Indian Institute of Technology Kanpur

COURSES OF STUDY

2026





Indian Institute of Technology Kanpur
KANPUR-208016

BIOLOGICAL SCIENCE AND ENGINEERING

Template for BT Program in Biological Sciences and Bioengineering

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-1 (9) ELC111/ELC112/ ELC113	ETH111 (3)	SCHEME-2 EME (9-11)	SCHEME-3 HSS-I (11)	SCHEME* HSS-II (9)	SCHEME* HSS-II (9)	SCHEME* HSS-II (9)	SCHEME* HSS-II (9)
MTH 111 (6)	MTH 113 (6)	ESO206 (9)	ESC201 (14)	BSE311 (9)	BSE321 (8)	DE-4	DE-6
MTH 112 (6)	MTH 114 (6)	E/SO (9-11)	BSE222 (9)	BSE312 (9)	BSE421 (9)	DE-5	DE-7
PHY 115 (11)	PHY 112 (11)	BSE211 (9)	BSE223 (9)	BSE411 (9)	OE-2(9)	OE-3	OE-5
PHY 111 (3)	CHM 111 (3)	BSE221 (9)	BSE322 (9)	BSE412 (9)	DE-2 (9)	OE-4	OE-6
TA 111 (9)	ESC 111 (7)	OE-1 (9)		DE-1 (9)	DE-3 (9)		
CHM 112 (4)	ESC 112 (7)						
CHM 113 (4)	LIF111 (6)						
PE111 (3)	PE112 (3)						
55	52	54-58	50-52	45-54	44-53	36-45	36-45

UGPs: BSE496 and BSE498 will be offered in ODD semesters and BSE497 and BSE499 will be offered in EVEN semesters. UGPs will be considered as DEs. All UGPs have 9 credits and letter grades. A student can take at most 1 UGP per semester (in any order).

Credit Table for BT Program in Biological Sciences and Bioengineering		
Course type	Recommended Credit range	Credit in the department template
Institute Core (IC)	112	112
E/SO	18-45	18-20
Department requirements	144-179	161 (98 DC + 63 DE)
Open electives (OE)	51-57	54
SCHEME	54-58	54-58
Total for 4-year BT/BS	391-420	399-405

Template for BTH program in Biological Sciences and Bioengineering

Two department UGP-1 and UGP-2 (9 credits each) should be completed in place of two DEs of the BT program. Additional three DEs (27 credits) should be taken from the following Honors course basket.

— Honors course basket (list of courses):

- BSE611A (09): Modern instrumental methods in biological sciences
- BSE642A (09): Microbiology and Immunology
- BSE652A (09): Developmental Biology
- BSE653A (09): Functional Genomics
- BSE654A (09): Human Molecular Genetics
- BSE655A (09): Physiology
- BSE661A (09): Biological Membranes

— **CPI criteria for BTH: 8.5**

Template for the BTM program in Biological Sciences and Bioengineering

Students have to take 54 credits of course from the Management Track Basket (MTB)

Template for 3rd to 8th semester for BTM program in Biological Sciences and Bioengineering					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 EME (9-11)/ HSS-I (11)	SCHEME-3 HSS-I (11)/ EME (9-11)	SCHEME* HSS-II (9)	SCHEME* HSS-II (9)	SCHEME* HSS-II (9)	SCHEME* HSS-II (9)
ESO206 (9)	ESC201 (14)	BSE311 (9)	BSE321 (8)	DE-3	DE-4
E/SO (9-11)	BSE222 (9)	BSE312 (9)	BSE421 (9)	OE-3	MTB-4
BSE211 (9)	BSE223 (9)	BSE411 (9)	OE-2 (9)	MTB-2	MTB-5
BSE221 (9)	BSE322 (9)	BSE412 (9)	DE-2 (9)	MTB-3	MTB-6
OE-1 (9)		DE-1 (9)	MTB-1		
54-58	50-52	45-54	44-53	36-45	36-45

* Students have to take only three SCHME (HSS-II) courses in semesters 5 to 8

Template for five year dual-degree program in Biological Sciences and Bioengineering

Template for 7th to 10th semester of dual-degree program in BSBE (Category-A)			
7th sem	8th sem	9th sem	10th sem
DE PG-1 (9)	DE PG-3 (9)	BSE702A (0)	Thesis credits (36)
DE PG-2 (9)	DE PG-4 (9)	Thesis credits (36)	
BSE601A (0)	BSE602A (0)		
	BSE701A (0)		
18	18	36	36

Minimum Credit Requirements in MT part for graduation:
PG Components: 36 credits Thesis: 72
credits

Remarks:

1) All DE courses should be taken with the consent of the Supervisor
2) Up to 36 OE credits may be waived from the BT program for students opting for the dual- degree program.

Category B dual-degree (UG from different department)

Template for 7th to 10th semester of dual-degree program in BSBE (Category-B)					
UG component		PG component			
Odd	Even	7th sem	8th sem	9th sem	10th sem
ESO206 (9)	UGP in BSBE (9)	BSE613A (9)	DE PG-3 (9)	BSE702A (0)	Thesis credits (36)
BSE221 (9)		DE PG-1 (9)	DE PG-4 (9)	Thesis credits (36)	
BSE311 (9)		DE PG-2 (9)	BSE602A (0)		
		BSE601A (0)	BSE701A (0)		
27	9	27	18	36	36

Minimum Credit Requirements in MT part for graduation:
PG Components: 45 credits
Thesis: 72 credits

Remarks:

1) All DE courses should be taken with the consent of the Supervisor
2) Upto 36 OE credits may be waived from the BT program for students opting for the dual- degree program.

Template for the double major: second major in Biological Sciences and Bioengineering

BSBE Double Major Template	
Odd Semester	Even Semester
Pre-requisites	
ESO206 (9)	
Mandatory BSBE Core Courses	
BSE211 (9)	BSE222 (9)
BSE221 (9)	BSE223 (9)
BSE311 (9)	BSE322 (9)
BSE312 (9)	BSE321 (8)
BSE411 (9)	BSE421 (9)
BSE412 (9)	
DC credits: 54	DC Credits: 45

Minors in Biological Sciences and Bioengineering

1. Tissue Engineering: (this Minor already exists)

– Three compulsory courses: BSE211 [09], BSE411 [09], BSE421 [09] *(the courses are the same as before but their credits are changing in the new UGARC)*

2. Engineering in Medicine:

(This is a new Minor offered in the new UGARC)
Requirement: Any 3 from the following basket of courses:

- BSE616A [09]: Biopharmaceuticals
- BSE644A [09]: Optical microscopy & bioimaging
- BSE656A [09]: Neurobiology
- BSE662A [09]: Decision making and the brain
- BSEXXXA [09]: Biodesign (to be floated)
- BSEYYYA [09]: Biosensors and Biomedical Devices (to be floated)

DEPARTMENT OF BSBE

Courses ID	Course Title	Credits L-T-P-D-[C]	Content
BSE211A	ORGAN SYSTEM, PHYSIOLOGY AND ANATOMY	3-0-0-0-9	Animal Tissues & Organ Systems: Concept of self assembly, energy and evolution, Basic structure of the cell, Organization of the cells to from different tissue systems, Assembly of different tissue system to form organ system, Crosstalk of different organ system to form adynamic living system Nervous System: Organizational assembly of the nervous network in the body and its cross talk with different organ system Sensory System: Basic anatomy of the different sensory system of the body, Signal reception from the outside environment by these different sensory modalities and relaying the information to the nervous system Endocrine System: Outline of the different endocrine system in the body and their functioning, Cross talk between endocrine and nervous system in carrying out physiological functions Circulatory System and Blood: Network of the blood vessel in the body and their fine structuralmodifications, Composition of the circulating fluid: Blood, Different between blood and plasma,Structure of the pumping station: the heart, Functioning of the heart, ECG recordings, Control system of the heart Immune System and Lymphatic System: Basic concept of immunity, Classification of immune system, Basic functioning of different components of immune system, Basic concept of lymphatic system, Crosstalk between immune system nervous system and endocrine system Muscoskeletal System: Anatomy of the muscoskeletal system, Tissue organization of thebone, cartilage and muscle, Role of the muscoskeletal system in movement Respiratory System: Structure of the lungs, Process of gas exchange (C02 and 02) in thelunQs to provide oxygen rich blood to the body Digestive System: Anatomy of the digestive system, Functioning of the individual orga Biology Eight Edition, N. A. Campbell & J. B. Reece (2008)
BSE221	BIOCHEMISTRY	3-0-0-0-9	Enzymes: Concepts, kinetics, catalytic strategies and regulation: Free energy as a thermodynamic function, formation of transition states, The Michaelis Menten model, enzyme inhibitors, coenzymes, proteases, oxygen transport, hemoglobin, allostery, isozymes. Glycolysis and Gluconeogenesis: Energy conversion pathways in organisms, control of glycolytic pathway, synthesis of glucose from noncarbohydrate precursors, reciprocal regulation of gluconeogenesis and glycolysis. The citric acid Cycle: Pathway, control, source of biosynthetic precursors, glyoxylate cycle. Oxidative phosphorylation and electron transport chain: Mitochondrial membrane, electron transfer, proton pumps and physical link to citric acid cycle, regulation of cellular machinery, Glycogen metabolism: Interplay of enzymes, epinephrine and glucagon signaling, reciprocal regulation of glycogen breakdown and synthesis. Fatty acid Metabolism: Triacylglycerols as energy stores, stages of processing, pathways of synthesis and degradation, acetyl Coenzyme A. Protein Folding and turnover: Stability, pathways of folding, chaperones, proteasomes, amino acid degradation, urea formation.

			Course Reference: 1. Biochemistry by Jermy M Berg, John L Tymoczko and Luber! Stryer, Publisher: W. H. Freeman; Seventh Edition (December 24, 201 0); 2. Principles of Biochemistry by Albert Lehninger, David L Nelson, Michael M Cox, Publisher: W. H.Freeman; Fifth Edition (June 15, 2008).
BSE222A	BIOCHEMICAL ENGINEERING		energetics of microbial metabolism; transport phenomena; enzyme catalyzed reactions andprocesses; bioreactor design and applications; sterilization; instrumentation and control. Bioseparations and Bioprocesses: Downstream processing; matrix design; pretreatment methods; separation of cell biomass; adsorption; filtration, precipitations; affinity precipitations; column chromatography; plate theory and principles of chromatography; different types of chromatography, polishing crystallization, drying, separation case studies; process integration; bioprocess integration for efficient production and recovery, scaleup consideration, process monitoring and process economics. Environmental Bioprocesses: Interaction of mixed microbial population; aerobic and anaerobic processes; applications; biological wastewater treatment, bioremediation. Enzyme Technology: Enzyme catalyzed reactions. Cell and Enzyme immobilization. Industrialapplications and case studies. **Course Reference**: 1. Blanch, H. W. and Clark, D. S; Biochemical Engineering. Marcel Dekker, Inc; 2. Bailey, J. E. and Ollis, D. F, Biochemical Engieering Fundamentals; McGrawHill, Inc.; 3. Belter, P. A., Cussler, E. L. and Hu, W. S. Bioseparations: Downstream Processing for Biotechnology; John Wiley & Sons; 4. Desai, Mohamed. A. Downstream Processing of Proteins: Methods and Protocols. Humana Press; 5. Shuler, M. L. and Kargi, F. Bioprocess Engineering Basic Concepts; 6. Amersham Biosciences literature notes on chromatography
BSE223A	BIOCHEMISTRY & BIOCHEMICAL ENGINEERING LAB	1-0-6-0-9	Fundamentals of Biochemistry: This section will deal with the experiments which can be used to determine the biomolecules both quantitatively and qualitatively. Experiment related to Spectrophotometry Beer Lambert Law. Experiment describing the preparation ofstandard plot for model protein such as bovine serum albumin (BSA). Quantifying theunknown protein using spectrophotometric measurements by UV adsorption, Lowrymethod, dye binding method, Bicinchoninic acid (BCA) method. Analysis of the presenceof glucose and quantifying the concentration using Dinitrosalicylic acid (DNSA) method. Enzyme activity, Enzyme kinetics, Starch conversion to glucose by salivary amylase. Paranitrophenyl. Dglucopyranoside (pNPG) assay for glucosidase. Analysis ofproteins by SDSPAGE. Biochemical Engineering Bioseparations and Bioprocesses: Experiments related to upstream processing and downstream processing. Fermentation and microbial mass culture. Downstream processing; harvesting of cell mass and extraction of protein/enzyme (adsorption, filtration}, cell sonication, precipitation, column chromatography, column regeneration, affinity column preparation, purification, protein and enzyme activity measurements, SDSPAGE analysis, data compiling. Ethanol Fermentation. Bioreactor operation (25 lts), tangential/cross flow filtration for cell harvesting, computer simulation, mass transfer phenomenon and cell growth kinetics.

			Course Reference: 1. Introductory Practical Biochemistry by S. K. Sawhney and Randhir Singh, Publisher: Alpha ScienceInternational, Ltd (August 1, 2005); 2. Protein Purification Applications Practical Approach by Simon Roe Oxford University Press; 3. Bioprocess EngineeringBasic concepts by Michael L. Shuler and Fikret Kargi; 4. Practical notes issued in the lab
BSE301A	SCIENTIFIC & PROFESSIONAL COMMUNICATIO N	0-0-2-0-2	Essential elements of written communication: discussion of a topic, identification of the key elements, clarity of the rationale in a scientific and technical work, elaboration of technical details, key elements and highlights of a finding/project, identification of what answers have been obtained, what remains to be answered. How to underscore the significance of a project/finding, and its larger meaning, conclusions Essential elements of verbal communication: what communication skills interests audience, how to navigate through complex set of information, the art of displaying the key messages, overcoming language barriers, translation of scientific message for the lay audience, making new ideas understandable, how to engage with the audience.
BSE311A	MOLECULAR CELL BIOLOGY	3-0-0-0-9	Molecular Genetic Techniques and Genomics: Genetic analyses of mutations to identify and study genes; DNA cloning and characterization; Genome wide analyses of gene structure and gene expression; Inactivating the function of specific genes in eukaryotes; Identifying and locating human disease genes Molecular Structure of Genes and Chromosomes: Chromosomal organization genes and non coding DNA; Mobile DNA; Structural organization of eukaryotic chromosomes; organelle DNAs Transcriptional Control of Gene Expression: Eukaryotic gene control and RNA polymerase; regulatory sequences in protein coding genes; activators and repressors of transcription; mechanism of transcription activation and repression. Post transcriptional Gene Control: Processing of eukaryotic prem RNA; transport across nuclear envelope; cytoplasmic mechanism of posttranscriptional control; processing of RNA and RNA, regulation of protein synthesis. Cell signalling: Signalling molecules and cell surface receptors; intracellular signal transduction; G protein coupled receptors. Membrane trafficking: Translocation of secretory proteins across the ER membrane; protein modifications, folding and quality control in the ER; export and sorting of proteins. Eukaryotic cell cycle: Biochemical and genetics studies on cell cycle; mechanisms regulating mitotic events; meiosis a special type of cell division. **Course Reference**: 1. Molecular Cell Biology, by Lodish et al (5^{th} edition or recent), W.H. Freeman and Company, New York; 2. Molecular Biology of the Cell, by Alberts et al (4^{th} edition or later), Garland Sciences, New York.
BSE312A	MOLECULAR BIOLOGY LAB	1-0-6-0-9	Microbiology: Introduction to sterilization techniques and certain equipment used for sterilization or maintenance of a sterile environment e.g. the autoclave and the laminar flow hood. Learning the basic principles of making solutions used for microbiological and molecular biological experiments, such as buffers, medium for microbial culture etc. Measurement of pH and introduction to the pH meter. Learning how to make liquid and solid medium for microbial culture and the various techniques for growing microbial cultures in liquid and solid medium. Learning the principles and application of a basic staining technique to identify bacterial subtypes e.g. Gram

			staining. Collection of soil samples and water samples from different locations on campus for identification and quantification of bacteria in these samples through Gram staining and other techniques using McConkey's medium and Triple-sugar iron medium. Learning the basic principles of light microscopy and the observation of bacterial cells under a compound microscope. Molecular Biology: Learning the basic principles about plasmid vectors and the use of antibiotic selection for growing bacterial cultures containing plasmid vectors. Learning the methods of determining the efficiency of cloning of desired DNA fragment in a plasmid vector through blue-white selection. Learning the principles of and generating chemical competent bacterial cells for transformation with plasmid DNA. Measuring the efficiency of transformation in the chemical competent bacterial cells. Isolation of plasmid DNA from bacterial cells after transformation. Restriction digestion of plasmid DNA. Learning the principles of and using gel electrophoresis to determine size of DNA fragments in sample. Learning about the technology for amplification of DNA sequences through the polymerase chain reaction (PCR). Using PCR to specifically amplify a piece of DNA and subsequent detection of amplification through gel-electrophoresis. Genetics: Learning about the use of *Drosophila melanogaster* as a model system for genetic studies. Learning about the life cycle of this model organism and the study of adult mutant phenotypes. Learning basic genetics techniques such as setting up a dihybrid cross. Learning about sex-linkage and how to set up a cross to demonstrate it. Learning various techniques necessary for carrying out molecular-genetic analysis of flies e.g. preparation of polytene chromosomes, dissection of salivary glands and wing imaginal discs from larvae and dissection of adult body parts etc. Learning the principles of the powerful UAS-GAL4 system for driving tissue specific expression of reporter genes and the detection of the reporter (LacZ) expression in the tissue of interest.
BSE321A Appu and Arun	STRUCTURAL BIOLOGY	2-0-2-2-10	Part I Principles of Protein Structure from primary sequence to three-dimensional structure. Elementary ideas of bonding and structure. The building blocks. Motifs of Protein structure. Prediction, design and engineering of protein structures. Part II. The Structural Basis of Protein Function. Four fundamental biochemical functions of proteins, Recognition, Complementarity and Active Sites. Flexibility and Protein Function, Location and nature of Binding Sites, Functional Properties of, Structural Proteins, Catalysis: Overview, ActiveSite Geometry, Proximity and GroundState Destabilization, Stabilization ofTransition States, Active Site Chemistry. Control of Protein Function. Mechanisms of Regulation. Part III Determination of 3D Structures using X-ray crystallography an overview of the method. Laboratory experiments protein preparation for crystallization experiments, protein crystallization, Evaluating the quality of crystals, Cryoprotecting crystals at low temperature for data collection. Xray diffraction data collection and processing a demonstration session. **Course Reference**: 1. Protein Structure and Function, By Gregory. A. Petsko and Dagmar Ringe, New Science Press; 2. Introduction to Protein Structure, Branden & Tooze, Garland Publishing; 3. Outline of Crystallography for Biologists, David Blow, Oxford University Press.
BSE322	BIOINFORMATICS &	3-0-0-9	Introduction to bioinformatics, biological databases and their growth, concept of homology, pairwise sequence alignment, dotmatrix plot. Dynamic programming, Edit distance, global and

	COMPUTATIONAL BIOLOGY		local alignments. Substitution matrices (PAM and BLOSUM families), statistical significance of alignments, BLAST. Multiple sequence alignment, sequence logos. Pattern finding in protein and DNA sequencing, Gibbs Sampler, Hidden Markov Models, Profiles. Introduction to phylogeny, reconstruction of phylogenetic trees, gene prediction. **Course Reference**: Bioinformatics Algorithms by Pavel Pevzner and Phillip Compeau, Active Learning Publishers (2018). Bioinformatics: Sequence and Genome Analysis by David W. Mount, Cold Spring Harbor Laboratory Press (2001).
BSE398A	UG PROJECT (UGP-I)	0-0-0-0-9	UG PROJECT (UGPI)
BSE399A	UG PROJECT (UGP-II)	0-0-0-0-9	UG PROJECT (UGPII)
BSE411	BIOMATERIALS	3-0-0-0-9	Classes of Materials used in medicine: Introduction to Materials Science: Bulk and surface properties of materials, Polymers, Metals, Ceramics, Natural Materials and Composites. Degradable polymers and their use in medicine: Polymers, Hydrogels, Silicone biomaterials and medical fibers. Biocompatibility of Materials, Degradation of materials in the biological environment. Types of polymer degradation. Influence of polymer properties on degradation. Influence of biological environment on polymer degradation. Biological testing of biomaterials: In vitro assessment of materials for tissue compatibility. Invivo assessment of tissue compatibility. Host reactions to biomaterials and their evaluations: The role of adsorbed proteins in tissue response to biomaterials. Cell, extracellular matrix, and tissue interactions with biomaterials. Inflammation, wound healing and foreign body response to biomaterials. Immune response to foreign materials. Toxicity, tumorigenesis and biomaterials. Specific examples of applications of biomaterials in medicine. **Course Reference**: 1. An Introduction to Materials in Medicine. Second Edition. Edited by: Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, and Jack E. Lemons. Publisher: Elsevier Academic Press.
BSE412	BIOMATERIAL, PHYSIOLOGY & BIO-MEMS LABORATORY	1-0-6-0-9	1. Smart polymers and Cryogel matrices and their applications in Bioengineering a) Synthesis and characterization of thermo-responsive Smart Polymers of poly(*N*-isopropylacrylamide) (PNIPAm) using radical polymerization. Synthesis of copolymers and hydrogels of thermo-responsive polymers. Measurement of cloud point or Lower Critical Solution Temperature (LCST). b) Synthesis of Chitosan-Gelatin Cryogels as tissue engineering scaffolds. Scanning Electron Microscopic (SEM) analysis for pore size and porosity determination. Mechanical and rheological properties of Cryogels. c) Protein adsorption and release on thermos-responsive hydrogels and chitosan-gelatin cryogels.

			2. Preparation and application of paper based biosensors a) Preparation of thermo-responsive hydrogels with lower critical solution temperature (LCST) a. Preparation of samples for different characterizations b. Acquisition of data, Poly(N-isopropylacrylamide) (PNIPAm) as parent molecule, samples for scanning electron microscopy (SEM), and Raman spectroscopy. b) Improvement in LCST: Preparation of samples for different characterizations and acquisition of data, added carbon materials, temperature sensitive UV spectroscopy. c) Surface coating of paper: Preparation of samples for different characterizations and acquisition of data, filter paper, SEM, Raman spectroscopy. d) Interaction with cells: Preparation of samples for different characterizations and acquisition of data, SEM, Raman spectroscopy. e) Surface deposition of electrodes and interaction with cells: Acquisition of data, resistance measurement. Books: 1. Biomaterials Science: An Introduction to Materials in Medicine by B. D. Ratner, A. S. Hoffman, F. J. Schoen, and J. E. Lemons. 2. Supermacroprous Cryogels: Biotechnological and Biomedical Applications. (Ashok Kumar Ed.) CRC Press, Taylor & Francis Group, Boca Raton, USA, 2016 3. A Beginners' Guide to Scanning Electron Microscopy; By Anwar Ul-Hamid 4. Introduction to Infrared and Raman Spectroscopy; By: Colthup, Norman B. Contributor(s): Wiberley, Stephen E. 5. Spectroscopy: principles and instrumentation; By: Vitha, Mark F. 6. Introduction to biosensors : from electric circuits to immunosensors; By: Yoon, Jeong- Yeol.
BSE421	TISSUE ENGINEERING		Quantitative Cell and Tissue Biology, Tissue Organization; Tissue Dynamics; Stem Cells; Cell-Fate processes; Coordination of Cellular-Fate Processes; – Cell and Tissue Characterization: Cell and Tissue Properties; Cell and Tissue Culture, Engineering Methods and Design: Biomaterial Scaffolds; Tailoring Biomaterials, Clinical Implementation: Conventional Clinical

			Approaches to Tissue Dysfunction; Producing Tissue-Engineered Therapies Text Book: Tissue Engineering. Authors: Bernhard O. Palsson & Sangeeta N. Bhatia Reference Book: Principles of Tissue Engineering. Authors: Robert P. Lanza, Robert Langer, Joseph Vacanti
BSE492	METHODS IN BIOTECHNOLOGY-I, EXPERIMENTAL BIOSEPERATION		To be Procured
BSE498	UG PROJECT (UGP-III)	0-0-9-0-9	UG PROJECT (UGPIII)
BSE499	UNDER GRADUATE PROJECT IV	0-0-0-0-9	UP PROJECT (UGP II)
BSE601	PROFESSIONAL COMMUNICATION	1-0-0-0-0	1. CRITICAL READING: Context, how? is the text argued, Central claims, Kinds of reasoning, Examine Evidence, Examine Interpretations, Evaluations, Limitation of study; 2. CRITICAL WRITING: Learning to write through building of arguments, Hypothesis building, Conference Abstracts, Manuscripts, Reviews / Book chapters / Books, Proposals, Patents; 3. ORAL PRESENTATION: Conference, Scientific, Teaching, Popular; 4. ETHICS: Experimentation, Writing No prescribed textbook.
BSE602	LABORATORY METHODS	2-0-0-0-0	Demonstration based course. Usage of different equipments will be demonstrated. Demonstration based course. No text book.
BSE611A	MODERN INSTRUMENTAL METHODS IN BIOLOGICAL SCIENCES	3-0-0-0-9	1. Applications of spectroscopic and other techniques to the study of biomolecules: UVVis spectroscopy, Circular dichroism, Fluorescence, NMR, Mass, IR and Raman spectroscopy, XRay diffraction; 2. Analysis of Proteins: Electrophoretic separation of proteins (single dimension native and denaturing gels, 2D and digital electrophoretic analysis), detection (staining, blotting and immune detection) specialized applications (in vitro synthesis of protein, labeling and Mass spectrometry), ultracentrifugation; 3. Techniques with Radioisotopes: Introduction Isotopes and Radioactivity Ionization Effects, Measurement Units, Measurement Techniques, Autoradiography, Biological Uses of Radioisotopes, Tracer Dilution Technique, Radioimmunoassay; 4. Cellular Imaging Techniques: Microscopy: Phase contrast, Fluorescence, Atomic Force and confocal; 5. Electron Microscopy: Negative staining, cryo EM, Transmission EM and Scanning EM
BSE612A	BIOCHEMICAL ENGINEERING	3-0-0-0-9	1. Introduction to biochemical engineering, bioprocesses, bioproducts and biochemical technology with specific examples Three lectures; 2. Upstream process: Microbial, mammalian and plant systems for bioprocess technology. Sterilization. Stoichiometry and energetics of microbial metabolism. Transport phenomena Five lectures; 3. Enzyme catalyzed reactions and processes. Cell and enzyme immobilization. Bioreactor design and applications. Instrumentation and control Six lectures; 4. Downstream process: Bioseparations, characteristics of biological materials, pretreatment methods, separation of cell

			biomass, adsorption, filtration, centrifugation, precipitation and extraction Four lectures; 5. Liquid chromatography principles, plate and rate theory, ion exchange, gel filtration, affinity chromatography, hydrophobic interaction and reverse phase chromatography Six lectures; 6. Integrated bioprocesses Bioprocess integration for efficient production and recovery, expanded bed separations, affinity precipitations, aqueous twophase processes, monolithic chromatographic separations Six lectures; 7. Polishing, crystallization, drying, scaleup consideration, process monitoring and process economics Three lecturesH. Environmental bioprocesses Interaction of mixed microbial population, biological wastewater treatment, anaerobic digesters, bioremediation Three lectures; 8. Case studies and new developments of bioprocesses paper readings and presentations. **Course Reference**: 1. Blanch, H. W. and Clark, D. S. Biochemical Engineering. Marcel Dekker, Inc.; 2. Bailey, J. E. and Ollis, D. F. Biochemical Engieering Fundamentals. McGrawHill, Inc.; 3. Belter, P. A., Cussler, E. L. and Hu, W. S. Bioseparations: Downstream Processing for Biotechnology, John Wiley & Sons; 4. Desai, Mohamed. A. Downstream Processing of Proteins: Methods and Protocols. Humana Press; 5. Shuler, M. L. and Kargi, F. Bioprocess Engineering Basic Concepts
BSE613A	BIOMATERIALS	3-0-0-2-11	Introduction to Materials Science: Bulk and surface properties of materials; Polymeric materials; synthesis, characterization, and fabrication methods Inert, biodegradable, hydrogels, Natural, Genetically engineered and Bioactive; Ceramics and glasses; Metals; Surface modification techniques. Biocompatibility of Biomaterials: Protein structure, interaction of proteins with synthetic material; characterization of cell material interactions; inflammatory responses; acute inflammation, chronic inflammation, foreign body response, assessment of material performance.
BSE614A	TISSUE ENGINEERING	3-0-0-0-9	What is tissue engineering? Scope and objective of tissue engineering; Principles of tissue engineering; Essential components of tissue engineering; Materials Science/Engineering aspects (degradable materials); Design and characterization of scaffolds (porosity, mechanical strength and 3D architecture); Cell Biology aspects (choice of cell type, progenitor cells and cell differentiations); Molecular biology aspects (cell signaling moleculesgrowth factors, cell attachment integrins); Drug delivery in tissue engineering; Commercial developments of tissue engineering; Future of tissue engineering.
BSE616	BIOPHARMACEUTICALS		**Course Objective:** The objective of this course is to expose students to drug discovery and recombinant protein drugs. The course will help students to get a deep understanding of scientific and technical aspects of the development, production, and clinical usage of biopharmaceuticals. It will facilitate the students to explore job avenues, research opportunities, and entrepreneurship. **Course Contents:**

			Module A. Introduction to biopharmaceuticals Introduction to biotechnology and biopharmaceuticals, historical perspective of pharmaceutical biotechnology, process of transforming new molecular entities into drugs, current trends in drug development, biotechnology industry perspective on drug development. **Module B. Drug Development process** Drug discovery approaches, modulatory effects, binding strength, effective and inhibitory concentration, side effects, ADME, Lipinski rule, the action of drugs on humans, pharmacokinetics, pharmacodynamics, routes of drug administrations, patenting, phases of clinical studies, design, and conduct of clinical trials, case studies of drug discovery. **Module C. Biopharmaceutical technologies** Role of the manufacturing process, process evaluation, drug substance manufacturing, drug product manufacturing, cell banking, expression systems, batch and continuous processes, sterility and sterile technology, raw material, and processing aids, purification of product, formulation and filling, labelling, and packaging, product analytics, quality criteria of analytical methods, process analytics, validation of analytical methods. **Module D: Quality assurance and quality control** Fundamental of quality assurance, benefits, the structure of quality management, documentation, audits, quality assurance in manufacturing measures to cross-contamination and product confusion, equipment qualification, process validation, product release, product recall. **Module E. Regulatory bodies** Field of pharmaceutical laws, authorities, institutions and their regulation, drug approval steps and processes, FDA, EMEA, German, Japanese, and Indian regulatory bodies. **Module F: Production facilities** Basic principles, GMP compliant design, zoning concept, single and multiple product plants, clean rooms, clean and plant utilities, water for injection, waste management. **Module G: Commissioning of manufacturing plant** Steps of engineering projects, planning, construction, commissioning, qualification, validation, project schedules, cost estimates, health safety, and the environment. **Module H: Economy**

			The life cycle of a drug, basic principles of cost calculation, typical costs of biotechnology manufacturing, investments, production concept, technology transfer, supply chain management. **Module I:** Case studies by practitioners of biopharmaceutical development and manufacturing. **Special Emphasis:** Teaching through case studies and involving students in the discussion. Problem solving in the class by an individual student and in teams. Learning through research articles and self-studying in the class and home assignments. Discussion/lectures by one or two biopharmaceutical professionals from the industry depending on their availability. Weekly ppt of the lectures will be shared. **Books Recommended:** 1) Biopharmaceuticals: Biochemistry and Biotechnology by Gary Walsh, Publisher: Wiley-Blackwell, ISBN-10: 0470843276 2) Manufacturing of Pharmaceutical Proteins (from technology to Economy) by Dr.-Ing. Stefan Behme, Wiley-VCH Verlag GmbH & Co. ISBN 978-3-527-32444-6 3) Biochemistry by Lubert Stryer, W.H. Freemanand Company. ISBN 13:978-1-4292-7635-1
BSE631A	BIOCHEMISTRY STRUCTURAL BIOLOGY	3-0-0-0-9	**Protein structure and folding** : Building blocks of biopolymers, conformational studies of biomolecules, Ramachandran map, protein secondary and supersecondary structures, different classes of tertiary structures, overview of different experimental techniques to determine biomolecular structures, intermolecular interactions, protein folding **Enzymes and the structure-function relationship**: Enzyme kinetics, structural basis of catalytic activity, MichaelisMenten kinetics, Enzyme inhibitors and complex reaction schemes, protein and RNA enzymes, basic concepts of metabolism and design **Nucleic acid structures**: Double-helical structures of RNA and DNA, functional versatility of RNA, protein-DNA interactions **Membrane proteins**: Lipids, bilayer assembly, biological membranes as solvent for membrane proteins, structural principles of membrane proteins, channels and receptors, signal transduction and GPCRs **References**: 1. **Introduction to Protein Structure by Carl Branden & John Tooze, Garland Publishing, 2nd Edition, New York**

			2. **The Molecules of Life: Physical and Chemical Principles by J. Kuriyan, B. Konforti and D. Wemmer, Garland Science, NY** 3. Biochemistry, L. Stryer, W.H. Freeman & Co, 4th Edition, 1995 4. Ramachandran & Sasisekharan, Adv. Protein Chem. (1968) 283-438 5. Proteins: Structures and Molecular Properties, T.E. Creighton, W.H. Freeman & Co, 2nd Edition 6. Biophysical Chemistry Part I: The conformation of Biological Macromolecules, Cantor and Schimmel, W.H. Freeman & Co, 1999 7. Principles of Protein Structure, Schulz and Schirmer, Springer-Verlag 8. Biomembrane: Molecular Structure & Function, R.B. Gennis, Springer-Verlag 9. Research papers and Review articles from journals
BSE633A	BIOINFORMATICS AND COMPUTATIONAL BIOLOGY	3-0-0-0-9	**Introduction to bioinformatics**: Distinction between bioinformatics and computational biology, biological databases and their growth, concept of homology and definition of associated terms **Pairwise sequence alignment**: Dotmatrix plot, dynamic programming algorithm, global (Needleman-Wunsch) and local (Smith-Waterman) alignments, BLAST **Scoring matrices**: PAM and BLOSUM families, gap penalty, statistical significance of alignment **Multiple sequence alignment**: Sum-of-pairs method, CLUSTAL W, Genetic Algorithm, Pattern finding in protein and DNA sequencing, Gibbs Sampler, Hidden Markov Model, Profile construction and searching, PSI-BLAST **Phylogenetic algorithms**: Introduction to phylogeny, maximum parsimony method, distance method (neighbour-joining), maximum-likelihood method **Gene Prediction and Comparative Genomics**: Gene prediction in prokaryotes and eukaryotes, homology and ab-initio methods, genome analysis and annotation, comparative genomics **References**: 1. Bioinformatics: Sequence and Genome Analysis, David W. Mount, Cold Spring Harbor Laboratory Press (2001) 2. Advances in Protein Chemistry, Vol 54 (2000) 3. Developing Bioinformatics Computer Skills. C. Gibas and P. Jambeck, O' Reilly (2001) 4. Biological Sequence Analysis: Probabilistic models of proteins and nucleic acids. R. Durbin, S. Eddy, A. Krogh and G. Mitchison, Cambridge University Press (1998)

			5. Understanding Bioinformatics. M. Zvelebil and J.O. Baum, Garland Science (2008) 6. Bioinformatics algorithms: an active learning approach. Phillip Compeau and Pavel Pevzner. Active Learning Pub (2015) 7. Inferring Phylogenies. Joseph Felsenstein, Oxford University Press (2004) 8. Journals: Bioinformatics, BMC Bioinformatics, Nucleic Acid Research, ISMB, J. Comp. Biol., PLoS Computational Biology
BSE634A	FUNCTIONAL GENOMICS	3-0-0-0-9	Introduction to Functional Genomics; The impact of genomics on biological research; Identification of a large set of genes involved in a biological process; RNA interference and RNAi screening. High-throughput expression analysis such as microarray; Recent developments in genomics, Next-generation sequencing methods (Whole Genome Sequencing, Whole Exome Sequencing and Transcriptomics) and its application in understanding diseases. Genome-wide search for interacting partners; Principles of Chromatin immunoprecipitation, or ChIP-Seq and ChIP-PCR, Identification of alternatively spliced genes; Sequence variations and disease susceptibility; Pharmacogenomics. Proteomics; Functional genomics in model organisms. High- throughput phenotypic analysis.
BSE651A	CELLULAR MOLECULAR BIOLOGY	3-0-0-0-9	1.Molecular Genetic Techniques and Genomics: Genetic analyses of mutations to identify and study genes; DNA cloning and characterization; Genome wide analyses of gene structure and gene expression; Inactivating the function of specific genes in eukaryotes; Identifying and locating human disease genes; 2. Molecular Structure of Genes and Chromosomes: Chromosomal organization genes and noncoding DNA; Mobile DNA; Structural organization of eukaryotic chromosomes; organelle DNAs; 3. Transcriptional Control of Gene Expression: Eukaryotic gene control and RNA polymerase; regulatory sequences in protein coding genes; activators and repressors of transcription; mechanism of transcription activation and repression; 4. Posttranscriptional Gene Control: Processing of eukaryotic premRNA; transport across nuclear envelope; cytoplasmic mechanism of posttranscriptional control; processing of rRNA and tRNA; 5. Cell signalling: Signalling molecules and cell surface receptors; intracellular signal transduction; G protein coupled receptorsF. Membrane trafficking: Translocation of secretory proteins across the ER membrane; protein modifications, folding and quality control in the ER; export and sorting of proteins; 6. Eukaryotic cell cycle: Biochemical and genetics studies on cell cycle; mechanisms regulating mitotic events; meiosis a special type of cell division. Molecular Cell Biology, by Lodish et al (5th edition or recent), W.H. Freeman and Company, New YorkMolecular Biology of the Cell, by Alberts et al (4th edition or later), Garland Sciences, New York.
BSE652	DEVELOPMENTAL BIOLOGY	3-0-0-0-9	**Topics:** 1. Introduction to animal development- 1 Lecture 2. Methods of studying developmental biology I: Fate mapping and lineage tracing- 2 Lectures

			3. Methods of studying developmental biology II: Candidate gene approach- 3 Lectures 4. Morphogenesis: Differentiation and cell-cell communication- 4 lectures 5. Axis formation and patterning: Drosophila and Xenopus- 4 Lectures 6. Axis formation and patterning: Limb patterning and skeletal development- 2 Lectures 7. Stem cells- 1 Lecture 8. Regeneration- 2 Lectures 9. Development and Disorders- 2 Lectures 10. Evolution and development- 1 Lecture. **Course Reference**: 1. Recommended Text Book: Developmental Biology, Scott F. Gilbert, Ninth Edition. 2. Other material: Journal articles referred to in the Lecture slides will be provided separately by the Instructor.
BSE653A	FUNCTIONAL GENOMICS	3-0-0-0-9	Introduction; The impact of genomics on biological research; Identification of a large set of genes involved in a biological process; High throughput expression analysis; Genomewide search for interacting partners; Identification of alternatively spliced genes; Sequence variations and disease susceptibility; Pharmacogenomics; Proteomics; Functional genomics in model organisms; High throughput phenotypic analysis; Recent developments in genomics.
BSE654A	HUMAN MOLECULAR GENETICS	3-0-0-0-9	Simple Mendelian traits; Loss of function mutations; Gain of function mutations; Gene interactions; Dynamic mutations; Genetics of neoplasia; Genomic imprinting and human disease; X-inactivation and DNA methylation; Gene mapping and positional cloning; Multifactorial inheritance; Genetics of behavioural disorders; Pharmacogenetics and biochemical genetics; Animal models in human genetics: Methods used for diagnosis and detection of gene mutations; Gene Therapy.
BSE655	PHYSIOLOGY	3-0-0-0-9	**Topics:** 1. Introduction to Physiology- 1 Lecture. 2. Membrane physiology: Nerve and muscle- 2 Lectures. 3. Heart and Circulation- 4 Lectures. 4. Body fluids and Kidneys- 2 lectures. 5. Blood cells, Immunity and Blood coagulation- 2 Lectures. 6. Respiration- 2 Lectures. 7. Avian, Space and Deep sea diving physiology- 1 Lecture. 8. Neurophysiology: General principles, Sensory and Motor systems- 4 Lectures. 9. Gastrointestinal physiology- 1 Lecture. 10. Temperature regulation- 1 Lecture 11. Endocrine and Reproductive physiology- 3 Lectures. **Course Reference**: 1. Recommended Text Book: Medical Physiology, Arthur C. Guyton, Eleventh Edition. 2. Other material: Journal articles and links to websites will be provided separately by the Instructor.
BSE656A	NEUROBIOLOGY	3-0-0-0-9	Introduction to neuroscience, functions of different parts of the brain such as the cerebral cortex and the limbic system, motor system, reflexes. Membrane potential, action potential. Synaptic

			transmission, Glia. Sensory perception, vision, olfaction. New developments, Techniques, brain disorders. **Course Reference:** Principles of Neural Science (5th edition) by Eric Kandel et al.
BSE699	M.TECH THESIS	------	M. Tech. Thesis
BSE701A	SEMINAR		Seminar
BSE702A	SEMINAR		Seminar
BSE799	PHD THESIS	------	Ph. D. Thesis
ESO206	PRINCIPLES OF BIOTECHNOLOGY	3-0-0-0-9	**Introduction**:Distinction between science, engineering and technology, introduction to biotechnology, interdisciplinary nature of biotechnology, old and new biotechnology, historical perspective, need for biotechnology. **Background biology**: A review of living systems and levels of biological organization, cell structure, differences between prokaryotic and eukaryotic cells, molecules of life with special emphasis on DNA structure, chromosome organization and gene concepts, flow of genetic information: DNA replication, transcription, translation, post translational modifications, protein folding, metabolic regulation, gene expression control in prokaryotes and eukaryotes, mutations causes and consequences, life cycle of viruses. **Recombinant DNA technology**: Introduction to recombinant DNA technology, restriction enzymes, ligation, transformation, selection, techniques to clone genes, cloning and expression vectors, host systems, construction and screening of DNA libraries, manipulation of cloned DNA sequences, southern, western, and northern blotting techniques, colony and DNA hybridization, DNA and protein sequencing, foot printing. **Applications**:Microbial biotechnology: microbial enzymes, fermentation; Medicine and diagnostics: discovery to translation path, monoclonal antibodies, vaccines, hormones, enzymes, molecular diagnosis of communicable and genetic diseases; Agriculture and animals biotechnology**: c**ultivation of animal and plant cells, media design, characterization of cell lines, micropropagation, secondary metabolites, transgenic plants, transgenic animals; Environment Biotechnology**:** contamination of land, air and water, biological intervention, microbial technologies; Products of daily use: food, beverages, cosmetics and detergents; Forensics: DNA fingerprinting. **Recent advances and future directions:**Expansion and mergers of new disciplines, genomics, proteomics, metabolomics,

			glycomics, cell-based technologies, personalized medicines, nanobiotechnology. **Quality systems, ethics, regulations, and laws** Quality control and assurance, animal protection in research, intellectual property, regulatory bodies, government policies. **Text books:** 1. Introduction to Biotechnology by William J Thieman and Michchael A Palladino. Pearson publisher. 2. Campbell Biology by Jane B Reece. Pearson publisher
LIF111	INTRODUCTION TO BIOLOGY	2-0-0-0-6	**Topics** **Part I: The molecular machines and mechanisms that make living systems function.** The importance and relevance of studying Biology today. Distinguishing characteristics of living systems. Origin of life on Earth. Life's chemical basis. Water and its importance for life. Structure and function of carbohydrates, lipids, proteins and nucleic acids. Cells: The internal structure and components of cells. Visualizing cells and organelles in action using various microscopic techniques. Components of cells and their functions: the cell membrane and transport across it. Trafficking within the cells. The cytoskeleton and movement of cells and internal components of cells. Organization of cells into tissues, organs, organ system and organism. Introduction to metabolism: Life at the expense of free energy. Enzymes and their functions. Energy metabolism: Photosynthesis and Cellular respiration. **Part II: Information processing in living systems.** DNA structure and function: Chromosomes. Discovery of DNA as the genetic material. DNA structure and function. DNA replication and repair. From DNA to protein: The central dogma: DNA to RNA to protein. The genetic code. Transcription and Translation**.** Control over genes: Gene expression in eukaryotes and outcome of gene regulation.Cell division (Mitosis), cell cycle, control of cell division and cancer. The importance of reductive division and how meiosis introduces variations in traits.Patterns of inherited traits: Mendel's experiments with pea plants and the observed patterns of inheritance. Human inheritance: Human genetic analysis, autosomal inheritance patterns, X-linked inheritance patterns and epigenetics.Biotechnology: Cloning DNA, DNA sequencing, Genomics, Genetic Engineering and designer plants. **Course Reference**: Recommended Text Book: Concepts and applications by Cecie Starr, Christine A Evers and Lisa Starr, 8th edition (Chapters 1-13 and 15)
BSE642A	Microbiology and Immunology	3-0-0-9	**Discoveries in microbiology– 3 lectures** Concepts of origin of life, abiogenesis and biogenesis, spontaneous generation theory, early discoveries in the development of

			microbiology; Structural features of Prokaryotes and microbial Eukaryotes. **General Microbiology – 10 lectures** Importance of microorganisms in natural processes; Diversity, metabolism, energetics and physiology of microorganisms; sterilization principle and methods; staining- principles and applications, nutrient requirement of microorganisms carbon, nitrogen and mineral metabolism; Autotrophic, heterotrophic and chemolithotrophic microorganisms; growth of microorganisms, generation time, different phases of growth curve; microbes in extreme environments; principles of microbial genetics, genetics of prokaryotic and eukaryotic microorganisms, plasmid, types and their importance, genetic variability in microorganisms. **Medical Microbiology– 8 lectures** Overview, Impact of infectious diseases, Koch's postulates; Microbial Toxins; Antibiotics and antibiotic resistance; Enteric Pathogens – Cholera , Salmonella, Shigella and *E.coli*; Extracellular pathogens – Staphylococcus, Streptococcus; Facultative intracellular pathogens – Mycobacterium; Obligate intracellular pathogens –Chlamydia, Rickettsia; Accidental pathogens – Pseudomonas, Chronic pathogens – Helicobacter pylori; ESKAPE pathogens, their effects on society will also be addressed. Sexually transmitted diseases – Gonorrhea, Syphilis, Biology of viruses; Viral borne diseases; and antimicrobial resistance (AMR). **Overview of Immune System – 5 lectures** Historical perspective; concepts for understanding human immune response; cells, receptors, microenvironment and organs of immune system; antigens; types of immune responses; innate immunity; physical and cellular effectors of innate immune response; adaptive immunity; cross talk between different arms of the immune system. **Humoral and cell-mediated Immunity – 8 lectures** B lymphocytes- maturation, activation and proliferation; immunoglobulins – structure and function; immunoglobulin genes, their rearrangement and antibody diversity; Major histocompatibility complex; antigen processing and presentation; dendritic cell maturation and activation; T-cell receptor complex; T-cell maturation, activation; TCR coupled signaling pathways, co-stimulatory signals; immune tolerance; cell mediated effector responses. **Microbial Immunity– 8 lectures**

			Cytokines; cytokine receptors; cytokine signaling; inflammation–mediators and process; anti-inflammatory agents; Host-pathogen interactions and immune response to infectious diseases; vaccines. **Suggested books** 1. Staley, Gunsalus, Lory and Perry (2007) Microbial Life 2nd Edition. 2. Pelczar MJ, Chan ECS and Krieg NR. (1993). Microbiology. 5th edition. McGraw Hill Book Company. 3. Willey JM, Sherwood LM, and Woolverton CJ. (2008). Prescott, Harley and Klein's Microbiology. 7th edition. McGraw Hill Higher Education. 4. Jefferey C. Pommerville (2012) Alcamo's Fundamentals of Microbiology 9th edition 5. Michael T. Madigan, John M. Martinko, Kelly S. Bender, Daniel H. Buckley, David A. Stahl, Thomas Brock (2015) Brock Biology of Microorganisms, 14th Edition 6. Kindt ,T. J. ,R. A. Goldsby, B. A. Osborne and J. Kuby ,*Immunology*, W H Freeman and Co, 6th edition or later 7. Delves, P. J., S. J. Martin, D. R. Burton and I. M. Roitt ,Immunology, Wiley-Blackwell. 12th edition or later
BSE659 (Dibyendu K Das)	Molecular Virology	3-0-0-0-9	Virus prehistory; Discovery of viruses; Definitive properties of viruses; Animal viruses; Strategy for viral propagation. Entering cell; Making viral RNA, viral protein, viral genomes; Overcoming Host defenses; Cultivation of viruses; Infectious unit; Growth cycle.Building a protective coat; Symmetry; Packaging of Nucleic acid genome; Enveloped viruses; Large viruses with multiple structural elements; Components of virions. Receptors for virus particles; Virus-receptor interactions; Uncoating; Membrane fusion; Movement of subviral particle inside cell; Import of viral genome into Nucleus, ribonucleoprotein, DNA genomes, retroviral genomes.Synthesis of viral RNA from RNA templates, RNA synthesis machinery, Mechanism of RNA synthesis; Retroviral transcription and integration; Synthesis of RNA from DNA templates. Translation machinery, initiation, elongation and termination; Polyprotein synthesis, Leaky scanning, Suppression of termination, Ribosomal Frameshifting; Regulation of translation during viral infection. Assembly of protein shells; Selective packaging of viral genomes; Acquisition of envelope; Budding of viral particles; Maturation of Virus particles
BSE644A	Optical microscopy and Bioimaging	3-0-0-0-9	Introduction and motivation: Human eyes and the microscopes, History of microscopes, Imaging techniques at different length scales, Recent advancements in microscopy and bioimaging, Interdisciplinary approach in bioimaging Light matter interactions: Electromagnetic spectrum and bioimaging methods, Wave particle duality-Maxwell's equations, Reflection, Refraction, Polarization, Total internal reflection, Dispersion, Diffraction. Microscope illumination and design: Geometrical optics, Image formation, Magnification, Simple & Compound microscopes, Conjugate planes, Kohler illumination, Optical design and anatomy of modern microscopes- Microscope parts,

			Aberrations in optical microscopy, Detectors- CCD, CMOS, APD, PMT, Demonstration-on Kohler illumination session. Contrast enhancement: Bright field and Dark field, Phase contrast, Differential interference contrast, polarized light microscopy, Fluorescence, Organic fluorophores, quantum dots and nanodiamonds fluorescent proteins, Photoactivable probes, covalent labelling and click chemistry, autofluorescence, Demonstration on sample preparation for fluorescence imaging. Fluorescence Microscopy, Practical applications and quantitative methods: Widefield Imaging, TIRF,Confocal, Multiphoton, spinning disc, Airyscan, FRET, FRAP, FCS, Demonstration on widefield and confocal imaging sessions. Super resolution fluorescence microscopy and quantitative bioimaging: Abbe's diffraction limit, Near field microscopy, Single molecule localization, STORM/PALM/DNA-paint, STED, SIM, Lattice light-sheet microscopy. Image processing and Analysis basics: Digital image- Bit depth, Math functions, , Image resizing, scaling, Image intensity analysis, Colocalization analysis, Filtering and Segmentation, Time series Analysis-kymographs, single particle tracking, Image registrations and Drift corrections, Image-J software-training with practical examples.
BSE663 Instructor- Shanu Jain	Medical Pharmacology	3-0-0-0-9	What is pharmacology? Routes of drug administration. Pharmacokinetics: membrane transport, absorption, distribution of drugs, metabolism and excretion of drugs. Pharmacodynamics: study of drug effects, what drugs do and how they do it. Mechanism of Drug action- enzyme, ion channels, transporters and receptors. Receptor pharmacology. Drug dosage, factors modifying drug action, Adverse drug effects. Xenobiotics. Phases and sites of drug metabolism. Cytochrome P-450, flavin-containing monooxygenases, hydrolytic enzymes, conjugating enzymes. Blood brain barrier. Neurotransmission. Muscarinic receptor and adrenergic agonists and antagonists. Anticholinesterase agents. Serotonin and dopamine. Drug therapy for depression, anxiety, epilepsy. Opioids, treatment of neuro-degenerative disorders, Drug addiction. Renin-Angiotensin system, Pharmacotherapy for myocardial ischemia, hypertension, congestive heart failure, anti arrhythmic drugs. Anti-coagulant and anti-platelet drugs. Hypercholesterolemia and dyslipidemia. The hypothalamic-pituitary axis. Thyroid and anti-thyroid drugs. ACTH, adrenal steroids. Endocrine pancreas. Pharmacotherapy of Type 2 diabetes, and hypoglycemia. Agents affecting bone mineral homeostasis. Histamine, bradykinin, and their antagonist. Eicosanoids and platelet activating factor, anti-inflammatory, anti-pyretic and analgesic agents. Immunostimulants/suppressants. Hematopoietic agents. Antibiotics, Anti-malarial, Anti-protozoan, Anti-viral, Anti fungal, Anti-helminth, Antitubercular drugs. Cytotoxic agents, targeted therapies: tyrosine kinase inhibitors, monoclonal antibodies, and cytokines. Natural products-based cancer chemotherapy. Genetic basis for variation in drug response. Types of genetic variants. Ethnic diversity. Polymorphism selection. Candidate genes versus genome-wide approaches. Functional studies of polymorphisms. Pharmacogenetic phenotypes. Large

			molecules/ biologics- monoclonal antibodies (mAbs), and antibody-drug conjugate (ADC). Targeted protein degradation. Time Resolved fluorescence, Fluorescence Polarization, Luminescence. BRET, Hi-Bit, ALPHALISA, CTG assay, Radioligand Binding Assays, Functional assays screens.
BSE662	Decision making and the Brain	3-0-0-0-9	This is an interdisciplinary course with a practical outlook: In this course we will examine life from the perspective of the choices or decisions we make every day. We will study the role of the brain in enabling these decisions and discuss computational models of decision making and how these computations are implemented in the brain. We will also discuss how changing environmental conditions and social contexts lead to changes in our decisions– also called adaptive decision making. Finally, we will learn about the impact of highly prevalent neurological and psychiatric conditions on decision making from a neurocomputational perspective. *Introduction to decisions, computations and the brain* We will discuss the kinds of decisions we make every day and consider how we make them – the decision-making process. Discuss rational and irrational decisions. Biases that lead to irrational decisions. Discuss where neuroscience fits in this scheme. Briefly review the methods and tools at our disposal today to observe the brain during decision making. *Neural basis of perceptual decisions* Perceptual decisions: how does the brain process information on based on physical features eg: color, motion and shape etc., to enable choices? *Neural basis of value-based decisions* Value-based decisions: How do we assign value to objects, which then allows us to choose one option over another? *Risky decisions and pharmacology* Overview of Neuroeconomics. Neural basis of risky decisions and loss aversion. Intertemporal discounting. Effects of neuromodulators like Dopamine, Serotonin, Norepinephrine, Cortisol on decision making. *Adaptive decision making and the brain* When the conditions change one needs to make suitable changes to their behavior. Here we will look at different ways in which we can learn to cope. We will examine the influence of affect on our decisions. We will also discuss Explore-exploit decision making and foraging style sequential decision making.

			We will examine the neural mechanisms underlying these decisions. *Suboptimal decision making in health and disease* Sometimes and in some individuals, due to the current conditions, decision making is rendered suboptimal. Here we will look at the impact of chronic stress, fatigue, and mood on the decision-making brain. We will also examine the impact of some common neurological conditions (e.g., Parkinson's disease, Alzheimer's dementia) and psychiatric conditions (e.g., anxiety, depression, ADHD, schizophrenia) on decision making
BSE658	Statistics for Modern Biology	3-0-0-0-9	Biological systems, like the brain for example, are composed of tens of thousands of components – here neurons. Furthermore, these different components can interact, attain different states at different points in time, and can even do so in multiple different ways. Statistical analysis tools can help one to understand such high dimensional systems and comprehend patterns in the activity. This course aims to introduce basic statistical analysis tools for biological data. Through a mix of theory and practical exercises with real world data you will get the opportunity to learn a stepwise approach to statistical analysis. *Why learn statistics?* Examine different data sets; discuss what is measured and how it is measured; discuss variables, measurements, validity, reliability, etc. *Introduction to R or Python or a different statistical language* Create variables, data frames; load, organize the data; generate simple plots; discover statistical analysis packages; learn to write simple scripts. *Descriptive statistics, models, distributions, graphical representations* Models, distributions, summary statistics, histograms, exploratory data plots, test data distribution assumptions. *t-tests, ANOVA, correlation, regression, classification and clustering* Comparing two means; comparing several means; determining covariance, correlation; regression models with one or more predictors; data classification: linear discriminant analysis, k-NN, etc. Data clustering: k-means, hierarchical clustering, heat map analysis *Resampling methods and Inferential statistics* Bias-variance trade-off, cross-validation, the bootstrap; Significance testing, effect size, multiple testing, error types – type 1,2 etc. *Linear models, model selection, mixed models, nonlinear effects, basic Bayesian statistics*

			Fit simple linear models; determine slopes, intercepts; linear model selection, Lasso, Ridge regression; develop mixed models with varying intercepts and slopes; Bayes' rule, Bayesian inference, Frequentist vs Bayesian inference.
BS BSE661A	Biomembranes		A basic introduction to biological membranes and its compositions, membrane structure, physiochemical properties of membrane lipids, lipid bilayers, and lipid-derived second messengers in Bacteria, yeast and higher eukaryotes. Membrane protein synthesis and their trafficking to the cell membrane, Structure and function of membrane-bound enzymes, transporters, pumps, mechanoreceptor and mechano-sensitivity of cell membranes, and ion channels and their roles in disease development. Gap Junctions, communication between cells, membrane guided immune response, Transport of metabolites across the plasma membrane. Components of electron transport chain, Hydrogen gradients and ATP synthesis and energy transduction; membrane receptors, G proteins, and signal transduction; membrane fusion. Experimental approaches, including single-particle reconstruction and tomography, x-ray crystallography, and electrophysiology, to understand the biological membrane structure and function at a molecular level. Biological membranes and microbial pathogenesis, cancers, and membrane-associated disease, Therapeutic approaches to target cell membrane components for drug design.
BSE672	Advanced Cell Biology		**Vesicular trafficking-**Trafficking of cargo from one organelle to another, historical aspects to vesicular trafficking (discoveries by Palade, Claude, Blobel, Scheckmann, Rothaman), mechanism of vesicular trafficking; function of COPII and COPI vesicles. Role of ER, ERES, ERGIC, Golgi ministack in vesicular trafficking. ER retention signals; glycosylation. Modern experimental approaches to study vesicular trafficking (Live fluorescence confocal microscopy, biochemical studies using modern probes e.g. RUSH). **Mechanism of vesicular trafficking-** Role of endocytosis in different diseases. Mechanism of phagocytosis, pinocytosis, and receptor mediated endocytosis. Mechanism of clathrin mediated endocytosis. Modern experimental approaches to study endocytosis with examples (confocal microscopy, co-IPs) **Endocytosis and Exocytosis-**Function of SNAREs, mechanism of SNARE action. Structural organization of SNAREs;

			involvement of HOPS in regulating SNARE function. Role of synaptotagmins and extended synaptotagmins in vesicular fusion. Modern experimental approaches to study SNARE function (confocal microscopy, co-IPs, lipid mixing assays, structural analysis) **Autophagy and Lysosomal Biology-** Introduction to autophagy and lysosomal biology. Mechanism of autophagosome formation, lysosomal biogenesis and dynamics of cellular membranes involved in autophagy-lysosomal system **Cell biological processes and their implication in human diseases-** Role of important cell biological processes in cancer, neurodegenerative diseases, immunological disorders and metabolic disorders. Modern experimental approaches to study cell biological processes such as autophagy-lysosomal system (confocal microscopy, co-IPs, mass spectrometry, high end microscopy). **Cell signaling-** Introduction to cell signaling. Phosphorylation, dephosphorylation, GEFs and GAPs, signaling for transcription factor activation. Role of signaling in cancer and other diseases. Development of drugs using signaling based pathways. Examples of signaling, PI3K/AKT/mTOR signaling pathway and its role in human pathologies. Experimental approaches to study cell signaling (western blotting, immunoprecipitation, confocal microscopy, biochemical techniques, mass spectrometry.
BSE664	Circuits and Systems Neuroscience	3-0-0-0-9	This course aims to deliver the fundamental concepts of neuronal circuits in the brain and their role in bringing out specific behaviour. The brain is one of the most complex organ in the mammals. The complexity comes from individual non-linear neuronal dynamics wiring up to form different sizes of networks. The course will help students to understand some basic concepts that happens once neurons wire-up. Further, it will take slightly more complicated physiological phenomena that are known to be basis of some routine behaviour. Finally, it will end with examples of some neurodegenerative disorders and the (so far) known circuit dysfunctional reasons. *Introduction and motivation* Basic structure and function of neurons: Parts of neurons and their connections. Electrical basis of neuronal function. Electrical and Chemical Synaptic connections *Cell types and circuits*

			Neuronal classification (Excitatory and Inhibitory subtypes) Strategies used to classify neurons. Advantages of forming circuits; Feed forward, Recurrent and feedback circuits. Examples from Brain circuits *Synaptic Physiology in a circuit context* Methods used to study synaptic physiology. EPSP and IPSP Plasticity definition and classification. Synaptic plasticity, their forms, and molecular mechanisms. Electrophysiological signatures of plasticity. Role of synapse in Network oscillations. Role of synaptic plasticity in memory formation *Network Oscillations* What are network oscillations and different ways of measuring them? Origin of network oscillation in different types of neuronal circuits. Association of different oscillation frequencies with different brain areas and behaviour. Role of synaptic physiology on network oscillation. Role of intrinsic physiology on network oscillation. *Circuits associated with Memory* What is memory? (Definition and classification). Molecular basis of memory. Important circuits associated with memory formation and consolidation. Electrophysiological and behavioral assays to study memory. *Circuits associated with Reward* Definitions in the reward circuit. The Dopamine reward system. Circuits involved; Ventral Tegmental Area, Nucleus Accumbens, striatum, Prefrontal Cortex, Ventral pallidum, hippocampus and amygdala and their interactions. Interactions between these areas and experimental examples for behavioural outcomes. Prediction error *Sensory coding and involved circuits* What are the different sensory systems and their associated circuits? Population coding in sensory systems with examples. Circuits involved in multi-modal integration of sensory information. Circuits involved in navigation. *Circuits associated with Motor functions* Introduction to motor systems. Functional segregation of central motor structures. Circuit architecture in the primary motor cortex: Primary and secondary motor areas. Properties and functions associated with primary motor cortex (M1) eg: direction tuning *Degeneration of neuronal circuits and diseases (specific stress on AD)*

<table>
<tr><td></td><td></td><td></td><td>Neurodegenerative diseases (Names, symptoms and associated brain circuits). Circuit dysfunction and current research on AD. Cholinergic hypothesis</td></tr>
<tr><td>BSE665</td><td>Electronics and Signal Processing for Biologists</td><td>3-0-0-0 (9)</td><td>Objectives:
Introduce fundamental concepts in electronics and signal processing.
Provide practical training through lab experiments and demonstrations.
Familiarize with MATLAB programming for bio signal processing.

Contents:

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<tr><th>s. No.</th><th>Title</th><th>Topics</th><th>No. of Lectures</th></tr>
<tr><td>1.</td><td>Introduction to electrical circuits & networks</td><td>• Basic concepts: voltage, current, R, L, C
• Kirchoff's laws, Ohm's law, Superposition
• Circuit Analysis — Mesh & Nodal Analysis
• Lab practical on R-C circuits*</td><td>4</td></tr>
<tr><td>2.</td><td>Semiconductor electronics</td><td>• Semiconductor basics, diodes, rectifiers
• BJT transistors, inverters, CE amplifiers
• Lab practical on diode and transistor circuits*</td><td>5</td></tr>
<tr><td>3.</td><td>Operational Amplifiers (Op-Amp)</td><td>• Differential Amplifiers
• Input & output impedance, CMRR, feedback.
• Inverting & non-inverting amplifiers
• Lab practical on basic op-amp circuits*</td><td>5</td></tr>
<tr><td>4.</td><td>Op-Amp Applications</td><td>• Active filters, multiple-feedback filters
• Instrumentation amplifiers
• Lab practical and hands-on demonstration on recording ECG, EMG, and EEG signals*</td><td>6</td></tr>
<tr><td colspan="4">Mid-Semester</td></tr>
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5.	Introduction to Signals & Systems	• Biological Systems & Bio signals • Examples of electrical, mechanical, thermal bio signals • Continuous & discrete-time signals • Sampling frequency, bandwidth, Nyquist Rate and SNR measurements	4
6.	Basic Signal Processing	• Measurement of signal properties: mean, variance, power, ensemble averaging. • Correlation & Covariance • Programming in MATLAB	4
7.	Frequency Analysis of	• Discrete Fourier Transform (DFT), FFT • Power Spectrum estimation • MATLAB-based examples	4
8.	Discrete-Time Systems & Digital Filters	• Discrete-time systems & its types • Analysis of I-Tl systems using Convolution • Transfer function, magnitude & phase response. • Introduction to filtering, filter types & characteristics • Design of Digital Filters using MATLAB	8
		Total	40

(*Prefabricated circuits on breadboards/PCBs will be provided to students in order to reduce the time required for laboratory experiments. Demonstrations will be conducted using off-the-shelf/commercial systems)

Short Summary:

This course aims to impart knowledge on fundamental topics in electronics and signal processing and familiarize students will real-world applications. The course content is relevant for students interested in pursuing a career in interdisciplinary fields such as Biomedical Engineering, Neuroscience and Neural Engineering, as well as Rehabilitation Engineering.

Recommended Books: Textbooks, Reference books

- Electronics for Biologists by Timothy Gawne, Ballacourage Books

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Hands-On Electronics: A Practical Introduction to Analog and Digital Circuits by Daniel Kaplan and Christopher White, Cambridge University Press
Electronic Principles 9th Edition by Albert Malvino, David Bates, Patrick Hoppe, McGraw Hill
Bio signal and Medical Image Processing 3rd Edition by John Semmlow and Benjamin Griffel, CRC Press
Signal Processing for Neuroscientists by Wim van Drongelen, Academic Press

Digital Signal Processing: principles, algorithms, and applications 4th Edition by John Proakis and Dimitris Manolakis, Pearson Education
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<tr>
<td>BSE666</td>
<td>Computational Biomedical Engineering</td>
<td>3-0-0-0 (9)</td>
<td>
<u>Course objectives:</u>
The goal of this course is to introduce students to computational approaches to biomedical problems. The course will introduce the students to state-of-the-art computational techniques, applications of computational tools, and instil an understand of how biological concepts and computational methods can be integrated to address complex biomedical problems. The overarching goal of the course is to provide students with a deep understanding of how computational modelling and simulation can be used to create personalized virtual representations of biological systems for various biomedical applications. After completing this course, the students are expected to have the knowledge and skills necessary to develop, analyse, and use technologies such as digital twins in healthcare.
<table>
<tr><th>S. No.</th><th>Topics</th><th>Number of Lectures</th></tr>
<tr><td>1</td><td>Signal and image processing algorithms, Spectra and correlations, computational modeling and simulation (physics-based models, solving PDEs, basics of finite element methods, inverting large matrices)</td><td>15</td></tr>
<tr><td>2</td><td>Linear and non-linear regression, basics of Optimization, inverse modeling, optimization algorithms and software libraries</td><td>12</td></tr>
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			<table><tr><td>3</td><td>Basics of Machine Learning, data-driven models, regression, neural networks,</td><td>10</td></tr><tr><td>4</td><td>Case studies: digital twins in healthcare, forward and inverse models, personalization, arterial networks, blood pumps, X-ray and MRI</td><td>3</td></tr></table> **Short summary for the course booklet:** This course introduces students to computational aspects of biomedical engineering, covering state-of-the-art techniques and integrating biological concepts with computational methods to address complex biomedical issues. By focusing on computational modelling, simulation, and personalized virtual representations, students will gain the skills to develop and utilize technologies such as digital twins in healthcare applications. **References**: • Iserles, A. (2009). A first course in the numerical analysis of differential equations (No. 44). Cambridge University Press. • Modelling and Simulation in Biomedical Engineering: Applications in Cardiorespiratory Physiology 1st Edition (2011) by Willem van Meurs • Computational Modelling and Simulation Examples in Bioengineering (IEEE Press Series on Biomedical Engineering), Wiley, 2021 • Bishop, C.M. Pattern recognition and Machine learning, Springer, 2007. • Kochenderfer, Mykel J., and Tim A. Wheeler. Algorithms for optimization. MIT Press, 2019
BSE667	Healthcare Ventures & Enterprises		Objectives: The course will expose students to the world of healthcare innovation. The emphasis will be on showing how real innovation is made possible by identifying 'problem statements' that are derived by working closely with clinicians, and observing customer behaviour. Students will also learn to appreciate how fundamental principles of innovation are universally relevant, *whether at a start-up, or as a new unit in a big company.* This course is in consonance with the recently-adopted 'Student Entrepreneurship Policy'; it prepares students for entrepreneurship through structured learning and hands-on experience
BSE668	Healthcare Ventures & Enterprises		Objectives: This is the second course that will expose students to the world of healthcare innovation. Having worked closely with clinicians, and observed customer behaviour in the

			previous course, students will now convert their updated hypotheses and ideas into prototypes- and where possible- experience the full journey of building a 'minimum viable product' (MVP). Students will also get exposed to key business concepts, and understand what it takes to be market-ready & investor-ready . They will continue to see how fundamental principles of innovation are universally relevant, *whether at a start-up, or as a new unit in a big company.* This course is in consonance with the recently-adopted 'Student Entrepreneurship Policy'; it prepares students for entrepreneurship through structured learning and hands-on experience
BSE676	Molecular Biophysics	3-0-0-0 (9)	The primary objective of this course is to provide postgraduate students with a strong and coherent foundation in molecular biophysics, emphasizing how physical principles govern the structure, stability, interactions, and functional dynamics of biological macromolecules. The course aims to help students view biomolecules such as proteins and nucleic acids not only as chemical entities, but also as dynamic physical systems shaped by thermal fluctuations and noncovalent forces. Through biologically relevant examples, students will gain an understanding of key processes, including protein folding and misfolding, molecular recognition, binding equilibria, cooperativity, and allosteric regulation. The course also aims to train students to interpret and critically evaluate experimental data obtained from widely used biophysical techniques. In addition, students will be introduced to modern computational tools, including molecular docking, molecular dynamics simulations, and AI-based structure-prediction methods, enabling them to appreciate how computational and experimental approaches complement each other in contemporary biomolecular research. Overall, the course is designed to strengthen conceptual understanding, develop quantitative intuition, and prepare students to apply molecular biophysics approaches in interdisciplinary research areas, including biology, biotechnology, medicine, and drug discovery
BSE673	Model Organisms in Biology	3-0-0-0 (9)	Model organisms have played a pivotal role in understanding the basic principles of biology. Due to evolutionary conservation of biological processes, the discoveries made in these organisms are often extended to different species, including humans. They have laid the foundation for many biological principles and translational research. The course will primarily discuss the original research articles related to landmark discoveries in different areas of biology. The significance of using different model organisms, including but not limited to Drosophila melanogaster (fly), yeast, bacteria, Caenorhabditis elegans (worms), zebrafish, mice etc will be discussed. The present day implications of these discoveries in both basic science and translational advancement will be highlighted.

			Learning outcome: The course content is intended to teach students the foundational stories of different areas of biology. It will highlight how basic biology puzzles were solved using model systems. As the course discussions will primarily consist of research articles, it is expected that it will enable students to i) select an exciting biological problem for their research, ii) select the right model organisms, tools, and techniques to carry out the research and iii) communicate the significance of their discovery to both scientific and non-scientific community.
BSE675	Experiential learning about medical devices and diagnostics-II	0-0-9-0-(9)	This course aims to deliver a practical exposure to the use of engineered products used in healthcare delivery to familiarize the students with the engineering and product space for biomedical engineering. The course will help students to understand the following topics: the current state-of-the art biomedical devices and diagnostics used in different clinical practices; the gaps and issues faced by doctors in such practices and finally thinking about possible ways of solving such gaps using concepts combining different engineering domains.
BSE674	Experiential learning about medical devices and diagnostics-I	0-0-9-0-(9)	This course aims to deliver a practical exposure to the use of engineered products used in healthcare delivery to familiarize the students with the engineering and product space for biomedical engineering. The course will help students to understand the following topics: the current state-of-the art biomedical devices and diagnostics used in different clinical practices; the gaps and issues faced by doctors in such practices and finally thinking about possible ways of solving such gaps using concepts combining different engineering domains.