Indian Institute of Technology Jodhpur

# B.Tech. in Bioengineering
# Curriculum Structure

॥ त्वं ज्ञानमयो विज्ञानमयोऽसि ॥

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## 1. Introduction

Every life form, beginning from microscopic bacteria to multicellular organisms, can be considered as a system that has been perfected over millennia by Evolution. Beginning from thermodynamically efficient cellular processes to the molecular motors driving the bacterial flagella, each product of evolution is an optimized engineering design that can be translated into real-life applications across disciplines. Today's interdisciplinary biology is well complemented by engineering domains including electronics, computer science, mechanics, and materials engineering. Computational biology, for example, permits solving biology problems using statistical, artificial intelligence and machine learning approaches. Extensive use of computational biology is essential in data-driven approaches including Genomics, Proteomics, Transcriptomics, and Metabolomics. This amalgamation of biology and computer science has transformed the landscape of the infectious and non-infectious diseases research allowing the development of new diagnostic and therapeutic modalities. Today's disease diagnosis is much more specific and sensitive, thanks to biosensors, which have far-reaching applications not only in healthcare but also in the environment, energy, and agriculture. Some applications include in-situ biosensors for human biochemical parameters, environmental contaminants, soil moisture, soil physicochemical parameters, etc. Advances in Biology have not only permitted the early diagnosis of disease but have also contributed abundantly to therapeutic interventions. It is now possible to intervene in diseases taking a multi-pronged approach, including the development of new drugs; production of recombinant therapeutics; development of implantable sensors, control systems; and editing genetic defects. Similarly, synthetic biology and genome editing tools have enabled the development of industrially important organisms for biofuel production as well as environmental remediation. Together, these technologies have significantly contributed to extending the healthy lifespan of the human race and have shown promise towards food, water, and energy security. In other words, bioengineering as a discipline has evolved to a great extent in last couple of decades and now demands a different intellectual outlook and scientific understanding for its further study. Therefore, an undergraduate academic program in Bioengineering should reflect this rapid evolution of the discipline, underlying scientific and technological advancements and interdisciplinary cross talk so as to capture the mind of the next generation.

The Indian Institute of Technology Jodhpur is committed to achieving excellence in shaping the young minds of tomorrow with a unique blend of teaching techniques and hands-on research-based learning. The Institute works towards the holistic development of students allowing them to be able to assume leadership positions in Industry, Academia, and Entrepreneurial ventures. The Department of Bioscience & Bioengineering is committed to this goal and has developed academic programs that are interdisciplinary in nature and include a substantial component of courses from other science and engineering Departments. The Department aspires to produce Graduates, who can develop solutions to tackle local and global problems related to healthcare, energy, environment, water, and food.

## 2. Objectives of the program

The B. Tech. program in Bioengineering at IIT Jodhpur aims to equip our graduates with in-depth knowledge and hands-on training in areas that will be relevant for the next decade. The curriculum aims to impart knowledge and skills to budding engineers to address future challenges. This includes innovative pedagogy and highly interdisciplinary approach towards problem-solving.

The key objectives of this program are:
(i) To provide a strong foundational understanding of concepts in biology, engineering, mathematics, and allied sciences, enabling students to approach bioengineering problems through interdisciplinary lenses.
(ii) To stimulate the development of disruptive technologies and futuristic research in the domains of healthcare, energy, and the environment

## 3. Expected Graduate Attributes

Graduates of the B. Tech program in Bioengineering will:

(i) be able to choose, design, develop, and implement engineering solutions to solve technical problems in bioscience and bioengineering using trans-disciplinary knowledge and skill set.
(ii) be able to think out-of- the box to solve critical challenges and be able to innovate novel technologies for affordable healthcare, clean energy, sustainable agriculture, and safe environment.
(iii) be able to work effectively as a member and leader in a multi-disciplinary team.
(iv) have the requisite skills and knowledge to be bio-entrepreneurs.
(v) be able to effectively communicate biological/ bioengineering problems and solutions within the professional sphere and with the society at large.
(vi) be committed to high ethical standards in professional and social practices.

## 4. Learning Outcomes

Graduates of the B. Tech program in Bioengineering:

(i) Will have a comprehensive understanding of the essential concepts of bioscience and bioengineering encompassing cell and molecular biology, physiology, immunology, microbiology, genetics, genetic engineering, multi-omics, computational and systems biology.
(ii) Will gain trans-disciplinary knowledge and skill sets pertaining to biosensors, bioimaging, biomedical device development, biomaterials engineering and drug discovery.
(iii) Will be able to design, develop and implement technological solutions related to affordable healthcare, clean energy, sustainable agriculture and safe environment adopting a trans-disciplinary approach.
(iv) Will gain a strong understanding of the fundamentals of basic science, engineering, designing, computing and will get hands-on training on cutting edge technologies.
(v) Will be able to apply the knowledge of artificial intelligence and machine learning in solving complex biological problems.
(vi) Will learn to think critically to solve complex problems pertaining to bioscience and bioengineering.
(vii) Will develop communication skills (verbal and written) to communicate effectively in the professional and social sphere.
(viii) Will be committed to high ethical standards.
(ix) Will gain the knowledge and skills required to be an innovator-entrepreneur.

## 5. New skill sets targeted

Ability to
(i)design and develop AI-based technologies in healthcare, environment, and agriculture.
(ii) analyze spatial complexity of living systems using imaging and image processing.
(iii) analyze and solve complex problems in the diverse fields of bioscience and bioengineering using omics and systems biology.
(iv) integrate multidisciplinary technologies for the development of lab-on-chip devices, biosensors, and other smart devices.
(v) integrate omics data to quantitative structure-activity relationship for drug discovery and development
(vi) design and develop smart biomaterials using micro- and nano-scale technologies
(vii) design novel strategies for tissue engineering application
(viii) design new therapeutic molecules in silico.

## 6. Topic clouds and Mapping of Topic clouds with proposed courses

**Table 1** Topics and Mapping of Topic with Courses

| Area | Topics | Category (Core/ Techniques /Systems) | Course (IE/IS/PC/PE) |
|---|---|---|---|
| **Omics** | • Cells and organelles<br>• Replication<br>• Transcription and translation<br>• Cell cycle | Core and Techniques | Concepts & Dynamics: Molecular Cell Biology (PC 4th)<br>**Pre/Co-Req:** Biochemistry (PC 3rd) |
| | • DNA, RNA, Proteins, metabolites<br>• Metabolic pathways<br>• Biochemical analysis<br>• Enzymes | Core and Techniques | Biochemistry (PC 3rd)<br>**Pre/Co-Req:** None |
| | • Inheritance<br>• Polymerase chain reaction<br>• Gene therapy | Core, Techniques and Systems | Genetics & Gene Manipulation (PC 5th)<br>**Pre/Co-Req:** None |
| | • Genomics<br>• Transcriptomics<br>• Proteomics<br>• Metabolomics<br>• Mass Spectroscopy | Core and Techniques | Introductory Omics (PC 6th)<br>**Pre/Co-Req:** None |
| | • Microbial communities<br>• Metagenome library<br>• Metagenome sequencing | Core and Techniques | Microbiomes and Metagenomics (PE)<br>**Pre/Co-Req:** None(PC 3rd) |
| | • Biological networks and pathways<br>• Data modeling<br>• Multi-omics integration | Systems | Computational methods for multi-omics (PE)<br>**Pre/Co-Req:** Introductory Omics (PC 6th) |
| | • Omics analysis algorithms<br>• DNA microarray<br>• Data normalization<br>• Data visualization | Core, Techniques and Systems | Microarray data analysis (PE)<br>**Pre/Co-Req:** None |
| | • Neural network<br>• Deep learning models<br>• Deep generative models<br>• Representation learning | Systems | Deep Learning (PC 6th)<br>(From CS)<br>**Pre/Co-Req:** Introduction to machine Learning (PC 3rd) |
| **Biomaterials Engineering** | • Biocompatibility and Biodegradability<br>• Biomaterial characterization<br>• Implants | Core, Techniques and Systems | Biomaterials Engineering (PC 6th)<br>**Pre/Co-Req:** None |

| | | | |
|---|---|---|---|
| | • Cell adhesion on substrate<br>• Biofilm formation<br>• Surface modification | Core and Techniques | Cell-material Interactions (PE)<br>**Pre/Co-Req:** Biomaterials Engineering (PC 6th) |
| | • Tissue repair and regeneration<br>• Scaffolds<br>• Animal cell culture | Core, Techniques and Systems | Tissue Engineering (PE)<br>**Pre/Co-Req:** Biomaterials Engineering (PC 6th) |
| | • Sustained, on-demand and targeted delivery<br>• Drug loading and drug release<br>• Pharmacokinetics and pharmacodynamics | Core, Techniques and Systems | Therapeutic delivery systems (PE)<br>**Pre/Co-Req:** Biomaterials Engineering (PC 6th) |
| | • Human locomotion<br>• Tissue mechanics<br>• Viscoelasticity | Core | Principles of Biomechanics (PE) (From ME)<br>**Pre/Co-Req:** Biomaterials Engineering (PC 6th) |
| | • 3D printing<br>• Field deposition model (FDM)<br>• Selective laser sintering<br>• Stereolithography | Techniques and Systems | Additive manufacturing (PE) (From ME)<br>**Pre/Co-Req:** Biomaterials Engineering (PC 6th) |
| | • Bio-transport<br>• Hemodynamics<br>• Momentum conservation<br>• Bio-rheology | Core and Systems | Bio-transport phenomena (PE) (From BSBE, CHE, ME)<br>**Pre/Co-Req:** None |
| **Computational & Systems Biology** | • Bioinformatics<br>• Bio computation<br>• Mathematical modelling | Core and Techniques | Computational and System Biology (PC 5th)<br>**Pre/Co-Req:** Concepts & Dynamics: Molecular Cell Biology (PC 4th) |
| | • Numerical Methods for PDE<br>• Ordinary Differential Equations | Core and Techniques | Mathematical Biology (PE) (From MA)<br>**Pre/Co-Req:** Computational Biology (PC 5th) |
| | • Methods and method development in computational biology | Core, Techniques and Systems | Algorithms in biology (PE)<br>**Pre/Co-Req:** None |
| | • Biosystems<br>• Boundary conditions | Core and Techniques | Modelling biological systems (PE)<br>**Pre/Co-Req:** None |

| | | | |
|---|---|---|---|
| | • Experiment design<br>• validation | Core | Design of experiments (PE)(From MA)<br>**Pre/Co-Req:** None |
| **Bioimaging** | • Optical microscopy<br>• Fluorescence microscopy<br>• Digital imaging<br>• Medical imaging | Core, Techniques and Systems | Bioimaging (PC 6th) (From CS/EE)<br>**Pre/Co-Req:** None |
| | • Fourier transform theory<br>• Filtering<br>• Image enhancement | Techniques and Systems | Digital Image processing (PE) (From CS/EE)<br>**Pre/Co-Req:** Bioimaging (PC 6th) |
| | • Image reconstruction<br>• Image restoration<br>• Deep learning<br>• 2D, 3D registration | Techniques and Systems | Bio-image computing (PE) (From CS)<br>**Pre/Co-Req:** Bioimaging (PC 6th) |
| | • Electron scattering and diffraction<br>• Scanning and transmission<br>• Immuno and cryo-electron microscopy | Techniques and Systems | Electron microscopy for biology (PE) (From CY)<br>**Pre/Co-Req:** Bioimaging (PC 6th) |
| **Biosensors** | • Impedimetric, voltammetric, amperometric, electrical, optical sensors<br>• Selectivity and sensitivity | Core, Techniques and Systems | Biosensors (PC 5th) (From EE)<br>**Pre/Co-Req:** Biochemistry (PC 3rd) |
| | • Genetic circuits for biosensors<br>• RNA based sensors<br>• Reporter genes | Techniques and Systems | Whole cell based biosensors (PE)<br>**Pre/Co-Req:** None |
| | • Lithography<br>• Micromachining<br>• MEMS | Techniques and Systems | Microsystems Fabrication Technology (PE)(From EE)<br>**Pre/Co-Req:** None |
| | • Aptamer sensor<br>• Cation-selective sensor<br>• Dendrimer based sensor | Techniques and Systems | Chemosensors (PE) (From CY)<br>Pre/Co-Req: Biosensors (PC 5th) |
| **Microbial systems for sustainable development** | • Microbial phylogeny<br>• Metabolism<br>• Microbial growth<br>• Applied microbiology | Core and Systems | Microbiology (PC 3rd)<br>**Pre/Co-Req:** None |
| | • Wastewater treatment<br>• Bio-geo chemical cycling | Systems | Microbial remediation and Environmental |

| | | | |
|---|---|---|---|
| | • Solid waste management<br>• In situ and ex situ bioremediation | | Biotechnology (PE)<br>**Pre/Co-Req:**<br>Microbiology (PC 3rd) |
| | • Probiotic, symbiotic, plant –microbe interaction<br>• Fortified food<br>• Nutritional supplements<br>• Single cell protein | Systems | Microbes in food and sustainable agriculture (PE)<br>**Pre/Co-Req:**<br>Microbiology (PC 3rd) |
| | • Solid , liquid, gaseous biofuels<br>• Engineering microbes for biofuel production<br>• Different generations of biofuels and sustainability analysis | Systems | Bioenergy (PE)<br>**Pre/Co-Req:**<br>Microbiology (PC 3rd)<br>Biochemistry (PC 3rd) |
| **Drug design and Development** | • Protein-protein interaction<br>• Protein crystallography<br>• Protein folding | Core and Techniques | Biophysics and Structural Biology (PC 6th)<br>**Pre/Co-Req:**<br>Biochemistry (PC 3rd) |
| | • Drug targets<br>• Computer-aided drug design<br>• Virtual screening | Core, Techniques and Systems | Principles of Drug discovery (PE)<br>**Pre/Co-Req:**<br>Biophysics and Structural Biology (PC 5th)<br>Biochemistry (PC 3rd) |
| | • Pharmacophore<br>• Drug metabolism<br>• Chiral drug molecule<br>• Antibiotics and antiviral | Core and Techniques | Medicinal chemistry (PE) (CY)<br>**Pre/Co-Req:** None |
| | • Virus life cycle<br>• Viral immunity<br>• Antiviral drugs | Core, Techniques and Systems | Viral infection and antiviral drug development (PE)<br>**Pre/Co-Req:** None |
| **Fundamental courses** | • Innate immunity<br>• Inflammatory response<br>• Cell signaling<br>• B- and T-cell lymphocytes<br>• Clinical immunology | Core and Techniques | The Human Immune System: Mechanisms to Detect, Defend and Attack (PC 4th)<br>**Pre/Co-Req:** None |
| | • Membrane transportation<br>• Muscle mechanics<br>• Membrane potential<br>• Cardiovascular, pulmonary, renal | Core | The Human Machine for Engineers: Quantitative Physiology (PC 5th)<br>**Pre/Co-Req:** None |

| | | | |
|---|---|---|---|
| | physiology | | |

## 7. Course Categories, credit distribution and Credit Structure of B. Tech Programmes

**Table 2** Proposed Course Categories and credit distribution in the proposed B. Tech Programmes

| S.N. | Course Type | Course Category | Regular B.Tech. | |
|---|---|---|---|---|
| | | | Credit | Total |
| 1 | Institute Core (I) | Engineering (IE) | **34** | **69** |
| | | Science (IS) | 16 | |
| | | Humanities (IH) | 12 | |
| 2 | Programme Linked (L) | Science (LS) | 7 | |
| 3 | Programme Core (P) | Programme Compulsory (PC) | **50** | **71** |
| | | Programme Electives (PE) | **18** | |
| | | B.Tech. Project (PP) | 3 | |
| 4 | Open (O) | Open Electives (OE) | 10 | **10** |
| 5 | Engineering Science (E) | Engineering Science Core (EC) | 0 | **0** |
| | | Engineering Science Elective (EE) | 0 | **0** |
| | | | **Total Graded** | **150** |
| 6 | Non-Graded (N) | Humanities (NH) | 6 | **15** |
| | | Engineering (NE) | 3 | |
| | | Design/Practical Experience (ND) | 6 | |
| | | **Total Graded + Non-Graded** | | **165** |

## 8. Credit Structure of B. Tech Programmes

**Table 3.** Credit Structure for B. Tech Programmes (Up 6000 Level)

| Type | L-T-P | Distribution of contact and beyond contact hours | | | Total Credits (TC=TH/3) |
|---|---|---|---|---|---|
| | | Contact Hours (CH) | Beyond Contact Hours (BCH) | Total Hours (TH) | |
| 1 hour of Lecture | 1-0-0 | 1 hr | 2 hr | 3 hr | 1 |
| 1 hour of Tutorial | 0-1-0 | 1 hr | 2 hr | 3hr | 1 |
| 1 hour of Lab/Project | 0-0-1 | 1 hr | 0.5 hr | 1.5 hr | 0.5 |

[#]Contact hour for project refers to the involvement of students in the laboratory, discussion, etc.

## 9. List of Programme Compulsory Courses

**Table 4** Programme Compulsory Courses

| S. No | Course Name | Semester | L-T-P | Contact Hours | Credit |
|---|---|---|---|---|---|
| 1 | Biochemistry | III | 3-0-0 | 3 | 3 |
| 2 | Microbiology | III | 3-0-2 | 5 | 4 |
| 3 | Data Structures and Algorithms | IV | 3-0-2 | 5 | 4 |
| 4 | Concepts and Dynamics: Molecular Cell Biology | IV | 2-0-2 | 4 | 3 |
| 5 | The Human Immune System: | IV | 3-0-0 | 3 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| | Mechanisms to detect, defend and Attack | | | | |
| 6 | Biochemistry Laboratory | IV | 0-0-2 | 2 | 1 |
| 7 | Computational and Systems Biology | V | 3-0-2 | 5 | 4 |
| 8 | The Human Machine for Engineers: Quantitative Physiology | V | 3-0-0 | 3 | 3 |
| 9 | Biophysics and Structural Biology | VI | 3-0-1 | 4 | 3.5 |
| 10 | Genetics and Gene manipulation | V | 3-0-2 | 5 | 4 |
| 11 | Biosensors | V | 3-0-2 | 5 | 4 |
| 12 | Bioimaging | VI | 3-0-0 | 3 | 3 |
| 13 | Introductory Omics | VI | 3-0-0 | 3 | 3 |
| 14 | Biomaterials Engineering | VI | 3-0-0 | 3 | 3 |
| 15 | Deep Learning | VI | 3-0-3 | 6 | 4.5 |
| | | | | **Total** | **50** |

## 10. Area-wise Programme Elective Courses

**Table 5** Stream-wise Programme Electives Courses

| S. No. | Stream | Courses | L-T-P | Credit |
|---|---|---|---|---|
| 1 | Omics | - Microbiomes and metagenomics (level 4)<br>- Computational methods for multi-omics (level 4)<br>- Microarray data analysis (level 4) | 3-0-0<br>3-0-2<br>3-0-0 | 3<br>4<br>3 |
| 2 | Biomaterials Engineering | - Cell-material interactions (level 3)<br>- Tissue engineering (level 4)<br>- Therapeutic delivery systems (level 4)<br>- Principles of biomechanics (level 4; from ME)<br>- Additive manufacturing (level 7; from ME)<br>- Bio-transport phenomena (level 4) | 3-0-0<br>3-0-0<br>2-0-0<br>3-0-0<br>3-0-0<br>3-0-0 | 3<br>3<br>2<br>3<br>3<br>3 |
| 3 | Computational and Systems Biology | - Mathematical biology (level 7; from MA)<br>- Algorithms in biology (level 6)<br>- Modelling of biological systems (level 3)<br>- Design of experiments (level 4; from MA) | 3-0-0<br>3-0-0<br>2-0-2<br>3-0-0 | 3<br>3<br>3<br>3 |
| 4 | Bioimaging | - Electron microscopy for biology (level 4/6; from CY)<br>- Special topics on biomedical imaging (level 4)<br>- Digital Image processing (level 4; from CS)<br>- Bio-image computing (level 7; CS) | 3-0-0<br>3-0-0<br>3-0-0 | 3<br>3<br>3 |
| 5 | Biosensors | - Whole cell based biosensors (level 4)<br>- Special topics in biosensors (level 4)<br>- Microsystems fabrication technology (level 7; from EE)<br>- Chemosensors (level 6; from CY) | 3-0-0<br>3-0-0<br>3-0-0<br>3-0-0 | 3<br>3<br>3<br>3 |
| 6 | Microbial systems for sustainable | - Microbial remediation and environmental biotechnology (level 4)<br>- Microbes in food and sustainable agriculture | 3-0-0<br>3-0-0 | 3<br>3 |

| | | | | |
|---|---|---|---|---|
| | development | (level 4)<br>- Bioenergy (level 4) | 3-0-0 | 3 |
| 7 | Drug design and development | - Principles of drug discovery (level 4)<br>- Medicinal chemistry (level 4)<br>- Viral infection and antiviral drug development (level 4) | 3-0-0<br>3-0-0<br>3-0-0 | 3<br>3<br>3 |

## 11. Specialization to be offered by the department

**Table 6** Specialization and courses

| S. No. | Name of Specialization | Specialization Core (8 credits) | Specialization Elective (12 Credits) |
|---|---|---|---|
| 1 | **Therapeutic engineering and drug discovery** | - Modern approaches of drug designing (3-0-0)<br>- Introduction to Precision Medicine (3-0-0)<br>- AI based drug discovery (2-0-0) | - Principles of drug discovery (3-0-0)<br>- Medicinal chemistry (3-0-0)<br>- Viral infection and antiviral drug development (3-0-0)<br>- Antimicrobial drugs and drug resistance (2-0-0)<br>- Anticancer drug discovery and development (3-0-0)<br>- Modern approaches for immunotherapy (3-0-0)<br>- Novel Drug Delivery Systems (3-0-0)<br>- Theranostic Systems (3-0-0)<br>- Industry collaborated project 4 credit (0-0-6) x 1 |
| 2 | **Microbial systems engineering** | - Engineering Microbes (3-0-0)<br>- Bioprocess Engineering and Fermentation (3-0-0)<br>- Mathematical modelling of microbes (1-0-2) | - Microbial nanotechnology (3-0-0)<br>- Metabolic engineering for biofuels (2-0-0)<br>- Microbial remediation and environmental biotechnology (3-0-0)<br>- Microbes in food and sustainable agriculture<br>- Bioenergy (3-0-0)<br>- Soil microbiome & microbial technology (2-0-0)<br>- Biofilms: Bacterial communities (3-0-0)<br>- Gut microbiomes in health and diseases (3-0-0)<br>- Downstream processing (3-0-0)<br>- Industry collaborated project 4 credit (0-0-6) x 1 |

## 12. Curriculum of B.Tech. Bioengineering (Regular)

**Table 7a.** Curriculum of B.Tech in BB

| Cat | Course | LTP | CH | NC | GC | Cat | Course | LTP | CH | NC | GC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **I Semester** | | | | | | **II Semester** | | | | |
| IE | Engineering Mechanics | 2-1-0 | 3 | - | 3 | IE | Introduction to Electrical Engineering | 3-0-2 | 5 | - | 4 |
| IS | Chemistry | 3-0-0 | 3 | - | 3 | IE | Introduction to Computer Science | 3-0-2 | 5 | - | 4 |
| IS | Physics | 3-0-0 | 3 | - | 3 | IE | Introduction to Bioengineering | 3-0-2 | 5 | - | 4 |
| IS | Chemistry Lab | 0-0-2 | 2 | - | 1 | | | | | | |
| IS | Physics Lab | 0-0-2 | 2 | - | 1 | | | | | | |
| IS | Mathematics I | 3-1-0 | 4 | - | 4 | IS | Mathematics II | 3-1-0 | 4 | - | 4 |
| IE | Engineering Visualization | 0-0-2 | 2 | - | 1 | IE | Engineering Realization | 0-0-2 | 1 | - | 1 |
| NE | Engineering Design I | 0-0-2 | 2 | 1 | - | NE | Engineering Design II | 0-0-2 | 2 | 1 | - |
| NH | Communication Skill I | 0-0-2 | 2 | 1 | - | NH | Communication Skill II | 0-0-2 | 2 | 1 | - |
| NH | Social Connect and responsibilities I | 0-0-1 | 1 | 0.5 | - | NH | Social Connect and responsibilities II | 0-0-1 | 1 | 0.5 | - |
| NH | Performing Arts I /Sports I | 0-0-1 | 1 | 0.5 | - | NH | Performing Arts II/Sports II | 0-0-1 | 1 | 0.5 | - |
| | **Total** | **11-2-12** | **25** | **3** | **16** | | **Total** | **12-1-14** | **27** | **3** | **17** |
| | **III Semester** | | | | | | **IV Semester** | | | | |
| LS | Probability, statistics and stochastic process | 3-1-0 | 4 | - | 4 | IE | Materials Science & Engineering F1: Materials selection, F2:Structure of materials, F3:Polymers | 3 × (1-0-0) | 3 | - | 3 |
| IE | Signals and Systems | 3-1-0 | 4 | - | 4 | IE | Thermodynamics | 3-1-0 | 4 | - | 4 |
| IE | Introduction to Machine Learning | 3-0-2 | 5 | - | 4 | PC | Data Structure and Algorithm | 3-0-2 | 5 | - | 4 |
| PC | Biochemistry | 3-0-0 | 3 | - | 3 | PC | Concepts & Dynamics: Molecular Cell Biology | 2-0-2 | 4 | - | 3 |
| PC | Microbiology | 3-0-2 | 5 | - | 4 | PC | The Human Immune System: Mechanisms to Detect, Defend and Attack | 3-0-0 | 3 | - | 3 |
| | | | | | | PC | Biochemistry Laboratory | 0-0-2 | 2 | - | 1 |
| LS | Nanoscience | 3-0-0 | 3 | - | 3 | IH | Humanities I | 3-0-0 | 3 | - | 3 |
| NE | Intro. To Profession | 0-0-2 | 2 | 1 | | | | | | | |
| | **Total** | **18-2-6** | **26** | **1** | **22** | | **Total** | **17-1-6** | **24** | **-** | **21** |
| | **V Semester** | | | | | | **VI Semester** | | | | |
| PC | Programme Compulsory | | | | | PC | Programme Compulsory | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Computational and System Biology | 3-0-2 | 5 | - | 4 | | Introductory Omics | 3-0-0 | 3 | - | 3 |
| | The Human Machine for Engineers: Quantitative Physiology | 3-0-0 | 3 | - | 3 | | Biomaterials Engineering | 3-0-0 | 3 | - | 3 |
| | | | | | | | Biophysics & Structural Biology | 3-0-1 | 4 | - | 3.5 |
| | | | | | | | Deep Learning | 3-0-3 | 6 | - | 4.5 |
| | Genetics and Gene Manipulation | 3-0-2 | 5 | - | 4 | | Bioimaging | 3-0-0 | 3 | - | 3 |
| | Biosensors | 3-0-2 | 5 | - | 4 | | | | | | |
| | Program Elective -I | 3-0-0 | 3 | | 3 | | | | | | |
| IH | Humanities II | 3-0-0 | 3 | - | 3 | PE | Program Elective -II | 3-0-0 | 3 | | 3 |
| NH | Professional Ethics I | 0-1-0 | 1 | 1 | - | NH | Professional Ethics II | 0-1-0 | 1 | 1 | - |
| | **Total** | **18-1-6** | **25** | **1** | **21** | | **Total** | **18-1-4** | **23** | **1** | **20** |
| | **VII Semester** | | | | | | **VIII Semester** | | | | |
| PP | B. Tech. Project | 0-0-6 | 6 | - | 3 | IH | Humanities IV | 3-0-0 | 3 | - | 3 |
| PE / OE | Programme Elective-III &IV | 6-0-0 | 6 | - | 6 | PE / OE | Programme Elective V & VI | 6-0-0 | 6 | - | 6 |
| | Open Electives - I&II | 6-0-0 | 6 | | 6 | | Open Electives -III & IV | 4-0-0 | 4 | | 4 |
| IH | Humanities III | 3-0-0 | 3 | | 3 | | | | | | |
| IS | Environmental Science | 2-0-0 | 2 | - | 2 | | | | | | |
| | **Total** | **17-0-6** | **23** | **-** | **20** | | **Total** | **13-0-0** | **13** | **-** | **13** |
| | | | | | | | | | | **9** | **150** |
| | | | | | | | | | | **6** | **-** |
| | | | | | | | | | | **15** | **165** |

## Distribution of courses in 7th & 8th Semester for specialization

| | VII Semester | | | | | | VIII Semester | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PP | B. Tech. Project | 0-0-6 | 6 | - | 3 | IH | Humanities IV | 3-0-0 | 3 | - | 3 |
| PE/ OE | Programme Elective-III &IV | 6-0-0 | 6 | - | 6 | PE / OE | Programme Elective V & VI | 6-0-0 | 6 | - | 6 |
| | Open Electives - I&II | 6-0-0 | 6 | | 6 | | Open Electives - III & IV | 4-0-0 | 4 | | 4 |
| | Specialization Elective -I | 3-0-0 | 3 | | 3 | | Specialization Elective -II | 3-0-0 | 3 | | 3 |
| IH | Humanities III | 3-0-0 | 3 | - | 3 | | Specialization Project | 0-0-8 | 8 | | 4 |
| IS | Environmental Science | 2-0-0 | 2 | - | 2 | | | | | | |
| | **Total** | **20-0-6** | **26** | **-** | **23** | | **Total** | **16-0-8** | **24** | **-** | **20** |
| | | | | | | | | | | **9** | **160** |
| | | | | | | | | | | **6** | **-** |
| | | | | | | | | | | **15** | **175** |

## 13. Detailed Course Content of Programme Compulsory Courses

| Title | **Biochemistry** | Number | BBL2XX0 |
|---|---|---|---|
| Department | Biosciences & Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Introduce basic chemical properties of biomolecules and principles governing chemical properties of cell.

**Learning Outcomes**

The students will have the ability to:

1. Understand the structure-function relationship of biomolecules in living system.

**Contents**

*Chemistry of Lipids [5 Lectures]:* Classes of Lipids and their structure; Membrane Lipids and their properties; Bio membrane organization; Sterols; Membrane Transport

*Chemistry of Amino Acids [5 Lectures]:* Amino acid structure and properties; Peptide bond; acid-base chemistry of amino acids; isoelectric point

*Chemistry of Proteins [5 Lectures]:* Protein structure and its importance; Enzymes; Michaelis-Menten kinetics; Enzyme inhibition

*Nucleic acid chemistry [5 Lectures]:* Nucleotides; DNA; RNA; Types of RNA

*Properties of Carbohydrates [4 Lectures]:* Aldoses, Ketoses; Epimers; Mutarotation; Glycosidic bond

*Carbohydrates Chemistry [5 Lectures]:* Common polysaccharides; Reducing & Non reducing sugars; Glycoproteins

*Bioenergetics [5 Lectures]:* Catabolism; Anabolism; Energy Coupling; High energy bonds formation and dissociation

*Metabolic pathways [5 Lectures]:* Glycolysis; TCA, Electron Transport Chain, Calvin cycle, Reverse TCA

*Active learning component [3 Lectures]:* Flipped classroom (group presentations), debates, case studies on applied biochemistry, group discussions, think-pair-share

**Text Book**

1. D. L. Nelson and M. N. Cox, Lehninger Principles of Biochemistry, WH Freeman, (2012), Sixth Edition.

**Reference Book**

1. D. Voet, C. W. Pratt and J. G. Voet, Principles of Biochemistry, Wiley (2012), Fourth Edition.

**Self-Learning Material**

1. S Dasgupta, *Biochemistry I,* NPTEL Course Material, Indian Institute of Technology Kharagpur, http://nptel.ac.in/courses/102105034/

| Title | **Microbiology** | Number | BBL2XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–2 [4] |
| Offered for | B.Tech | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Give students foundational knowledge on the microbial world
2. Provide context as to how these microbes play an essential role in human health and environment

**Learning Outcomes**

The students are expected to have the ability to:

1. Understand the biology of microbes and how they impact life on earth
2. Explore unique structure-function relationships in microbes
3. Analyse the diversity in microbial metabolism and its adaptability to environmental changes

**Contents**

*Introduction:* the ubiquitous micro-organisms*,* microbial cell structure and function, primitive microbes to modern ones; bacteria, fungi, algae, protozoa and viruses (5 lectures)
Microbial nutrition and metabolism: nutritional classification of microbes, basics of metabolism (4 lectures)
*Metabolic pathways*: Overview of catabolic and anabolic pathways and diversity in microbial metabolism (5 Lectures).
*Microbial growth and kinetics:* Different phases of microbial growth, formulation of culture medium, batch and continuous systems (5 lectures)
*Microbial evolution*: systematics and taxonomy, Different classes of bacteria (4 lectures).
*Applications of Microbes*: production of microbial metabolites & industrial Microbiology (4 lectures)
*Microbial ecology*: methods, ecosystems, nutrient cycling (4 lectures)
Environmental Microbiology: bioremediation, role of microbes in wastewater treatment and toxic waste treatment (4 lectures)
Medical Microbiology: interaction of microbes with higher organisms, microbial diseases ( 4 lectures)
Food Microbiology: microbial spoilage of food, prevention of food spoilage, microbial activity in various kinds of foods (3 lectures).

**Laboratory Experiments**

Biosafety, Microscopic examination of microbial world - Staining; Preparation and sterilization of microbial growth media, Microbial motility and Chemotaxis; Cultivating microbes by streak plate and pour plate method. Enumeration of microbes by turbidometry; Microbial enumeration by plate count; Effect of pH and temperature on microbial growth; Safely discarding microbial cultures

**Textbook**

1. R. Y. Stanier, General Microbiology, Macmillan (1999), 5$^{th}$ edition.
2. M. Pelczar, A. Chen, A. Krieg, Microbiology, Tata McGraw Hill Education (2001), 5$^{th}$ edition.
3. R. M. Atlas, R. Bartha Microbial Ecology: Fundamentals and applications, Pearson, (1997), 4$^{th}$ edition.

**Reference Books**

1. Brock, et al., Biology of Microorganisms, Benjamin Cummings (2012), 13$^{th}$ edition
2. D. L. Nelson and M. N. Cox, Lehninger Principles of Biochemistry, WH Freeman, (2012), Sixth Edition.
3. P. Harley, Klein's Microbiology, McGraw Hill Higher Education, (2008), 7th edition,

**Online Course Material**

1. David Schauer, and Edward DeLong. *20.106J Systems Microbiology.* Fall 2006. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

| Title | **Concepts and dynamics: molecular cell biology** | Number | BBL2XX0 |
|---|---|---|---|
| Department | Biosciences & Bioengineering | L-T-P [C] | 2–0–2 [3] |
| Offered for | B. Tech | Type | Compulsory |
| Prerequisite | Biochemistry | | |

**Objectives**

The instructor will:

1. Offer both basic and advance concepts in cellular and molecular biology. The focus of the course is to provide basic understanding of functional machineries of cells.
2. Apprise the students about the dynamics of cellular processes and the regulatory mechanisms involved.

**Learning Outcomes**

The students are expected to:

1. Have the ability to understand the structure and function of cells as a fundamental unit of life.

**Contents**

*Cell organelles and cellular signalling [5 Lectures]:* Structure and function of cellular organelles

*Cellular architecture [5 Lectures]*: Cytoplasmic and nuclear compartment, basic protein structure and cellular signalling

C*ell division and proliferation [5 Lectures]:* Biological principles of mitosis and meiosis; difference of cell
division among prokaryotes and eukaryotes and cell cycle regulation in health and diseases.

*Mechanisms of cell death & diseases [5 Lectures]:* phases and significance linked with apoptosis, morphological and biochemical changes associated with apoptotic cells.

*Regulation of gene expression [4 Lectures]:* DNA replication, prokaryotic & eukaryotic transcription prokaryotic transcription; transcription unit and TATA binding proteins, translation.

*Cellular quality control mechanisms [4 Lectures]:* cellular stress conditions and their effects; protein quality control mechanisms and nucleic acid quality control mechanism.

***Laboratory experiments:*** bacterial transformation, mammalian cells transfections; DNA gel electrophoresis; cell death assays; localization of proteins in different cellular compartments; DNA ligation and digestion; animal cell culture and immunocytochemistry.

**Textbook**

1. B. Alberts., *Molecular Biology of the cell,* Garland Science, 2014, 6th Edition
2. G. Karp and N. L Pruitt., *Cell and Molecular Biology*, John Wiley and Sons, 2016, 8th Edition

**Reference Book**

1. L. Benjamin, *Gene IX*, Jones and Barlett Publishers, 2007, 9th Edition
2. J.D. Watson, *Molecular Biology of the Gene*, Benjamin Cummings, 2007, 6th Edition

**Self-Learning Material**

NPTEL Lectures: on *Molecular Cell Biology*, Devarajan Karunagaran, IIT Madras http://nptel.ac.in/syllabus/102106025/

| Title | **The Human Immune System: Mechanisms to Detect, Defend and Attack** | Number | BBL3XX0 |
|---|---|---|---|
| Department | Biosciences & Bioengineering | L-T-P [C] | 3-0-0 [3] |
| Offered for | B. Tech | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Provide an overview of the human immune system and its components
2. Emphasize immune responses in context of bacterial, viral and parasitic infections.

**Learning Outcomes**

The students are expected to have the ability to:

1. Evaluate applications of immunology in industry
2. Apply their knowledge for design of immunological experiments

**Contents**

Immunology-fundamental concepts and anatomy of the immune system[8 Lectures]: Components of innate and acquired immunity (2lectures); complement and inflammatory responses(2lectures); Innate immune response(1lecture); mucosal immunity(1lectures); antigens and immunogens (2lectures), haptens; Major Histocompatibility complex and disease susceptibility(1lecture).

Immune responses generated by B and T lymphocytes [6 Lectures]: Immunoglobulins - structure, function signalling(3lectures), kinetics of immune response, memory(3lectures);

B cell and T-cell maturation, activation and differentiation [6 Lectures]: antigen processing and presentation(3lectures), cell-cell co-operation, Hapten-carrier system(3lectures).

Antigen-antibody interactions [8 Lectures]: Precipitation, agglutination and complement mediated immune reactions and associated immunological techniques(4lectures), cell cytotoxicity assays, microarrays, transgenic mice, gene knockouts(4lectures).

Clinical immunology [4 Lectures]: Immunity to infection, hypersensitivity: Type I-IV(1lecture); autoimmunity; treatment of autoimmune diseases(1lecture); transplantation: immunological basis of graft rejection(1lecture); tumor immunology; Immunodeficiencies; immune tolerance, immunotherapy(1lecture).

**Textbook**

1. K. Murphy, P. Travers, M. Walport, C. Janeway, *Janeway's Immunobiology*. New York: Garland Science (2012) 8th edition.

**Reference Books**

1. T. J. Kindt, R. A. Goldsby, B. A. Osborne, J. Kuby. *Kuby Immunology*. New York: W.H. Freeman (2002), First edition.
2. J. Brostoff, J. K. Seaddin, D. Male, I. M. Roitt, *Clinical Immunology*. London: Gower Medical Pub (2002), First edition.

**Self-Learning Materials**

1. C*ellular and molecular immunology*, Fall 2005, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

| Title | **Biochemistry Laboratory** | Number | BBL2XX0 |
|---|---|---|---|
| Department | Biosciences & Bioengineering | L-T-P [C] | 0–0–2 [1] |
| Offered for | B. Tech | Type | Compulsory |
| Prerequisite | Biochemistry | | |

**Objectives**

The Instructor will:

1. Give hands-on training on standard biochemical techniques and its applications.

**Learning Outcomes**

The students will be able to:

1. Perform and implement biochemical techniques in research and industrial applications.

**Contents**

*Identification of biomolecules in samples:* proteins, carbohydrates and lipids
*Protein isolation and purification:* salting out, chromatography (ion-exchange and affinity), SDS-PAGE
*Characterization of proteins using spectroscopic techniques:* absorbance, fluorescence and secondary structure determination
*Protein estimation by different methods:* BCA, Bradford and Lowry
*Identification and quantification of nucleic acids:* absorbance and gel based methods

**Text Book**

1. D. K. Geetha *Practical Biochemistry*, Jaypee Brothers Medical Publishers (2016) 2nd Edition.

**Self-Learning Material**

1. Elizabeth Taylor. 5.36 Biochemistry Laboratory. Spring 2009. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu.

| Title | **Computational and Systems Biology** | Number | BBL3XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3-0-2 [4] |
| Offered for | B.Tech. | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

To train the students in the interdisciplinary areas on the interface of biology and computation.

To provide fundamental understanding of methods in computational biology along with hand on training.

**Learning Outcomes**

1. Application of computational methods for modelling biological systems.
2. Ability to model and infer from biological models.

**Course Content**

*Genome and Sequences [Lectures 2]*: Sources of information of biological origin, gene and protein sequences, sequence homology and its biological significance (2 lectures)

*Building biological databases with SQL [Lectures 6] :* Common database types, relational database design (3 lectures), database access using SQL (2 lectures), biological databases (1 lecture)

*Sequence Alignment [Lectures 10]*: Need for aligning biological sequences, Smith-Waterman algorithm, Needleman-Wunsch algorithm (4 lecture), Multiple Sequence Alignment (2 lecture) , Phylogeny (2 lecture), Applications, BLAST (2 lecture)

*Gene and promoter prediction [Lectures 4]:* Gene prediction, promoter and regulatory element prediction

*Protein Structure Prediction [Lectures 6]*: Protein folding (1 lecture), *Ab initio* and knowledge-based prediction of structures, Force fields (3 lectures), Homology modelling (2 lectures)

*Introduction to Mathematical Modelling [2 lecture]*: Introduction to Modelling, why model biological systems?, examples of models, the modelling process, scope/assumptions, types of models

*Introduction to Static Networks [12 lectures]*: Representation of Biological Networks (1 lecture), Introduction to Network Biology (3 lectures), Network Topology, Power-law Networks/Network Perturbations (3 lectures), Community Detection / Network Motifs (3 lectures), Reconstruction of Gene networks (2 lectures)

**Lab: *[10-12 Sessions]***

Database searches and data retrieval, Database creation and data retrieval using MySQL, Writing code for translation of nucleic acid sequence to protein sequence, Writing code for dynamic programming and performing global alignment, Pairwise sequence alignment: BLAST, Multiple Sequence alignment: CLUSTAL OMEGA, Gene prediction tools (Glimmer, GeneMark) Visualisation and analysis of 3D-structures of proteins and protein-ligand interactions using graphics tool (RasMol), Homology modelling using SWISS-MODEL, Network Biology (Cytoscape), Network Biology (Topologies), Motif and module detection, Parameters of network (Cytoscape),, Network Perturbations, reconstruction of gene regulatory network

**Text Book**

D. Mount, Bioinformatics: Sequence and Genome Analysis, Cold Spring Harbor laboratory Press (2004), Second Edition.

**Reference Books**

1. R. Durbin, S. Eddy, A. Krogh, G. Mitchison, Biological Sequence Analysis, Cambridge University Press (1998) First Edition.
2. C. Branden, J. Tooze, Introduction to Protein Structure, Garland Science (1999) Second Edition.
3. P Baldi, S Brunak, Bioinformatics: The Machine Learning Approach, Bradford Publishers (2001) Second Edition.

**Multimedia Content**

1) NPTEL course link: Bioanalytical Techniques And Bioinformatics (http://nptel.ac.in/courses/102103044/)
2) Video lectures on Foundation of Computational and Systems Biology, MIT Open Courseware, (https://ocw.mit.edu/courses/biology/7-91j-foundations-of-computational-and-systems-biology-spring-2014/index.htm).
3) Lecture Notes for Introduction to Computational Molecular Biology and Genomics by Prof. Mona Singh, (https://www.cs.princeton.edu/~mona/computational_biology_notes.html).

| Title | **The Human Machine for Engineers: Quantitative Physiology** | Number | BBL3XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B.Tech | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Provide an understanding of the hierarchical organization of chemical and electrical signals and control mechanisms for energy, mechanics, flow and transport.
2. Provide an understanding of the workings of the human body in context of engineering principles so as to develop an interdisciplinary outlook to biological as well as engineering problem-solving.

**Learning Outcomes**

The students will have the ability to:

1. Understand and analyse basic human physiology from an quantitative perspective
2. Imagine engineering solutions that can solve biological problems and/or get inspired by biology to solve engineering problems.

**Contents**

Physical and Chemical Foundations of Physiology [6 Lectures]: Homeostasis, feedback control systems, pressure driven flow, electrochemical potential and free energy(2 lectures), membrane transport across a biological membrane(4lectures).

Physiology of excitable Cells [10 Lectures]: The origin of the resting membrane potential, GHK equation, action potentials(4lectures), membrane excitability, modeling action potentials(2lectures), saltatory conduction, skeletal muscle mechanics, neuromuscular transmission, excitation–contraction coupling motor units, type of contractions, fatigue and tetanus(4lectures).

Cardiovascular Physiology [7 Lectures]: electricity in cardiac cells, control of cardiac automaticity(2lectures), ECG(1lecture), cardiovascular mechanics, and dynamics(2lectures), microcirculation control mechanisms, cerebral and pulmonary circulation, congestive heart failure, shock(2lectures).

Pulmonary Physiology [6 Lectures]: breathing, resistance to air flow(2lectures), alveolar gas exchange, acid-base balance(2lectures), neural control of respiration(2lectures).

Renal Physiology [13 Lectures]: Body fluid compartments and overview of renal function(2lectures), Measurements of function and clearance(2lectures), Glomerular filtration/Renal Hemodynamics(2lectures), Tubular transport of electrolytes and water(2lectures), Concentration and dilution of urine(2lectures), Regulation of sodium balance(2lectures), extracellular volume and Blood pressure, Renal mechanisms of hypertension(1lecture).

**Text Books**

1. J. Feher *Quantitative Human Physiology,* Academic Press, 2nd Edition (2016).
2. K. E. Barrett, S. M. Barman, *Ganong's Review of Medical Physiology,* McGraw Hill Education, 26th Edition, (2019).

**Reference Books**

1. E.N. Marieb *Human Anatomy and Physiology*, Pearson Education (2006), 6th Edition.
2. W. F. Boron, E. L. Boulpaep *Medical Physiology*, Elsevier (2017) 3rd Edition.

**Self-Learning Material**

1. Dennis Freeman, 6-021j *Quantitative Physiology: Cells and Tissues*, Fall 2004, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

2. Venegas, J, Mark, F. *Quantitative Physiology: Organ Transport Systems,* MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

| Title | **Biophysics and Structural Biology** | Number | BBL3XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–1 [3.5] |
| Offered for | B. Tech | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The instructor will provide

1. In-depth understanding of three dimensional structure of bio-macromolecules and macromolecular assemblies governing the cellular life.
2. Introductory idea of the state of the art tools and techniques in understanding the interactions of biological molecules.

**Learning Outcomes**

After completion of the course the students are expected to have the ability to -

1. Conceptualize the basic principles of macromolecular structural assembles and their implications in the regulation of biological phenomena.
2. Understand the basic principles of modern day techniques of structural biology and their applications in academia-industrial settings.

**Contents**

*Structural hierarchy of macromolecules [14 Lectures]:* Introduction to structural biology, structure-function relationship (5 Lectures); protein folding and its regulation, Role of chaperones (4 Lectures); higher order protein assembly, Structural basis of eukaryotic DNA compaction, molecular machines (5 Lectures).

*Determination of macromolecular structure [14 Lectures]:* Introduction to macromolecular crystallography: Macromolecular crystallization methods and basics of crystal symmetry (5 Lectures); Analysis of X-ray diffraction data and validation of crystal structure (5 Lecture); Small Angle X-ray Scattering (SAXS) and Neutron diffraction to study macromolecular structures (4 Lecture).

*Biophysics of macromolecular interactions [14 Lectures]***:** Physical forces in macromolecular interactions (2 lectures), protein -protein and protein -nucleic acid interactions (3 lectures), structure of heme, myoglobin and haemoglobin, oxygen binding mechanism (3 lectures), Bohr effect, Energetics of active transport (3 lectures), Principles of spectroscopic methods for studying macromolecular interaction (3 lectures).

**Lab components**

1. Introduction to Macromolecular Structure
2. Retrieving biochemical information from protein primary structure.
3. Prediction of protein 3D structure model from amino acid sequence
4. Validation of protein 3D structure model
5. Analysis of protein 3D structure -
    a. Overall structure and enzyme active site
    b. Enzyme allosteric site
    c. Enzyme substrate specificity
    d. Enzyme inhibition by small molecule/peptide
6. Protein -small molecule docking and analysis
7. Protein-protein docking and analysis
8. Protein-DNA docking and analysis
9. Analysis of the effect of mutation(s) in protein interactions

**Text Books**

1. A. M. Pherson, Introduction to Macromolecular Crystallography, Wiley-Blackwell (2009), 2nd Edition.
2. W. Bialek, Biophysics – Searching for Principles, Princeton University Press (2012).

3. R. Glaser, Biophysics: An Introduction, Springer (2012) 2nd edition.

**Reference Books**

1. D. Voet, C. W. Pratt and J. G. Voet, Principles of Biochemistry, Wiley (2012), Fourth Edition.

**Self-Learning Material**

1.https://ocw.mit.edu/courses/biological-engineering/20-430j-fields-forces-and-flows-in-biological-systems-fall-2015/

| Title | **Genetics and Gene Manipulation** | Number | BBL3XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3-0-2 [4] |
| Offered for | B. Tech | Type | Compulsory |
| Pre-requisite | None | | |

**Objectives**

The Instructor will:

1. Provide an overview of the principles of heredity and gene manipulation
2. Highlight how gene manipulation can be applied to engineer simple and complex life forms and safety considerations associated with genetic engineering

**Learning Outcomes**

The students will have the ability to:

1. Choose the best method to manipulate DNA for genetic engineering applications
2. Engineer simple biological systems for biotechnological applications
3. Practise safety and ethical considerations while manipulating and engineering biological systems

**Contents**

*Fundamentals of Genetics [18 Lectures]:* Introduction, genetic distances, chromosome mapping, natural selection, crossovers and recombination (6 lectures), genetic drift, effect measures (6 lectures), study designs, Hardy-Weinberg law, linkage disequilibrium, linkage and association analysis, principles of inheritance, simple and complex diseases, heritability estimation, genetic markers, DNA fingerprinting (6 lectures)

*Gene Manipulation [12 Lectures]:* Polymerase Chain Reaction (2 lectures), DNA modifying enzymes (1 lecture), strategies for gene cloning (3 lectures), gene editing (1 lecture), vectors, selection & screening (2 lectures), sequencing DNA (1 lecture), heterologous expression of genes (2 lectures)

*Genetic Engineering [6 Lectures]:* Gene transfer to animal cells & transgenic animals (2 lectures), gene transfer to plant cells & transgenic plants (2 lectures), genetically modified organisms (2 lectures)

*Applications of Genetic Engineering [4 Lectures]:* Production of important metabolites (1 lecture), introducing new traits, improving existing traits (1 lecture), gene therapy, development of model systems, animal cloning (2 lectures)

*Ethical & Safety Considerations [2 Lectures]:* Biosafety considerations for recombinant DNA research (1 lecture), Ethical considerations for Genetic Engineering (1 lecture)

**Laboratory Experiments (12 exercises)**

Cloning strategies; Transformation, Selection & Screening; Clone confirmation & Sequencing of cloned DNA; Directional cloning; Heterologous protein expression; Site directed mutagenesis

**Text Books**

1. S. B. Primrose, and R. M. Twyman, Principles of Gene Manipulation & Genomics, Blackwell Publishing (2006), 7th Edition.
2. N. M. Laird, and C. Lange, The Fundamentals of Modern Statistical Genetics, Springer: New York (2011), First edition.

**Reference Books**

1. M. Nagarajan, Ed. Metagenomics: Perspectives, Methods, and Applications, Elsevier (2017) 1st Edition,
2. D. P. Snustad, M. J. Simmons, Principles of Genetics, John Wiley and Sons (2011), 6th Edition.

**Self-Learning Material**

1. https://nptel.ac.in/courses/102/103/102103013/
2. https://nptel.ac.in/courses/102/103/102103074/

| Title | **Introductory Omics** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B.Tech. | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Introduce the organization of a genome and highlight the complexity of the encoded proteome and resulting metabolome
2. Describe methods to access the genome, proteome and metabolome for specific applications
3. Highlight applications of genomics, proteomics and metabolomics in biological research

**Learning Outcomes**

The students will have the ability to:

1. Sequence and analyse the genome of a simple organism to understand its functioning
2. Appreciate the usage of proteomics approaches to obtain a global picture of cellular activities
3. Understand the metabolic complexity of simple organisms from the perspective of their genome and proteome

**Contents**

*Genomics & Transcriptomics [12 Lectures]:* Organization of the genome, Genome mapping (2 lectures), Genome sequencing (3 lectures), Comparing genomes (2 lecture), Functional Genomics (2 lectures), Epigenomics (1 lecture), Genome sequencing projects (1 lectures), Genome databases (1 lectures)

*Proteomics [10 Lectures]:* Separation of proteins, Analysis of protein expression *[3 Lectures]*, Detection of post-translational modifications *[2 Lectures]* , Reverse phase protein microarrays *[2 Lectures]*, Structural proteomics, Interactomics *[3 Lectures]*

*Metabolomics [14 Lectures]:* NMR for metabolomics (2 lectures), Gas chromatography (2 lectures), High-performance liquid chromatography (2 lectures), Mass spectrometry (5 lectures), Global metabolite profiling from biological samples (3 lectures)

*Applications of Omics [6 Lectures]:* Genomics & proteomics in Medicine, Biomarkers, Pharmacogenomics & personalized medicine (3 lectures), Plant genomes (1 lecture), Microbial genomes (1 lecture), Proteomics and metabolomics for biomarker discovery & disease diagnosis (1 lectures)

**Text Book**

1. S. B. Primrose and R. M. Twyman *Principles of Gene Manipulation & Genomics*, Blackwell Publishing (2006)

7th Edition.

**Reference Books**

1. A. M. Lesk, *Introduction to Genomics*, Oxford University Press (2017), 3rd Edition.
2. R. Twyman, *Principles of Proteomics*, CRC Press (2013), 2nd Edition.

**Self-Learning Material**

1. https://nptel.ac.in/courses/102/103/102103017/

| Title | **Biomaterials Engineering** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1.Provide an insight on the fundamental concepts of biomaterials engineering.

2. Give an overview of techniques for characterizations of different types of biomaterials for various applications.

**Learning Outcomes**

The students will have the ability to:

1. Analyze the suitability of the material to be used as a biomaterial.
2. Compare the performance of different biomaterials.
3. Design a strategy for modification of biomaterials for a specific application.

**Contents**

*Fundamental of Biomaterials [14 Lectures]:* Introduction to biomaterials (2 lectures), types of biomaterials (1 lectures), processing of biomaterials (4 lectures), surface properties and surface modification of biomaterials (3 lectures), physicochemical characterization of biomaterials (4 lectures). (offered by MM department)

*Biological properties of biomaterials [14 Lectures]:* Concepts of biocompatibility, immune-compatibility, hemocompatibility and biodegradability (5 lectures), Bioconjugations, Biomineralization (4 lectures), Biological characterization of biomaterials (5 lectures) (offered by BSBE)

*Applications of Biomaterials [14 Lectures]:* Biomimetic and stealth biomaterials (3 lectures), types and applications of implants (4 lectures), biomaterials for drug delivery systems (3 lectures), biomaterials for tissue engineering (3 lectures), regulatory affairs (1 lecture) (offered by BSBE)

**Text Books**

1. B. Bikramjit, Biomaterials Science and Tissue Engineering, Cambridge University Press (2017), First edition.

**Reference Books**

1. W. R. Wagner, Shelly E. Sakiyama-Elbert, Guigen Zhang, Michael J. Yaszemski, Biomaterials Science: An Introduction to Materials in Medicine, Academic Press Inc (2020), 4th edition.

**Self-Learning Material**

1. Prof. Bikramjit Basu, IIT Kanpur, https://nptel.ac.in/courses/113/104/113104009/

## 14. Detailed Course Content
## of
## Programme Elective Courses

## Omics

| S. No | Title of the course | Offered by |
|---|---|---|
| 1 | Microbiomes and Metagenomics | BSBE |
| 2 | Computational Methods for Multi-omics | BSBE |
| 3 | Microarray Data Analysis | BSBE |

| Title | **Microbiomes and Metagenomics** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B.Tech | Type | Elective |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Introduce microbial communities that are ubiquitous and are functionally adapted to specific environments
2. Outline methods to understand microbial community structure in a given environment
3. Describe strategies to access the genomic diversity specific to these microbial communities

**Learning Outcomes**

The students will have the ability to:

1. Unravel microbial communities associated with specific environments using culture-dependent / independent methods
2. Access metagenomes associated with unique environments to bioprospect enzymes, metabolites and bioactive compounds

**Contents**

*Fractal 1. Quantitative ecology of Microbial communities [14 Lectures]:* Development of microbial communities (2 lectures), selection and succession, diversity and stability of communities (3 lectures), indices for diversity (2 lectures), structure and function of some natural microbial communities (2 lectures), accessing the microbiome: from sample collection to detection of microbial populations, counting microbes (3 lectures), measuring microbial biomass and metabolism (2 lectures)

*Fractal 2. The current standard in microbiome profiling [14 Lectures]:* Extraction of environmental DNA (2 lectures), PCR considerations in microbiome research (2 lectures), multiplexing samples, next generation sequencing primer (2 lectures), exploiting NGS methods for microbiome profiling (2 lectures), data analyses (4 lectures), assessment of community diversity (2 lectures)

*Fractal 3. Metagenome sequencing [14 Lectures]:* Metagenome library construction and sequencing (2 lectures), metagenome amplification, shotgun metagenome sequencing (3 lectures), single-cell metagenomics (2 lectures), predicting genes and gene function from metagenomes (2 lectures), metabolic reconstruction of microbial communities (2 lectures), bioprospecting from metagenomes (3 lectures)

**Text Books**

1. R. Atlas, R. Bartha, *Microbial Ecology: Fundamentals and Applications*, Pearson (1998), 4th edition.
2. J. Izard, M. Rivera, Eds. *Metagenomics for Microbiology*, Elsevier (2015), First edition.

**Reference Books**

1. M. Nagarajan, Ed. Metagenomics: Perspectives, Methods, and Applications, Elsevier (2017), 1st Edition.
2. Research articles, Case reports & Review articles as provided by the Instructor

**Self-Learning Material**

1. https://www.coursera.org/learn/microbiome

| Title | **Computational Methods for Multi-omics** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–2 [4] |
| Offered for | B.Tech | Type | Elective |
| Prerequisite | Introductory Omics | | |

**Objectives**

The Instructor will:

1. Introduce to basic knowledge of computational and statistical methods in omics data analysis
2. Highlight how multi-omics data is to be preprocessed, assessed for integrity, analyzed and interpreted appropriately

**Learning Outcomes**

The students are expected to have the ability to:

1. Identify key methods for analysis and integration of omics data based on a given dataset
2. Efficiently analyze large scale multi-omics data sets
3. Make biological inference from the analyzed data

**Contents**

*Fractal 1: Basics of Multi-omics Analysis (14 lectures)*

Genome first and phenome first approaches, biological networks and pathways (4 lectures), multi-omics data types and repositories, multi-omics data examples, biological interpretation (4 lectures); homogeneity and heterogeneity issues, batch effect correction, normalization and transformation (4 lectures); processing of high-throughput multi-omics data sets (2 lectures)

*Fractal 2: Horizontal Multi-omics Integration (14 lectures)*

Horizontal integration scheme, single-level omics data, meta-analysis methods (4 lectures); integration methods for multiple biological networks, integration of genetically regulated gene expression data (4 lectures); correlation motif model, ChIP-X data integration, analysis of allele-specific binding in ChIP-Seq (3 lectures); illustrative case-studies (3 lectures)

*Fractal 3: Vertical Multi-omics Integration (14 lectures)*

Vertical integration schemes including parallel integration and hierarchical integration (3 lectures); clustering methods, latent variable approach (4 lectures); Bayesian methods, network-based methods, HotNet algorithm (4 lectures); illustrative case-studies (3 lectures)

**Laboratory Experiments (14 classes)**

perform multi-omics integration for cancer TCGA data sets; analyze the complex structure of repeated measurements from different biological assays using open access data sets ; develop a meta-analysis approach for integrating data on blood lipid levels; apply visualization approaches for the multi-omics analyses and biological interpretation.

**Textbook**

1. G. Tseng, D. Ghosh, X. J. Zhou, Integrating Omics Data. Cambridge University press (2015), First edition.

**Reference Books**

1. A. Vlahou, F. Magni, H. Mischak, J. Zoidakis, Integration of Omics Approaches and Systems Biology for clinical applications. Wiley (2018), First edition.

**Self-Learning Material**

1. George Michailidis, University of Michigan, Data-driven Approaches and Multi-omics Integration, https://www.youtube.com/watch?v=OoBvkRpBqf0

| Title | **Microarray Data Analysis** | Number | BB4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3-0-0 [3] |
| Offered for | B.Tech. | Type | Elective |
| Prerequisite | None | | |

**Objective**

(1) Training students to analyze microarray technology/RNA sequencing gene expression data.
(2) To be knowledgeable about high dimensional biology data analysis. The course will help to minimize a major bottleneck in the utilization of these data.
(3) To familiarize the students with the use of advanced tools and methodologies for analyzing microarray/RNA seq expression data
(4) Assignments will help them to practice and learn about the tools required in the microarray data analysis

**Learning Outcomes**

(1) Be able to understand the structure of the data, the statistical procedures used to remove the inherent noise present in the data (pre-processing of the data)
(2) Be able to decide which data analysis tool to use
(3) Be able to understand new methods to describe observations made on a biological phenomenon and to make inferences on the biological significance of the results

**Contents**

*Fractal 1:* DNA Microarray: Gene expression biology, The technical foundations, Why are microarray important?(1 lecture) What is a DNA microarray and RNA seq data?(2 lectures), Types of microarrays- two-channel cDNA arrays, single-channel Affymetrix genechips, microarray platforms (5 lectures), Designing a microarray experiment-The basic steps (2 lectures); Microarray Databases: NCBI and microarray data management, GEO (Gene Expression Omnibus), Array Express, The benefits of GEO and Array Express (4 lectures).

*Fractal 2:* Microarray Data Normalization : Importance of microarray data pre-processing, Background correction (4 lectures), Data normalization, Measuring dissimilarity of expression pattern using dissimilarity measures (3 lectures), Pre-processing of RNA seq data (5 lectures), Visualizing microarray/RNA seq data using- Principal Component Analysis (2 lectures)

*Fractal 3:* Microarray Data Analysis: Identification of differentially expressed genes- using statistical and computational approaches (4 lectures), Classifying samples from two populations (4 lectures), grouping co-expressed genes (2 lectures). Visualization and Functional Analysis: Bio-molecular pathways, gene ontology, enrichment analysis, hypergeometric distribution, calculation of P-Value, hypothesis testing, multiple hypothesis testing (4 lectures)

**Text books**

1. R. M. Simon, E. L. Korn, L. M. McShane, M. D. Radmacher, Wright G. W., Zhao Y., "Design and Analysis of DNA Microarray Investigations", Springer-Verlag New York, 2003, First Edition.
2. Korpelainen E., Tuimala J., Somervuo J., Huss M., Wong G., "RNA-seq Data Analysis: A Practical Approach", CRC Press, USA, 2014, First edition.

**Reference book**

1. Knudsen S., "Guide to Analysis of DNA Microarray data", John Wiley & Sons, USA, 2004, First Edition.
2. Stekel D., "Microarray Bioinformatics", Cambridge University Press, 2003, First edition.
3. Draghic S., "Data Analysis tools for DNA Microarray", Chapman and Hall/CRC Press, USA 2002, First edition.

**Self learning Materials:** Microarray based DNA Detection---- http://nptel.ac.in/courses/104103018/41

## Biomaterials Engineering

| S. No | Title of the course | Offered by |
|---|---|---|
| 1 | Cell-Material Interactions | BSBE |
| 2 | Tissue Engineering | BSBE |
| 3 | Therapeutic Delivery Systems | BSBE |
| 4 | Principles of Biomechanics | ME |
| 5 | Additive Manufacturing | ME |

| Title | **Cell-Material Interactions** | Number | BBL3XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Elective |
| Prerequisite | Biomaterials Engineering | | |

**Objectives**

The Instructor will

1. Provide an insight about cell-material interactions at different length scale essential for the design and development of wearable devices, implants, therapeutic formulations and engineered organs.

**Learning Outcomes**

The students will have the ability to:

1. Analyse the nature of cell-material interactions at molecular level.
2. Choose appropriate techniques for analysing cell-material interactions.
3. Develop an appropriate surface modification strategy for improving the performance of device/formulations.

**Contents**

Fractal 1. *Fundamentals of cell-material interactions [14 Lectures]:* Cell-material interactions over a length scale from macro to nano, mechanism of adhesion of cells (4 lectures), ECM and its interactions with cells (3 lectures); Reticuloendothelial cell clearance, interaction of immune cells with materials (4 lectures)), interaction of microbes with substrate (3 lectures).

Fractal 2. *Influence of material properties on cell-material interactions [14 Lectures]**:*** Influence of the surface and bulk properties of the materials on physiology of anchorage dependent cells (5 lectures), effects of size and morphology of the materials on their interactions with the cells (4 lectures), Important techniques for characterizing cell-material interactions (5 lectures).

Fractal 3. *Tuning of cell-material interactions [14 Lectures]**:*** Strategies to tune the cellular function by modifying material properties for biomedical applications (5 lectures), anchorage promoting peptides, tuning the mechanism of biofilm formation (4 lectures), design of stimuli-responsive (optical, electric and magnetic) surfaces for modulating cell behaviour (5 lectures).

**Text Books**

1. J. Y. Wong, J. D. Bronzino, Biomaterials, CRC Press (2019), first edition.

**Reference Books**

1. W. R. Wagner, S. E. Sakiyama-Elbert, G. Zhang, M. J. Yaszemski, Biomaterials Science: An Introduction to Materials in Medicine, Academic Press Inc (2020), 4th edition.

**Self-Learning Materials**

1. MIT Open Courseware, Prof. Ioannis Yannas and Prof. Myron Spector, Course number: 20.441J/ 2.79J/3.96J/HST.522J. https://ocw.mit.edu/courses/biological-engineering/20-441j-biomaterials-tissue-interactions-fall-2009/lecture-notes/

| Title | **Tissue Engineering** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Elective |
| Prerequisite | Biomaterials Engineering | | |

**Objectives**

The Instructor will:

1. Provide an understanding of the process of repair and regeneration in various tissues and the role of different factors therein.
2. Fundamental concepts and technical aspects of tissue engineering.

**Learning Outcomes**

The students will have the ability to:

1. Design a tissue-engineered product for a specific application.
2. Analyze and compare the performance of different tissue-engineered products.

**Contents**

Fractal 1. *Fundamental concepts of tissue engineering [14 Lectures]:* Fundamentals of tissue repair and regeneration; manipulation of repair and regeneration (4 lectures); introduction to basic principles of tissue engineering (5 lectures); components of an engineered tissue: role of biomaterials, growth factors, bioactive molecules and cells (5 lectures).

Fractal 2. *Fabrication and characterization of solid support systems [14 Lectures]:* Fabrication techniques of films and hydrogels (4 lectures); fabrication of scaffolds (5 lectures); Physico-chemical characterizations of different solid support systems (5 lectures).

Fractal 3. *Development of engineered tissue in vitro [14 Lectures]*: Animal cell culture (2D and 3D) (5 lectures); strategies for the development of cell-seeded tissue engineering construct (5 lectures); implantation and integration of tissue-engineered products (3 lectures); Ethical and regulatory issues in tissue engineering (1 lecture).

**Text Books**

1. B. Palsson, S. Bhatia, Tissue Engineering, Pearson Prentice Hall (2016), First edition.

**Reference Books**

1. J. P. Fisher, G. Antonios, G. Mikos, J. D. Bronzino, D. R. Peterson, Tissue Engineering: Principles and Practices, CRC Press (2017), First edition.

**Self-Learning Material**

1. Introduction to Tissue Engineering, Prof. S. Swaminathan, Centre for Nanotechnology & Advanced Biomaterials, SASTRA University. https://nptel.ac.in/courses/102/106/102106036/;
2. Tissue Engineering, Prof. Vignesh Muthuvijayan, Department of Biotechnology, IIT Kanpur. https://nptel.ac.in/courses/102/106/102106081/

| Title | **Therapeutic Delivery Systems** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 2–0–0 [2] |
| Offered for | B. Tech | Type | Elective |
| Prerequisite | Biomaterials Engineering | | |

**Objectives**

The Instructor will:

1. Provide deep insight on the fundamental concepts and advances on various types of therapeutic delivery systems.
2. An understanding principles/rationales of therapeutic delivery systems.

**Learning Outcomes**

The students will have the ability to:

1. Design a therapeutic delivery system for a specific application.
2. Decipher and modulate the mechanism of therapeutic drug loading and release.
3. Formulate novel strategies for personalized drug delivery.

**Contents**

Fractal 1. *Introduction to therapeutic delivery systems [14 Lectures]*: Overview of therapeutic delivery systems (3 lectures); rationales of designing therapeutic delivery systems (3 lectures), classification of therapeutic delivery systems (3 lectures); characterization of therapeutic delivery systems (5 lectures).

Fractal 2. *Essential concepts of therapeutic delivery systems [14 Lectures]*: Strategies of drug loading, mechanism of drug release, kinetics of drug release (3 lectures), essentials of pharmaco-kinetics and pharmacodynamics (3 lectures), principles of sustained, targeted and on-demand delivery (5 lectures), case studies on therapeutic delivery systems (3 lectures).

**Text Books**

1. Y. Chien, Novel Drug Delivery Systems (Drugs and the Pharmaceutical Sciences) CRC Press, 2nd edition (2019)ISBN-10: 0367402912

**Reference Books**

1. P. Stroeve, Morteza Mahmoudi Drug Delivery Systems: 1 (World Scientific Series: From Biomaterials Towards Medical Devices), (2018) First edition.

**Self-Learning Material**

1. Drug delivery: Principles and Engineering, Prof. Rachit Agarwal, Department of BioSystems Science and Engineering, IISc Bangalore. https://nptel.ac.in/courses/102/108/102108077/

| Title | **Bio-Transport Phenomena** | Number | BBL4XX0 |
|---|---|---|---|
| Department | BSBE/ME/ChE | L-T-P [C] | 3-0-0 (3) |
| Offered for | B.Tech | Type | PE |
| Prerequisite | None | | |

**Objective:**

The Instructor will:

1. Provide knowledge about momentum, heat and mass transfer in bio-systems and their analogous behavior.
2. Train the student to create bio-engineering knowledge using the transport phenomena approach with special focus on combined transport problems.

**Learning Outcomes:**

The students are expected to have the ability to:

1. Identify and analyze the properties and mechanisms of momentum, energy and mass transport.
2. Analyze, design and solve problems combining these transport phenomena in bio-engineering.

**Contents:**

*Basics of Transport phenomena and Momentum Transport (14 Lectures):* Introduction, Formulation of transport problems from nature, conservation principle, Basic concepts of Vector and Tensor Analysis. (6 Lectures) Basic concepts, laminar and turbulent flows, boundary layers, equations of change, dimensional analysis, applications to Newtonian & Non-Newtonian fluids. (8 lectures)

*Fundamentals of biological transport processes (14 Lectures):* Driving forces for fluid transport in biological systems, biological transport process on different length scale , Bio-rheology of blood and other body fluids ( 5 lecture), Transport across cell membrane; diffusion, filtration and osmosis (3 lecture), facilitated and active transport processes (3 lecture), interstitial fluid transport, fluid flow in bone canaliculi and streaming potential ( 3 lecture),

*Circulatory and respiratory transport processes (14 Lectures): Models for blood flow;* steady flow in tubes, pulsatile flow in a rigid tube, pulsatile flow in an elastic tube (3 lecture), blood flow in capillaries and bolus flow, blood flow dynamics in arteries and veins (3 lecture), heart-valve hemodynamics (3 lecture), air flow in the lungs: Mechanics of breathing, gas exchange and transport (4 lecture), *Application of the principle of bio-transport phenomenon in medical device development(1 lecture).*

**Text Books:**

1. G. A. Truskey, F. Yuan, D. F. Katz, Transport Phenomena in Biological Systems, Prentice Hall, New Jersey (2009), 2nd edition.
2. R. B. Bird, W. E. Stewart, E. N. Lightfoot, Transport Phenomena, Wiley India (2006), 2nd edition.

**Reference Books:**

1. C. E. Welty, R. E. Wicks, G. L. Wilson, G. L. Rorrer,(2007), *Fundamentals of Momentum*, *Heat, and Mass Transfer*. Wiley India Pvt. Ltd (2007), 5th edition.
2. C. J. Geankoplis *Transport Processes and Separation Process Principles*, Prentice-Hall of India (2004), 4th edition.
3. R. S. Brodkey, H. C. Hershey, *Basic concepts in transport phenomena, a unified approach*. Vol 1, Brodkey Publishing (2003), 1st edition.
4. W. J. Thompson, (2000) *Introduction to Transport Phenomena*, Prentice Hall (2000), First edition.

**Online Course Material:**

'Transport Phenomena' by Prof. S.K. Gupta, NPTEL: https://nptel.ac.in/courses/103/102/103102024/

**Computational and Systems Biology**

| S. No | Title of the course | Offered by |
|---|---|---|
| 1 | Algorithms in Biology | BSBE |
| 2 | Modelling Biological Systems | BSBE |
| 3 | Mathematical Biology | MA |
| 4 | Design of experiments | MA |

| Title | **Algorithms in Biology** | Number | BBL6XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–0[3] |
| Offered for | B.Tech | Type | Elective |
| Prerequisite | None | | |

**Objectives:**
To develop an understanding of the main algorithmic approaches used in solving computational problems that arise in the analysis of biomolecular data (such as DNA/RNA/amino acid sequences, mass spectra of proteins, whole genomes, or gene expression levels).

**Learning outcomes:**
The students are expected to:
Understand various algorithms related to biological data analysis.
Develop new efficient algorithm to solve biological data.

**Contents**
*Fractal 1 Greedy Algorithms:* Genome Rearrangements (7 lectures), A greedy approach to motif finding (7 lectures)

*Fractal 2 Dynamic programming algorithms:* The power of DNA sequence comparison (2 lectures), global sequence alignment, local sequence alignment (4 lectures), alignment and gap penalties (2 lectures), multiple alignment (2 lectures), Gene Prediction, Similarity-Based Approaches to Gene Prediction (4 lectures)

*Fractal 3 Clustering algorithms:* identification of co-expressed groups of genes(2 lectures), construction of phylogenetic trees (3 lectures), detection of communities in a biological network (3 lectures)*Gene selection algorithms:* types of gene selection algorithms, SAM, Limma, CFS, mRMR, MRMS(4 lectures), ensemble gene selection algorithm (2 lecture)

**Textbook**
1) N. C. Jones, P. A. Pevzner An Introduction to Bioinformatics Algorithms, MIT Press (2014), First edition.
2) G. Benson, R. Page (Eds.) Algorithms in Bioinformatics", Springer International Edition (2004) First edition.
3) D. Gusfields, Algorithms on strings, trees and sequences: Computer Science and Computational Biology, Cambridge University Press (1997), First edition.

**Reference Books**
1) S. S. Kremer, Molecular Bioinformatics: Algorithms and Applications, Walter de Gruyter (1996) First edition.
2) R. Durbin, S. R. Eddy, A. Krogh, G. Mitchison. Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acid, Cambridge University Press, (1999), First edition.
3) S. Mitra, S. Datta, T. Perkins, G. Michailidis Introduction to Machine Learning and Bioinformatics, New York: Chapman & Hall/CRC Press (2008), First edition.

**Self Learning Material**
1) https://www.bioinformaticsalgorithms.org/lecture-videos
2) MIT Open Courseware: https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-096-algorithms-for-computational-biology-spring-2005/lecture-notes/

| Title | **Modelling Biological Systems** | Number | BBL3XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 2-0-2 [3] |
| Offered for | B.Tech. | Type | Elective |
| Prerequisite | None | | |

**Objectives**

The main objective of the course is to introduce students to various aspects of mathematical modelling in the particular context of biological systems.

**Learning Outcomes**

Students will have a knowledge of important concepts related to the mathematical modelling of complex systems, especially metabolic networks, protein interaction networks and gene regulatory networks, and will be able to apply them to model the behaviour of biological systems as well as develop strategies for manipulating them.

**Contents**

*Kinetic/Dynamic Modelling of Biological Systems [14 lectures]:* Introduction to Dynamic Modelling (2 lectures), Computer Simulation (3 lectures), Parameter Estimation (3 lectures), Sensitivity Analysis (2 lectures), case study (3 lectures)

*Modelling metabolic networks/Constraint-based analyses [7 lectures]:* Introduction to Constraint-based Analyses of Metabolic Networks (2 lectures), Constraint-based Analyses of Metabolic Networks: FBA and MoMA (5 lectures); *Current/Advanced Topics in Systems Biology [7 lectures]:* Robustness in Biological Systems (4 lectures), Robustness and Evolvability in Biological Systems (3 lectures)

**Lab:** [10-12 Sessions]
Introduction to MATLAB, Solving ODEs/Parameter Estimation with MATLAB, Parameter Estimation with MATLAB, Simulation with Cell Designer (TCA cycle), Constraint-based Analyses of Metabolic Networks (FBA and MoMA)

**Text Books**

Voit E, A First Course in Systems Biology. Garland Science (2012), First edition.

**Reference Books**

1. E. Klipp, Systems biology : a textbook. Wiley-VCH (2009), First edition.
2. MEJ Newman, Networks : an introduction. Oxford Univ. Press (2011), First edition.

**Self Learning Material:**

NPTEL Lectures: *Computational Systems Biology*, Karthik Raman, IIT Madras https://nptel.ac.in/noc/individual_course.php?id=noc18-bt22

## Bioimaging

| S. No | Title of the course | Offered by |
|---|---|---|
| 1 | Electron microscopy for Biology | CY |
| 2 | Digital Image processing | CS |
| 3 | Special topics in Biomedical Imaging | BSBE |
| 4 | Bio-image computing | CS |

## Biosensors

| S. No | Title of the course | Offered by |
|---|---|---|
| 1 | Whole cell based biosensors | BSBE |
| 2 | Microsystems fabrication technology | EE |
| 3 | Special topics in biosensors | BSBE |
| 4 | Chemosensors | CY |

| Title | **Whole Cell based Biosensors** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Elective |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Introduce the basic regulatory mechanisms of gene expression in prokaryotes
2. Outline how these gene expression circuits can be rewired to make effective biosensors
3. Briefly expand into synthetic biology approaches to construct whole-cell biosensors

**Learning Outcomes**

The students will have the ability to:

1. Choose the right regulatory circuits for design of effective biosensors
2. Genetically engineer living prokaryotic systems for sensing

**Contents**

*Genetic circuitry [20 Lectures]:* Transcriptional and post-transcriptional regulation of gene expression in bacteria (4 lectures), two-component systems (3 lecture), reporter genes and their usage (2 lectures), choice of host strain, free living biosensors (2 lectures), immobilized biosensors, immobilization strategies (2 lectures), DNA manipulation for construction of reporter fusions (1 lecture), RNA-based sensing (4 lectures), specificity, sensitivity, cross-reactivity (2 lecture).

*Case studies [14 Lectures]:* Whole cell biosensors for sensing: antimicrobials (1 lecture), organics, plant nutrients (3 lectures), microbial metabolites (2 lectures), heavy metals, xenobiotics (3 lectures), pH, temperature (2 lectures), synthetic biology for whole cell biosensor development (3 lectures).

*Seminars on current topics in whole cell biosensors [8 Lectures]:* Student-led seminars on current topics in whole cell biosensors. Students will present and discuss instructor-approved research articles describing development of biosensors using living cells.

**Text Book**

*1. J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levine, and R. Losick, Molecular Biology of the Gene, Pearson Education (2014) 7th Edition.*
*2. S. B. Primrose, and R. M. Twyman, Principles of Gene Manipulation & Genomics, Blackwell Publishing (2006), 7th Edition*

**Reference Materials**

1. T. Gerald, Ed. *Handbook of cell biosensors*, Springer (2020), 1st Edition.

**Self-Learning Material** None

## Microbial Systems for Sustainable Development

| S. No | Title of the course | Offered by |
|---|---|---|
| 1 | Microbial remediation and environmental biotechnology | BSBE |
| 2 | Microbes in food and sustainable agriculture | BSBE |
| 3 | Bioenergy | BSBE |

| Title | **Microbial remediation and Environmental Biotechnology** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B Tech. | Type | Elective |
| Prerequisite | Microbiology | | |

**Objectives**

1. To acquaint students with the way wastes/wastewaters as well as toxic wastes are treated
2. The instructor will teach methods pertaining to sustainable wastewater recycling

**Learning Outcomes**

The students will have the ability to:

1. Address the increasing water, soil or air pollution problems arising due to industrialization and how biotechnology can circumvent these problems
2. Students will be able to design a treatment process based on the characteristics of the wastewater to be treated

**Contents**

*Fractal 1:* Introduction, Stoichiometry and bacterial energetics (5 lectures), reactors for wastewater treatment, Carbon removal, Nitrification and denitrification, phosphorus remova (6 lectures)l, Detoxification of hazardous chemicals (3 lectures).

*Fractal 2:* Bioremediation, Type of bioremediation (4 lectures), Engineering strategies for bioremediation (5 lectures), case studies on bioremediation (5 lectures)

*Fractal 3:* Strategies in solid waste management, landfill & associated hazards (4 lectures) , chemistry of biodegradable wastes, composting, solid state fermentation (5 lectures), solid waste to biofuel, chemistry of non-biodegradable wastes, the case studies (5 lectures)

**Textbooks**

1. B.E. Rittmann, P. L. McCarty, Environmental Biotechnology: Principles and Applications, Tata McGraw Hill (2001), 2nd edition.

**Reference books**

1. M. Shuler, F. Kargi, Bioprocess Engineering: Basic Concepts, Prentice Hall (2002), 2nd edition.
2. R. Y. Stanier, General Microbiology, Macmillan (1999), 5th edition.

**Self Learning Material**

1. Gargi Singh, Applied Environmental Microbiology, NPTEL Course Material, Department of Civil Engineering, Indian Institute of Technology, Roorkee, http://nptel.ac.in/courses/105107173/

| Title | **Microbes in food and sustainable agriculture** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Biosciences & Bioengineering | Structure | 3-0-0 [3] |
| Offered for | B. Tech. | Type | Elective |
| Prerequisite | Microbiology | | |

**Objectives**

1. This course will emphasize on the role of microbes in food, additives and sustainable agriculture and its practical applications in the field.

**Learning Outcomes**

The students will have the ability to:

1. Be able to utilize the potential of microbes in creating a sustainable food and agriculture alternatives.

**Contents**

*Plant-microbe interactions [14 Lectures]*:

Plant community ecology and soil symbiont interactions, soil resources, local niche in shaping community *[5 Lectures],* Microbial interactions, role of root exudates in microbial community growth, types of microbial community *[5 Lectures],* Factors affecting plant-microbiome interactions (environmental and genetic) *[4 Lectures]*

*Microbes for better food and health [14 Lectures]*:

Prebiotics, probiotics and synbiotics, microbes as nutritional supplement *[5 Lectures],* microbial preparation of dairy products, microbial production of antibiotics *[5 Lectures],* Fermented beverages and health benefits, quality control *[4 Lectures]*

M*icrobes for sustainable agriculture [14 Lectures]:*

Microbes as symbiotic microbes, nitrogen fixers and phosphate solubilizer *[5 Lectures],* Microbial herbicides and pesticides, microbes for nutrient recycling *[5 Lectures],* Phytohormone production and genetically modified food *[4 Lectures]*

**Text Books**

1. R. Chandra, R. C. Sobti. Microbes for Sustainable Development and Bioremediation. CRC Press (2020), First edition.

**Reference Books**

1. S. Tulasi, J. B. Naraian, A. Prakash, Microbes in food and sustainable agriculture. Springer (2012), First edition.

**Self-Learning Materials**

1. Microbiology. Gurvinder Kaur Saini. https://nptel.ac.in/courses/102/103/102103015/)
2. Applied environmental microbiology. Gargi Singh. https://nptel.ac.in/courses/105/107/105107173/

| Title | **Bioenergy** | Course | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3-0-0 [3] |
| Offered for | B Tech. | Type | Elective |
| Prerequisite | Microbiology and Biochemistry | | |

**Objectives**

1. To acquaint students with the principles and applications of bio-energy harnessing systems ranging from conventional processes to the latest developments in the area

**Learning Outcomes**

The students will have the ability to:

1. Use biomass as sustainable fuel
2. Utilize the knowledge of bioenergy systems while integrating bioenergy with other renewable energy systems

**Contents**

*Fractal 1. Thermochemical biomass conversion [14 lectures]:* Chemical composition, biomass types and characteristics (4 lectures), biomass pre-treatment and processing, biomass gasification technology (5 lectures), biomass boilers, catalytic conversion of biomass to liquid biofuels, life cycle analysis (5 lectures) (offered by CY).

Fractal 2. *Biochemical biomass conversion [14 lectures]:* Anaerobic fermentation technology, biogas production, process, microbiology (4 lectures), different types of bioreactors, basic process kinetics, various types of biofuels,1$^{st}$ and 2$^{nd}$ generation biofuels, algal biofuels (5 lectures), ASTM standards for biofuels, basic biochemical processes, genetic engineering (5 lectures).

Fractal 3. *Bioelectrochemical systems [14 lectures]:* Introduction to microbial fuel cells (MFCs), the Nernst equation and electrochemical potential difference, the biochemical redox reactions, (5 lectures), the exoelectrogenic microbes, MFC components, applications of MFC (5 lectures), bio electrochemical system for hydrogen production, artificial photosynthesis *(4 lectures).*

**Textbooks**

1. German Solar Energy Society, Ecofys, (2006) *Planning and installing bioenergy systems: A guide for installers, architects and engineers*, Earthscan, 2. Vertes, A. A., Qureshi, A., Yukawa, H., Blaschek, H.P.,(2010) *Biomass to Biofuels,* Wiley.

**Reference Books**

1. R. Y. Stanier, General Microbiology, Macmillan (1999), 5$^{th}$ edition.
2. M. Pelczar, A. C. Krieg, Microbiology, Tata McGraw Hill Education (2001), 5$^{th}$ edition.

**Self Learning Material**

1. Michelle O'Malley, *Fueling Sustainability: Engineering Microbial Systems for Biofuel Production,* Spring 2011, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

## Drug Design and Development

| S. No | Title of the course | Offered by |
|---|---|---|
| 1 | Principles of drug discovery | BSBE |
| 2 | Medicinal chemistry | CY, BSBE |
| 3 | Viral infection and antiviral drug development | BSBE |

| Title | **Principles of drug discovery** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Elective |
| Prerequisite | Biophysics and Structural Biology (PC)<br>Biochemistry (PC) | | |

**Objective**

The instructor will:

1. Focus on route of drug design and discovery

**Learning Outcomes**

The students will have the ability to:

1. Appreciate the underlying principles of drug design and development

**Contents:**

*Fractal 1. Target Identification and Validation [14 Lectures]:* Drug targets, computer aided drug design, principles of QSAR (4 Lectures); pharmacokinetics, administration and dosing (2 Lectures); drug testing: *in vivo and in vitro (2 Lectures)*; drug discovery: natural lead, synthetic lead, combinatorial synthesis (3 Lectures); pharmacokinetics based drug design (3 Lectures).

*Fractal 2. Artificial Intelligence Applications in Drug Discovery[14 Lectures]:* drug target identification, drug databases, virtual screening (4 lectures); classifying new drugs, predicting drug responses, applications in clinical trials (4 lectures); deep learning based survival prediction, disease prognosis prediction (3 lectures); data driven medicine, drug-target interaction prediction (3 lectures)

*Fractal 3. Bench-to-Bed side[14 Lectures]:* Chemical development (2 Lectures), patenting (2 Lectures), process development (2 Lectures); toxicology (1 Lectures), pharmacology (2 Lectures), drug metabolism (1 Lectures); clinical trials (2 Lectures); commercialization: regulatory affairs, pipeline development, pharmaceutical market places, business opportunities (2 Lectures).

**Text Books**

1. K. Stromgaard, P. K. Larsen, U. Madsen, Drug Design and Discovery, CRC Press (2016), 5th Edition.

**Reference Books**

1. E. Stevens, Medicinal Chemistry: The Modern Drug Discovery Process, Pearson Publisher (2013), 1st Edition.

**Self Learning Materials**

https://ocw.mit.edu/courses/sloan-school-of-management/15-136j-principles-and-practice-of-drug-development-fall-2013/

| Title | **Medicinal Chemistry** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering , and Chemistry | L-T-P [C] | 3–0–0 [3] |
| Offered for | B.Tech | Type | Elective |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Provide understanding of representing stereochemical structures of drug molecules and their important features.
2. Provide knowledge of disconnection of drug molecules followed by targeting them synthetically by designing synthetic routes and methods development to achieve them in concise and atom economical way.

**Learning Outcomes**

The students are expected to have the ability to:

1. Design and develop a method for targeted biologically active natural products or drug molecule from the knowledge of the retrosynthesis and synthetic organic chemistry.
2. Appreciate and understand the importance of stereochemistry avail in drug molecules.

**Contents**

*Fractal 1. Pharmacophore [14 lectures]:* Stereochemical feature of pharmacophore (2 Lectures), Natural and synthetic pharmacophores (2 Lectures), introduction and importance of natural product chemistry in drug development (2 Lectures), analogue-based lead designing (2 Lecture), Examples of Synthetic and natural Product-based landmark drugs (1 Lecture), Drug metabolism: Concept of prodrugs (1 Lecture), adverse drug reaction (2 Lectures), biotransformation (2 Lectures).

Fractal 2. *Basic Concept of Organic Synthesis [14 lectures]:* functional group interconversions, (4 Lectures) donor and acceptor, (1 Lecture) chemo-, regio-and stereo-selectivities, (3 Lectures) natural and umpolung reactivities, (2 Lectures) 1,3 and 1,5-difunctional compounds, (2 Lectures) importance and role of chiral drug molecules and selective synthesis of chiral drug molecule. (2 Lectures).

*Fractal 3. Synthetic procedure of biologically active molecules [14 lectures]:* Few applications of retrosynthetic strategies in the total synthesis of selected organic molecules such as: Drugs acting on Central Nervous System (2 Lectures), Anti-inflammatory agents (such as paracetamol, naproxine, ibuprofen, aspirin, diclofenac)(4 Lectures), Antibiotics and Antifungal agents (2 Lectures), Antiviral agents (1 Lecture), Medicinal Plant products [tetrahydrocannabinol (THC)] (2 Lectures), Importance of peptides in drug discovery (tubulysin, dolastatin, milnamide) general aspects of Peptides and Peptidomimetics in designing therapeutic molecule (3 Lectures).

**Text Books**

1. S. Warren, Organic Synthesis, The Disconnection Approach Wiley (2014), Third edition.
2. E. M. Carriera, L. Kvaerno Classics in Stereoselective synthesis, Wiley (2009), First edition.
3. L. Kurti, B. Czako, Strategic Applications of Named Reactions in Organic Synthesis, Elsevier (2005), First edition.
4. D. S. Johnson, J. J. Li, The Art of Drug Synthesis. Wiley (2007), First edition.

**Reference Books**

1. K. C. Nicolaou, S. A. Snyder, Classics in Total Synthesis-II: Further Targets, Strategies, Methods, Wiley (2003), First edition.
2. R. K. Bansal, Heterocyclic Chemistry, New Age International Private Limited (2017), 5th edition.

**SelfLearning Material**

1. NPTEL Lectures: Organic synthesis - https://nptel.ac.in/courses/104105087/
2. NPTEL Lectures: Medicinal Chemistry- https://nptel.ac.in/courses/104106106/

| | | | |
|---|---|---|---|
| Title | **Viral infection and antiviral drug development** | Number | BL4XX0 |
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Elective |
| Prerequisite | Biochemistry | | |

**Objectives**

The Instructor will:

1. Provide the fundamental knowledge of Viral pathogenesis and Host cell responses
2. Provide the detailed knowledge of antiviral drug targets, mechanism of existing antiviral drugs and future antiviral therapeutics and drug designing endeavours.

**Learning Outcomes**

The students are expected to have the ability to:

1. Understand the molecular mechanism of viral pathogenesis and host antiviral immune responses.
2. Understand the mode of action of common antiviral therapeutics and the fundamentals of antiviral drug designing strategies.

**Contents**

*Basic concept of Virus and Viral pathogenesis:*(14 lectures) Virus a unique infectious agent, Classification of virus (5 Lectures); Example of pathogenic virus and their life cycles (Host specificity, attachment, replication, proliferation, maturation, release and cross species infectivity) (5 Lectures); Virus induced cell transformation (4 Lectures)

*Viral infection versus host defense mechanisms:* (10 lectures) Host immune responses against viral infection (Nonspecific immunity, humoral immunity (4 Lectures) and cell mediated immunity(4 Lectures) Immunopathological effects of viral infections (2 Lectures)

*Antiviral therapies*: (18 lectures) Identification and validation of antiviral drug targets (4 Lectures), Strategies to develop antiviral drugs (small molecule and peptide based) (4 Lectures) Therapeutic antibodies as antiviral drugs, AON and RNAi based antiviral therapies, Immunization (active and passive) as antiviral therapy (5 Lectures); Mode of action of common antiviral drugs (5 Lectures).

**Text Books**

1. E. Lycke and E. Norrby, Text Book of Medical Virology, Elsevier (1983), First edition.
2. T. J. Kindt, B. A. Osborne, R. A. Goldsby, J. Kuby, Immunology, New York Publisher (2007), 6th Edition.
3. E. D. Clercq, Advances in Antiviral Drug design, Volume 5, Elsevier (2007), First edition.

**Reference Books**

1. Chorghade, M. S., Drug Discovery and Development, Volume 1, Wiley (2006), First edition.

**Self Learning Material**

Dr. Jun Wang, from The University of Arizona, USA Lecture on Influenza Drug Development (https://www.youtube.com/watch?v=8zE3BV6CQcs)

Dr. Vincent Racaniello, from Columbia University, USA Lecture on antiviral drugs (https://www.youtube.com/watch?v=w4N63NY_jDc)

# 15. Detailed Course Content of Departmental Specializations

## Microbial Systems Engineering

| Specialization Core (8 credits) | Specialization Elective (12 Credits) |
|---|---|
| - Engineering Microbes (3-0-0)<br>- Bioprocess Engineering and Fermentation (3-0-0)<br>- Mathematical modelling of microbes (1-0-2) | - Microbial Nanotechnology (3-0-0)<br>- Metabolic Engineering for biofuels (2-0-0)<br>- Microbial remediation and environmental biotechnology (3-0-0)<br>- Microbes in food and sustainable agriculture (3-0-0)<br>- Bioenergy (3-0-0)<br>- Soil Microbiome & Microbial Technology (2-0-0)<br>- Biofilms: Bacterial communities (3-0-0)<br>- Gut microbiomes in health and diseases (3-0-0)<br>- Downstream processing (3-0-0)<br>- Industry collaborated project<br>4 credit (0-0-6) x 1 |

| Title | **Engineering Microbes** | Number | BBL6XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3-0-0[3] |
| Offered for | B.Tech | Type | Specialization Compulsory |
| Prerequisite | Genetics & Gene Manipulation | | |

**Objectives**

The Instructor will:

1. Introduce advanced methods for genetic engineering microbes
2. Discuss case studies outlining the application of introduced methods to develop engineered microbes for applications in various domains

**Learning Outcomes**

The students will have the ability to:

1. Select the appropriate method for genetic engineering of microbes
2. Develop solutions for their chosen domain of research using genetically engineered microbes or microbial communities

**Contents**

*Genetic manipulation of microbes [16 Lectures]:* Strain development for specific applications (2 lectures), basic metabolic engineering (3 lectures), microbial community engineering (2 lectures), construction of reporter strains and biosensors (4 lectures), applications of genetically engineered microbes in healthcare, food production, energy production and environmental remediation (5 lectures).

*Gene & genome engineering [16 Lectures]:* Introduction to CRISPR-Cas biology (3 lectures), engineering CRISPR-cas systems (5 lectures), applications of CRISPR-Cas in microbial system engineering (4 lectures), introduction to microbial genomes, minimal genome concept (2 lectures), synthetic genomes (2 lectures).

*Advanced Genetic engineering research prospects in industry [10 Lectures]:* Medicines and genetic engineering; insulin (3 lectures), albumin and human growth hormones production (2 lectures); generation of monoclonal antibodies and vaccines (2 lectures); gene coding for a useful protein and cloning concepts (3 lectures).

**Text Book**s

1. S. B. Primrose, and R. M. Twyman, *Principles of Gene Manipulation & Genomics*, Blackwell Publishing (2006), 7th edition.
2. Reviews & Research articles provided by the Instructor

**Reference Books**

1. Reviews & Research articles provided by the Instructor

**Self Learning Material**

http://nptel.ac.in/courses/102103013/
https://ocw.mit.edu/courses/ biology/7-03-genetics-fall-2004/lecture-notes/

| Title | **Bioprocess Engineering & Fermentation** | Number | BBL7XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3-0-0 [3] |
| Offered for | B Tech. | Type | Specialization Compulsory |
| Prerequisite | Microbiology and Biochemistry | | |

**Objectives**

1. Introducing the students to principles and applications of industrial biotechnology.
2. Enable students to use their knowledge of microbiology and biochemistry for bioprocess design.

**Learning Outcomes**

The students will have the ability to:

1. Understanding enzymatic and microbial process kinetics
2. Ability to identify and understand the key principles and limitations underlying bioprocess design

**Contents**

*Basics of Biochemical Engineering:* Basics of reactions and thermodynamics (5 lectures); Isolation, screening and maintenance of industrially important microbes; strain improvement (3 lectures)
*Stoichiometry, bacterial energetics and Microbial growth kinetics:* substrate partitioning and cellular yield, energy reactions, overall reactions for biological growth (5 lectures), Microbial growth, Basic rate expressions, mass balances, Nutrient and electron acceptors (3 lectures).
*Bioreactors:* Introduction to bioreactors (2 lectures), Batch and Fed-batch bioreactors, Continuous bioreactors, plug flow reactors (5 lectures) and control of bioprocess parameters (2 lectures).
*Fermentation economics:* Various types of dimensionless analysis in mass transfer; heat transfer and momentum transfer (5 lectures); Importance of dimensionless number in designing the bioreactors, and scale up (3 lectures)
*Industrial Processes and Process economics:* Process technology for the production of primary metabolites (4 lectures), Discussion on the national and international scenario of the products (2 lectures).*Applications of biotechnology in production of biological:* Microbial production of useful metabolites (3 lectures)

**Textbooks**

1. M. Shuler, F. Kargi, Bioprocess Engineering: Basic Concepts, Prentice Hall, Englewood, Cliff (2002), 2nd edition.
2. P. F. Stanbury, A. Whitaker, Principles of Fermentation Technology. Oxford: Pergamon (1997), third edition.
3. P. Doran, Bioprocess engineering principles, Academic Press (1995), 1st edition.

**Reference books**

1. R. G. Harrison, P. Todd, S. R. Rudge, D. P. Petrides, Bioseparations Science and Engineering. Oxford University Press (2015) 2nd Edition.
2. C. Ratledge, B. Kristiansen, Basic Biotechnology, Cambridge University Press (2001), 2nd edition.
3. W. Crueger and A. Cruger, Biotechnology: A text book of Industrial Microbiology, Panima publishing Corporation, Delhi (2004), 2nd edition.

**Self-Learning Materials**

1. Kristala Jones Prather. 10.442 Biochemical Engineering. Spring 2005. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

| Title | **Mathematical modelling of microbes** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 1-0-2 [2] |
| Offered for | B.Tech. | Type | Specialization Compulsory |
| Prerequisite | None | | |

**Objectives**

The main objective of the course is to introduce students to various aspects of mathematical modelling in the particular context of microbial systems.

**Learning Outcomes**

Students will have a knowledge of important concepts related to the mathematical modelling of microbial systems, and will be able to apply them to model the behaviour of biological systems as well as develop strategies for manipulating them.

**Contents**

Introduction, Growth of microbial populations, Volume and macromolecular content of cells (4 lectures), Biochemical reactions underlying microbial growth (2 lectures), Growth in a changing environment, Connecting metabolism and growth: flux balance analysis (4 lectures), Connecting gene expression, metabolism and growth: coarse-grained whole-cell models (4 lectures)

**Laboratory Experiments**

Modelling microbial growth, Simulation with CellDesigner, Flux balance analysis

**Text Books**

E. Voit, A First Course in Systems Biology. Garland Science (2012), First edition.

**Reference Books**

1. E. Klipp, Systems biology : a textbook. Wiley (2009), First edition.
2. MEJ Newman, Networks : an introduction. Oxford Univ. Press (2011), First edition.

**Self Learning Materials**

NPTEL Lectures: *Computational Systems Biology*, Karthik Raman, IIT Madras https://nptel.ac.in/noc/individual_course.php?id=noc18-bt22

| Title | **Microbial Nanotechnology** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Specialization Elective |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Provide deep insight on fundamental concepts and advances in microbial nanotechnology.
2. Provide overview on the mechanistic understanding on how nanomaterials interact with microbes.

**Learning Outcomes**

The students will have the ability to:

1. Design a greener and eco-friendly synthetic strategy to prepare nanomaterials in bulk scale.
2. Compare their intrinsic antimicrobial activities of different nanomaterials.
3. Design a nanomaterial with a specific size and shape for a particular application.

**Contents**

*Fractal 1. Microbial Synthesis of Nanoparticles [14 Lectures]**:*** Biosynthesis of plasmonic nanoparticles by microbes and their mechanism (5 lectures), biosynthesis of magnetic nanoparticles by microbes and their mechanism (5 lectures), physico-chemical characterization of nanomaterials (4 lectures).

*Fractal 2. Interactions of Microbes with Nanomaterials [14 Lectures]:* Nanomaterial–microbe cross-talk: physicochemical principles and biological consequences (5 lectures), role of bacteriophages in nanotechnology (4 lectures), and antimicrobial properties of nanomaterials (5 lectures).

*Fractal 3. Microbial Nanovesicles and Viral Nanoparticles [14 Lectures]**:*** Magnetosomes (3 lectures), bacterial membrane vesicles(3 lectures), applications in vaccines and immunotherapeutics (2 lectures), Engineered nanoparticles from viruses (3 lectures), case studies on applications of viral nanoparticles in biomedicine (3 lectures).

**Text Books**

1. R. Prasad, B. Siddhardha, M. Dyavaiah, Nanostructures for Antimicrobial and Antibiofilm Applications (Nanotechnology in the Life Sciences), Springer (2020), First edition.
2. N. Cioffi, M. Rai, Nano-Antimicrobials: Progress and Prospects, Springer (2012), First edition.

**Reference Books**

1. R. Prasad, Microbial Nanobionics: Volume 1, State-of-the-Art (Nanotechnology in the Life Sciences) (2019), Springer, ISBN-10: 3030163822.
2. R. Prasad, Microbial Nanobionics: Volume 2, Basic Research and Applications (Nanotechnology in the Life Sciences) (2019), Springer, ISBN-10: 3030165337.

**Self-Learning Material**

N/A

| Title | **Biofilms: Bacterial communities** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Biosciences & Bioengineering | L-T-P [C] | 3-0-0 [3] |
| Offered for | B.Tech | Type | Specialization Elective |
| Pre-requisite | Microbiology | | |

**Objectives**

1) Introduce students to the concept of social living and community formation in bacteria.
2) To enable students understand role of biofilms in healthcare and environment.

**Learning Outcomes**

Students will be able to appreciate the importance of biofilm formation with respect to their beneficial and detrimental roles.

**Contents**

Biofilm formation [14 Lectures]:
Introduction and significance [5 Lectures]: Composition of biofilm matrix, Structure and function of matrix, Factors contributing to biofilm formation (intrinsic and extrinsic)
Biofilm life cycle [5 Lectures]: Stages of Biofilm Development, Physiology of biofilms, Viability, metabolism, social interactions
Biofilm evolution [4 Lectures]: Population distribution with the matrix (active and persister cells), multispecies biofilm, Evolutionary significance of biofilms

Occurrence and Relevance of Biofilms [14 Lectures] :
Environmental Biofilms [5 Lectures]: types of biofilms, bacterial species contribution, multi-species biofilm, biofouling, corrosion, plant root nodule interactions, sulfur cycle.
Clinical Biofilms [5 Lectures]: opportunistic infections, hospital acquired infections, antibiotic resistance, gene transfer through biofilm community.
Methods to study biofilms [4 Lectures]: microscopy (confocal), staining (congo red and crystal voilet), quantification of biofilm biomass

Biofilms in engineering systems [14 Lectures]:
Biofilms in treatment of waste water treatment, biofiltration, bioremediation, decomposition [5 Lectures], Implications food and agriculture industry, as metabolizers [4 Lectures], generation of electric signals, biocatalysis, microbial fuel cells [5 Lectures]

**Text Book**

1. L. F. Melo, T. R. Bott, M. Fletcher and B. Capdeville. Biofilm-Science and Technology. Springer (1992), First edition.

**Reference:**

1. M. Ghannoum, G. A. Toole, Microbial Biofilms. ASM Press (2013), First edition

**Self-Learning material:**

1. https://www.coursera.org/learn/bacterial-infections

| Title | **Metabolic Engineering for biofuels** | Number | BBL7XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 2–0–0 [2] |
| Offered for | B.Tech | Type | Specialization Elective |
| Prerequisite | Microbiology and Genetics and gene manipulation | | |

**Objectives**

The instructor will Introduce basic concepts in metabolic engineering and explores modern approaches in metabolic and strain engineering.

**Learning Outcomes**

The students will have an ability to:

1. understand microbial metabolism and describe the major metabolic pathways
2. Use stoichiometric models to assess metabolic pathways and adopt appropriate genetic engineering strategies.
3. Apply genome-scale models to depict metabolic designs that improve flux towards biofuel production.

**Contents**

Introduction to metabolic engineering: Microbial physiology and metabolism, Enzyme & growth Kinetics (5 lectures)

Modelling and Flux balance analysis: Modelling kinetics, methods to measure fluxes, metabolic flux analysis, flux balance analysis (5 lectures)

Synthetic Biology for biofuels: Reading writing DNA, Assembling and sequencing DNA (5 lectures)

Design: Design Transcription, translation, post translation and design pathways (5 lectures)

Genome engineering for biofuels: Genome engineering tools (4 lectures)

Case studies on biofuel production optimization (4 lectures)

**Textbooks**

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

**References books**

1. C. S. Smolke, Metabolic pathway engineering handbook: Fundamentals. New York: CRC Press. (2010) 1st edition.
2. C. S. Smolke, Metabolic pathway engineering handbook: Tools and applications. 1st ed. New York: CRC Press (2010). 1st edition.

| Title | **Soil Microbiome & Microbial Technology** | Number | BBL7XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 2–0–0 [2] |
| Offered for | B.Tech | Type | Specialization Elective |
| Prerequisite | Microbiology and Genetics and gene manipulation | | |

**Objectives**

The instructor will Introduce soil microbiology and soil microbiome in connection with agricultural productivity and crop nutrient content.

**Learning Outcomes**

The students will have an ability to:

1. depict the desirable soil microbiome
2. Understand pant microbe interaction and its effect on crop productivity and it nutrient content.
3. Engineer microbes for enhancing crop productivity.

**Contents**

*Introduction:* Microbiomes of soil, plant and animal the good and the bad soil microbiome, Analytical approaches for microbiome research (5 lectures)

*Soil Microbiome and plant growth connection:* Microbiome of soil, factors that shape the host microbiome (5 lectures)

*Ecological connection*: Microbial symbiosis and host nutrition, the microbiome and host behaviour, host microbiomes and disease (5 lectures)

*Adapting to environmental change:* The changes in microbiomes, impact assessment *(4 lectures)*

*Engineering soil microbiomes:* Microbial technologies and altering soil microbiomes for improved crop productivity and nutrient production by plants (5 lectures)

*Synthesis and future directions:* Future approach to agricultural sustainability, case studies (4 lectures

**Textbooks**

R. Antwis, X. Harrison, M. Cox, M. (Eds.). (2020). *Microbiomes of Soils, Plants and Animals: An Integrated Approach* (Ecological Reviews). Cambridge: Cambridge University Press. doi:10.1017/9781108654418

**Reference books**

D. R. Montogomery, A. Bikle, The Hidden Half of Nature: The Microbial Roots of Life and Health. W. W. Norton & Company (2016), First edition.

| Title | **Gut Microbiome in Health & Disease** | Number | BBL6XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B.Tech. | Type | Specialization Elective |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Introduce the microbiome with a special emphasis on the human gut microbiome
2. Outline the process of establishment of the gut microbiome and will highlight the functions of a healthy microbiome
3. Highlight dysbiosis in the gut microbiome associated with certain diseased states and changes in the environment

**Learning Outcomes**

The students will have the ability to:

1. Appreciate the importance of the various factors including the diet in shaping the gut microbiome
2. Study the gut microbiome using well defined and well thought out experimental strategies
3. Understand the metabolic roles of the microbiome and ideate towards development of novel therapies that may target the microbiome

**Contents**

*Introducing the Human Microbiome [8 Lectures]:* Microbes on & within us, The great plate count anomaly (1 lecture), The microbiome in early life (3 lectures), Development of the microbiome with age (4 lectures)

*Exploring the Human Gut Microbiome [8 Lectures]:* Accessing the microbiome (bacteria, fungi, viruses) (2 lectures), Culture based & culture independent methods (2 lectures), Sequencing based approaches, Next-generation sequencing based approaches (2 lectures), Interpreting microbiome data (2 lectures)

*Functions of the Gut Microbiome [8 Lectures]:* Metabolic functions of the microbiome (4 lectures), Microbiome in immunity, Infection control by the microbiome (2 lectures), Microbiome in nutrition (2 lectures)

*Factors impacting the Microbiome [6 Lectures]:* Mode of delivery, Diet & nutrition (2 lectures), Drugs & antibiotics (1 lecture), Ethnicity & race, Host genetics (2 lectures), Early-life infections, Medical procedures, Probiotics, Prebiotics (1 lecture)

*Gut microbiome dysbiosis & Disease [7 Lectures]:* Obesity, Type II Diabetes (2 lectures), Cancer, Autoimmune disorders (2 lectures), Gut-brain axis (2 lectures), Inflammatory bowel disease (1 lecture)

*Therapies targeting the Microbiome [3 Lectures]:* Probiotics, Prebiotics (1 lecture), Fecal microbiota transplantation (2 lecture), Targeted depletion, Phage therapy (2 lecture)

**Text Book**

1. D. Haller, Ed. *The Gut Microbiome in Health & Disease*, (2018), Springer (2018), 1st Edition.
2. L. Pray, L. Pillsbury, E. Tomayko, *Workshop Summary: The Human Microbiome, Diet & Health*, The National Academies Press (2012), First edition.

**Reference Books**

1. Research articles, Case reports & Review articles as provided by the Instructor

**Self Learning Material**

1. https://www.coursera.org/learn/microbiome
2. https://www.edx.org/course/nutrition-and-health-human-microbiome

| Title | **Downstream processing** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Specialization Elective |
| Prerequisite | Bioprocess Engineering and Fermentation | | |

**Objective**

The instructor will provide an insightful overview of the integrative nature of different unit operations used for the downstream processing of microbial product .

**Learning Outcomes**

The students will have the ability to:

1. Appreciate the underlying principles of downstream processing.
2. Design an effective and economic downstream processing strategy for a particular microbial product.

**Contents:**

*Fractal 1.*Fundamental of downstream processing [14 Lectures]: Scope of downstream processing, selection of bio-separation techniques (5 lectures), unit operations in downstream processing (4 lectures), intracellular vs extracellular products, isolation of intracellular products , methods of cell disruption (5 lectures)

*Fractal 2:* Bioseparation 1 [14 Lectures]: Methods of solid-liquid extraction (2 lectures), centrifugation and filtration (basic principles, design characteristics) (5 lectures), reverse osmosis, ultracentrifugation, sedimentation (5 lectures), electrophoresis and dialysis (2 lectures).

*Fractal 3:* Bioseparation 2 [14 Lectures]: Evaporation (2 lectures), liquid-liquid extraction, chromatographic techniques (ion exchange, affinity and gel permeation) (5 lectures), spray drying and lyophilization (5 lectures), crystallization in final product formulation (2 lectures).

**Text Books**

1. P. M. Doran, Bioprocess Engineering principles, Academic press (2012), 2nd edition.

**Reference Books**

1. G. Roger, G. Harrison, W. Paul, W. Todd , S. R. Rudge ,P. Demetri. Petrides, Bioseparations Science and Engineering (Topics in Chemical Engineering), OUP USA (2015), 2nd edition.

**Self Learning Materials**

NPTEL course, Prof. Mukesh Doble, IIT Madras, https://nptel.ac.in/courses/102/106/102106022/

## Therapeutic Engineering and Drug Discovery

| Specialization Core (8 credits) | Specialization Elective (12 Credits) |
|---|---|
| - Modern approaches of drug designing (3-0-0)<br>- Introduction to Precision Medicine (3-0-0)<br>- AI-based drug discovery (2-0-0) | - Antimicrobial drugs and drug resistance (2-0-0)<br>- Anticancer drug discovery and development (3-0-0)<br>- Modern approaches for immunotherapy (3-0-0)<br>- Novel Drug Delivery Systems (3-0-0)<br>- Theranostic Systems (3-0-0)<br>- Industry collaborated project 4 credit (0-0-6) x 1 |

| Title | **Modern approaches of drug designing** | Number | BBL6XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Specialization Compulsory |
| Prerequisite | Biophysics and Structural Biology<br>Biochemistry | | |

**Objectives**

The instructor will provide:

1. In-depth understanding of the modern approaches involved in drug designing and drug screening.
2. Introductory idea of the drug targets and their identification.
3. Detailed understanding of work flow of modern drug designing.

**Learning Outcomes**

The students will have the ability to:

1. Conceptualize the basic principles of state of the art techniques used in drug designing and screening
2. Understand the basic principles of modern day drug designing steps.
3. Conceptualize the basic principles and applications of modern day drug designing approaches to meet up the demands of pharmaceutical industries.

**Contents**

*Introduction to Drugs, Drug Discovery and Drug targets [9 Lectures]:* Definition of drugs; criteria of a good drug; historical perspective of drug designing approaches; brief outline of modern day drug designing approaches (4 Lectures)*;* Drug targets and Drug target hot spots (5 Lectures).

*Rational drug designing approaches and techniques [18 Lectures]: in silico* based approaches to identify drug target hotspots (homology modelling, virtual screening, molecular dynamic simulation) (5 Lectures). Biochemical and Biophysical principles to develop drug screening assays (4+4 Lectures); Single molecule based high throughput methods of drug screening (5 Lectures)

*Ligand based drug designing approaches [10 Lectures]:*Identification of molecular scaffold and pharmacophore mapping; pharmacophore screening (3 Lectures); pharmacophore modification and combinatorial chemistry (3 Lectures); lead optimization (2 Lectures)

*Validation of therapeutic leads [5 Lectures]:* Preclinical pharmacology and toxicology analysis of top therapeutic leads (ADMET analysis); drug testing (brief idea of different phases of clinical trial).

**Text Books**

1. K. Stromgaard, P. K. Larsen, U. Madsen, Drug design and discovery, Taylor and Francis (2016), 5$^{th}$ edition.

**Reference Books**

1. D. Ekinci. Medicinal Chemistry and Drug design, Intech open (2012), First edition.

**SelfLearning Material**

http://www.louisville.edu/~mjwell04/design.html
http://www.pharmacy.umaryland.edu/courses/PHAR531/lectures_old/compchem_1.html

| Title | **Introduction to Precision medicine** | Number | BBL6XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3-0-0 [3] |
| Offered for | B.Tech | Type | Specialization Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Provide an introduction to precision medicine

**Learning Outcomes**

The students are expected to have the ability to:

1. Understand fundamentals of techniques to create and analyse effective methods for precision medicine

**Contents**

*Introduction to Precision Medicine [8Lectures]:* fundamentals of genetics as these apply to personalized medicine (DNA structure; RNA; protein structures; function of DNA; coding; DNA variations; types of genetic variants).

Ethical Aspects of Precision Medicine *[5 Lectures]:* Privacy, Informed consent and social justice, case studies.

*Studying Genetic Variation [5 Lectures]:* how we study genetic variation in families and populations. Family history and inheritance patterns, ancestry, and linkage. *Contemporary techniques and technologies [8 Lectures]:* Technologies used to study genetic variation, including genome-wide association and sequencing.

*Case studies in Precision Medicine I [8 Lectures]:* specific cases in personalized medicine. Familial hypercholesterolemia: how we use genomic medicine to move from a rare disease to a common medication, using genomics to find new drug targets, and a discussion of the side effects of statin therapy.

*Case studies in Precision Medicine II [8 Lectures]:* Other case studies will include: cystic fibrosis, Marfan syndrome, heart failure, neuropsychiatric diseases, cancer and diabetes.

**Textbook**

1. H. P. Deigner, M. Kohl, Precision Medicine Tools and Quantitative Approaches, 1st Edition, Academic Press
2. R.A. Goldsby, J. K. Thomas and A. Barbara, K. Osborne., *Kuby Immunology*, Freeman,2002, 6th Edition

**Reference Books**

1. K. Murphy, P. Travers, M. Walport, M. Janeway, C. *Janeway's Immunobiology*. New York: Garland Science (2011), 8th edition.
2. M. T. Madigan, J. M. Martinko, J.M. Brock, *Biology of Microorganisms*, Prentice-Hall, Inc., (2006), 11th Edition.

**Self Learning Material**

1. NPTEL Video Lectures on Human Molecular Genetics by Prof S Ganesh, Indian Institute of Technology Kanpur (https://nptel.ac.in/courses/102/104/102104052/)
2. NPTEL Video Lectures on Essentials in Immunology by Prof. R. Manjunath, Prof. Dipankar Nandi , Prof. Anjali Karande, Indian Institute of Science Bangalore (http://nptel.ac.in/courses/104108055/)
3. NPTEL Video Lectures on Cellular and Molecular Immunology by Prof. Sachin Kumar, Indian Institute of Technology Guwahati (http://nptel.ac.in/courses/102103038/)

| Title | AI- based drug discovery | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 2–0–0[2] |
| Offered for | B.Tech | Type | Specialization Compulsory |
| Prerequisite | Nil | | |

**Objectives:**
This course will involve a deep dive into recent advances in AI in healthcare, focusing in particular on deep learning approaches for drug discovery problems.

**Learning outcomes:**
The students are expected to:
1) Understand various methods for representation of a molecule, molecular descriptors, structure computation software.
2) Select/Develop an appropriate DL/ML techniques to perform a particular drug discovery related analysis.

**Contents**

*Fractal 1 [14 lectures]:* Introduction, Chemical formats: Key features of SDL, MDL and PDB files, SMILES systems (4 lectures), Morgan algorithm for consistent labelling and structural ordering, Canonical Smile, CML file, Conversion of file formats (4 lectures), Molecular descriptor (0-4D descriptors), molecular interaction field (MIF) (2 lectures) and comparative molecular field analysis (CoMFA) (1 lecture), molecular fingerprints (path based and sub structure), descriptor to data matrix conversion.(3 lectures)

*Fractal 2 [14 lectures]:* Identification of relevant molecular descriptors using feature selection techniques and deep learning (3 lectures), application of supervised learning and deep learning for predictive modelling of QSAR (3 lectures), ligand based virtual screening (1 lecture), ADME and drug sensitivity prediction (2 lectures), unsupervised learning for denovo drug molecule design, drug repurposing, and meta data based analysis of target-disease-drug association. (5 lectures)

**Textbook**
1) N. Brown, Artificial Intelligence in Drug Discovery, Royal Society of Chemistry (2020), 1st edition.
2) M. Chang, Artificial Intelligence for Drug Development, Precision Medicine, and Healthcare, Taylor & Francis Group (2020), 1st edition.

**Reference Books**
1) A.R R. Leach, Molecular Modelling: Principles and Applications, Prentice Hall, (2001), 2nd edition.
2) B. Ramsundar, P. Eastman, P. Walters, V. Pande, Deep Learning for the Life Sciences: Applying Deep Learning to Genomics, Microscopy, Drug Discovery, and More, "O'Reilly Media, Inc. (2019), 1st edition.

**SelfLearning Material**
1. AI in Drug Discovery Decision Support, IBM Watson Health, https://www.youtube.com/watch?v=SWd7ehX0rus
2. Deep Learning for Drug Discovery, BayesGroup.ru, https://www.youtube.com/watch?v=Xf2uI4S9IMo

| Title | **Antimicrobial drugs and drug resistance** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 2–0–0 [2] |
| Offered for | B.Tech. | Type | Specialization Elective |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Outline how antimicrobials work against microbes and how microbes are evolving resistance against these life-saving drugs
2. Highlight the key drivers of antimicrobial resistance (AMR) and describe what can be done to curb AMR
3. Discuss key problems in solving the AMR problem

**Learning Outcomes**

The students will have the ability to:

1. Appreciate the importance of correct use of current antibiotics
2. Identify potential targets in microbes for development of new antimicrobials
3. Ideate about solving problems associated with AMR emergence and tackling AMR

**Contents**

*Antimicrobials [7 Lectures]:* Classes of antimicrobials, Mechanism of actions of antimicrobials (2 lectures), Cellular targets of antimicrobials (2 lectures), Correct use of antimicrobials (1 lecture), Laboratory testing for antibiotic susceptibility (2 lectures)

*Resistance to Antimicrobials [7 Lectures]:* General mechanisms of resistance to antimicrobials (3 lectures), Evolution of antimicrobial resistance (1 lecture), Genetics of antimicrobial resistance (1 lectures), Molecular testing for antibiotic resistance (1 lecture), Transmission of antimicrobial resistance (1 lecture)

*Drivers of Antimicrobial Resistance [4 Lectures]:* Inappropriate usage of antimicrobials (1 lecture), Industrial use of antimicrobials (2 lectures), Persistence as a driver of antimicrobial resistance (1 lecture)

*Tackling Antimicrobial Resistance [10 Lectures]:* Case studies on clinical impact of antimicrobial resistance (2 lectures), Development of new antimicrobials, Finding novel drug targets in drug resistant bacteria (2 lectures), Drug repurposing (1 lecture), Antimicrobial stewardship & responsible use of antimicrobials (1 lecture), Alternative therapies for drug resistant infections (2 lectures), Tracking drug resistant bacteria: Molecular epidemiology (2 lectures)

**Text Book**

1. J. M. Willey, L. M. Sherwood, C. J. Woolverton, C. J., *Prescott's Microbiology*, McGraw Hill (2013), 9th Edition.
2. M. T. Madigan, K. S. Bender, D. H. Buckley, W. M. Sattley, D. A. Stahl, *Brock Biology of Microorganisms*, Pearson (2018), 15th edition.

**Reference Books**

1. Research articles, Case reports & Review articles as provided by the Instructor

**SelfLearning Material**

1. https://www.coursera.org/learn/antimicrobial-resistance

| Title | **Anticancer Drug Discovery and Development** | Number | BBL6XX0 |
|---|---|---|---|
| Department | Bioscience & Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Specialization Elective |
| Prerequisite | Biochemistry | | |

**Objectives**

The Instructor will:Provide the insights of the molecular mechanism of carcinogenesis.

Provide the knowledge of anticancer drug discovery, mechanism of cancer drug resistance and upcoming anticancer therapeutics.

**Learning Outcomes**

The students are expected to have the ability to:

1. Understand the molecular mechanism of carcinogenesis and cellular factors regulating carcinogenesis.
2. Understand the mode of action of common anticancer drugs, molecular mechanism of cancer drug resistance.
3. Adopt the importance of upcoming therapeutic strategies to combat cancer.

**Contents**

*Carcinogenesis:* (14 lectures) Molecular mechanism of carcinogenesis, Genetic and Epigenetic factors regulating the carcinogenesis (5 Lectures); Retrotransposones and carcinogenesis (4Lectures); Carcinogenesis associated phenomena (Alteration of kinase activities, Protein turnover kinetics, tissue invasion and angiogenesis) (5 Lectures).

*Target identification and anticancer drug discovery:* (14 lectures) Brief history of Cancer chemotherapy (2 Lectures); Biomarkers, Cancer specific validation and use of biomarkers for anticancer drug discovery (4 Lectures), Example of drug targets for cancer chemotherapy [Cell cycle checkpoint proteins and their regulators (2 Lectures); Tumor suppressors (2 Lectures); Cellular Growth factors (2 Lectures) Protein turnover enzymes (2 Lectures)]

*Anticancer therapies*: (14 lectures) Strategies to develop anticancer drugs (small molecule and peptide based) (5 Lectures); Mode of action of common anticancer drugs and Cancer drug resistance (5 Lectures); Therapeutic antibodies as anticancer drugs (2 Lectures), AON and RNAi based anticancer therapies, Gene editing as cancer therapy (2 Lectures).

**Textbook**

1. B. C. Baguley, and D. J. Kerr, Anticancer Drug Development, (2001), Elsevier (2001), First edition.

2. L. Wolfgang, Principles of Cancer Treatment and Anticancer Drug Development, (2019), Springer (2019), First edition.

**Reference Books**

1. M. S. Chorghade, Drug Discovery and Development, Volume 1, Wiley (2006).

**Online Course Material**

1. Changing strategies in the war on cancer (Part2) (https://www.adcreview.com/the-review/cancer/changing-strategies-in-the-war-on-cancer-part-2/)

2. Changing strategies in the war on cancer (Part3) (https://www.adcreview.com/the-review/cancer/changing-strategies-in-the-war-on-cancer-part-3/)

3. Discovery of biomarkers predictive of anticancer drug response in preclinical settings by Dr. Benjamin Haibe Kains, University of Toronto, Canda. (https://www.youtube.com/watch?v=KtR3Ufnn09o)

| Title | **Modern approaches for immunotherapy** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Specialization Elective |
| Prerequisite | The human immune system: mechanisms to detect, defend and attack | | |

**Objective**

The instructor will:

1. provide an insight about the potential of the component of immune systems as therapeutics

**Learning Outcomes**

1. Student will be able to understand the possible consequences of using different component of immune systems as therapeutics.
2. Students will be able to design an immunotherapeutics

**Contents:**

*Fractal 1: Fundamentals of Immunotherapeutics [14 Lectures]:* Principle and scope of immune-therapeutics, classification of immune-therapeutics (4 lectures), immune modulators and immunoadjuvant (5 lectures), soluble cytokine receptor and recombinant cytokines (5 lectures).

*Fractal 2: Antibody Engineering [14 Lectures]:* Human monoclonal antibody, human hybridoma and phage display library (4 lectures), chimeric, humanized and fully human antibodies (4 lectures), engineered therapeutic antibodies (type, synthesis, and mechanism of action) (4 lectures), antibody fragments (2 lectures).

*Fractal 3 Cellular immunotherapeutics [14 Lectures]:* Principle of cell based adoptive immune therapy (3 lectures), tetramer technology and selection of antigen specific CTL (2 lectures), CAR T cell therapy, NK cell therapy (4 lectures), Dendritic cell vaccine, immune-adjuvant therapy, exosome mediated treatment (5 lectures).

**Text Books**

1. B. T. Smith, Concepts in Immunology and Immunotherapeutics, American society of health-system pharmacists (2008) , 4th Edition.

**Reference Books**

1. P. A. Ascierto , D. F. Stroncek , E. Wang, Developments in T Cell Based Cancer Immunotherapies, Humana (2015), 1st edition.

**Self-Learning Materials**

1. MITOpenCourseware, https://ocw.mit.edu/courses/biology/7-012-introduction-to-biology-fall-2004/video-lectures/lecture-22-immunology-1/
2. MITOpenCourseware, https://ocw.mit.edu/courses/biology/7-341-of-mice-and-men-humanized-mice-in-cancer-research-spring-2015/

| Title | **Novel Drug Delivery Systems** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | B. Tech | Type | Specialization Elective |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Provide deep insight on different strategies in designing a drug delivery system to overcome potential physiological barriers.
2. Provide conceptual basis to integrate different drug delivery systems with modern electronic platforms for remote monitoring and management of patients.

**Learning Outcomes**

The students will have the ability to:

1. Design a drug delivery system for a specific application.
2. Formulate novel strategies for personalized drug delivery.

**Contents**

Fractal 1. *Sustained and stimuli-responsive drug delivery systems [14 lectures]:* particulate and vesicular drug delivery systems (5 lectures), hydrogels (2 lectures), pH, temperature, light and magnetic field responsive drug delivery systems (5 lectures), iontophoretic drug delivery systems (2 lectures).

Fractal 2. *Site-specific drug delivery [14lectures]:* Route of drug administration and its limitations, site-specific drug delivery systems (4 lectures), delivery vehicles to cross blood brain barrier (BBB), colon-specific drug delivery, ocular drug delivery system (5 lectures), transdermal patches to cross skin barrier, tumor specific drug delivery, lung specific drug delivery (5 lectures).

Fractal 3. *State-of-art drug delivery systems [14 Lectures]*: IoT and remote controlled drug delivery systems (5 lectures), biomimetic systems for drug delivery (3 lectures); delivery of cell based therapeutics (3 lectures), case studies on state-of-art drug delivery systems (3 lectures).

**Text Books**

1. W. R. Wagner, Biomaterials Science: An Introduction to Materials in Medicine, Academic Press Inc (2020); 4th edition.
2. R.K. Keservani, A.K. Sharma, Nanoparticulate Drug Delivery Systems, Apple Academic Press (2019), 1st edition.

**Reference Books**

1. Controlled and novel drug delivery, N.K. Jain, 2019, CBN Publishers, 1st edition.

**SelfLearning Materials**

1. Prof. Rachit Agarwal, IISc Bangalore, https://nptel.ac.in/courses/102/108/102108077/
2. MIT Open Courseware, https://ocw.mit.edu/courses/biology/7-341-the-microbiome-and-drug-delivery-cross-species-communication-in-health-and-disease-spring-2018/

| Title | **Theranostic Systems** | Number | BBL4XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3-0-0 [3] |
| Offered for | B. Tech | Type | Specialization Elective |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Provide an insight on the design principles of theranostic systems.
2. Introduce various techniques for characterizations of theranostic systems.
3. Decipher the possible mode of application of theranostic systems in diseased conditions.

**Learning Outcomes**

The students will have the ability to:

1. Design and develop a theranostic system for a specific application.
2. Compare the performance of different theranostic materials on the basis of their physico-chemical and biological properties.

**Contents**

*Fractal 1. Introduction to theranostic systems [14 lectures]:* Key features of theranostic systems (1 lectures); combinatorial modalities of theranostic system (1 lectures); basic theranostic templates: mesoporous materials (2 lectures), carbon nanostructures (2 lectures), membrane vesicles (2 lectures); surface engineering of theranostic platforms (2 lectures); up- and down-conversion, magnetic, plasmonic and radioactive platforms (4 lectures).

*Fractal 2. Physico-chemical characterization of theranostic systems [14 lectures]:* photophysical and photochemical properties (3 lectures), magnetic properties ($T_1$ and $T_2$ relaxations) (2 lectures), hyperthermia (4 lectures); plasmonic properties: localized surface plasmon resonance (LSPR) (3 lectures), quantification of radioactivity (2 lectures).

*Fractal 3. Case studies on theranostic systems [14 lectures]:* Case studies on theranostic systems for cancer (5 lectures), vascular and brain diseases (5 lectures); Case studies on laparoscopy and endoscopy-guided theranostic systems (4 lectures).

**Text Books**

1. Z. Dai, Advances in Nanotheranostics I: Design and Fabrication of Theranostic Nanoparticles (Springer Series in Biomaterials Science and Engineering Book 6) 1st edition (2016) ISBN-10: 978-3-662-48544-6.
2. Z. Dai, Advances in Nanotheranostics II: Cancer Theranostic Nanomedicine (Springer Series in Biomaterials Science and Engineering Book 7) 1st edition (2016) ISBN 978-981-10-0063-8 .

**Reference Books**

1. S.T. Selvan, K. Narayanan, Introduction to Nanotheranostics (Springer Briefs in Applied Sciences and Technology) 1st edition (2016) ISBN 978-981-10-1008-8
2. J. Conde, Handbook of Nanomaterials for Cancer Theranostics, Elsevier, (2018) ISBN: 978-012-81-3339-2.

# Program-linked Science Elective/Open Elective

| Title | **Neuroscience** | Number | BBL2XX0 |
|---|---|---|---|
| Department | Bioscience and Bioengineering | L-T-P [C] | 3-0-0 [3] |
| Offered for | B. Tech | Type | Program-linked Science course/Open Elective |
| Prerequisite | None | | |

**Objectives:**

1. The course provides insights of human nervous systems.
2. This course offers an introduction to the basic principles of brain functioning.

**Learning Outcomes**

The students will have the ability to: Gain experience for the future forefront of their research career and this can be applied to fields, where understanding brain response to complex machine sensory information inputs.

**Contents:**

*Introduction of Neuroscience [5 Lectures]*: Nervous systems: basic structure, development and complexity and cellular component of nervous tissue.

*Neuronal architecture [5 Lectures]*: structure and functional properties of neurons, types of neurons and supporting cells of nervous tissue.

*Neurotransmitters and Synaptic Integration [5 Lectures]*: Neurotransmitters signaling, action potential propagation, synapse and synaptic transmission and electrical or chemical synapses.

*Brief Anatomy of Brain [5 Lectures]*: Brain structure overview, white and gray matter and different sectional views of brain.

*Fundamentals of Sensory Systems [5 Lectures]*: Sensory systems principles, sensitization and desensitization of sensory receptors and sensory coding.

*Somatosensory System [5 Lectures]*: Organization of somatosensory system, various receptors *viz* mechanoreceptors, proprioceptors, nociceptors, thermal receptors and visceral sensations.

*Motor System [5 Lectures]*: Neuromuscular junction, primary and secondary motor cortex and integration of sensory signals to motor actions and motor neuron diseases.

*Auditory System [5 Lectures]*: Structure of internal ear, temporal responsiveness, ribbon synapse and mapping at auditory cortex.

Visual System *[5 Lectures]*: Structural organization of visual pathways; visual perception and processing, photoreceptors and high-level visual processing.

**Text Book:**

1. Zigmond., *Fundamental Neuroscience*, Elsevier (2018), 5th Edition.

**Reference Books**

1. E. R. Kandel., *Principles of Neural Science*, Elsevier (2018), 5th Edition.

**Self-Learning Material**

Dr. Varadhan SKM, Neuroscience of Human Movement, NPTEL Course Material Department of Biomedical Engineering IIT Madras, Link: https://nptel.ac.in/noc/courses/noc18/SEM2/noc18-ge13/