Department of Biomedical Engineering

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Chair:
Vincent Turitto

The Department of Biomedical Engineering confers a doctoral degree in biomedical engineering (Ph.D. in Biomedical Engineering). Currently, ten faculty members hold tenure-track positions in the department. Several departments at IIT contribute courses and faculty to the graduate program: Biological, Chemical and Physical Sciences; Chemical and Environmental Engineering; Computer Science; Electrical and Computer Engineering; Mechanical, Materials and Aerospace Engineering; the Institute of Psychology; and the Center for Ethics in the Professions.

An M.D./Ph.D. program is in place whereby students with engineering backgrounds can receive a Ph.D. in Biomedical Engineering at IIT and an M.D. from the University of Chicago. Qualified students are admitted to the MSTP (Medical Scientist Training Program) at the University of Chicago and subsequently apply to the Department of Biomedical Engineering for their Ph.D. studies.

Degree Offered

Doctor of Philosophy in Biomedical Engineering

Research Areas

Cell and Tissue Engineering
Medical Imaging
Neural Engineering

Faculty

Mark Anastasio, Associate Professor. Ph.D., University of Chicago. Development and analysis of tomographic reconstruction algorithms, analytical and numerical analysis of inverse problems in biomedical imaging, theoretical imaging science.

Konstantinos Arfanakis, Assistant Professor. Ph.D., University of Wisconsin-Madison. Magnetic resonance imaging (MRI), MRI acquisition and post-processing, diffusion tensor MRI (DTI), functional MRI (fMRI).

Robert Arzbaecher, Emeritus Professor. Ph.D., University of Illinois, Urbana-Champaign. Instrumentation, signal processing and control.

Eric M. Brey, Assistant Professor. Ph.D., Rice University. Angiogenesis, microvascular models, wound healing, tissue engineering.

Jennifer J. Kang Derwent, Assistant Professor. Ph.D., Northwestern University. Models of thrombotic retinal vessel occlusion, blood flow, electroretinography.

Paul Fagette, Senior Lecturer. Ph.D., University of California, Riverside. History of modern American science, medical science, and technology.

Connie Hall, Assistant Professor. Ph.D., University of Memphis. Inhibition of thrombosis, biomaterials and surface coatings, computational transport analysis.

Thomas C. Irving, Associate Professor. Ph.D., University of Guelph (Canada). Structure and biophysics of macromolecular systems, muscle structure and physiology, synchrotron radiation instrumentation.

Derek Kamper, Assistant Professor. Ph.D., Ohio State University. Neural control, biomechanics and rehabilitative medicine.

David Mogul, Associate Professor. Ph.D., Northwestern University. Neuronal networks, control of epilepsy, brain electrophysiology.

Emmanuel Opara, Research Professor. Ph.D., University of London. Development of a bioartificial pancreas, cell microencapsulation techniques, biocompatibility of biopolymers.

Georgia Papavasiliou, Senior Lecturer. Ph.D., Illinois Institute of Technology. Mathematical modeling, design of polymeric biomaterials for tissue engineering and drug delivery applications.

Philip R.Troyk, Associate Professor. Ph.D., University of Illinois, Chicago. Polymers for electronics, neural implants, solid-state power systems.

Vincent Turitto, Director of Pritzker Institute of Biomedical Science and Engineering and Professor. D.Engr.Sci., Columbia University. Blood flow and thrombosis, atherosclerosis, cellular biodynamics, biomaterials.

Miles Wernick, Professor. Ph.D., University of Rochester. Medical imaging, image processing, pattern recognition.

Yongyi Yang, Associate Professor. Ph.D., Illinois Institute of Technology. Image and signal processing, data compression, applied mathematical and statistical methods.

Affiliated Program Faculty, IIT

Hamid Arastoopour, Max McGraw Professor of Energy/Environment/Economics and Dean, Armour College of Engineering. B.S., Abadan Institute of Technology (Iran); M.S., Ph.D., Illinois Institute of Technology. Computational multiphase flow, pulverization and agglomeration of particles, fluidization, fluid-particle flow and material processing.

Ali Cinar, Professor of Chemical Engineering, Dean of the Graduate College, and Vice Provost for Research. B.S., Robert College (Turkey); M.S., Ph.D., Texas A & M. Process modeling, monitoring, and control; agent-based systems for process supervision, complexity, AI applications, modeling and simulation of biomedical systems, diabetes.

Victor Perez-Luna, Assistant Professor, Department of Chemical and Environmental Engineering. B.S., M.S., Universidad de Guadalajara (Mexico); Ph.D., University of Washington. Surface analysis and modification, biomaterials, biosensors and tissue engineering.

Benjamin C. Stark, Professor and Associate Chair of Department of Biological, Chemical & Physical Sciences and Director of the Master of Biology Program. B.S., University of Michigan; M.Ph., Ph.D., Yale University. Biochemistry and molecular biology of bacterial respiration, fermentation, bioremediation.

Fouad A. Teymour, Johnson Polymer Professor of Chemical Engineering and Chair of Department of Chemical and Environmental Engineering. B.S., M.S., Cairo University (Egypt); Ph.D. University of Wisconsin, Madison. Polymer reaction engineering, mathematical modeling, nonlinear dynamics.

Admission Requirements

Minimum cumulative undergraduate GPA: 3.2/4.0
GRE minimum scores:
1800 (combined)
1200 (quantitative + verbal) 3.0 (analytical writing)

Meeting the minimum admission standards for GPA and GRE scores does not guarantee admission. Test scores and GPA are just two of several important factors considered. The admissions committee will also consider recommendations from three college faculty members acquainted with the character, research ability, potential, qualifications and motivation of the applicant, and the needs of the depaartmental faculty. Entering graduate students are assigned a temporary academic adviser who will provide initial guidance. As their research and other academic interests become defined, students select a permanent research adviser,who will also guide them through their academic studies.

Doctor of Philosophy in Biomedical Engineering

84 credit hours
Qualifying examination (written and oral)
Thesis research proposal/comprehensive examination
Dissertation and oral defense

This degree is awarded in recognition of a high level of mastery in subject matter and a significant original research contribution in biomedical engineering. The Ph.D. recipient will be capable of a continuing effort toward the advancement of knowledge and achievement in research and other scholarly activities and may pursue a career in a medical, an industrial or an academic environment.

A minimum of 84 credit hours is required for the Ph.D. in Biomedical Engineering. Students who have received an M.S. degree from another university may petition for transfer of up to 32 credit hours applicable toward the Ph.D. degree. Students must pass the Ph.D. qualifying examination within the first year of full-time Ph.D. studies. This is a written and oral examination intended to explore both the depth and breadth of the student's academic abilities. Within two and one-half years of matriculation, students will be required to defend their thesis research proposal (comprehensive examination). A written dissertation and oral defense are also required for receiving the doctoral degree. Dissertation format and deadlines are established by the Graduate College.

There are no specific courses that are required for the doctoral degree in biomedical engineering. However, a minimum of three courses in life science, three courses in mathematics, and six courses in biomedical engineering or other engineering-related courses are required. The specific courses selected to meet these requirements will depend on the entering qualifications of the student and the nature of the thesis research proposal. In general, the student's thesis committee will determine the specific courses requirements necessary for graduation.

Biomedical engineering courses

BME 500	Introduction to Biomedical Engineering
BME 501	Biomedical Instrumentation
BME 502	Computational Neuroscience I: Single Neuron Computation
BME 503	Mathematics and Statistics for Neuroscience I
BME 504	Neuroethology
BME 505	Mathematics and Statistics for Neuroscience II
BME 506	Computational Neuroscience II: Vision
BME 507	Cognitive Neuroscience
BME 508	Mathematics and Statistics for Neuroscience III
BME 530	Inverse Problems in Biomedical Imaging
BME 532	Medical Imaging Science
BME 533	Biostatistics
BME 535	Magnetic Resonance Imgaing
BME 538	Neuroimaging
BME 551	Physiological Signal Analysis & Control Theory I
BME 552	Physiological Signal Analysis & Control Theory II
BME 570	Engineering Biocompatible Materials
BME 581	Fluid Dynamics for Biomedical Engineers
BME 582	Advanced Mass Transport for Biomedical Engineers
BME 595	Seminar in Biomedical Engineering
BME 597	Wave Physics and Applied Optics for Imaging Scientists
BME 597	Neural Prosthesis
BME 691	Research and Thesis for Ph.D. degree

Life science courses (represenative)

BIOL 403	General Biochemistry
BIOL 414	Genetics for Engineering Scientists
BIOL 430	Animal Physiology
BIOL 445	Cell Biology
BIOL 513	Advanced Biochemistry
BIOL 515	Molecular Biology
BIOL 527	Immunology and Immunochemistry
BIOL 550	Bioinfomatics and Biotechnology
BIOL 565	Vertebrate Physiology

Doctor of Philosophy in Biomedical Engineering continued

Approved math/applied math courses

MATH 461	Fourier Series and Boundary-Value Problems
MATH 471	Numerical Methods I
MATH 472	Numerical Methods II
MATH 476	Statistics
MATH 489	Partial Differential Equations
MATH 510	Ordinary Differential Equations
MATH 512	Partial Differential Equations
MATH 519	Complex Analysis
MATH 532	Linear Algebra
MATH 542	Stochastic Processes
MATH 546	Introduction to Time Series
MATH 555	Tensor Analysis
MATH 564	Applied Statistics
MATH 577	Computational Mathematics I
MATH 578	Computational Mathematics II
MATH 581	Theory of Finite Elements

Engineering or physics courses (representative) that may count toward math requirement

MMAE 501	Engineering Analysis 1b
MMAE 502	Engineering Analysis II
MMAE 503	Advanced Engineering Analysis
MMAE 505	Numerical Methods in Engineering
MMAE 506	Computational Methods in Engineering Analysis
MMAE 517	Computational Fluid Mechanics
CHE 535	Applications of Mathematics to Chemical Engineering
CHE 536	Computational Techniques in Engineering
PHYS 501	Methods of Theoretical Physics I
PHYS 502	Methods of Theoretical Physics II

Selected engineering electives

CS 480	Artificial Intelligence
CS 525	Advanced Database Organization
CS 580	Medical Informatics
CS 583	Expert Systems
CHE 450	Principles of Polymer Science and Engineering
CHE 532	Process Modeling
CHE 533	Statistical Analysis of Process Data
CHE 544	Kinetic Theory of Multiphase Flow
CHE 555	Polymer Processing
CHE 573	Bioseparations
CHE 575	Polymer Rheology
CHE 586	Particulate Technology
CHE 761	Statistical Design of Experiments for Process Improvement
CHE 577	Biochemical Engineering
CHE 579	Enzyme Reactor Engineering
CHE 582	Interfacial and Colloidal Phenomena with Applications
CHE 583	Pharmaceutical Engineering
CHE 585	Drug Delivery
ECE 433	Real-Time Data Acquisition and Processing
ECE 511	Analysis of Random Signals
ECE 565	Multidimensional Signal Processing
ECE 566	Statistical Pattern Recognition
ECE 567	Statistical Signal Processing
MMAE 407	Biomechanics
MMAE 467	Polymeric Materials
MMAE 507	Introduction to Continuum Mechanics
MMAE 510	Fluid Mechanics
MMAE 512	Dynamics of Viscous Fluids
MMAE 517	Computational Fluid Dynamics
MMAE 579	Characterization of Polymers

Department of Biomedical Engineering

Course Descriptions

Note: For description of courses other than BME, see the appropriate departmental listing.

BME 500
Introduction to Biomedical Engineering
Introduction to the concepts and research in biomedical engineering. Provides an overview of current biomedical engineering research areas, emphasis on application of an engineering approach to medicine and physiology.

BME 501
Biomedical Instrumentation
Bioelectric phenomena, transducers, amplifiers. Processing of ECG, EMG and EEG signals. (3-0-3)

BME 502
Computational Neuroscience I
This course briefly review the historical development of computational neuroscience and discusses the functional properties of individual neurons. The electrotonic structure of neurons, functional properties of synapses, and voltage-gated ion channels are discussed. (3-0-3)

BME 503
Math/Statistics: Neuroscience I
Prerequisites: Consent of Instructor. This quarter introduces mathematical ideas and techniques in a neuroscience context. Topics will include some coverage of matricies and complex variables; eigenvalue problems, spectral methods and Grens functions for differential equations; and some discussion of both deterministic and probabilistic modeling in the neurosciences. (2-0-2)

BME 504
Neurobiology
Neurobiology Prerequisites: Consent of Instructor. This course is concerned with the structure and function of systems of neurons, and how these are related to behavior. Common patterens of organization are described from the anatomical, physiological, and behavioral perspectives of analysis. The comparative approach is emphasized throughout. Laboratories include exposure to instrumentation and electronics, and involve work with live animals. A central goal of the laboratory is to expose students to in vivo extracellular electrophysiology in vertebret preparations. Laboratoratries will be attended only on one day a week but may run well beyond the canonical perios. (2-0-2)

BME 505
Math/Statistics: Neuroscience II
Prerequisites: BME 503, consent of instructor. This quarter treats statistical methods important in understanding nervous system function. It includes basic concepts of mathematical probability; information theory, discrete Markoy processes, and time series. (2-0-2)

BME 506
Comp Neuroscience II: Vision
This course considers computational approaches to vision. It discusses the basic anatomy and physiology of the retina and central visual pathways, and then examines computational approaches to vision based on linear and non-linear systsms theory, and algorithms derived from computer vision. (3-0-3)

BME 507
Cognitive Neuroscience
Consent of Instructor. This course is concerned with the relationship of the nervous system to higher order behaviors such as perception and encoding, action, attention and learning and memory. Modern methods of imaging neural activity are introduced, and information theoretic methods for studying neural coding in individual neurons and populations of neurons are discussed. (2-0-2)

BME 508
Math/Statistics: Neuroscience III
Prerequisites: BME 503, BME 505, Consent of Instructor. This quarter covers more advanced topics including perturbation and bifurcation methods for the study of dynamical systems; symmetry methods and some group theory. A variety of application to neuroscience will be described. (2-0-2)

BME 521
Medical Imaging
Study of modern technology for medical imaging. Theory and operation of CAT, SPECT, PET, MRI, Xray and echo imaging modalities. (3-0-3)

BME 522
Mathematical Methods in BME
Prerequisites: Graduate standing in BME or consent of instructor. This course is an introductory graduate level course that integrates mathematical and computational tools that address directly the needs of biomedical engineers. The topics covered include the mathematical or diffusion, pharmacokinetic modesl, biological fluid mechanics, and biosignal representations and analysis. The use of MATLAB will be emphasized for numerically solving problems of practical relevance. (3-0-3)

BME 525
Concepts of Tissue Engineering
This course seeks to provide students with an introduction to the field of Tissue Engineering. The first portion of the course will introduce the field, including a discussion of cell sorcing, biomaterials, DA, and ethical consideration. The second portion of the course will present case studies in specific tissue and organ systems in which these concepts are put together in an attempt to develop a clinically applicable tissue engineered product. (3-0-3)

BME 530
Inverse Problems in Biomedical Imaging
This course will introduce graduate students to the mathematical theory of inverse problems. Concepts from functional analysis will be applied for understanding and characterizing mathematical properties of inverse problems. This will permit for the analysis of the stability and resolution of image reconstruction algorithms for

various existing and novel biomedical imaging systems. The singular value decomposition (SVD) is introduced and applied for understanding fundamental properties of imaging systems and reconstruction algorithms. (3-0-3)

BME 532
Medical Imaging Science
This course is an introduction to basic concepts in medical imaging, such as: receiver operating characteristics, the rose model, point spread function and transfer function, covariance and auto-covariance, noise, filters, sampling, aliasing, interpolation, and image registration. (3-0-3)

BME 533
Biostatistics
This course is designed to cover the tools and techniques of modern statistics with specific applications to biomedical and clinical research. Both parametric and nonparametric analysis will be presented. Descriptive statistics will be discussed although emphasis is on inferential statistics and experimental design. (3-0-3)

BME 535
Magnetic Resonance Imaging
This course is an introduction to magnetic resonance imaging (MRI). It includes basic MR physics, the principles of selective excitation, signal detection, and MR image reconstruction, different pulse sequences, MRI hardware, issues on image quality and artifacts, and advanced MRI techniques. (3-0-3)

BME 538
Neuroimgaging
This course describes the use of different imgaging modalities to study brain function and connectivity. The first part of the course deals with brain function. It includes an introduction to energy metabolism in the brain, cerebral blood flow, and brain activation. It continues with an introduction to magnetic resonance imaging (MRI), perfusion-based fMRI, BOLD fMRI, fMRI paradigm design and statistical analysis, introduction to positron emission tomography (PET) and studying brain function with PET, introduction to magnetoencephalography (MEG) and studying brain function with MEG. The second part of the course deals with brain connectivity. It includes an introduction to diffusion tensor MRI, explanation of the relationship between the diffusion properties of tissue its structural characteristics, and white matter fiber tractography techniques. (3-0-3)

BME 540
Wave Physics and Applied Optics for Imaging Scientists
This course will introduce students to fundamental concepts in wave physics and the analysis of optical wavefields. These principles will be utilized for understanding existing and novel imaging methods that employ coherent radiation. Solutions to inverse scattering and inverse source problems will be derived and algorithmic realizations of the solutions will be developed. Phase-contrast imaging techniques and X-ray imaging systems that employ coherent radiation will be studied.

BME 542
Advanced Concepts in Image Science
Prerequisites: BME 530, BME 532 or consent of instructor. This graduate level course introduces students to fundamental concepts in image science that are related to the optimization and evaluation of biomedical imaging systems. Topics covered include: deterministic descriptions of imaging systems, stochastic descriptions of imaging systems, statistical cdecision theory, and objective assessment of image quality. (3-0-3)

BME 543
Bioinstrumentation and Electronics
Principles of circuit analysis are applied to typical transducer and signal recording situations found in biomedical engineering. Basic electrical and electronic circuit theory is reviewed with an emphasis on biomedical measurement applications. A special topic is individually studied by the student and presented to the class electrical physics class or basic circuits. (3-0-3)

BME 551
Physiological Signal Analysis & Control Theory I
This is the first of a 2 part course co-taught at IIT and the University of Chicago. essential elements of signal processing and control theory as it is applied to physiological systems will be covered. Part I will cover data acquisition and sampling, Laplace and Fourier transforms, filtering, time and frequency domains, sytem descriptions and lumped vs. distributed parameters. Students will use Matlab to test concepts presented in class. (2-0-2)

BME 552
Physiological Signal Analysis & Control Theory II
This is the second part of a 2 part course co-taught at IIT and the University of Chicago. Part II will cover time and frequency domain analysis, impulse vs. step response functions, open vs. closed loop responses, stability, systems identification and control, non-linear control. Students will use Matlab to test concepts presented in class. (2-0-2)

BME 553
Quantitative Physiology
Prerequisites: BME 100. The primary objective of this course is to introduce students to basic physiological concepts using a quantitative approach. The main systems that control the human body functions will be reviewed to enable the students to understand the individual role of each major functional system as well as the need for the integration or coordination of the activities of the various systems. Attempts will be made to highlight the patho-physiological consequences of defects or failures in the organ systems, and the relevant corrective approaches. This course will include lectures from individuals who have relevant expertise in the different organ systems because of the complexity of the human body. (3-0-3)

BME 570
Engineering Biocompatible Materials
The primary objective of this course is to introduce students to synthetic materials that are routinely used as componets of various medical devices implanted in the human body. In this course, students will critically examine prosthetic materials used in specific devices (for example: muscle, eye, skin, vascular). The biological environment relevant to the discussed implant will be reviewed. Problems with current materials will be analyzed and strategies and techniques required to engineer sophisticated biomaterials for future applications will be developed. Legal procedures required to obtain FDA approval for such materials will be taught. Industry personnel specializing in medical implants will deliver guest lectures. (3-0-3)

BME 575
Neuromechanics of Human Movement
This course will explore how we control movement of our extremities, with concepts drawn from mechanics and neurophysiology. The progression from neurological signals to muscle activation and resulting movement of the hand or foot will be modeled, starting at the periphery and moving back toward the central nervous system. Biomechanics of the limbs will be modeled using dynamic simulation software (Working Model) which will be driven by a neural controller, implemented in MATLAB. Issues related to sensory feedback and redundancy will be addresses.

BME 581
Fluid Dynamics for Biomedical Engineers
This course is primarily focused on the development of theoretical and experimental principles necessary for the delineation of fluid flow in various "in vitro" chambers and the cardiovascular system. Its content will primarily deal with the basic concepts of flow in various geometries, the heterogeneous nature of blood and the application of such principles in flow chambers designed to expose blood elements to defined flow conditions. The relationship to flow in the normal and diseased vascular system will also be considered. (3-0-3)

BME 582
Advanced Mass Transport for Biomedical Engineers
The development of theoretical and mathematical principles necessary for the delineation of mass transport processes in biological and medical systems. Herogeneous reactions which occur at or in the vicinity of cells. Basic transport mechanisms in the vasculature, across cells or within tissues.(3-0-3)

BME 597
Neural Prostheses
The goal of this course is to provide students the fundamentals of sensory and motor neural prosthetic devices. Principles of recording from, and electrical stimulation of, neural tissue will be presented. Students will study past and current literature for specific neural prosthesis systems.

BME 691
Research and Thesis for Ph.D. degree
(Variable credit)

Classes co-offered at the University of Chicago:

BME 502
Computational Neuroscience I: Single neuron computation

BME 503
Mathematics and Statistics for Neuroscience I

BME 504
Neuroethology

BME 505
Mathematics and Statistics for Neuroscience II

BME 506
Computational Neuroscience II: Vision

BME 507
Cognitive Neuroscience

BME 508
Mathematics and Statistics for Neuroscience III