BIOE 100 INTRODUCTION TO BIOENGINEERING (2+0) 2

Introduction to the concept of Bioengineering and its branches. Overview of topics and engineering application areas that comprise the Bioengineering profession. Fundamentals of Biochemical and Bioprocess Engineering. Impact of Bioengineering and biotechnology on society. Elements of Bioengineering education. Description of the scientific basis of Bioengineering with particular emphasis on definitions and concepts in Biochemical, Bioprocess and Metabolic Engineering. Description of the research conducted by faculty in the department.

Text book: ***Departmental notes.***

BIOE 110 INTRODUCTION TO BIOMEDICAL ENGINEERING AND INSTRUMENTATION (4+0) 4

Applications, diagnosis and treatment, biomedical instrumentation administration, security issues, Biomedical Technology and the Biomedical Engineer, their present and future. Digital processing of biological signals, Physiology of the heart and Electrocardiogram (ECG), Blood pressure measurements, Physiology of the brain and Electroencephalogram (EEG), Electromyography, Electromechanics of biological fluids.

Text book: ***Introduction to Biomedical Engineering, John Enderle, Susan M. Blanchard, Joseph Bronzino, Academic Press***

BIOE 111 GENERAL BIOLOGY FOR ENGINEERS (2+2) 3

Atomic basis of life and biomolecules; cell structure and function; cell metabolism; movement of materials across membranes; photosynthesis, fermentation and respiration; cell division; Mendelian genetics; molecular basis of genetics; control of gene expression; recombinant DNA technology; human genetics; mechanisms and evidence of evolution; the origin and history of life.

Text book: ***Molecular Biology of the Cell****, B.Alberts, A.Johnson, J.Lewis et al., Macmillan Publishers.*

BIOE 201 MICROBIOLOGY FOR BIOENGINEERS (2+2) 3

Overview of the microbial world including a survey of the structure, functioning, and diversity of microorganisms. Introduction to the fundamental concepts of microbial physiology, ecology, genetics, and pathogenesis. Laboratory procedures including sterile technique, microscopy, enrichment and isolation, and preservation. Extensive experience in the cultivation of microorganisms.

Text book: ***Departmental notes.***

BIOE 202 MOLECULAR BIOLOGY AND GENETICS (3+2) 4

Structure and properties of nucleic acids; DNA replication, repair, and recombination; molecular biology of gene expression and its regulation in prokaryotes and eukaryotes; protein structure and translational control; and molecular biotechnology with an emphasis on recombinant DNA technology, protein engineering, vaccines and therapeutics, immunodiagnostics, and genetic engineering of mammalian and plant organisms. The regulation of gene expression; methods for studying nucleic acids and proteins; cell division and apoptosis; cell differentiation; development control; cancer genetics.

Text book: ***Molecular Biology****, D.Clark, Elsevier*
Molecular Biology of the Cell*, B.Alberts, A.Johnson, J.Lewis et al., Macmillan Publishers.*
Molecular Genetics of Bacteria, *J.W.Dale, S. F.Park , John Wiley&Sons*
Principles of Genome Analysis and Genomics, *S.B.Primrose, R.M.Twyman, Blackwell Pub.*

BIOE 211 BIOENGINEERING PRINCIPLES (4+0) 4

Covers all the main aspects of the Bioprocess Engineering field. Introductory lectures on the concepts of mass and energy balances, thermodynamics, hydrodynamics, heat and mass transfer, and unit operations. Reaction principles, kinetics of biological processes, heterogeneous reactions, and reactor engineering principles. Practical examples and numerical solutions to problems related to topics. Relevant phenomena related to biochemical operations and processes. Principles of material and energy balances, metabolic stoichiometry, cell growth kinetics.

Textbook: ***Bioprocess Engineering Principles,*** *P.M.Doran, Academic Press*
Bioprocess Engineering: Basic Concepts, *M.L.Shuler, F.Kargı, Prentice Hall*
Biochemical Engineering Fundamentals*, J.E.Bailey and D.F.Ollis, McGraw-Hill*
Biochemical Engineering, *H.W.Blanch and D.S.Clark, Marcel Dekker*

BIOE 222 BIOMATERIALS

General Overview/definitions, classifications, and benefits of biomaterials. Natural biomaterials (cartilage, bone, arthrosis and muscles), Synthetic biomaterials, Biometals and their production Bioceramics, glasses, glass-ceramics, Pyrolitic carbon and its applications,bio polymers, Dental implant materials, Orthopedic applications, Evaluation of blood–materials interaction, Mechanical properties of biomaterials, Implant and device failure, Drug delivery, Implant retrieval and evaluation

Text book: ***Biomaterials for Delivery and Targeting of Proteins and Nucleic Acids,*** *Ram I. Mahato, CRC Press*

STAT 252 BIOSTATISTICS (3+0) 3

Introductory statistical methods for biological data: describing data; introduction to probability, probability distributions; statistical methods including sampling distributions, point and interval estimation, and statistical inference (hypothesis tests and confidence intervals). Intermediate statistical methods: comparing groups (analysis of variance); analyzing associations (linear and logistic regression); and methods for categorical data (contingency tables and odds ratio). Factoral design of biological experiments. Course content integrated with statistical computing in biological systems.

Text book: ***Probability and Statistics for Engineering and the Sciences,*** *J.L.Devore, Duxbury Press*

- **Harrell, F.E. (2001), Regression Modeling Strategies, With Applications to Linear**
- **Models, Logistic Regression, and Survival Analysis, New York: Springer.**
- **Weisberg S. (2005), Applied Linear Regression, 3rd.Ed., New York: John Wiley & Sons:**
- **Carroll, R. J. and Ruppert, D. (1988), Transformation and Supplemental Weighting in Regression, New York, Chapman and Hall.**
- **Draper, N. R. and Smith, H. (1998), Applied Regression Analysis, 3rd. Ed., New York: John Wiley & Sons.**
- **Miller, R. G. (1986) Beyond ANOVA, Basics of Applied Statistics, New York: John Wiley & Sons.**
- **Mosteller, F. and Tukey, J. W. (1977), Data Analysis and Regression: A Second Course in Statistics, Reading, MA:**
- **Addison-Wesley. Scheffe', H. (1959), The Analysis of Variance, New York:**
- **John Wiley & Sons.**
- **Seber, G. A. F. (1977), Linear Regression Analysis, New York: John Wiley & Sons.**
- **Vittinghoff, E., Glidden, D.V., Shiboski, S.C., and McCulloch,**
- **C.E. (2004). Regression Methods in Biostatistics:Linear, Logistic, Survival, and Repeated Measures Models,New York: Springer.**

BIOE 262 MATHEMATICAL APPLICATIONS IN BIOENGINEERING SYSTEMS (2+2) 3

Bioengineering applications of mathematical methods: Vector and tensor analysis, matrix algebra, direct and iterative solution of linear equation systems, linear transformations, eigenspectra analysis, solution of nonlinear equation systems, interpolation and approximation, numerical integration and differentiation, systems of linear differential equations, numerical solution of differential equations.

Text book: ***Mathematical Methods for Scientists and Engineers: Linear and Nonlinear Systems, P.B.Kahn, John Wiley & Sons***
Modeling Biological Systems: Principles and applications , (2005) **James W. Haefner,** ***Springer***
Mathematical Modeling of Complex Biological Systems A Kinetic Theory Approach Series: **Modeling and Simulation in Science, Engineering and Technology** ***Bellouquid, Abdelghani, Delitala, Marcello***

BIOE 302 INDUSTRIAL MICROBIOLOGY (3+0) 3

This course covers the commercial exploitation of microorganisms for processes and products that are of major economic, environmental and social importance for the world. Two aspects of industrial microbiology will be covered: one related to the production of valuable microbial products via fermentation processes, and the second related to the role of microorganisms in providing services , particularly for waste treatment and pollution control.

Text book: ***Industrial Microbiology: An Introduction,*** *M.J. Waites, N.L. Morgan, J.S. RockeyG. Higton, Blackwell Science*

BIOE 303 MODERN TECHNIQUES IN BIOCHEMICAL ENGINEERING (3+0) 3

Light and electron microscopy, Spectroscopic techniques in biology, circular dichroism, the principles of chromatography, protein purification using chromatographic techniques, electrophoretic methods, identification of proteins and nucleic acids by electrophoresis, radioctive labeling methods, membrane filtration and dialysis techniques, centrifugation methods.

Text book: ***Protein NMR Spectroscopy****, J.Cavanagh, Elsevier*

Handbook of Industrial Crystallization, A.Myerson, Elsevier
Emerging Technologies in Protein and Genomic Material Analysis, G.Marko-Varga,

BIOE 304 PROTEIN INTERACTIONS (3+0) 3
In the cell proteins are not found as isolated macromolecules. In order to fulfill their functions they interact with other proteins, nucleic acids (DNA, RNA) or small organic molecules. The basic principles governing these interactions and examples of these interactions will be the focus of this course.
Text book: ***Protein Interactions,*** *G. Weber,* *Chapman & Hall*

BIOE 311 BIOENGINEERING LAB I (0+4) 2
Introduction to laboratory experiences, experimental design and analysis and applications of engineering and scientific principles in the areas of biochemical and bioprocess engineering. Implementation of statistical techniques such as basic t-test and ANOVA, regressions and correlations to laboratory experiments.
Text book: ***Experiments in Molecular Biology,*** *Z.Burton, Elsevier*
Methods in Biotechnology, *Schmauder, Taylor& Francis*
Lab Ref, *J.Roskams, L. Rodgers, Cold Spring Harbor Laboratory*

BIOE 312 BIOENGINEERING LAB II (0+4) 2
The course utilizes a team-approach to facilitate research and learning, instructing students to work in groups to plan experiments, carry them out, analyze data and present findings. Experiments associated with biochemical and bioprocess engineering technologies.
Text book: ***Experiments in Molecular Biology,*** *Z.Burton, Elsevier*
Methods in Biotechnology, *Schmauder, Taylor& Francis*
Lab Ref, *J.Roskams, L. Rodgers, Cold Spring Harbor Laboratory*

BIOE 314 MOLECULAR BIOPHYSICS (3+0) 3
Structural foundations, especially that of proteins and nucleic acids. Experimental techniques (X-ray, diffraction, NMR, EM/cryoEM, AFM, CD/ORD, Raman and fluorescence spectroscopy), as well as structural systematics and informatics.
Text book: ***Biological Physics Update****, P. Nelson, Palgrave Macmillan*
Molecular and Cellular Biophysics*, M. B. Jackson, Cambridge University Press*

BIOE 322 PROTEIN/PEPTIDE TRANSPORT (3+0) 3
Proteins rarely reside in the compartment where they are synthesized. In order to fulfill their function they are transported across biological membranes to compartments where they are required. There are different mechanism of protein transport across membranes. The basic mechanisms and the principles governing the mechanism of protein transport will be covered.
Textbook: ***Protein Targetting, Transport, and Translocation,*** *G von Heijne & R.E. Dalbey, Academic Press*
Current Topics in Membranes and Transport: Membrane Protein Biosynthesis and Turnover (Current Topics in Membranes, 24) *P.A. Knauf & J. S. Cook, Academic Press*
Membrane Protein Transport, Volume 3 (Membrane Protein Transport) *by S.S. Rothman*

BIOE 324 BIOTRANSPORT PHENOMENA (4+2) 5
Fundamentals of heat and mass transport used in engineering design and analysis of biochemical, chemical and physical processes; principles of steady state and transient energy and mass balances including chemical and biological generation terms. Fundamental principles and applications related to fluid mechanics; mass, momentum, and energy transfers in biosystems and other systems for engineers and scientists.
Text book: ***Unit Operations of Chemical Engineering,*** *McCabe,Smith&Harriot, McGraw-Hill*
Transport Phenomena, *Bird, Stewart & Lightfoot, Wiley*
Biochemical Engineering Fundamentals, *J.S. Bailey, McGrawHill*
Transport Phenomena in Biological System, *G.A.Truskey, F.Yuan, D.F.Katz, Prentice-Hall*
Introduction to Transport Phenomena, *W. J. Thomson, Prentice-Hall*
Transport Phenomena, *Bird, Stewart, Lightfoot, Wiley*

BIOE 331 BIOCHEMICAL REGULATION AND SIGNAL TRANSDUCTION (3+0) 3
A study of metabolic regulation in biochemical processes and pathways emphasizing theories of metabolic flux and enzyme regulation in the context of cellular signaling processes. Exploring the various molecular and biochemical pathways through which cells communicate with themselves and the extracellular environment.
Text book: ***Departmental notes***
Biochemistry of Signal Transduction and Regulation, *Krauss, Wiley*
Signal Transduction*, Gomperts et al., Academic Press*

BIOE 332 INTRODUCTION TO SYSTEMS BIOLOGY (3+0) 3

Introduction to systems biology, methods and techniques, high throughput techniques including gene expression and protein-protein interaction screens. Definition of biological structures and processes as systems. Interactions and networks, graph theory, biological network analysis. Principles of mathematical modelling, first principle models versus data-driven models. Constructing qualitative models by data integration. Quantitative modeling and simulation, analysis of dynamical models. Metabolic networks and quantitative description of these. Elementary flux models. Kinetic models for enzyme catalyzed reactions and for signal transduction pathways. Pathway reconstruction.

Text book: ***Systems Biology: Properties of Reconstructed Networks,*** *B.Palsson, Cambridge Univ. Press*
Intro. to Systems Biology: Design Principles of Biological Circuits, *U.Alon, Chapman & Hall*

BIOE 333 PROTEIN FOLDING (3+0) 3

Protein folding has become the focus of intense scientific inquiry since protein structure determines its functions. This course will deal with how proteins adopt their folding conformations and with the developing experimental techniques to attack this problem.

Text book: ***Protein folding,*** *T.E. Creighton*
Introduction to Protein Structure. *C. Branden & J. Tooze*

BIOE 334 STRUCTURAL BIOLOGY (3+0) 3

The course covers organic molecules (proteins, nucleic acids, lipids), general principles of protein structure, folding, and function basis of inferring structure and function from genomic sequence. Computational methods on protein sturucture prediction, macromolecular function and protein design, and key methods in drug discovery.

Text book: ***Advances in Protein Chemistry, C. Anfinsen, Elsevier***
Computational Structural Biology, T.Schwede, M.C.Peitsch, World Scientific Publishing
Protein Flexibility and Folding, L.A. Kuhn, Elsevier
Protein Biotechnology, G. Walsh, D. R.Headon, John Wiley & Sons
Protein Modules and Protein-Protein Interactions, J. Janin, Elsevier

BIOE 336 INTEGRATED DOWNSTREAM PROCESSING (3+0) 3

Engineering fundamentals of separations and purification of biological molecules. Case studies and examples illustrate principles and practice of centrifugation, precipitation, crystallization, filtration, membrane separations, chromatography, and affinity separation of recombinant proteins and other biomolecules. Process scale-up and economics of biotechnology products and processes are mentioned in the context of their impact on purification development.

Text book: ***Departmental notes.***

BIOE 341 BIOREACTION ENGINEERING (3+0) 3

Fundamentals of microbial and biochemical kinetics used in analysis and design of biological systems. Topics include mathematical and computer modeling of biological kinetics and systems, estimating model coefficients, basic reactor concepts, development of microbial kinetic models as basis for batch and continous reactor design, diffusion and biological reaction in immobilized biocatalyst systems.

Text book: ***Advances in Biochemical Engineering: Reaction Engineering,*** *A.Fiechter, Springer*
Reaction Kinetics and Reactor Design, *J.B.Butt, CRC*
Chemical Reaction Engineering, *O.Levenspiel, Wiley*

BIOE 350 BIOPROCESS OPTIMIZATION (3+0) 3

Fundamentals of analytical optimization. Survey of one dimensional line-search methods, and multi-dimensional unconstrained and constrained numerical optimization algorithms. Applications of linear programming, nonlinear programming, mixed integer linear/ nonlinear programming, and parameter estimation in bioengineering. Feasible-path and infeasible-path techniques for bioprocess flowsheet optimization.

Text book: ***Applied Optimization with MATLAB Programming****,P.Venkataraman, Wiley*
Operations Research – Applications and algorithms, *W.L.Winston, Brooks Cole*

BIOE 351 COMPUTER AIDED BIOENGINEERING (2+2) 3

The course covers the analysis of nucleic acid and protein sequences, with an emphasis on the application of algorithms to biological problems. Topics include sequence alignments, database searching, comparative genomics, and phylogenetic and clustering analyses. Pairwise alignment, multiple alignment, DNA sequencing, scoring functions, fast database search, comparative genomics, clustering, phylogenetic trees, gene finding/DNA statistics. In addition, an introduction to the features of biological data will be given: how that data are organized efficiently in databases, and how existing data resources can be utilized to solve a variety of biological problems. Relational databases, object oriented databases,

ontologies, data modeling and description, survey of current biological database with respect to above, implementation of database focused on a biological topic.

Text book: ***Computer Applications in Biotechnology*** *T. Yoshida, Elsevier*
An Introduction to Bioinformatics Algortihms, *N.C.Jones, P.A.Pevzner*

BIOE 352 INTRODUCTION TO BIOINFORMATICS (3+0) 3

Fundamentals of molecular biology and bioinformatics tools and databases used for the prediction of protein function and structure. Similarity searches and multiple sequence alignments. A theoretical understanding of popular computational methods, as well as some experience with protein sequence analysis methods applied to real data.

Text book: Introduction to Bioinformatics*, A. M. Lesk, Oxford University Press*
An Introduction to Bioinformatics Algorithms (Computational Molecular Biology)*,*
N. C. Jones, MIT Press

BIOE 353 CELLULAR AND METABOLIC ENGINEERING (3+0) 3

A comprehensive review of metabolic biochemistry, cell growth and metabolite production. Concepts of stoichiometry, kinetics, and thermodynamics of metabolic pathways. Methods for identifying key enzymes in metabolic networks. Metabolic flux analysis (MFA) and metabolic control analysis (MCA). Discussion on metabolic regulation at the genome, proteome (enzyme), metabolme, operon and cell levels. Numerous examples of pathway modification. Methods of quantification of cellular processes performance.

Text book: ***Metabolic Engineering: Principles and Methodologies,*** *G.N.Stephanopoulos et al., Wiley*
An introduction to Cellular and Metabolic Engineering, *S.Cortassa et al., Elsevier*
Metabolic engineering: debottlenecking met. networks: *Torres, Voit, Cambridge Univ. Press,*

BIOE 354 METABOLIC CONTROL ANALYSIS (3+0) 3

Principles of metabolic control analysis (MCA). Techniques and algorithms for linear, nonlinear and branched pathways. Available software. Applications of MCA to available kinetic models of dynamic metabolic systems.

Text book: ***Regulation and Control Mechanisms in Biol. Systems,*** *V.S.Vaidhvanathan, Prentice-Hall*
Understanding the Control of Metabolism*, D. Fell, Portland Press*
The Regulation of Cellular Systems, *R.Heinrich and S.Schuster, Chapman and Hall*

BIOE 355 BIOLOGICAL CONTROL SYSTEMS (3+0) 3

Regulation and control mechanisms at the prokaryote and eukaryote levels.

Text book: ***Regulation and Control Mechanisms in Biol. Systems,*** *V.S.Vaidhvanathan, Prentice-Hall*

BIOE 356 BIOPROCESS DYNAMICS AND CONTROL (4+0) 4

A systematic introduction to dynamic behavior and automatic control of bioprocesses. Topics include dynamic modeling of linear and nonlinear biochemical processes, laplace transforms, dynamic system representation via transfer functions, stability of systems, conventional feedback controllers, dynamic behaviour of feedback controlled systems , controller design using frequency response techniques, and digital controllers. Case studies on modeling and analysis of biological control mechanisms.

Text book: ***Process Dynamics, Modeling and Control****, B.A.Ogunnaike, W.H.Ray,* Elsevier
Process Dynamics and Control*, D.E.Seborg, T.F.Edgar, D.A.Mellichamp, Prentice Hall*
Modeling and Optimization of Fermentation Processes*, L.D.Parham, B.Volesky,* Elsevier

BIOE 360 BIOPROCESS VALIDATION AND QUALITY CONTROL (3+0) 3

Introduction to quality management: fundamentals, historical background, technical and behavioral dimensions. Quality in design and development: conceptual and technical design, planning and integrating product and process design using Quality Function Deployment, robust product, parameter and process design using Taguchi methods. Quality assurance standards for design and production: ISO 9000 quality assurance systems, ISO 14000 enviromental management systems, as applied in bioprocess engineering practice.

Text book: ***Departmental notes***

BIOE 361 INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGY (3+0) 3

This course discusses the commercial applications of bioprocesses to environmental problems. The fundamentals of many industrial sectors, including brewing, recombinant fermentation technologies. Industrial enzyme production, the production of biomass/single cell protein and the production of industrial alcohol.

Text book: ***Environmental Biotechnology,*** *H.J.Jordening, J.Winter, Wiley*

BIOE 363 FERMENTATION PROCESSES (3+0) 3

This course emphasizes the application of biological and engineering principles to problems involving microbial, mammalian, and biological/biochemical systems. The aims of the course are to review fundamentals and provide an up-to-date account of current knowledge in biological and biochemical technology with special emphases in microbial systems. The lectures will emphasize and place perspectives on biological systems with industrial practices. A wide range of microbial processes will be examined and used to illustrate how complex products can be made economically from microorganisms.

Text book: ***Principles of Fermentation Technology,*** *P.F.Stanbury, Elsevier*
Modeling and Optimization of Fermentation Processes, *L.D.Parham, B.Volesky, Elsevier*

BIOE 365 COMPUTATIONAL BIOENGINEERING (3+0) 3

Introductory Computational Biology, Programming and Statistics, Molecular Biophysics and Molecular Design,Molecular Evolution, Phylogenetics, and Optimization of Function, Cellular Biophysics and Cellular Design, Functional Genomics and Statistical Genetics, Tissue and Organismal Biophysics and Design.

Text Book: ~~***Computer Modeling in Bioengineering: Theoretical Background, Examples and Software***~~*, Miloš Kojić, Nenad Filipović, Boban Stojanović, Nikola Kojić*
~~***Dictionary of Bioinformatics and Computational Biology***~~*,John M. Hancock, Marketa J. Zvelebil*
~~***Intelligent Bioinformatics: The Application of Artificial Intelligence Techniques to Bioinformatics Problems***~~*,Edward Keedwell, Ajit Narayanan*
~~***An Introduction to Computational Biochemistry***~~*,C. Stan Tsai*

BIOE 381 BIOENGINEERING THERMODYNAMICS (3+0) 3

This course is an introduction to the laws of thermodynamics and their application to biological and environmental systems. Topics include zeroth, first, second, and third laws, open and closed systems, enthalpy and specific heat, Gibb's free energy and chemical potential for biological and environmental systems. Applications include biochemical potentials, water potential, adsorption, osmosis, radiation, membranes, surface tension, and fugacity.

Text book: ***Thermodynamics and Kinetics for the Biological Sciences****,G.G. Hammes*, *John Wiley & Sons*
Chemical, Biochemical and Engineering Theormodynamics, *I.S.Sandler, John Wiley & Sons*
Biothermodynamics, J.T.*Edsall, and H. Gutfreund, John Wiley & Sons*

BIOE 392 BIOPROCESS DESIGN I (3+2) 4

Design and analysis of systems for processing biological materials. Topics include design and computational simulation of unit operations, including basic bioreactor operation, bioseparations, and preservation techniques. Practice on the concepts in the context of a term-project that includes development of a flowsheet for production of a given chemical.

Text book: ***Bioseparations Science and Engineering,*** *R.G. Harrison et al., Oxford University Press*
Bioseparations, *P.A. Belter, E.L. Cussler, W. Hu, Wiley Interscience Publication*
Analysis, Synthesis and Design of Chemical Processes, *R.Turton et al., Prentice Hall*

BIOE 401 RECOMBINANT DNA TECHNOLOGY (3+0) 3

An introduction to recombinant DNA techniques. Topics covered include: plasmids and other cloning vectors; construction of chromosomal genebanks; gene expression analysis; techniques such as PCR and DNA sequencing; bioinformatics.

Text book: ***Departmental notes***

BIOE 412 INTRODUCTION TO PROTEIN STRUCTURE AND FUNCTION (3+0) 3

Introduction to protein structure and conformations. DNA: mechanical properties and packing. Structural classes of proteins. Thermodynamics of protein denaturation. Hydrophobicity. Kinetics of biomolecular changes. Molecular motors and transcription machinery. Mechanism of protein-protein, protein-DNA, protein-inhibitor binding and interactions. Analysis of Protein Data Bank and Nucleic Acid Data Bank structures. Computational methods for simulating biomolecular systems. Methods in protein engineering and design.

Text book: ***Introduction to Protein Structure****, C. I. Branden and J. Tooze, Garland Science,*
Protein Structure and Function*, G. Petsko and D. Ringe, OUP Oxford*

BIOE 413 BIOMOLECULAR INTERACTIONS (3+0) 3

Protein-protein interactions. Combined computational methodologies for the analysis of sequence-structure-dynamics-function of complex biomolecular systems. Networks of interaction and communication pathways within proteins. A case study of recognition and binding processes in the complex structures of HIV-1 protease bound to substrates and drugs.

Text book: ***Prediction of Protein Structures, Functions, and Interactions,*** *J. Bujnicki, Wiley-Blackwell*
Protein-protein Interactions and Networks: Identification, Computer Analysis, and Prediction*, A. Panchenko and T. Przytycka, Springer*

BIOE 414 MICROBIAL PROTEOMICS (3+0) 3

Whole cell modeling, structural proteomics and computational analysis, biomolecular interactions, physiological proteomics, metabolic reconstruction using proteomics data.

Text book: ***Microbial Proteomics: Functional Biology of Whole Organisms ,****I.H.Smith, M.Hecker*

BIOE 421 TISSUE ENGINEERING (3+0) 3

The selection, processing, testing and performance of materials used in biomedical applications with special emphasis upon tissue engineering. Topics include material selection and processing, mechanisms and kinetics of material degradation, cell-material interactions and interfaces; effect of construct architecture on tissue growth; and transport through engineered tissues.

Text book: ***Departmental notes***

BIOE 423 PROTEIN ENGINEERING (3+0) 3

The topics that will be covered in this course will include manipulation of gene expression in prokaryotic and eukaryotic cells and directed evolution of proteins. Directed evolutions arose from the power of natural selection to evolve proteins or RNA with desirable properties not found in nature. The tools used for manipulation of gene expression and directed evolution will be covered.

Text book: ***Directed Molecular Evolution of Proteins.*** *S. Brakmann &, K. Johnsson , Wiley-VCH*

BIOE 430 BIOCONVERSION OF LIGNOCELLULOSICS (3+0) 3

The science and technology related to the conversion of lignocellulosics, the enzymes and the microbes involved in the conversion, methods for hydrolysis of cellulosic materials, reaction kinetics and mechanisms of cellulases, cellulase production processes, bioconverion of lignocellulosics into value-added products.

Text book: ***Departmental notes***

BIOE 432 INTRODUCTION TO BIODEGRADABLE POLYMERS (3+0) 3

Definition of Biodegradability, Mechanisms and evaluation methods of Polymer Degradation, Biodegradation Behaviour of Polymers in Liquid Environments and in the soil, General Characteristics of biodegradable polymers (e.g. Polymer Molecular Size, Structure and Chemical Composition), Naturally, Synthetic and Modified Naturally Biodegradable Polymers, Processability (e.g. Extrusion, Film Blowing and Casting, Moulding and Fibre Spinning), Industrial Applications and Market Evolution of Biodegradable Polymers.

Text book: ***Departmental notes***

BIOE 435 RECONSTRUCTION OF BIOLOGICAL NETWORKS (3+0) 3

Techniques in integration of high-throughput experimental data with mathematical models. Review of databases for biochemical, genome, proteome, transcriptome and metabolome data. Reconstruction of metabolic networks, protein-protein interaction networks, transcriptional regulatory networks and signal transduction networks. Case studies on several industrially and medically important microorganisms.

Text book: ***Selected journal publications.***

BIOE 440 DYNAMICS OF BIOMOLECULES
(3+0) 3

Structural and dynamic properties of complex macromolecular systems. Innovative computational methods for interpreting experimental results. Normal mode analysis. Vibrational collective dynamics of proteins with elastic network models. Molecular dynamics. Algorithm developments and applications in biophysical systems.

Text book: ***Normal Mode Analysis: Theory and Applications to Biological and Chemical Systems (Mathematical and Computational Biology)****, Q. Cui and I. Bahar, Chapman&Hall*
The Art of Molecular Dynamics Simulation*, D. C. Rapaport, Cambridge University Press*

BIOE 441 MASS SPECTROMETRY DATA ANALYSIS IN PROTEOMICS (3+0) 3

Practical approach for analyzing raw mass spectrometry (MS) data in proteomics

Text book: ***Mass Spectrometry Data Analysis in Proteomics (Methods in Molecular Biology),*** *R. Matthiesen*

BIOE 442 ENZYMES IN INDUSTRIAL APPLICATIONS (3+0) 3

Enzymes have long been used by industrial product makers as major catalysts to transform raw materials into end products. This course will focus on the their varied uses of enzymes, the classes in which they are grouped, and which chemical reagents they have replaced on current mass production lines. The most important industrial enzymes in use today—including carbohydrate-hydrolyz-ing enzymes, proteases, ester cleavage-fat-hydrolyzing enzymes, and immobilized

enzymes will be examined. Then specific applications of technical enzymes in such areas as food processing, beverage production, animal nutrition, leather, and textiles will ve covered.

Text book: ***Industrial Enzymes and Their Applications.*** *Helmut Uhlig, Wiley*
Industrial Enzymes: Structure, Function and Applications. *J. Polaina & A.P. MacCabe*

BIOE 452 INTRODUCTION TO COMPUTATIONAL STRUCTURAL BIOLOGY (3+0) 3

Applying computational and statistical methods to the analysis of DNA and protein structures. Homology modeling and protein structure prediction. Theoretical description of basic interactions, along with computational methods to estimate them. Statistical mechanical theory of molecules. Molecular dynamics and other sampling methods. Modeling protein flexibility, from side chains to loops to slow modes. Reaction paths and basics of path sampling. Protein-protein and protein-small molecule docking. Supramolecular assembly. Introduction to Quantitative Structure Activity Relationship (QSAR) in drug design.

Text book: Computational Structural Biology: Methods and Applications*, T. Schwede and M. C. Peitsch, World Scientific Publishing*

BIOE 453 STATISTICS FOR BIOINFORMATICS DATA MINING (3+0) 3

This course provides an intermediate-level understanding of statistical foundations to prepare students for the competent use of data analysis methods in common practice in bioinformatics. Statistical ideas covered include probability distributions, likelihood theory, Bayesian and frequentist concepts, estimation, hypothesis testing and significance testing, multiplicity adjustments, the EM and MCMC algorithms, random walks, Poisson processes and Markov chains. Application areas include biological sequence analysis and microarray analysis.

Text book: Elements of Statistical Learning: Data Mining, Inference and Prediction, *T. Hastie, R. Tibshirani and J. Friedman, Springer*

BIOE 454 DESIGN AND SIMULATION OF PROTEINS AS MACROMOLECULES (3+0) 3

Introduction to statistical mechanics of macromolecular systems. Models of different complexities for simulating polymers. On-lattice and off-lattice approaches for design and numerical analysis. Monte Carlo/Metropolis algorithms. Molecular forces dominating the stability and conformational kinetics of polymers. Molecular dynamics and Brownian dynamics simulations. Statistical analysis of simulation trajectories.

Text book: ***Conformational Theory of Large Molecules: The Rotational Isomeric State Model in Macromolecular Systems****, W. L. Mattice and U. W. Suter, Wiley-Interscience*
Random Walks in Biology*, H. C. Berg, Princeton University Press*

BIOE 455 MACHINE LEARNING
(3+0) 3

Thorough grounding in the methodologies, technologies, mathematics and algorithms currently needed by people who do research in learning and data mining or who may need to apply learning or data mining techniques to a target problem. The topics of the course draw from classical statistics, from machine learning, from data mining, from Bayesian statististics and from statistical algorithmics. A tentative list of topics to be covered includes the following: Maximum likelihood vs. Bayesian inference; Regression, Classification, and Clustering; Graphical Methods, including Causal Inference; The EM Algorithm; Data Augmentation, Gibbs, and Markov Chain Monte Carlo Algorithms; Techniques for Supervised and Unsupervised Learning; Sequential Decision making and Experimental Design.

Text book: Introduction to Machine Learning (Adaptive Computation and Machine Learning), *E. Alpaydin, MIT Press*

BIOE 456 PLANTWIDE PROCESS CONTROL (3+0) 3

An introduction to the problem of designing plantwide control system architectures. Steady state gain calculation, singular value decomposition, relative gain array, niederlinski index, cascade control, averaging level control loop tuning, dynamic simulation, model based control.

Text book: ***Process Dynamics, Modeling and Control,*** *B.A.Ogunnaike, W.H.Ray,* Elsevier
Process Dynamics and Control, *D.E.Seborg, T.F.Edgar, D.A.Mellichamp, Prentice Hall*
Modeling and Optimization of Fermentation Processes, *L.D.Parham, B.Volesky,* Elsevier

BIOE 458 NANOTECHNOLOGY (3+0)3

Advances in Atomic and Molecular Nanotechnology, Nanosystems Intermolecular Forces and Potentials,Thermodynamics and Statistical Mechanics of Small Systems,Monte Carlo Simulation Methods for Nanosystems,Molecular Dynamics Simulation Methods for Nanosystems,Computer-Based Simulations and Optimizations for Nanosystems,Phase Transitions in Nanosystems,Positional Assembly of Atoms and Molecules, Molecular Self-Assembly,Dynamic Combinatorial Chemistry,Molecular Building Blocks — Diamondoids

Text book: ***Principles of Nanotechnology, Molecular-Based Study of Condensed Matter in Small Systems****, G Ali Mansoori*

BIOE 460 MOLECULAR MODELLING (3+0) 3

Algorithms for alignment of biological sequences and structures, computing with strings, phylogenetic tree construction, hidden Markov models, computing with networks of genes, basic structural computations on proteins, protein structure prediction, protein threading techniques, homology modeling, molecular dynamics and energy minimization, statistical analysis of 3D biological data, integration of data sources, knowledge representation and controlled terminologies for molecular biology, graphical display of biological data, machine learning (clustering and classification), and natural language text processing.

Text book: Molecular Modelling: Principles and Applications*, A. R. Leach, Prentice Hall*

BIOE 461 COMPUTATIONAL METHODS IN BIOLOGY (3+0) 3

Biophysical simulation methods and algorithms, including molecular dynamics, Monte Carlo, mathematical optimization, and "non-algorithmic" computation such as neural networks. Practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning.

Text book: ***Understanding Molecular Simulation: From Algorithms to Applications (Computational Science)****, D. Frenkel and B. Smit, Academic Press*

Computational Biology: A Statistical Mechanics Perspective*, R. Blossey, Chapman&Hall*

BIOE 462 ENVIRONMENTAL BIOENGINEERING (3+0) 3

The Environmental Bioengineering lecture is designed to introduce the fundamental principles and current trends in the microbiology and effective treatment solutions for wastewater engineering. Some selected topics in microbiology of activated sludge, biological nitrogen and phosphorus removal and anaerobic digestion systems will be covered. Discussions of concepts of biotechnology as applied to biodegration of solid and toxic wastes, and degradation of recalcitrant organic matters will be conferred. This will be accomplished by providing basic information in the form of lectures and demonstrations. Recent advances in biological wastewater treatment and in application of new bioreactor configurations will also be discussed.

Text book: ***Environmental Biotechnology: Principles and applications,*** *B.E.Rittmann, P.L.McCarty, McGraw-Hill.*

BIOE 463 BIOMASS AND BIOREFINERIES (3+0) 3

Biomass energy basics, Different sources of biomass, Benefits of using biomass, Definiton of biorefineries, Biochemical and thermochemical Biomass Conversion Technologies, Description of different biorefinery platforms including sugar, thermochemical, biogas, carbon-rich chains and plant products platforms.

Text book: ***Departmental notes.***

BIOE 465 BIOMEDICAL IMAGING AND DIAGNOSTICS (3+0) 3

The main objective of this course is to introduce undergraduate students to major biomedical imaging modalities including X-ray radiography, computed tomography (CT), nuclear medicine (SPECT and PET), magnetic resonance imaging (MRI), and ultrasound. Optical imaging will not be covered.

Text Book: ***Medical Imaging Signals and Systems, Jerry L. Prince and Jonathan Links, Prentice Hall***

BIOE 468 PROTEOMICS AND MASS SPECTROMETRY (2+2) 3

Introduction to proteomics, the proteome and technology, protein identification, co- and post-translational modifications, clinical and biomedical applications of proteomics, biological applications of proteomics.

Text book: ***Protein Biochemistry and Proteomics,*** *H.Rehm, Academic Press*

Introduction to Proteomics*, D.C. Liebler, Humana Press*

Proteome Research:New Frontiers in Functional Genomics*, M.R.Wilkins et.al., Springer*

BIOE 471 MANAGEMENT OF BIOPROCESS DEVELOPMENT (3+0) 3

Case studies for a number of real bioindustrial processes, production and presentation of a business plan for the translation of a life science discovery into a real outcome.

Text book: ***Departmental notes.***

BIOE 472 PLANNING AND MANAGEMENT OF RESEARCH (3+0) 3

Design and evolution of biotechnology strategies, biotechnology infrastructure, biotechnology sourcing, biotechnology transfer, R&D management, process development and planning, Team-based projects on the design of processes for producing advanced materials

Text book: ***Departmental notes.***

BIOE 473 BUSINESS IN A COMPETITIVE ENVIRONMENT IN BIOENGINEERING (2+2) 3
Lectures and seminars, with specialist presentations by leading industrialists and researchers
Text book: ***Departmental notes.***

BIOE 474 BIOREMEDIATION: PRINCIPLES AND PRACTICES (3+0) 3
State of the art description of advances in pollution treatment and reduction using biological means; identify and address, at a fundamental level, broad scientific and technological areas that are unique to the subject. The lectures cover the removal of both hazardous and nonhazardous contaminants from the liquid, solid, and gas phase using biological processes. This includes the biological treatment of wastes of municipal and industrial origin; bioremediation of leachates, soils, and sediments; and biofiltration for contaminated gases.
Text book: ***Bioremediation Technologies: Principles and Practice,*** *R.L.Irvine, S.K.Sikdar, CRC*

BIOE 480 STOICHIOMETRIC MODELING OF METABOLIC NETWORKS (3+0) 3
Basic concepts of mathematical modelling and computer simulation of metabolic networks. These concepts include, among others, stoichiometry matrix, balance equations, steady states, stability analysis, null-space to the stoichiometry matrix, conservation relations, elementary flux modes and dynamic simulation. The theoretical knowledge is applied to several concrete biochemical examples.
Text book: ***Systems Biology: Properties of Reconstructed Networks,*** *B.Palsson, Cambridge Univ. Press*
Metabolic engineering: debottlenecking met. networks: *Torres, Voit, Cambridge Univ. Press,*

BIOE 481 THERMODYNAMICS AND STATISTICAL MECHANICS (3+0) 3
Methods of statistical mechanics used to calculate observable properties of systems in thermodynamic equilibrium. Principles of classical thermodynamics, canonical and grand canonical ensembles for classical and quantum mechanical systems, partition functions and statistical thermodynamics, fluctuations, ideal gases of quanta, atoms and polyatomic molecules, degeneracy of Fermi and Bose gases, chemical equilibrium, ideal paramagnetics and introduction to simple interacting systems. Applications to biochemical systems.
Text book: ***Molecular Driving Forces: Statistical Thermodynamics in Chemistry and Biology,***
S. Bromberg and K. A. Dill, Garland Science

BIOE 483 MEDICAL IMAGING (3+0)3
Medical imaging technology, systems, and modalities. Projection radiography: X-Ray systems, digital radiography. Computed tomography (CT): principles, reconstruction methods, hardware. Magnetic resonance imaging (MRI): mathematics, spin physics, NMR spectroscopy, fourier transforms, imaging principles. Ultrasound (US): mathematical principles, echo equation, impulse response, diffraction, lateral and depth resolution, phased array systems, noise removal. Nuclear Medicine: positron emission tomography (PET), single photon emission computed tomography (SPECT), imaging methods, resolution, 3-D imaging.
Text book: ***Medical imaging systems, Albert Macovski. Prentice-Hall,***

BIOE 491 BIOPROCESS DESIGN II (3+2) 4
Fundamentals of engineering investments and economics. Flowsheet synthesis and process equipment design concepts. Methods for quantification of fixed capital investment, cash-flow analysis, profitability analysis and decision making. Practice on the concepts in the context of a term-project that will range from investigation of market potential of a given chemical to the detailed design and economic evaluation of a process to produce that product.
Text book: ***Plant Design and Economics for Chemical Engineers,*** *M.S.Peters et al., McGraw-Hill*
Analysis, Synthesis and Design of Chemical Processes, *R.Turton et al., Prentice Hall*

BIOE 497 BIOENGINEERING PROJECT I (0+4) 2
In consultation with and under the direction of a faculty member, students pursue a term project individually or in teams. This project involves designing, dimensioning and preparation of complete bioengineering drawings of a selected engineering project. These creative inquiry projects may be interdisciplinary.

BIOE 498 BIOENGINEERING PROJECT II (0+4) 2
In consultation with and under the direction of a faculty member, students pursue a term project individually or in teams. This project involves designing, dimensioning and preparation of complete bioengineering drawings of a selected engineering project. These creative inquiry projects may be interdisciplinary.