics data in clinical context, Gene therapy. (4)
7. Plant Biotechnology: Basic techniques in plant tissue culture, Micropropagation and its commercial exploitation, Production of haploids and its applications, Chloroplast transformation and Molecular Pharming, Plant-microbe interactions, Plant disease resistance. (4)

8. Agricultural Innovations: Biofortification of crops, Introduction to moss biology, Use of mosses in biotechnology, Moss-made pharmaceuticals, Molecular breeding, Transgenic and genetic manipulation, Molecular marker approach to tag disease resistance and avirulence genes, Genome editing for crop genome improvement. (4)

Text / Reference Books:

1. Molecular Biology: Principles of Genome Function, Nancy Craig et al., Oxford University Press, Third edition 2021.
2. Molecular Biology: Structure and Dynamics of Genomes and Proteomes J. Zlatanova and K.E. vanHolde 2016, Garland Science, Taylor and Francis Group.
3. Lewin's Essential Genes, J. Krebs et al., Fourth Edition 2021.
4. Genomes 4, T. A. Brown, Fourth Edition Garland Science, 2018.
5. Plant Cell and Tissue Culture Edited by Indra K. Vasil and Trevor A. Thorpe, Kluwer Academic Publishers
6. Plant Tissue Culture: Theory and Practice By S. S. Bhojwani and M. K. Razdan Elsevier Publishers
7. In Vitro Cultivation of Plant Cells BIOTOL Biotechnology by Open Learning Butterworth/Hernemann Ltd.
8. Genomic Medicine: Principles and Practice. Dhavendra Kumar (Editor), Charis Eng (Editor). Oxford University Press; 2nd edition (24 Oct. 2014).
9. The CRISPR/Cas9 system and its applications in crop genome editing. Crit Rev Biotechnol. 2019 May;39(3):321-336. doi: 10.1080/07388551.2018.1554621.
10. Genome Editing: A Practical Guide to Research and Clinical Applications, 1st Edition - March, 2021

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	1	1	1	2	2	1	3	1
CO2	2	1	3	3	3	3	1	2	1
CO3	2	1	2	1	2	2	2	2	3
CO4	2	2	1	1	3	2	2	1	1

Code	Title	Lectures	Credits	Hrs/ Sem
CT-637	Application of membranes in bioprocessing	3	3	30

Course outcomes:
At the end of the course, the student should be able to:

CO1. Understand the various membrane processes, principles, separation mechanisms, selection criteria and their industrial applications.
CO2. Understand the various transport models, different types membrane fouling and their control, and the effects of process parameters on system performance.
CO3. Understand the basic principles and application of affinity ultrafiltration, membrane bioreactor and electric field enhanced ultrafiltration.
CO4. Know the state-of-the-art and future scope of application of membranes in various processes industries.

1. Membrane processes: Microfiltration, Ultrafiltration, Nanofiltration and Reverse osmosis; Membrane configuration, Criterion of selection of suitable membrane; Membrane fouling and its control; Membrane cleaning and compaction; Concept of integrated membrane process; Process design and energy requirement. [10]

2. Solute and solvent transport modeling: Pore blocking model, Concentration polarization model, Resistance in series model, Gel layer model, Osmotic pressure model, Combined fouling model etc. Estimation of various fouling resistances. [15]

3. Affinity ultrafiltration and membrane bioreactor. Electric field enhanced ultrafiltration. [7]

4. Applications: Purification and concentration of protein, enzymes etc.; Dairy processing; Sugar refining; Fruit juice processing; Treatment of plant extract; Alcoholic beverages etc. [10]

Text / Reference Books:

1. J.A. Howell, V. Sanches, R.W. Field, Membrane in Bioprocessing: Theory and Applications, Chapman & Hall Inc, London, U.K., 1993
2. R. Rautenbach and R. Albrecht, Membrane Processes, John Wiley & Sons Ltd., 1994
3. Leos J. Zeman and Andrew L. Zydney, Microfiltration and Ultrafiltration; Principles and Applications, Marcel Dekker, 2016
4. Munir Cheryan, Ultrafiltration and Microfiltration Handbook, CRC Press, 2016
5. Marcel Mulder, Basic Principle of Membrane Technology, second Edition, Kluwer Academic Publishers, 1996

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	3	1	3	1	2	3	1	3
CO2	1	1	2	1	1	2	3	2	1
CO3	1	1	2	1	1	2	3	2	1
CO4	2	3	2	3	2	3	3	2	3

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-511	Biologics and Biosimilars	3	3	30

Course Outcomes:
At the end of the course, the student should be able to:

CO1. Understand the design and development of different kinds of biologics, biomimetics, and biosimilars.
CO2. Gain a perspective of the complexity to establish biosimilarity of therapeutic proteins and biologics.
CO3. Know the regulatory framework about the Biosimilars.

1. Introduction to Biopharma Generics in Biopharma, definition of biologics, biosimilars, super biologics, differences between chemical genetics, biosimilars and biobetter. The developmental and regulatory challenges in biosimilar development, Prerequisites for Biosimilar development, Biosimilar market potential. (5)

2. Types of biosimilar drugs Peptides, proteins, antibodies, Enzymes, Vaccines, Nucleic acid based therapies (DNA, RNA, etc), Cell based therapies (including stem cells). (3)

3. Characterization methods Aggregation- precipitation, floccule strength, precipitate ageing & kinetics, adsorption of proteins & peptides on surfaces, effect of temperature on protein structure, hydration & thermal stability of proteins - solid powders, suspension on non-aqueous solvents, reversed micelles, aqueous solution of polyols, analytical and spectrophotometric characterization of proteins, protein sequencing and structure determination. (7)

4. Bioequivalence studies Immunogenicity & allergenicity of biosimilars; factors affecting immunogenicity - structural, post-translational modifications, formulations, impurities, manufacturing and formulation methods for biosimilars; types of bioequivalence (average, population, individual), experimental designs & statistical considerations for bioequivalence studies (Non-replicated designs – General Linear Model; Replicated crossover designs), introduction to "ORANGE BOOK" & "PURPLE BOOK". (7)

5. Case studies Indian companies working in this space & their product pipeline (Biocon, Intas, Dr Reddy's, Reliance, Bharat Biotech, Lupin, Cipla, Shanta, etc); products - Erythropoietin, growth hormone, granulocyte stimulating factors, interferons, streptokinase, monoclonal antibodies. (5)

6. Practicals: List of 25 FDA approved biosimilars in the global pharma market - their reference product & biosimilar equivalents. (3)

Text Books/References:

1. Laszlo Endrenyi, Paul Declerck and Shein-Chung Chow, Biosimilar Drug Development, Drugs and Pharmaceutical Sciences, Vol 216, CRC Press.
2. Cheng Liu and K. John Morrow Jr., Biosimilars of Monoclonal Antibodies: A Practical Guide to Manufacturing, Preclinical and Clinical Development, Wiley, Dec 2016. 3. https://www.drugs.com/medical-answers/many-biosimilars-approved-unitedstates-3463281/

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	1	3	3	1	2	1	3	3
CO2	3	3	1	3	2	1	3	2	1
CO3	1	2	3	1	2	3	1	1	2

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-515	Bioinformatics	3	3	30

Course Outcomes:

At the end of the course, the student should be able to:

CO1. Gain "hands on" practical experience with internet based bioinformatics tools and data.

CO2. Explore the internet based resources by themselves.

CO3. Understand the correct use of the databases and software tools.

CO4. Develop programming skills and an understanding of the web-based analytical and bioinformatic tools

CO5. Obtain hands-on training in analytical and bioinformatic tools

1. INTRODUCTION TO COMPUTERS AND INTERNET. Fundamental principles of the Linux operating system, Basic Linux commands that will allow the student to navigate through files and directories, Familiarity with at least one text based editor program for Linux (emacs or gedit), Concepts of IP address, http, https, sftp etc., Use of commands like *wget* for non-interactive downloading of data from the internet., Fundamentals of *bash*, *sed* and *awk* scripting. Ability to write simple scripts in these languages. (6)

2. WEB-BASED DATABASES IN BIOLOGY: Navigating through the following websites and understanding the use of software tools and data available in each of them, NCBI (www.ncbi.nlm.nih.gov), DDBJ (http://www.ddbj.nig.ac.jp/), Expasy Bioinformatics Resource Portal (www.expasy.org), The European Bioinformatics Institute Portal (www.ebi.ac.uk), Kyoto Encyclopedia of Genes and Genomes (http://www.genome.jp/kegg/), UniprotKB (http://www.uniprot.org/), PFAM Database (http://pfam.xfam.org/), Protein Data Bank (www.pdb.org). (6)

3. FAMILIARITY WITH SEQUENCE ANALYSIS TOOLS. Alignment tools (BLAST, CLUSTAL, etc.), Pattern Searching tools, Domain / Motif Search Tools, Promoter Analysis Tools. (5)

4. FAMILIARITY WITH MOLECULAR MODELLING SOFTWARE. Use of any one modelling and visualization software e.g., VMD, PyMol, Homology Modelling. Use of any one homology modelling software like MODELLER, Docking. Use of any one docking software like AUTODOCK-VINA (6)

5. PROGRAMMING FOR BIOINFORMATICS. Perl, HTML, Java, R, MySQL (7)

Text Books/References:

1. Fundamental concepts of Bioinformatics, by Dan E Krane and Michel Raymer, Pearson, 2003.
2. Bioinformatics and computational biology in drug discovery and development. William T. Loging, 2016.
3. Bioinformatics: A practical guide to the analysis of genes and proteins. Baxevanis and Ouellette, Wiley Student Edition, 2009.

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Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	3	2	1	3	1	3	2	1
CO2	2	2	3	3	3	2	2	3	1
CO3	3	2	3	3	3	3	2	3	2
CO4	3	2	2	1	1	1	2	1	2
CO5	3	1	3	2	1	2	1	3	3

Code	Title	Lectures	Credits	Hrs/sem
IBT-517	Advanced Fermentation Technology	3	3	30

Course Outcomes:

At the end of the course, the student should be able to:

CO1. Learn problems on production of bioproducts via fermentation.
CO2. Understand the different fermentation processes for products having societal use.
CO3. Apply their knowledge in downstream of industrial products.

1. Selection of industrially important cultures; Isolation of pure culture & genetic improvement of industrial microorganisms with applications. (6)

2. Process technology for the production of primary metabolites, Baker's yeast, Single Cell Protein, ethanol. (6)

3. Biosynthesis and fermentative production of antibiotics – penicillin, semi-synthetic penicillin,streptomycin, tetracyclines, chloramphenicol; Microbial production of antifungal antibiotics;Metabolic regulations in industrial fermentation; microbial production of amino acids-lysine,glutamic acid, microbial transformation of steroids; microbial production of vitamin-β-carotene,vitamin B12, vitamin B6. (10)

4. Recombinant DNA Technology for production of protein (insulin), vaccine hepatitis),monoclonal antibodies (Herceptine). (8)

5. Microbial assay techniques for estimation of antibiotics and vitamins. Application of antibiotics in animal nutrition and food preservation, mycotoxins and microbial insecticides. (4)

6. Use of microbes in mineral beneficiation; Production of biodegradable polymers, biofertilizers, microbial exopolysaccharides – xanthan, gellan etc. (8)

Text Books/References:

1. Biotechnology, A Text book of Industrial Microbiology, W. Crueger and A. Crueger, Sinauer Association.
2. Principles of Fermentation Technology, Stanbury, Whitaker and Hall, Aditya Text Pvt. Ltd.
3. Bioprocess Engineering: basic concepts, Michael L. Shuler and FikretKargi
4. Bioprocess Engineering, B. K. Lydersen , K.L. Nelson B.K. Lydersen and N.D'Elia, John Wiley and sons.

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Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	1	3	3	2	3	3	1	1
CO2	2	1	1	1	1	2	1	1	1
CO3	2	2	2	1	3	2	1	2	3

Code	Title	Lectures	Credits	Hrs/sem
IBT-519	Metabolic Engineering	4	4	40

Course outcome:
At the end of the course, students should be able to:

CO1. Identify the appropriate host and/or metabolic pathways to produce a desired product or remediate a toxin;

CO2. Compare potential metabolic engineering strategies using quantitative metabolic modeling.

1. Introduction
   Stoichiometry, Kinetics and Thermodynamics Of Cellular Reactions. (3)

2. Material Balances And Data Consistency
   Material balances on pathways and whole cell balances; Over and under-determined systems; Data consistency for over-determined systems. (3)

3. Regulation Of Metabolic Pathways
   Regulation of metabolic pathways; role of enzymes, substrate, product and regulatory molecules; Hierarchical control in cellular systems. (3)

4. Manipulation Of Metabolic Pathways
   Pathway manipulation strategies for overproduction of various metabolites, examples of ethanol overproduction, overproduction of intermediates in main glycolytic pathway and TCA cycle like pyruvate, succinate etc.; Need for multiple genomic modifications; Modulating fluxes in desired pathways; Tools for multiple genomic modifications examples- TALENS CRISPR-Cas systems as well as traditional systems of gene knock ins and knock outs and promoter engineering. (6)

5. Synthetic Biology
   Metabolic pathway synthesis; Relation with bioprocess design; BIOBRICKS approaches; Introduction to tools of synthetic biology. (5)

6. Metabolic Pathway Synthesis & Flux Analysis
   Metabolic flux analysis; Building stoichiometric matrix; Steady state and pseudo steady state assumptions; Using different optimizing functions to solve linear programming problem; FBA, understanding flux cone and constraints; Introducing additional constraints from thermodynamics; Brief introduction to developments in this area; MOMA (Minimization of Metabolic Adjustment), iFBA (Integrated Flux Balance Analysis) etc (6)

7. Determination and Application of Metabolic Flux
   Experimental determination of metabolic fluxes; C13 labeling, NMR and GC-MS based methods for flux determination. (4)

Text Books/References:

1. Stephanopoulos, G.N., Aristidou, A.A., Nielsen, J. (1998) Metabolic Engineering: Principles and Methodologies. 1st ed. San Diego: Academic Press.

2. Smolke, C.S. (2010) Metabolic Pathway Engineering Handbook: Fundamentals. 1st ed. New York: CRC Press.

3. Smolke, C.S. (2010) Metabolic Pathway Engineering Handbook: Tools and Applications. 1st ed. New York: CRC Press.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	2	2	1	1	1	1	1	1
CO2	1	2	2	3	2	3	2	2	1

Code	Title	Lectures	Credits	Hrs/sem
IBT-521	Biomanufacturing Principles and Practice	**4**	**4**	**40**

Course outcome:
At the end of the course, students should be able to:

CO1. Imbibe knowledge of GMP and GLP requirements which is critical for those who opt for careers in biomanufacturing.
CO2. Create and understand the quality documents created during the cGMP.

1. BIOMANUFACTURING PRINCIPLES:
Overview and design of biomanufacturing, quality by design approach, technical considerations, phases and scale up: life cycle of manufacturing, raw material considerations, compliance and quality in biomanufacturing, lean biomanufacturing; Process analytical technology (PAT) during biomanufacturing: background and need tools for data acquisitions (software in fermenters, flow filtrations, chromatography, analysis and design process analyzers, process control tools and continuous improvement and knowledge management; Standard manufacturing operating procedures of biotechnology, including upstream and downstream processing of proteins, and quality control of protein production, and final fill and finish of product; Case studies to be included at least: therapeutic proteins, monoclonal antibodies, human vaccines. (6)

2 QUALITY SYSTEM:
Introduction to quality system, main elements of a quality system. Essential of quality system Practical implementation of a quality system. Structure of quality manual, correlation between GMP requirements (WHO) and ISO 9001:2000. (4)

3. PRINCIPLES AND PRACTICE OF (GOOD MANUFACTURING PRACTICE) GMP
Personnel, Premises, Facilities and Equipment: Principles of human resource management, duties of senior management, organizational structures, qualification andprofiles requirement, workplace and job descriptions, material & personnel flow and layout, air cleanliness classes and grades, construction elements, barrier systems, isolators and safety cabinets, building services, heating ventilation air conditioning (HVAC), process gases, qualification of premises and HVAC systems, pharma monitoring of HVAC systems, particle monitoring, Facility planning, materials, hygienic design in solids handling, system controllers and process control systems, technical documentation, calibration, maintenance, cleaning of facilities, containment (personnel protection) in solids handling

Pharmaceutical water: Water qualities, generation of pharmaceutical water, distribution and storage of pharmaceutical water, qualification of water supplies, operation of water supplies, pure steam systems

Qualification: Official requirements, preparation of the qualification, qualification documentation, design qualification (DQ), Installation qualification (IQ), operational qualification (OQ), Performance qualification (PQ), special cases of qualification

Process and cleaning Validation: Official requirements, Validation - a key element of quality

management, validation planning and procedure, validation documentation, process validation and product lifecycle, how to validate cleaning procedures, cleaning validation master plan, establishing the scope of validation, acceptance criteria and limit calculation

Computer system Validation: Introduction and terminology, legal aspects, system life cycle, system classification and risk management, validation of computerised systems

Quality Risk Management: Principles and requirements, Potential applications and uses of quality risk management, the quality risk management process, methods and tools of quality risk management

Production: Sanitation, personnel hygiene, production hygiene, sanitation programme. environmental monitoring, GMP in the production process, weigh-in, identification, in- process control prevention of cross-contamination

Sterile Production and Packaging: Introduction, Air lock concepts, manufacture of terminally sterilised products, sterilisation processes, aseptic processing, freeze-drying, testing for sterility, testing for endotoxins, testing for leakage and for particles, microbiological monitoring

Laboratory Controls: Sampling, substances used in laboratories, qualifying laboratory instruments, calibration in the lab, validation of analytical methods, stability testing, test results outside defined criteria (OOX), raw data documentation, batch release, microbiological testing, pharmacopoeias, laboratory data management systems (LDMS)

Documentation: Official requirements, GMP-compliant documentation, batch documentation, standard operating procedures (SOPs), site master file, electronic batch recording and batch release, document management systems

Inspections: Principles, inspection procedures, inspectors, organization of inspections, self-inspection, inspection of contract manufacturers, inspection of suppliers, questionnaire for preparing GMP-inspections, Inspection of API manufacturers.

Active Pharmaceutical Ingredients: Introduction, regulatory principles, marketing authorisation documentation for active substances, GMP certificates, auditing active substance manufacturers, chemical active substances, biotechnological active substances (18)

4. GMP IN REGULATION

Information, national bodies and pharmaceutical associations

EU directives and guidelines, USA: CFR and FDA guidelines, ICH-guidelines, PIC/S guidelines, GMP of other regions, WHO guidelines (2)

Text Books/References:

1. Introduction to Biomanufacturing. By Northeast Biomanufacturing Center and collaboration, 2012.
2. Introduction to Biomanufacturing, by Mark Witcher. In Encyclopedia of Industrial Biotechnology.
3. Good Manufacturing Practices for Pharmaceuticals (e-resource): A plan for total quality control. Sidney Willig and James Stoker.
4. Biotechnology Operations: Principles and Practices; by John M. Centanni, Michael J. Roy; CRC press

5. Lean Biomanufacturing, 1st Edition; Author Nigel Smart; Woodhead Publishing
6. GMP manual; Publisher Maas &Peither America, Inc. GMP Publishing

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	2	2	1	3	3	1	1	1
CO2	3	3	1	2	3	2	1	2	3

Code	Title	Lectures	Credits	Hrs/sem
PES- 903	Environmental Biotechnology and Bioremediation	4	4	40

Course outcome:
At the end of the course, students should be able to:

CO1. The course is designed to educate research scholars about environmental biotechnology and its application in various sectors.

CO2. Understanding the basic concepts of enzymes and their importance. Students will acquire skills on working with enzymes and analyzing their various properties. They will develop ability to immobilize enzymes and use them for various industrial and environmental applications.

CO3. Students will gain in-depth knowledge of recent approaches of waste treatment and management along with resource recovery options in a sustainable manner.

CO4. Identification of skills to explore different bioremediation processes for the benefit of society and environment and address the associated challenges.

1. Basics of Environmental Biotechnology: Introduction, scope and importance, Applications, Genetic engineering, GMOs and Bioethical issues. Biomarkers, Biosensors of pollution: BOD sensors, Ammonia sensors, Microbial protein characterization, purity and molecular weight, Biofuels and bioplastics. (8)

2. Enzyme Technology: Introduction, Basics of enzymology- Activity assay and characterization. Enzyme immobilization: Concept, methods of immobilization, applications of immobilized enzymes in environmental research Industrial enzymes: Enzyme applications in food industry, paper and pulp industry, textile industry, pharmaceutical, dairy, distillary, detergency. (10)

3. Wastewater treatment Technologies: Aerobic and anaerobic methods for treatment of wastewaters– Role of microbes like methanogens, acetogens and fermentative bacteria; biofilms ; Constructed wetland technology. (8)

4. Bioremediation Technologies:Ex-situ and in-situ Bioremediation, microbial removal of toxic microbes, Role of Microbes in enhanced oil recovery. (4)

Text Books/References:

1. Alan Scragg (2005) Environmental Biotechnology, 2nd Edition, Oxford

University Press.

2. Bruce Rittman, Perry L. McCarty (2000) Environmental Biotechnology: Principles and Applications, 2nd Edition, McGraw-Hill.

3. I. S. Thakur (2011) Environmental Biotechnology: Basic Concepts and Applications. 2ndEdn, I K International Publications.

4. B.C. Bhattacharya and Rintu Banerjee (2007). Environmental Biotechnology, Oxford University Press, 2007.

5. L. Stryer (2002) Biochemistry, 5th edition, W.H. Freeman and Company.

6. N. C. Price and L. Stevens (2000) Fundamentals of Enzymology, 3rd edition, Oxford University Press, USA.

7. Wolfgang Aehle (2007) Enzymes in Industry: Productions and Applications, 3rd edition Wiley-VCH.

8. M.J. Pelczar, E.C.S Chan, N.R. Krieg, 1998. Textbook of Microbiology, 5th edition Tata McGraw Hill Publishing Co. Ltd., New Delhi.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	3	1	3	3	1	3	2	3
CO2	3	3	2	3	2	2	2	2	2
CO3	3	3	3	1	3	3	1	3	3
CO4	2	3	3	3	1	1	3	2	3

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Code	Title	Hours/week	Credits	
IBT-551	Industrial Microbiology Laboratory	4	2	

List of practicals:

1. Aseptic techniques and media preparation for culturing the microbes.
2. To isolate and enumerate bacteria from the given soil sample by the serial dilution technique using aseptic techniques.
3. To culture a bacterium from soil sample using sub-culture methods and to demonstrate methods for purifying and maintaining bacterial cultures in laboratory for long term.
4. To perform the Gram staining procedure to compare morphological features and arrangements of bacterial cells.
5. To perform IMViC Test for biochemical characterization of bacterial isolates.
6. Molecular characterization of bacterial isolates using 16S rRNA sequencing.
7. Determining the antibiotic sensitivity by Kirby-Bauer Assay.
8. To plot a growth curve and determine the generation time and specific growth rate of bacterial culture.
9. To determine the ability of bacteria to oxidize glucose using Methyl Red test and Voges Proskauer test.
10. To test the citrate utilization test of the bacteria.
11. To demonstrate the ability to hydrolysis of casein by the given bacteria.
12. To demonstrate the ability to hydrolysis of starch by the given bacteria.

Text / Reference Books:

1. Alfred E. Brown, Heidi Smith. Benson's Microbiological Applications, Laboratory Manual in General Microbiology. (2014). McGraw Hill; 13th edition.

2. John P. Harley. Laboratory Exercises in Microbiology. (2013). McGraw-Hill Science Engineering; Lab Manual edition.

3. Michael J. Leboffe, Burton E. Pierce. Microbiology: Laboratory Theory & Application. (2010). Morton Pub Co; 3rd edition.

Code	Title	Hours/week	Credits	
IBT-553	Fermentation Process Laboratory	4	2	

List of Practicals

A) Microbial Biochemistry (Analytical)

1. Cultivate Bacteria and Other Microbes in Liquid Culture and Solid Media
2. Estimation of Lipids, Carbohydrates and Proteins (Bradford, Lowry's Method)
3. Estimation of substrates alcohol, Acetic Acid, sugars and other metabolites by High performance liquid chromatography (HPLC)
4. Isolation of Carotenoids (and lipids) and Analysis by Thin Layer Chromatography (TLC)
5. Isolation of Secondary Metabolites and analysis by TLC

B) Fermentation Technology Lab

1. Assembly of bioreactors and Calibration of Probes (pH and Dissolved Oxygen)
2. Sterilization
3. Cascade control of Dissolved Oxygen
4. Growth of control
5. Batch/Fed batch with concentrated feed
6. Continuous Stirred Tank Reactor running at different dilution rate
7. Estimation of Growth/Product formation & Substrate utilization kinetics
8. Estimation of Kla by dynamic gasing out and gas balancing.

Code	Title	Lectures	Credits	Hrs/ Sem
CT-514	Design and Analysis of Biological Reactors	3	3	30

Course Outcomes:
At the end of the course, students should be able to:

CO1. Apply engineering concepts to the design and operation of non-ideal, catalytic heterogeneous reactors.
CO2. Apply specific methodologies, techniques, and resources to conduct research and produce innovative.
CO3. Solve problems in new or situations (multidisciplinary) contexts related to the field of study.
CO4. Use IT tools to acquire further knowledge in the field of biological and environmental engineering.
CO5. Use acquired knowledge as a basis for originality in the application of ideas, often in a research context and work in a multidisciplinary team

1. Ideal Bioreactors: Fed-Batch Reactor, Enzyme-catalyzed reactions in CSTRs, CSTR reactors with recycle and wall growth, The ideal plug-flow and tubular reactor. Reactor Dynamics: Dynamics model, Stability. (8)

2. Reactors with non-ideal mixing: Mixing time in agitated tanks, Resident time distributions, Models for no ideal reactors, Mixing-Bio reaction interactions, reactors in series. Sterilization Reactors: Batch Sterilization, Continuous Sterilization, Axial flow with dispersion (continuous sterilization) Immobilized Bio Catalysis: Formulation and characterization of immobilized cell bio catalysts, Application of immobilized cell biocatalysts. (8)

3. Multiphase Bio reactors: Conversion of heterogeneous substrates, Packed bed reactors, Bubble column Bio-reactors, Fluidised bed Bio-reactors, Trickle bed reactors Fermentation Technology: Medium formulation, Design and operation of a typical aseptic, aerobic fermentation process, Alternate bioreactor configurations, air-lift bioreactor, bubble column bio reactor. (7)

4. Plant and Animal Cell culture Technology: Reactor types and controls, hollow fiber reactor, perfusion reactor medium requirements for animal cell cultivation, Reactor for large-scale production using animal cells. Case study on a plant and animal cell products - alkaloids, steroids, proteins, erythropoietin factor-VIII protein etc. (7)

Text Books/Reference:

Biochemical Engineering Fundamentals by James E. B

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Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	2	2	1	3	3	3	3	2
CO2	3	1	1	2	1	2	1	3	2
CO3	1	1	3	1	1	3	3	3	1
CO4	2	1	2	2	2	3	3	3	3
CO5	2	2	3	2	2	3	2	3	3

Code	Title	Lectures	Credits	Hrs/Sem
IBT 504	Advanced Downstream Processing	3	3	30

Course outcome:
At the end of the course, students should be able to:

CO1. Understand the principle of various steps in downstream process
CO2. Decide upon effective strategies of downstream processing based on characteristics of biomolecules
CO3. Design and understand bioprocesses in totality.

1. Properties of Biomolecules as basis of separation Design of batch and continuous systems (4)

2. Principles of solid liquid separation: Filtration, centrifugation and membrane separation. (4)

3. Theory and design of equipment: Extractive separation, solvent-based separation, Aqueous two-phase separation, design of multistage equipment based on partition coefficient, Chromatographic separation, equilibrium theory and column design, non-linear and mass transfer effects, loading effects, non-linear absorption isotherms and scale-up. (12)

4. Continuous chromatography and SMB Technology: Theory and practical aspects, Industrial application. (3)

5. Cell disruption methods: Handling intracellular & extracellular products of fermentation (3).

6. Crystallization: Principles, scale-up and equipment design (3)

7. Drying: Principles, equipment design. (3)

8. QBD principles and practice. (4)

9. Integrated Principles and practice. (4)

10. Flow sheets with mass and energy balances, examples: rec-protein purification from IB and intracellular soluble fraction. (4)

Text Books/ References:

1. Bioseparation science and engineering. Roger Harrison, Paul Todd etal, Oxford Univ. Press.
2. Transport processes and separation process principles. 4th Ed. Christie John Geankoplis, PHI-EEE.
3. Handbook of downstream processing, by Goldberg, Springer.
4. Downstream processing in b iotechnologty (2013). By Wisselingh and Krijgsman Duff. Academic Press.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	1	1	1	2	3	2	3	3
CO2	2	1	2	1	3	1	1	1	1
CO3	1	2	2	2	2	2	2	2	2

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Code	Title	Lectures	Credits	Hrs/sem
BT-510	Biophysics and Structural Biology	3	3	30

Course Outcomes:
At the end of the course, students should be able to:

CO1. Understand the physical principles and structure-function relationships in biological macromolecules.
CO2. Apply biophysical principles to understand, model and predict biomolecular structure and interactions.
CO3. Understand the use of various biophysical techniques and instrumentation for studying structure, function and interaction of macromolecules.

1. Interactions in Biological Systems Intra- and intermolecular forces, van der Waals, Electrostatic, and Hydrogen bonding interactions, Hydrophobic interactions, and weak interactions. (4).

2. Structure of Protein Conformational properties of polypeptides and Ramachandran Plot, Primary and secondary structure, Super secondary structures, fibrous protein structures, Tertiary and Quaternary structure, Structural features of membrane proteins. (6)

3. Structure of Nucleic AcidConformational parameters of Nucleic acids, Chargaff's rule, DNA polymorphism, Hyperchromicity, DNA supercoiling, and Circular DNA, Types and structures of RNA, mRNA, rRNA and tRNA. (6)

4. Equilibrium and Kinetics Folding-Unfolding equilibrium and denaturation of proteins and nucleic acids, Effect of temperature and solvent conditions on the thermodynamics of folding-unfolding equilibrium, Kinetics of protein folding (6)

5. Techniques for studying Macromolecular Structure and interactions
Analytical Ultracentrifugation, Sedimentation velocity and equilibrium, determination of mol. Weights, UV-Visible Absorbance and Fluorescence spectroscopy, Circular Dichroism spectroscopy, Microcalorimetry (DSC and ITC), X-ray crystallography, Nuclear Magnetic Resonance (NMR). (8)

Text Books/ References:

1. Proteins: Structure and Molecular Properties by T. E. Creighton.
2. Nucleic Acids: Structure, properties and function by V. A. Bloomfield and D. M. Crothers.
3. Biophysical Chemistry Part I and II by C. R. Cantor and P. R. Schimmel.
4. Physical Biochemistry by K. E. Van Holde
5. Physical Biochemistry by David Freifelder.
6. Introduction to Protein Structure by C. Branden and J.Tooze.
7. Biophysical Chemistry of Nucleic acids and Proteins by T. E. Creighton.
8. Protein Physics by A. V. Finkelstein and O. B. Ptitsyn.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	2	2	1	2	1	1	1	3
CO2	1	1	3	3	2	2	3	2	1
CO3	1	3	1	1	3	1	1	3	3

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Code	Title	Lectures	Credits	Hrs/ Sem
IBT-508	Recombinant DNA Technology	3	3	30

Course Outcomes:
At the end of the course, students should be able to:

CO1. Discuss the different tools and techniques used in rDNA technology.
CO2. Use the knowledge of different tools and techniques employed in rDNA technology to design strategies and conduct experiments to isolate, manipulate, analyze and express nucleic acids.
CO3. Apply the concepts of rDNA technology to analyze and solve problems in basic and applied biotechnology/life sciences research.
CO4. Understand the safety and ethical concerns involved in rDNA technology.

1. Introduction to rDNA Technology (2)

2. Enzymology: Restriction Endonucleases, DNA Ligase, Alkaline Phosphatase, Polynucleotide Kinase, DNA and RNA Polymerases, Exonucleases, Reverse Transcriptase. (3)

3. Vectors: Characteristics of vectors, Different kinds of vectors- Plasmids, Bacteriophage based vectors, Phagemids, Cosmids, Artificial chromosomes, Plant and Animal Virus based vectors, Shuttle vectors, Expression vectors. (3)

4. Gene transfer, Selection and Screening techniques: Bacterial and eukaryotic hosts, Methods of introduction of foreign DNA into host cells; Selection and Screening strategies. (3)

5. Analysis, Expression and Mutagenesis of cloned genes: Restriction enzyme analysis, DNA and RNA probes, Methods for labeling of probe, Radioactive labeling, Non-radioactive labeling, Direct and Indirect labelling, Southern hybridization, Northern hybridization, RT-PCR, qRT-PCR, Heterologous protein expression, Western blotting, Fusion proteins, Site-directed mutagenesis. (5)

6. Gene libraries: Construction of genomic and cDNA libraries, Linkers, Adaptors, Homopolymer tailing, Amplification of gene libraries, Screening of libraries bycolony and plaque hybridization, immunological screening. (3)

7. Polymerase Chain reaction (PCR): Basic principles of PCR and use of different heat stable enzymes, Designing of primers, Variations in PCR, Applications of PCR. (3)

8. Genome Analysis and Editing: Sanger's dideoxy chain termination method, Next Generation Sequencing platforms, Microarray technology, RNA Seq, CRISPR-Cas genome editing tools. (4)

9. Applications of Recombinant DNA Technology (2)
10. Safety and Ethical Concerns in Recombinant DNA Technology (2)

Text books/References:

1. Gene Cloning and DNA Analysis: An Introduction, T.A. Brown, Wiley-Blackwell, 8th Edition, 2020.
2. Genetic Engineering: Emerging Concepts and Technologies, Edited by P. Faraday, Syrawood Publishing House, 2018.
3. Molecular Biotechnology: Principles and Applications of Recombinant DNA, B.R.Glick and C.L. Patten, American Society for Microbiology Press, 5th Edition, 2017.
4. Molecular Cloning: A Laboratory Manual, M.R. Green and J. Sambrook, Cold Spring Harbor Laboratory Press, 4th Edition, 2014.
5. From Genes to Genomes: Concepts & Applications of DNA Technology by J.W. Dale & M.V. Schartz, Wiley-Blackwell, 2011.
6. Principles of Gene Mani.pulation and Genomics, Primrose and Twyman, 2006.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	2	2	1	1	1	2	1	3
CO2	1	3	2	2	2	1	1	1	2
CO3	3	2	2	3	2	2	3	3	3
CO4	2	1	3	1	2	1	2	1	2

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-510	Industrial Enzymology	3	3	30

Course Outcomes:

At the end of the course, students should be able to:

CO1. Understand the basic concept of Enzyme kinetics, structure and engineering.
CO2. Demonstrate knowledge for improvement of industrially important recombinant and non-recombinant enzymes.
CO3. Understand the importance in industry for immobilized enzymes.
CO4. Understand the role of safety and regulatory policies in industrially enzymes.

1. Introduction and basics of enzymes

Introduction to enzymes, Enzyme classification, Factors influencing enzyme activity, Enzyme assays, Specificity and Mechanism of Enzymes Action, Mechanism of catalysis, Metal-activated enzyme and metalloenzyme, Coenzymes in enzyme catalyzed reactions. Enzyme Kinetics: Interpretation of Km, Vmax, Turnover number and Kcat: Specific activity of enzymes. (6)

2. Enzyme production and purification

Recombinant versus non-recombinant production, Approaches to recombinant protein production, Heterologous protein production in *E.coli,* Heterologous protein production in yeast, Heterologous protein production in fungi, Proteins from plants, Animal tissue as a protein source, Heterologous protein production in transgenic animals, Heterologous protein production using animal cell culture.(5)

3. Immobilization of enzymes

Introduction, Methods of immobilization, Kinetics of immobilized enzymes, Effects of immobilization on enzymes, Use of immobilized enzymes, Bioreactors using immobilized enzymes (3).

4. Industrial enzymes and their applications

Introduction, Sales value and manufacturers, sources and engineering, environmental benefits, enzyme detection and quantification, extremophiles, enzymes in organic solvents, Industrial enzymes (proteases, carbohydrases, lipases, penicillin acylase, amino acylase and amino acid production, cyclodextrins and cyclodextrin glycosyltransferase, enzymes and animal nutrition and enzymes in molecular biology). (7)

5. Enzyme structure and engineering: Primary structure, higher-level structure, active site of enzymes, enzyme structural stability, enzyme structure prediction, protein folding, Intrinsically disordered proteins, enzyme engineering, post-translational modifications of proteins. (6)

6. Enzyme safety and regulatory considerations

Safe handling of enzymes, Possible health effects, control technology, Product regulatory considerations. (3)

Text books / References:

Enzymes: Biochemistry,Biotechnology and Clinical Chemistry by T.and P.L. Bonner: Woodhead publishing limited, 2007.

Enzymes in Industry: Production and Applications by (Ed.) WolfgangWILEY-VCH Verlag GmbH & Co. KGaA., 2004.

Introduction to Proteins Structure by Branden and Tooze, Garland Group, 1999.

Proteins: Biochemistry and Biotechnology by Gary Walsh: John Wiley & Sons, 2014.

Proteins: Biochemistry and Biotechnology by Gary Walsh: John Wiley & Sons, 2014.

Biocatalysts and Enzyme Technology, 2nd Edition,Klaus Buchholz, Kasche, Uwe Theo Bornscheuer, Wiley

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	3	1	3	1	1	1	2	1
CO2	1	1	3	1	3	1	1	2	2
CO3	2	1	2	2	1	3	3	3	1
CO4	3	1	3	2	2	3	1	1	3

Code	Title	Lectures	Credits	Hrs/ Sem
CT-534	Bioprocess Instrumentation and Control	3	3	30

Course Outcomes:

At the end of the course, students should be able to:

CO1. Understand the operations of biosensors and their applications.

CO2. Make students learn about digital process control with bioinstrumentation

CO3. Understand data interpretation and Control in biological process.

CO4. Learn fundamentals of digital process control and use of computers in controlling and optimization of microbial fermentation processes

1. Biochemical process variables and their measurements; Control principles and their application in bioreactors. On-line, in-line and off-line sensors in Bioreactor. (8)

2. Physical and chemical parameters in bioreactors, theory of electrode processes and their applications; measurement and control of pH, temperature, dissolved oxygen, aeration and agitation, redox potential, foam, etc (6)

3. Introduction to biosensors; Transduction principles used in biosensors; Characteristics of biosensors; Biosensors based on amperometric, potentiometric, thermistor FET, fiber optics and bioluminescence, Microbial biosensors. (8)

4. Fundamentals of digital process control; Use of computer in control and optimization of microbiological processes. Computer Interfaces and peripheral devices; Data logging, Data analysis, Process control. (8)

Text Books/References:

2. J. F. Van Impe, Advanced Instrumentation, Data Interpretation and Control of Biotechnological Processes, Kluwer Academic.

3. Stanbury, Whitaker and Hall, Principles of Fermentation Technology, Aditya Text Pvt. Ltd.

4. S. Aiba, A.E. Humphery and N.F. Millis., Biochemical Engineering.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	2	2	1	2	3	3	3	1
CO2	2	3	3	1	3	3	1	3	1
CO3	2	2	3	1	2	3	2	3	2
CO4	2	3	3	2	3	3	2	3	2

Code	Title	Lectures	Credits	Hrs/ Sem
BT-512	Virology	3	3	30

Course Outcomes:

At the end of the course, students should be able to:

CO1. Understand the principles of virology, virus life cycle and immune responses and its modulation during viral infection.

CO2. Understand intricacies of host immune responses and the prophylactic approaches to deal with viral infections.

CO3. Apply knowledge on mechanisms used by viruses for successful reproduction, survival and spread within the host and host-pathogen interactions to develop antiviral drugs and vaccines.

1. Introduction to virology: History, Taxonomy, Baltimore classification. (2)

2. Plant viruses: Importance of Plant viruses, cell-to-cell movement, virus-resistant transgenic plants. (3)

3. Virus structure: Viral diversity with respect to structures, symmetry of viruses, triangulation number, factors governing viral capsid assembly and genome packaging. (4)

4. Virus attachment, entry and uncoating: Virus-host interactions in cellular entry, pathways involved in virus entry, uncoating of viral particles, nuclear import. Viral transmission directly from cell to cell. (4)

5. Translation and Replication of viral genomes: Translation strategies- diversity and regulation, genome diversity and replication strategies, host factors influencing viral replication. (5)

6. Virus assembly and egress. Intracellular trafficking, assembly within nucleus and at cellular membranes, post assembly modification and virus release. (4)

7. Antiviral response and immune-evasion strategies by viruses: Stages of viral life-cycle that trigger immune response, modulation of immune responses, specific examples of viral immune evasion. (4)

8. Antiviral vaccines and drugs. History and types of vaccines- live virus vaccines, inactivated virus vaccines and virus-like particle vaccines. Overview and mechanisms of antiviral drugs, adaptive mutations and drug resistance. (4)

Text Books/References

1) Fields Virology, 6 edition, 2013,By David M. Knipe and Peter Howley

2) Plant Virology Roger Hull 5th Ed 2014

3) Principles of Virology, Fourth Edition.2015,Jane Flint, Vincent Racaniello, Glenn Rall, Anna Marie Skalka

4) Latest review articles and papers on the subject

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	3	1	3	2	3	1	1	2
CO2	1	3	2	3	3	3	3	1	1
CO3	3	2	3	2	3	3	2	2	3

Code	Title	Lectures	Credits	Hrs/ Sem
BT-506	Clinical Immunology and Immunotechnology	3	3	30

Course Outcomes:
At the end of the course, the student will be able to:

CO1. Understand the hallmarks of immune system.
CO2. Design and Analyse immunological assays.
CO3. Well versed with the advances made in the field of clinical immunology and vaccinology.

1. Fundamental Concepts and Anatomy of the Immune System.
Components of innate and acquired immunity; complement; organs and cells of the immune system: structure and function of antigens and antibodies; antigen processing and presentation; major histocompatibility complex, immunological basis of self–non-self-discrimination and immunological memory. (4)

2. Receptors and Cell Signalling.
Immunoglobulin superfamily; B-cell receptor; T-cell receptor; cytokines, chemokines and their receptors; signal transduction pathways; B and T cell activation (4)

3. Principles and Applications of Laboratory Tests in Immunology
Principles of antigen-antibody interactions;; antibody assays - precipitation, agglutination, immune-electrophoresis and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, immunofluorescence, immunoelectron microscopy, flow cytometry and ELISPOT assay; total and differential counts in human peripheral cells,; CMI techniques- lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, HLA typing. (6)

4. Techniques for Generation of Antibodies
Production of polyclonal and monoclonal antibodies, hybridoma technology, Genetic engineering techniques to make human antibodies- chimeric antibodies & humanized antibodies, therapeutic and diagnostic antibodies. (5)

5. Vaccinology
Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein- based vaccines; Peptide vaccines; conjugate vaccines. (5)

6. Clinical Immunology
Immunity to Infection: Bacteria, viral, protozoan infections (one example from each group); Hypersensitivity – Type I-IV; Types of autoimmune diseases and their treatment; Transplantation and immunosuppressive therapy; Tumor immunology –Immune response to tumors and tumor evasion of the immune system. (6)

Text Books/References

1. Kuby Immunology By Owen, Punt, Jones &Stranford, 8th, Seventh Edition, 2018, W H Freeman.
2. The Elements of Immunology by FahimHalim Khan, Pearson Education, 2009.
3. Essentials of Immunology: Ivan Riot- Blakswell Scientific Publications, Oxford, 6th Edition.
4. Infection and immunity by John Playfair and Gregory Bancroft, 3rd edition, Oxford Univ.press. 2008.
5. Monoclonal antibodies: Principles and practice by J.W. Goding. 3rd edition, Academic Press.
6. Recent Research/Review Articles.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	2	2	3	3	1	3	1	3
CO2	1	3	2	2	1	2	1	2	2
CO3	2	2	3	3	3	3	3	2	3

Code	Title	Lectures	Credits	Hrs/ Sem
CT-512	Process design for waste water treatment	3	3	30

Course Outcomes:

At the end of the course, the student will be able to:

CO1. About the availability and distribution of water

CO2. Different methods of treating water to make it potable, and Mathematical models for some of the processes.

1. Water Quality-Physical, chemical and biological parameters of water, Water Quality requirement, Potable water standards, Wastewater Effluent standards, Water quality indices. Fundamentals of Process Kinetics, Bioreactors classification–Design principles. (7)

2. Physico chemical process: Theory and design of Clarification, Sedimentation, Coagulation, flocculation, Filtration, flotation, and neutralization. (5)

3. Evaluation of kinetic Parameters- Activated Sludge biological process, New biological process- passive immobilization in packed and fluidized bed, biological nitrification, and denitrification.Attached Growth Biological Treatment Systems Trickling Filters- Rotating Biological Contactors- Activated Biofilters etc. Waste stabilization Ponds and Lagoons: Aerobic and anaerobic pond, facultative pond, and aerated Lagoons. Anaerobic filters- Expanded fluidized bed reactors-Upflow anaerobic sludge blanket reactors. Granular bed reactors- Two stage/phase anaerobic reactors. Complete waste treatment case studies for typical wastes- poultry industry waste, food industry, fermentation industry waste (alcohol, beer, and wine) cheese and dairy industry waste. (10)

4. Filters: Bag filters, drum and disc filters, Disinfecting- Chlorine treatment, Ultraviolet light treatment, Ozone treatment, advanced oxidation process, electrohemical process. (8)

Text Books /Reference:

1. Weber, W.J. Physicochemical processes for water quality control, John Wiley and sons, Newyork, 1983.
2. Peavy, H.S., Rowe, D.R., Tchobanoglous, G. Environmental Engineering, McGraw Hills, New York 1985.
3. Metcalf and Eddy, Wastewater engineering, Treatment and Reuse, Tata McGraw- Hill, New Delhi, 2003.
4. Benefield, L.D. and Randall C.W. Biological Processes Design for wastewaters, Prentice-Hall, Inc. Eaglewood Cliffs, 1982.
5. Grady Jr. C.P.L and Lin H.C. Biological wastewater treatment: Theory and Applications, Marcel Dekker, Inc New York, 1980.

6. Metcalf & Eddy, Inc. Wastewater Engineering, Treatment and Reuse. 3rd Edition, Tata McGraw-Hill, New Delhi, 2003

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	2	3	3	1	2	2	1	2
CO2	1	2	1	2	2	1	3	1	1

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Code	Title	Lectures	Credits	Hrs/ Sem
CT-510	Membrane Science & Technology	3	3	30

Course Outcomes:

At the end of the course, the student should be able to:

CO1. Understand various techniques for synthesis of polymeric membrane, mixed matrix membrane and composite membrane.

CO2. Understand basic principles and preparation techniques of adsorptive membrane. pH-responsive and thermo-responsive membrane.

CO3. Know about all kinds of characterization techniques, for both porous and non-porous membrane, and the effects of various parameters on membrane morphology.

CO4. Understand various membrane modules and their applications.

1. Basic concept of membrane separation processes: Pressure-driven membrane process, Concentration-driven membrane process, Electric-driven membrane process.
Membrane module: Plate-and-frame module, tubular module, hollow fibre module etc. Comparison of module configuration. Dead-end filtration cell and cross-flow filtration cell. (8)

2. Synthesis of polymeric membrane: Porous and non-porous membrane; Selection of polymer and solvent; Phase inversion membranes; Thermodynamic aspects; Mechanism of membrane formation; Effects of various parameters on membrane morphology. (8

3. Characterization of membrane: Permeability, Molecular weight cut-off, Porosity and pore size, Surface hydrophilicity, Surface charge, and Solute rejection etc. (7)

4. Fabrication and characterization of mixed matrix nanocomposite membrane and thin film nanocomposite membrane; Basic principles of adsorptive membrane. pH-responsive and thermo-responsive membrane. (7)

Text Books/Reference:

1. Marcel Mulder, Basic Principle of Membrane Technology, second Edition, Kluwer Academic Publishers, 1996.

2. Leos J. Zeman and Andrew L. Zydney, Microfiltration and Ultrafiltration; Principles and Applications, Marcel Dekker, 2016.

3. Munir Cheryan, Ultrafiltration and Microfiltration Handbook, CRC Press, 2016.

4. Peter M. Bungay, Harold K. Lonsdale, Maria NorbertadePinho, Synthetic Membranes: Science, Engineering and Applications, D. Reidal Publishing Company, Holland, 1986

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	2	3	3	2	1	1	3	2
CO2	1	1	1	1	1	2	3	2	2
CO3	2	1	3	2	2	2	3	2	3
CO4	1	2	2	3	2	1	3	3	2

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-520	Continuum Analysis of Biological processes	4	4	40

Course Outcomes:

At the end of the course, the student should be able to:

CO1. Describe of the concepts mass conservation and apply them to derive the continuity equation.

CO2. Apply the principles of mass flux and Fick's laws for practical problems on diffusion

CO3. Identify the types of flow and make shell momentum balance.

CO4. Describe the principles of charge conservation, Maxwell's relations and apply them to biological systems.

1. Application of mass conservation to a biological cell and macroscopic systems, equation of continuity for single component system, continuity equation in rectangular, cylindrical and spherical co-ordinate systems. (8)
2. Primary driving force for mass flux – Fick's laws – shell mass balance approach – steady state diffusion: across membranes, tubular walls, porous spherical matter – Unsteady state diffusion. Prediction of diffusivity - macromolecular solutions, dispersions. (8)
4. Newtonian & Non-Newtonian flow, Shell momentum balances, equation of motion, pulsatile flow, turbulent flow, macroscopic aspects. Prediction of viscosity - macromolecular solutions, dispersions (8)
5. Lorentz force law, charge density, Maxwell's relations, expression for charge conservation, Ions – applications in electrophoresis. (6)

Text Books/References:

1. Suraishkumar, G.K., Continuum analysis of biological systems – conserved quantities, fluxes and forces, 1/e, Anamaya publishers, New Delhi, 2014.

2. Bird, R.B., W.E. Stewart and E.N. Lightfoot, Transport Phenomena, John Wiley & Sons, Inc., 2001

3. Thomson. J, Transport Phenomena, Pearson Education Asia Ltd., 2001.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	1	2	3	1	3	1	1	1
CO2	1	3	2	1	3	2	3	2	1
CO3	2	1	3	2	2	2	3	2	3
CO4	1	2	2	3	2	1	3	3	2

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-522	Multivariate statistics and design of experiments	4	4	40

Course Outcomes:
At the end of the course, the student should be able to:

CO1. Understand statistical principles involved in optimizing multiple parameters/variables that often affect the performance of biological systems in academics/industry.
CO2. Design proper experiments in many areas of biotechnology, agriculture and industry to produce statistically stable data for better interpretation and robust conclusions.

1. Multivariate normal distribution
The multivariate normal density and its properties, Sampling from a multivariate normal distribution, Multivariate normal likelihood, Maximum likelihood estimation of m and s, Assessing the assumption of normality,Detecting outliers and cleaning data. (4)

2. Comparisons of several multivariate means
Paired comparisons, Comparing mean vectors from two populations, Comparing several multivariate population means (One way Anova), Two way multivariate analysis of variance/factorial designs. (4)

3. Multivariate linear regression
The classical linear regression model, Least squares estimation. Sum of squares decomposition, Likelihood ratio tests for regression parameters, Model checking. (4)

4. Principal component Analysis
Methodology and geometric interpretation of PCA (2)

5. Factor analysis
The orthogonal factor model, Methodology of factor analysis, Factor rotation, Comparison between PCA and factor analysis (4)

6. Canonical correlation Analysis
Canonical variates and canonical correlations, Interpretation of population canonical variables (2)

7. Clustering and ordination
Similarity measures, Hierarchical clustering: Single linkage, complete linkage and average linkage methods., Non-hierarchical methods: K-means and K-medioids, Multidimensional scaling: Euclidean scaling, Kruscal's stress function and its use, Correspondence analysis,

Algebraic development of method and its interpretation in two dimensions, Procrustes Analysis: Methodology, Orthogonal and oblique procrustes.(5)

8. Design and optimization

Modelling; differences between hard and soft modeling, Error estimation and estimation of model parameters, Factorial design, Partial factorial designs, Optimisation techniques (steepest descent etc)., Factor Analysis, Partial least squares modeling (5)

Text Books/References:

1. Applied Multivariate Statistical Analysis. By Richard A. Johnson and Dean W. Wichern, PHI
2. Design and Optimisation in Organic synthesis, by Rolf Carlson

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	1	3	1	2	2	2	2	1
CO2	3	1	2	2	2	2	1	2	3

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-524	Bioprocess Modelling and Control	4	4	40

Course Outcomes:
At the end of the course, the student should be able to:

CO1. Quantitatively analyze cell growth, product formation, stoichiometry, energetic and kinetics, as well as on the implement biotic phase models in different modes of bioreactor operations, like batch, fed-batch and continuous systems.
CO2. Understand bioprocess control theory, with emphasis on bioprocess control.
CO3. Grasp fundamentals of bioprocess engineering and process control.
CO4. Develop comprehensive models of cellular behavior in bioreactors, in order to predict their performance as well as optimize and control operations.

1. Macroscopic theory for open systems
Conserved and non-conserved quantities, Balance equations for the chemical state vector of a system, Elemental mass balancing, Balance of energy and entropy (2)

2. Stoichiometry and energetics of microbial growth and product formation
Elementary balance equations for biomass, Growth without product formation, Anaerobic growth without external e^- acceptors or with e^- acceptors other than O_2, Thermodynamic treatment of the energetic of growth, Enthalpy and free energy changes during growth, Thermodynamic efficiency, Aerobic and anaerobic growth, Energy availability in various oxidation/reduction reactions (6)

3. The Linear Equation for Substrate consumption
The concept of maintenance energy, Aerobic growth without product formation with maintenance, Anaerobic growth with maintenance, Calculation of true yields and maintenance during anaerobic and aerobic growth, Biochemically structured balances of microbial metabolism, Concept of ATP yield of growth, Aerobic growth, the p/o ratio, Biochemically structured model of aerobic growth on one substrate, Growth on mixed substrates, Growth with formation of product under anaerobic and partially aerobic conditions (6)

4. Kinetics of substrate utilization, product formation and biomass production in cell cultures
Ideal reactors for kinetics measurements (The ideal batch reactor, The ideal continuous-flow stirred-tank reactor (CSTR)); Kinetics of balanced growth (Monod growth kinetics, Kinetic implications of endogenous and maintenance metabolism, Other forms of growth kinetics, Other environmental effects on growth kinetics); Transient growth kinetics (Growth-cycle phases for batch cultivation, Unstructured batch growth models, Growth of filamentous organisms) (6)

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5. Structured kinetic models

Compartmental models, Metabolic models, Modeling cell growth as an optimum process (4)

6. Product formation Kinetics

Unstructured models (Parameter estimation for a simple batch fermentation), Chemically structured product formation kinetics models, Product formation kinetics based on molecular mechanisms: genetically structured models, Product formation kinetics by filamentous organisms, Segregated kinetic models of growth and product formation. (6)

7. Instrumentation and control

Physical and chemical sensors for the medium and gases (Sensors of the physical environment, Medium chemical sensors, Gas analysis); On-line sensors for cell properties; Off-line analytical methods (Measurements of medium properties, Analysis of cell population composition); Data analysis (Data smoothing and interpolation, State and parameter estimation); Process control (Direct regulatory control, Cascade control of metabolism); Advanced control strategies (Programmed batch bioreaction, Design and operating strategies for batch plants, Continuous process control) (5)

8. Laplace-domain Analysis of Advanced control systems

Cascade control (Series cascade, Parallel cascade); Feed-forward control (Linear feed-forward control, Nonlinear feed-forward control); Open loop-unstable processes (Simple systems, Effects of lags, Pd control, Effect of reactor scale-up on controllability); Processes with inverse response; Model-based control (Direct synthesis, Internal model control) (5)

Text Books/References:

1. New Directions in Bioprocess Modeling and Control: Maximizing Process Analytical Technology, 2006, Michael A. Boudreau , Gregory K. McMillan
2. Bioprocess Technology: Kinetics and Reactors Anton Moser

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	1	1	2	2	3	3	1	2
CO2	1	2	3	1	3	2	2	3	2
CO3	1	2	2	1	2	2	3	3	3
CO4	1	3	2	3	3	3	1	2	2

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Code	Title	Lectures	Credits	Hrs/ Sem
IBT-526	Advanced Instrumentation in Industrial Analytical Techniques	4	4	40

Course Outcomes:
At the end of the course, the student should be able to:

CO1. Learn the principle and theory of analytical techniques.
CO2. Have fundamental understanding of the chemistry-based instrumentation.
CO3. Know the methodology of selection of analytical techniques.
CO4. Understand the basic operation of various instruments like Spectrophotometer, AAS, GC and HPLC

1. Photometry: Introduction to Chemical Instrumentation analysis, Advantages over classical methods, Classification; Spectro, Electro analytical and Seperative methods, Solution preparation: Concept of Normality , Molarity , Molality and percentage , Laws governing Photometry : Beer's and Lambert's Law; Limitations of Lambert's Beer's law ; Origin of absorption spectra; Colorimeters: Standard series and balancing method of determination Spectrophotometers(UV-Visible), Monochromators, filters, grating, prisms, Single wavelength and single beam monochromatic systems , Dual wavelength and double beam monochromatic system. (10)
2. Flame and Atomic Absorption Spectrophotometer: Flame photometry; Principle, Elementary Theory, Construction details, fuel gases, atomiser, burner, optical system, recording system. Atomic absorption spectrophotometer; Theoretical concepts, Instrumentation, Hollow cathode lamps, Burners and flames, optical and electronic systems; Non-Flame Techniques; Background correction methods in AAS; Spectral and Chemical interference in AAS (10)
3. Fundamentals of Chromatography: General description, definition, terms and parameter used in chromatography; Linear and Column chromatography; Theories of elution Chromatography; Measures of column efficiency; Column resolution; Classification of chromatographic methods, criteria for selection of stationary and mobile phase nature of adsorbents, Rate theory, Methodology for selection of stationary phase, Quantitative and qualitative analysis by Chromatography (10)
4. HPLC AND GC: High pressure liquid chromatography; Apparatus, Pumps, Column packing, Characteristics of liquid chromatography, detector; UV, IR, Refractometer and fluorescence detector. Gas Chromatography; Principle, Comparison of GSC and GLC, Columns packed and tubular; Study of detectors; Thermal conductivity, Flame ionisation, Electron capture; Factors affecting the separation and various separating applications; Statistical evaluation of measurement data and uncertainty estimation. (10)

Text Books/ References:

1. DA. Skoog,(2000), Principles of Instrumental analysis, fifth edition , Saunders college publication
2. D.H.Williams and J.Fleming (1995). Spectroscopic methods in organic chemistry, Sixth edition, McGrawHill
3. B.K. Sharma (2007), Instrumental methods of chemical analysis, Krishna Prakash Media
4. J.Willard. (1999). Instrumental methods of analysis,7th Edition , CBS publishers
5. Arun Bahl and B. S. Bahl (2016) , Advanced Organic Chemistry, S. Chand
6. J. Mendham (2009) ,Vogel's Quantitative Chemical Analysis, A.I. Vogel, Prentice Hall, 6th Edition

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	2	1	2	1	2	3	3	2
CO2	1	2	3	1	1	2	1	1	1
CO3	3	3	3	3	1	3	2	1	1
CO4	1	1	3	3	3	2	3	2	1

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Code	Title	Hours/week	Credits	
IBT-552	Recombinant DNA Technology Laboratory	4	2	

List of Practicals

1. To isolate plasmid from *E. coli* cells, and quantification by spectrophotometry.
2. To electrophorese plasmid DNA on an agarose gel.
3. To digest the plasmid DNA with restriction enzyme(s) and run the digest on an agarose gel.
4. To ligate a gene of interest with the digested plasmid DNA.
5. To prepare *E. coli* competent cells.
6. To transform the ligation mixture into competent *E. coli* cells.
7. To select for recombinant clones by blue-white selection, followed by screening using restriction digestion.
8. To set up a PCR reaction.
9. To isolate genomic DNA from bacterial/yeast cells.
10. To isolate RNA from yeast cells, and quantification by spectrophotometry.

Code	Title	Hours/week	Credits	
IBT-554	Downstream Process Lab	4	2	

List of Practicals

A. Downstream Process (Experiments)

1. Conventional filtration
2. Centrifugation in batch and continuous centrifuge
3. Cell disruption
4. Protein precipitation and its recovery
5. Ion-exchange chromatography
6. Membrane based filtration-ultra filtration in cross flow modules and micro filtration
7. Adsorption process in batch and continuous mode.

B. In process and final quality control (Analytical)

1. Estimation of impurities (endotoxins)
2. Estimation of proteins & carbohydrates (high throughput plate methods)
3. Estimation of residuals such Proteins and DNA

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-601	Bioproduct development and Bio entrepreneurship	3	3	30

Course Outcomes:

At the end of the course, the student should be able to:

CO1. Develop a perspective on the importance of interdisciplinary influences in the success of biotechnology products and services in the market and build on them further or apply them in a business environment.

CO2. Have a holistic picture of a business environment with reference to biotechnology products and services.

1. Understanding Biotechnology Entrepreneurship, The biotechnology Industry, essential elements for growing biotechnology clusters, Biotechnology product sectors, Technology Opportunities, evaluating ideas, Commercialization of Bio-agricultural Products, Biotechnology Business Models, Risk Management. (8)

2. Company Formation, Ownership Structure, and Securities Issues, Licensing the Technology: Biotechnology Commercialization Strategies Using University and Government Labs, Intellectual Property Protection Strategies for Biotechnology Innovations. (6)

3. Biotechnology Products and their Customers, Developing a Successful Market Strategy, Biotechnology Product Coverage, Coding, and Reimbursement Strategies, Public Relations Strategies to Support Biotechnology Business Goals. (6)

4. Biotechnology Product Development, Therapeutic drug development & clinical trials, Development & commercialization of in vitro diagnostics, Regulatory Approval and Compliances for Biotechnology Products, Biomanufacturing of Biotechnology Products, (6)

5. Company Growth Stages and the Value of Corporate Culture, Ethical Considerations for Biotechnology Entrepreneurs. (4)

Text books / Reference books:

1. Mauborgne, René, Blue Ocean Strategy (Expanded Edition), Boston: Harvard Business School Press; 2015. ISBN: 978-1-59139-619-2,
2. Schrage, Michael, The Innovator's Hypothesis, Boston: MIT Press; 2014. ISBN: 978-0-262-02836
3. Westerman et al., Leading Digital, Boston: Harvard Business School Press; 2014. ISBN : 9781625272478.
4. Web-resources and Suggested reviews/ research papers.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	3	3	2	1	1	3	3	1
CO2	3	3	2	3	3	1	3	1	1

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-603	Applied Animal Tissue Culture	3	3	30

Course Outcomes:

At the end of the course, the student should be able to:

CO1. Understand the basic concepts of animal tissue culture and cell growth properties, describe advantages and limitations of animal tissue culture technique

CO2. Use the knowledge of different animal tissue culture techniques to design strategies and design and interpret various cell-based assays

CO3. Apply the concepts of animal biotechnology to analyze and solve problems in basic and applied biotechnology/life sciences research. Understand, examine and discuss the ethical, legal and social issues related to Animal Biotechnology.

1. Biology of cultured cells, growth characteristics, cell adhesion, proliferation, differentiation, Energy metabolism, contact inhibition, anchorage dependence; cell-cell communication. (6)
2. Equipments and Materials for animal cell culture, Introduction to balanced salt solutions, media components and its preparation, Defined and serum free media and their advantages and disadvantages. (6)
3. Types of cell culture (primary and secondary culture) development and routine maintenance of cell lines, authentication and validation, Cloning and selection, cell synchronization and cell manipulation, cell sorting, measurement of cell viability and cytotoxicity. Propagation of stem cells, culture of tumor cells, Introduction to cell culture reactors and scale-up (in suspension and in monolayer) and automation. (6)
4. Tools, techniques and applications; Multicellular spheroids (3D tissue culture model for cancer research), Introduction to concepts of tissue engineering, Transgenic animals and their applications, In Vitro Fertilization and Embryo Transfer, Gene therapy. (6)
5. Application of animal cell culture technology in drug testing, cancer research, vaccine, production production of monoclonal antibodies, recombinant therapeutic proteins and other biotechnological products of industrial and medical benefits. Ethical issues in animal biotechnology. (6)

Text Books/References:

1. Animal Cell Culture: A Practical Approach by R. Ian Freshney, Eigth edition, 2021, Wily-Blackwell Publication
2. Animal Cell Culture by John R.W. Masters, Third Edition, 2000 Oxford University Press
3. S. B. Primrose, Molecular Biotechnology (Second Edition). 1991. Blackwell Scientific Publications Ltd.
4. Recent Research/Review Articles.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	2	3	3	1	3	1	3	3
CO2	1	3	3	1	1	2	2	3	1
CO3	2	2	3	1	1	2	1	3	3

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Code	Title	Lectures	Credits	Hrs/ Sem
CT-603	Membrane Technology for Water and Waste water Treatment	3	3	30

Course Outcomes:
At the end of the course, the student should be able to:

CO1. Understand the various membrane processes, principles, separation mechanisms, selection criteria and their industrial applications.
CO2. Understand the various transport models, different types membrane fouling and their control, and the effects of process parameters on system performance.
CO3. Understand the basic principles and applications of micellar enhanced ultrafiltration.
CO4. Understand the application of membrane to various industrial effluents such textile, paper and pulp, and electroplating.

1. Membrane processes: Microfiltration, Ultrafiltration, Nanofiltration and Reverse osmosis; Membrane configuration; Criterion of selection of suitable membrane; Membrane fouling, Factors affecting membrane fouling; Flux enhancement techniques; Membrane cleaning and compaction; Concept of integrated membrane process; Process design and energy requirement. (8)
2. Solute and solvent transport modeling: Pore blocking model, Concentration polarization model, Resistance-in-series model, Gel layer model, Osmotic pressure model, Combined fouling model etc., Estimation of various fouling resistances. (7)
3. Micellar enhanced ultrafiltration (MEUF): Basic principles, Micellization and critical micelle concentration, Evaluation of MEUF process. Effects of various parameters on permeate flux and rejection. (7)
4. Applications: Water treatment, Treatment of textile effluent, pulp and paper effluent, electroplating effluent etc. (8)

Text Books/Reference:

6. Leos J. Zeman and Andrew L. Zydney, Microfiltration and Ultrafiltration; Principles and Applications, Marcel Dekker, 2016.
7. Munir Cheryan, Ultrafiltration and Microfiltration Handbook, CRC Press, 2016.
8. Marcel Mulder, Basic Principle of Membrane Technology, second Edition, Kluwer Academic Publishers, 1996.
9. R. Rautenbach and R. Albrecht, Membrane Processes, John Wiley & Sons Ltd. 1994.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	1	2	3	3	2	1	2	3
CO2	3	3	3	3	2	1	1	1	2
CO3	3	2	2	3	2	2	1	2	2
CO4	2	2	2	2	2	2	2	1	3

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-607	Plant Metabolomics	3	3	30

Course Outcomes:
At the end of the course, the student should be able to:

CO1. Understand fundamental concepts in the field of plant secondary metabolites and bioactive compounds.
CO2. Demonstrate knowledge on the biogenesis and chemical structure of the secondary metabolites.
CO3. Understand the potential of biotechnology in the commercial exploitation of these compounds.
CO4. Develop critical and analytical attitude on the use of plant bioactive compounds for medicinal purposes.

1. Plant secondary metabolites: Introduction, types of secondary metabolites, Biochemistry of secondary metabolites- terpenoids, phenolic compounds, alkaloids and sulphur-containing compounds. (5)
2. Plant secondary metabolite biosynthesis: Alkaloids, betalains, cyanogenic glycosides, glucosinolates and non-protein amino acids, phenylpropanoids, terpenoids, sterols, cardiac glycosides, brassinosteroids, phytoecdysteroids and steroid saponins. (5)
3. Analytical tools to study secondary metabolites: Gas chromatography-mass spectrometry (GC-MS), liquid chromatography mass-spectroscopy (LC-MS), capillary electrophoresis-mass spectrometry (CE-MS), fourier transform ion cyclotron resonance-mass spectrometry (FTICR-MS), matrix-assisted laser desorption/ionization (MALDI), ion mobility spectrometry (IMS) and nuclear magnetic resonance (NMR). (7)
4. Techniques for plant secondary metabolites production: Plant tissue culture, Obtaining of Fast-Growing and High-Productive Cell Lines, Strategies to Increase Secondary Metabolite Production, Release and Product Recovery – Exudation, Two-Stage Systems and Permeabilisation method. (5)
5. Commercial production of secondary metabolites: Production of the Artemisinin in Artemisia, Production of Shikonin from *Lithospermum erythrorhizon* culture, Production of Caffeine in Coffee Cell Cultures. (3)
6. Industrial applications of plant secondary metabolites: Alkaloids, Phenylpropanoids and Flavonoids, Steroids, Cardiac Glycosides & Triterpenoids, Iridoids, other terpenoids & Naphthaquinones. (5)

Text Books/ References:

1. Michael Wink. Biochemistry of Plant Secondary Metabolism (2010). 2nd Edition. John Wiley & Sons.
2. Arthur Germano Fett-Neto. Biotechnology of Plant Secondary Metabolism (2016) Springer

3. Harinder P. S. Makkar, P. Siddhuraju, Klaus Becker. Plant Secondary Metabolites (2007) Springer

4. S.Mohan Jain. Protocols for In Vitro Cultures and Secondary Metabolite Analysis of Aromatic and Medicinal Plants (2016) Second Edition, Springer

5. Joseph B. Lambert, Eugene P. Mazzola, Clark D. Ridge. Nuclear Magnetic Resonance Spectroscopy (2019) First Edition, Wiley

6. Imma Ferrer, E. M. Thurman. Advanced Techniques in Gas Chromatography–Mass Spectrometry (GC–MS–MS and GC–TOF–MS) for Environmental Chemistry (2014) Elsevier Science

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1	2	1	3	2	1	2	1	3
CO2	3	2	1	2	3	1	3	2	3
CO3	1	3	2	2	2	1	2	1	2
CO4	2	2	1	2	2	2	1	2	1

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-609	Advanced Biochemistry	4	4	40

Course Outcomes:
At the end of the course, the student should be able to:

CO1. Gain fundamental knowledge in biochemistry;
CO2. Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.

1. Protein structure

Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation. (7)

2. Enzyme Kinetics

Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens. (6)

3. Glycobiology

Sugars-mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules-glycoproteins and glycolipids; lipids- structure and properties of important members of storage and membrane lipids; lipoproteins. (3)

4. Structure and functions of DNA, RNA and Lipids

Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material. (4)

5. Bioenergetics

Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources of glucose; Citric acid cycle, entry to citric acid cycle, citric acid cycle as a source of biosynthetic precursors; Oxidative phosphorylation; importance of electron transfer in oxidative phosphorylation; F1-F0 ATP Synthase; shuttles across mitochondria; regulation of oxidative phosphorylation; Photosynthesis – chloroplasts and two photosystems; proton gradient across thylakoid membrane. (8)

6. Role of vitamins & cofactors in metabolism

Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabo¬lism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/ exit of various biomole¬cules from central pathways; principles of metabolic regulation; steps for regulation; TOR (target of rapamycin) & autophagy regulation in relation to C & N metabolism, starva¬tion responses and insulin signaling. (12)

Text Books/ References:

1. Stryer, L. (2015). Biochemistry. (8th ed.) New York: Freeman.
2. Lehninger, A. L. (2012). Principles of Biochemistry (6th ed.). New York, NY: Worth.
3. Voet, D., &Voet, J. G. (2016). Biochemistry (5th ed.). Hoboken, NJ: J. Wiley & Sons.
4. Dobson, C. M. (2003). Protein Folding and Misfolding. Nature, 426(6968), 884-890. doi:10.1038/nature02261.
5. Richards, F. M. (1991). The Protein Folding Problem. Scientific American, 264(1), 54-63. doi:10.1038/scientificamerican0191-54.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	2	1	2	2	1	3	3	2
CO2	2	1	2	3	2	2	3	3	3

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-611	Clinical trials and Bioethics	4	4	40

Course Outcomes:

At the end of the course, the student should be able to:

CO1. Understand fundamental concepts in design of clinical trials;
CO2. Describe study designs commonly used and pre-study requirements;
CO3. Describe roles of Regulatory Affairs in clinical trials;
CO4. Identify key issues in data management for clinical trials;
CO5. Utilize a systematic framework for evaluating the ethics of a clinical research protocol;
CO6. Apply appropriate codes, regulations, and other documents governing the ethical conduct of human subject research to their own research.

1. Fundamentals of clinical trials

Fundamentals of clinical trials; Clinical trials in practice; Reporting and reviewing clinical trials; Legislation and good clinical practice - overview of European directives and legislation governing clinical trials in 21st century; International perspectives; Principles of International Committee on Harmonisation (ICH)-GCP; CDSCO Guidance. (6)

2. Reporting and reviewing clinical trials

Drug development and trial planning - pre-study requirements for clinical trials; Regulatory approvals for clinical trials; Regulatory submissions; Consort statement; Trial responsibilities and protocols - roles and responsibilities of investigators, sponsors and others; Requirements of clinical trial protocols; Legislative requirements for investigational medicinal products. Consent- principles of informed consent; Consent processes; Medical Writing, Clinical Study Report; Investigational New Drug Application (INDs); Biologics License Application (BLA); Common Technical Document (CTD) for application dossiers. (12)

3. Project management and ethics

Project management in clinical trials - principles of project management; Application in clinical trial management; Risk assessment; Research ethics and Bioethics - Principles of research ethics; Ethical issues in clinical trials; Use of humans in scientific experiments; Ethical committee system including a historical overview; informed consent; Introduction to ethical codes and conduct; Introduction to animal ethics; Animal rights and use of animals in the advancement of medical technology; Introduction to laws and regulation regarding use of animals in research. (10)

4. Data management

Data protection; Legislation and its application; Data management – Introduction to trial master files and essential documents; Data management, Data listing; C-DISC (Clinical Data Management), medDRA, Statistical evaluation - Basic statistics for clinical trials. (6)

5. Reporting and reviewing clinical trials

Quality assurance and governance - quality control in clinical trials; Monitoring and audit; Inspections; Pharmacovigilance; Research governance; Trial closure and pitfalls-trial closure; Reporting and legal requirements; Common pitfalls in clinical trial management; Adverse event & serious adverse event reporting; Drug Recall. (6)

Text Books/ References:

1. Fundamentals of Clinical Trials. (Authors: Friedman, Lawrence M., Furberg, Curt D., DeMets, David; LA; Latest Edition; Publisher: Springer).

2. The Oxford Textbook of Clinical Research Ethics (Authors: Ezekiel J. Emanuel, Christine C. Grady, Robert A. Crouch et. al.; Latest Edition; Publisher: Oxford Univ. Press)

3. ICH guidelines for Good Clinical Practice (https://www.ich.org/fileadmin/Public_Web_Site/ICH_Products/Guidelines/Efficacy/E6/E6_R1_Guideline.pdf)

4. ICH: Structure and Content of Clinical Study Reports (E3)

5. "Guidance for Industry, ICH M4: Organization of the CTD" U.S. Department of Health and Human Services Food and Drug Administration Center for Drug Evaluation and Research (CDER) Center for Biologics Evaluation and Research (CBER) August 2001

6. CDSCO – Guidance for Industry.

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	1	1	3	3	1	3	1	2
CO2	3	1	3	1	3	2	2	1	2
CO3	3	3	1	3	3	1	1	1	3
CO4	2	1	1	3	2	1	1	1	3
CO5	3	3	3	1	2	1	3	1	3
CO6	2	3	2	2	3	2	2	3	3

Code	Title	Lectures	Credits	Hrs/ Sem
IBT-613	Nanobiotechnology	4	4	40

Course Outcomes:

At the end of the course, the student should be able to:

CO1. Have a general and broad understanding of the multi-disciplinary field of nanotechnology.

CO2. Understand of top-down approach of microelectronics and micromechanics with bottom-up approach of chemistry/biochemistry;

CO3. Grasp a development that is creating new and exciting cross-disciplinary research fields and technologies.

CO4. Develop a insight into complete systems where nanotechnology can be used to improve everyday life.

1. Introduction to nanobiotechnology

Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials. (7)

2. Nanofilms

Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation. (5)

3. Nanoparticles

Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers. (7)

4. Applications of nanoparticles

Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development. (7)

5. Nanomaterials

Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in sythesis, applications of nanobiocatalysis in the production of drugs and drug intermediates. (7)

6. Nanotoxicity

Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life cycle assessment, containment. (7)

Text Books/ References:

1. GeroDecher, Joseph B. Schlenoff, (2003); *Multilayer Thin Films: Sequential Assembly of Nanocomposite Materials*, Wiley-VCH Verlag GmbH & Co. KGaA
2. David S. Goodsell, (2004); *Bionanotechnology: Lessons from Nature*, Wiley-Liss
3. Neelina H. Malsch, *Biomedical Nanotechnology,* CRC Press
4. Greg T. Hermanson, (2013); *Bioconjugate Techniques*, (3rd Edition); Elsevier
5. Recent review papers in the area of Nanomedicine

Course Outcome (CO) to Programme outcomes (PO) Mapping (Scale 1: Low; 2: Medium; 3: High)									
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	2	2	3	3	1	1	1	1	3
CO2	3	2	3	1	1	3	1	2	3
CO3	1	1	1	2	1	2	2	2	2
CO4	3	2	2	1	3	1	2	3	2

Code	Title	Hours/week	Credits	
IBT-651	Animal Tissue Culture	4	2	

List of Practicals

Practical No.1: To learn about Animal Tissue Culture lab design, layout and equipments.

Practical No. 2: To learn about various aseptic techniques used while working in an animal tissue culture laboratory

Practical No. 3: To carryout heat inactivation of serum followed by Media preparation and filtration

Practical No.4:

b. To learn about routine maintenance of adherent cells growing as monolayer
c. To learn routine subculture of cellscby trypsinisation

Practical No.5: To perform Cell Counting using Hemocytometer

a. To trypsinize the monolayer of cells growing in a 25cm^2 flask
b. To count the number of cells per ml using Hemocytometer
c. To calculate the percentage viability of cells using dye exclusion method
d. To learn counting cells with CASY electronic cell counter

Practical No. 6: To learn the technique of cryopreservation of adherent mammalian cells.

Practical No. 7: To learn how to revive frozen (cryopreserved) mammalian cells.

Practical No.8: To assess cytotoxicity of the drug Cisplatin in cancer cell line using MTT assay/3D Spheroid culture

Practical No. 9: To learn the technique of Immunocytochemistry/flowcytometery

Practical No. 10:To perform colony formation.