To train the next generation of leaders in bioengineering, Rice's Bioengineering department has created an innovative teaching program that transcends boundaries between bioengineering, basic science, and clinical medicine, integrating the academic, industrial, and societal perspectives. Our hands-on approach to education is supported by a long-standing tradition of cross-disciplinary research and education.

The Rice Bioengineering program is a comprehensive training program that provides student with:

- A fundamental understanding of the life and medical sciences.
- Advanced analytical and engineering capabilities.
- Translational research capability for transferring biotechnical advances from bench to bedside.

With this educational background, graduates will be well prepared to participate in independent or collaborative research and development endeavors in industry or academia.

Graduate programs in bioengineering offer concentrations in areas such as biomedical imaging and diagnostics, cellular and biomolecular engineering, computational and theoretical bioengineering, biomaterials and drug delivery and biomaterials, systems and synthetic biology, and tissue engineering and biomechanics. Research areas include biomechanical engineering, biological systems modeling, bioinformatics, cellular and molecular engineering, controlled release technologies, metabolic engineering, spectroscopy, statistical mechanics, systems engineering and instrumentation, thrombosis, tissue engineering, and transport processes.

**Bachelor's Program**

- Bachelor of Science in Bioengineering (BSBE) Degree (ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/bioengineering-bsbe)

**Master's Programs**

- Master of Bioengineering (MBE) Degree (ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/bioengineering-mbe)

- Master of Science (MS) Degree in the field of Bioengineering*

**Doctoral Program**

- Doctor of Philosophy (PhD) Degree in the field of Bioengineering (ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/bioengineering-phd)

**Coordinated Programs**

- Master of Business Administration (MBA) Degree / Master of Bioengineering (MBE) Degree (ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/business-administration-mba-bioengineering-mbe)

- Doctor of Philosophy (PhD) Degree in the field of Bioengineering / Doctor of Medicine (MD) Degree with Baylor College of Medicine (ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/bioengineering-phd-md)

* Although students are not normally admitted to a Master of Science (MS) degree program, graduate students may earn the MS as they work towards the PhD.

**Chair**

K. Jane Grande-Allen

**Professors**

Gang Bao
Michael Deem
Rebekah Drezek
Jane Grande-Allen
Herbert Levine
Jianpeng Ma
Antonios Mikos
Rebecca Richards-Kortum
Ka-Yiu San

**Associate Professors**

Michael Diehl
Oleg Igoshin
Robert Raphael
Junghae Suh
Jeffrey Tabor
Tomasz Tkaczyk

**Assistant Professors**

Jordan Miller
Omid Veiseh
David W. Zhang

**Professors in the Practice**

Z. Maria Oden

**Lecturers**

Bilal Ghosn
Renata Ramos
Eric Richardson
Bioengineering

Professors, Joint Appointments
John Clark
Fathi Ghorbel
Ramon Gonzalez
Naomi Halas
Jeffrey Hartgerink
Lydia Kavaraki
Marek Kimmel
Marie Lynn Miranda
Frank Tittel
Kyriacos Zygourakis

Associate Professors, Joint Appointments
Matthew Bennett
Ching-Hwa Kiang
Angel A. Marti
Laura Segatori
Jonathan Silberg

Assistant Professors, Joint Appointments
Caleb Kemere
Jacob Robinson
Aryeh Warmflash

Adjunct Professors
Maria Elena Bottazzi
William Brownell
Ill-Min Chung
William Cohn
Mary Dickinson
Rena D'Souza
Charles Fraser
Ann M. Gillenwater
Peter J. Hotez
Ragha Kalluri
Anirban Maitra
John McDevitt
David R. Piwnica-Worms
Eric Richardson
Robert C. Robbins
Rodigo Ruano
Jacqueline Shanks
Andrew Sikora
Karen Storthz
Mark Wong
Samuel Miao-Sin Wu

Adjunct Associate Professors
Catherine Ambrose
Sharmila Anandasabapathy
Elizabeth Cosgriff-Hernandez
Miguel Cruz
M. Waleed Gaber
Stephen H. Little
Joseph Ludwig
Andrew Sikora
Konstantin Sokolov

Adjunct Assistant Professors
Aviva Presser Aiden
Aaron Foster
Michael J. Heffernan
Kurt Kasper
Steven Millward
Medhi Razavi
Niki Zacharias Millward

For Rice University degree-granting programs:
To view the list of official course offerings, please see Rice’s
Course Catalog (https://courses.rice.edu/admweb/SWKSCAT.cat?p_action=cata)
To view the most recent semester’s course schedule, please see Rice’s
Course Schedule (https://courses.rice.edu/admweb/SWKSCAT.cat)

Bioengineering (BIOE)
BIOE 202 - CAREERS IN BIOENGINEERING
Short Title: CAREERS IN BIOENGINEERING
Department: Bioengineering
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Lower-Level
Description: This seminar is suitable for freshman, sophomores, and non-
majors. A series of guest lectures will introduce students to a variety of
career options in bioengineering. Students will participate in at least one
field trip to an industry partner or hospital to learn more about careers in
bioengineering.

BIOE 252 - BIOENGINEERING FUNDAMENTALS
Short Title: BIOENGINEERING FUNDAMENTALS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Lower-Level
Prerequisite(s): MATH 101 and MATH 102 and MATH 211 (may be taken concurrently) and CHEM 122 and CAAM 210 and (PHYS 101 or PHYS 125 or PHYS 111) and (PHYS 102 or PHYS 126 or PHYS 112)
Description: Introduction to material, energy, charge, and momentum
balances in biological systems. Steady state and transient conservation
equations for mass, energy, charge and momentum will be derived
and applied using basic mathematical principles, physical laws,
stoichiometry, and thermodynamic properties. Problem based learning
groups will solve open-ended problems. Required for students intending
to major in bioengineering. MATH 211 is a concurrent prerequisite and
may be taken the same semester.
BIOE 322 - FUNDAMENTALS OF SYSTEMS PHYSIOLOGY
Short Title: FUND OF SYSTEMS PHYSIOLOGY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 252 and MATH 211
Description: This course will teach the fundamentals of human physiology from an engineering perspective, with specific focus on the nervous, cardiovascular, respiratory and urinary systems. Lectures, assignments and exams will be quantitative and will introduce engineering principles, such as conservation of mass and energy, controls and system analysis, thermodynamics and mass transport, and apply them to the study of physiologic systems. This course is limited to undergraduates. Students may receive credit for only one of BIOE 302, BIOE 322, and BIOC 332. Mutually Exclusive: Credit cannot be earned for BIOE 302 and BIOE 322.

BIOE 307 - SYSTEMS BIOLOGY OF BLOOD VESSELS
Short Title: SYS BIOLOGY OF BLOOD VESSELS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 252
Description: How blood vessels respond to hypoxia is a process critical to the progression of many diseases and conditions including cardiovascular disease, cancer, cerebrovascular disease, diabetes, obesity and arthritis. Physiological processes such as exercise, aging, and wound healing also depend on hypoxia-induced microvessel changes. This course introduces engineering concepts of hypoxic response, angiogenesis, and capillary remodeling - from the effects at the intracellular level to the whole body. Topics covered include computational systems biology modeling of hypoxia and angiogenesis, the use of angiogenesis in tissue engineering and regenerative medicine, imaging of blood vessel dynamics, capillaries of the brain, and the design of new blood vessels. Graduate/Undergraduate Equivalency: BIOE 507. Mutually Exclusive: Credit cannot be earned for BIOE 307 and BIOE 507.

BIOE 330 - BIOREACTION ENGINEERING
Short Title: BIOREACTION ENGINEERING
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 252 and (BIOC 201 or BIOS 201)
Description: Application of engineering principles to biological processes. Mathematical and experimental techniques for quantitative descriptions of enzyme kinetics, metabolic and genetic networks, cell growth kinetics, bioreactor design and operation.
BIOE 332 - BIOENGINEERING THERMODYNAMICS

Short Title: BIOENGINEERING THERMODYNAMICS

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Lecture

Credit Hours: 3

Restrictions: Graduate level students may not enroll.

Course Level: Undergraduate Upper-Level

Prerequisite(s): BIOE 252 and MATH 212

Description: This course provides a mathematically rigorous and quantitative coverage of the fundamentals of thermodynamics with applications drawn from contemporary bioengineering problems. Fundamental topics will include the Zeroth, First and Second Law, Entropy Inequality, Gibbs and Helmholtz Free Energies, The Third Law, Maxwell Relations, chemical potential, equilibrium, phase transitions, solution thermodynamics, protein-ligand binding, translation initiation and genetic circuits. The course will cover the role that thermodynamics plays in molecular engineering and synthetic biology.

BIOE 342 - LABORATORY IN TISSUE CULTURE

Short Title: LABORATORY IN TISSUE CULTURE

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Laboratory

Credit Hour: 1

Restrictions: Graduate level students may not enroll.

Course Level: Undergraduate Upper-Level

Prerequisite(s): BIOE 440 or STAT 440 or BIOC 311 or BIOS 311

Description: Introduction to tissue culture techniques, including cell passage, cell viability, and cell attachment and proliferation assays. Students complete quantitative analysis of their data. Engineering design and applications are featured in graded work. Sections 1 and 2 are taught during the first half of the semester. Sections 3 and 4 are taught during the second half of the semester. Students may be required to attend lab on a university holiday. Instructor Permission Required. Cross-list: BIOC 320.

BIOE 348 - MOLECULAR TECHNIQUES IN BIOENGINEERING

Short Title: MOLECULAR TECHNIQUES IN BIOE

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Lecture

Credit Hours: 3

Restrictions: Graduate level students may not enroll.

Course Level: Undergraduate Upper-Level

Prerequisite(s): BIOC 341 and (BIOE 342 (may be taken concurrently) or BIOC 320 (may be taken concurrently))

Description: Introduction to the fundamental physical principles of light interaction with matter, separation (by charge, size, confirmation) and detection techniques utilized in the field of bioengineering. These include absorbance and fluorescence spectroscopy, light and fluorescence microscopy, flow cytometry, electrophoresis, PCR, Blotting, and ELISA. BIOE 342/BIOC 320 may be taken concurrently with BIOE 348.

BIOE 360 - APPROPRIATE DESIGN FOR GLOBAL HEALTH

Short Title: APPRO DESIGN FOR GLOBAL HEALTH

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Seminar

Credit Hours: 3

Restrictions: Graduate level students may not enroll.

Course Level: Undergraduate Upper-Level

Prerequisite(s): GLHT 201

Description: Seminar-style introductory design course covering epidemiology, pathophysiology, health systems, health economics, medical ethics, humanitarian emergencies, scientific and engineering design methods, and appropriate health technology case studies. To register, you must be enrolled in the GLHT minor and submit a 250 statement to beyondtraditionalborders@rice.edu by Monday of preregistration. The minor and course prerequisite is waived for students majoring in Bioengineering. Instructor Permission Required. Cross-list: GLHT 360.

BIOE 361 - METABOLIC ENGINEERING FOR GLOBAL HEALTH ENVIRONMENTS

Short Title: METAB ENG GLOBAL HEALTH ENVVMNT

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Lecture

Credit Hours: 3

Restrictions: Graduate level students may not enroll.

Course Level: Undergraduate Upper-Level

Prerequisite(s): (BIOE 362 or GLHT 362) and (PHYS 126 or PHYS 102 or PHYS 112 or PHYS 142) and MATH 102

Description: Importance of nutritional and pharmaceutical compounds, impact of cost of compounds on global health; Overview of biochemical pathways; metabolite analysis; Genetic engineering and molecular biology tools for ME; Pharmaceuticals and drug discovery approaches (antibiotics, antivirals; anti-parasite compounds); anti-diarrhea treatments; vaccines. Cross-list: BIOC 361, GLHT 361.

Course URL: www.btb.rice.edu

BIOE 365 - SUSTAINABLE WATER PURIFICATION FOR THE DEVELOPING WORLD

Short Title: SUST WTR PURIF FOR DEV WORLD

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Lecture/Laboratory

Credit Hours: 3

Restrictions: Graduate level students may not enroll.

Course Level: Undergraduate Upper-Level

Description: This course is an overview of sustainable strategies for safe water supply in off-the-grid, low-income regions. Topics covered include water quality and treatment, sustainability and WASH (water, sanitation and hygiene). A major element of the course is a project to solve a water-related issue in a real-world context. Cross-list: CEVE 314, GLHT 314. Repeatable for Credit.
BIOE 370 - BIOMATERIALS  
Short Title: BIOMATERIALS  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Graduate level students may not enroll.  
Course Level: Undergraduate Upper-Level  
Prerequisite(s): BIOE 252 and CHEM 211 and (MECH 211 or CEVE 211) (may be taken concurrently)  
Description: This course will introduce both basic materials science and biological concepts with an emphasis on application of basic quantitative engineering principles to understanding the interactions between materials and biological systems. Topics covered include chemical structure of biomaterials, physical, mechanical, and surface properties of biomaterials, biomaterial degradation, and biomaterial processing. Additional topics include protein and cell interactions with biomaterials, biomaterial implantation, and acute inflammation, wound healing and the presence of biomaterials immune responses to biomaterials, biomaterials, immune responses to biomaterials, biomaterials and thrombosis, as well as infection, tumorigenesis, and calcification of biomaterials that can collectively apply to design of biomaterials for myriad applications. MECH 211 or CEVE 211 may be taken concurrently with BIOE 370.

BIOE 372 - BIOMECHANICS  
Short Title: BIOMECHANICS  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Graduate level students may not enroll.  
Course Level: Undergraduate Upper-Level  
Prerequisite(s): BIOE 252 and MATH 212 and (MECH 211 or CEVE 211) (may be taken concurrently)  
Description: This course introduces the fundamental principles of mechanics applied to the analysis and characterization of biological systems. Topics covered include normal and shear stresses, normal and shear strains, mechanical properties of materials, load, deformation, elasticity and elastoplastic behavior. Quantitative analysis of statically determinate and indeterminate structures subjected to tension, compression, torsion and bending will be covered. Additionally, aspects of blood rheology, viscoelasticity, and musculoskeletal mechanics will be addressed.

BIOE 380 - INTRODUCTION TO NEUROENGINEERING: MEASURING AND MANIPULATING NEURAL ACTIVITY  
Short Title: INTRO TO NEUROENGINEERING  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Graduate level students may not enroll.  
Course Level: Undergraduate Upper-Level  
Prerequisite(s): (PHYS 102 or PHYS 112 or PHYS 126 or PHYS 142)  
Description: This course will serve as an introduction to quantitative modeling of neural activity and the methods used to stimulate and record brain activity. Cross-list: ELEC 380, NEUR 383. Mutually Exclusive: Credit cannot be earned for BIOE 380 and BIOE 480/BIOE 590/ELEC 480/ELEC 580.
BIOE 391 - NUMERICAL METHODS
Short Title: NUMERICAL METHODS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 252 and CAAM 210 and MATH 211 and MATH 212 (may be taken concurrently)
Description: Introduction to numerical approximation techniques with bioengineering applications. Topics include error propagation, Taylor’s Series expansions, curve fitting, roots of equations, optimization numerical differentiation and integration, ordinary differential equations, and partial differential equations. Matlab and other software will be used for solving equations. Math 212 may be taken concurrently with BIOE 391.

BIOE 392 - NEEDS FINDING AND DEVELOPMENT IN BIOENGINEERING
Short Title: NEEDS FINDING & DEV IN BIOE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: Students in this course will learn and develop the engineering skill of needs finding in the field of bioengineering focused on designing for disabilities. Students will work in groups with patients with disabilities to identify daily needs and develop design criteria to meet those needs including preliminary prototype development. Instructor Permission Required. Cross-list: GLHT 392.

BIOE 393 - ADVANCES IN BIONANOTECHNOLOGY
Short Title: ADVANCES IN BIONANOTECHNOLOGY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 370 (may be taken concurrently)
Description: This course covers nanotechnology applications in bioengineering. Students learn about cutting edge research that uses the tools of nanotechnology to tackle medical problems. Topics include bionanotechnology-related research for diagnosis, detection, and treatment of disease; cell targeting; drug design and delivery; gene therapy; prostheses and implants and tissue regeneration. (REGISTRATION NOTE: The prerequisite BIOE 370 can also be taken concurrently with BIOE 403)

BIOE 400 - ENGINEERING UNDERGRADUATE RESEARCH
Short Title: ENGINEERING UG RESEARCH
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-4
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: Independent investigation of a specific topic or problem in modern bioengineering research under the direction of a selected faculty member. Research project has a strong engineering component. Repeatable for Credit.

BIOE 401 - UNDERGRADUATE RESEARCH
Short Title: UNDERGRADUATE RESEARCH
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-4
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: Independent investigation of a specific topic or problem in modern bioengineering research under the direction of a selected faculty member. Repeatable for Credit.

BIOE 403 - SYNTHETIC BIOLOGY
Short Title: SYNTHETIC BIOLOGY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 332
Description: Design of biology at scales from molecules to multicellular organisms will be covered by lecture, primary literature, and student presentations. Students will execute a team based design challenge. Graduate/Undergraduate Equivalency: BIOE 508. Mutually Exclusive: Credit cannot be earned for BIOE 408 and BIOE 508.

BIOE 408 - SYNTHETIC BIOLOGY
Short Title: SYNTHETIC BIOLOGY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 332
Description: Design of biology at scales from molecules to multicellular organisms will be covered by lecture, primary literature, and student presentations. Students will execute a team based design challenge. Graduate/Undergraduate Equivalency: BIOE 508. Mutually Exclusive: Credit cannot be earned for BIOE 408 and BIOE 508.

BIOE 419 - INNOVATION LAB FOR MOBILE HEALTH
Short Title: INNOVATION LAB - MOBILE HEALTH
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Students with a class of Freshman may not enroll. Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: This course will be an innovation lab for mobile health products. The students will organize themselves in groups with complementary skills and work on a single project for the whole semester. The aim will be to develop a product prototype which can then be demonstrated to both medical practitioners and potential investors. For successful projects with an operational prototype, the next steps could be applying for OWLspark (Rice accelerator program) or crowd sourcing (like Kickstarter) and/or work in Scalable Health Labs over summer. ELEC Juniors can also continue the project outcomes as a starting point for their senior design. Cross-list: ELEC 419. Graduate/ Undergraduate Equivalency: BIOE 534. Mutually Exclusive: Credit cannot be earned for BIOE 419 and BIOE 534. Repeatable for Credit.
Course URL: www.ece.rice.edu/~ashu/ELEC419.html
BIOE 420 - TRANSPORT PHENOMENA IN BIOENGINEERING
Short Title: TRANSPORT PHENOMENA IN BIOE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): MATH 211 and MATH 212 and (BIOE 332 or CHBE 411) and BIOE 391
Description: BIOE/CHBE 420 covers transport phenomena as applied to biological systems and biomedical devices. Conservation of momentum and mass equations are first derived and then used to analyze transport of momentum and mass in biology, physiology, and in biomedical devices. This course is designed for senior bioengineering students. Cross-list: CHBE 420.

BIOE 421 - MICROCONTROLLER APPLICATIONS
Short Title: MICROCONTROLLER APPLICATIONS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 385
Description: This class covers the usage of microcontrollers in a laboratory setting. We will start with basic electronics and, in the lab component, design, program, and build systems utilizing widely-available microcontrollers (e.g. Arduino, Raspberry Pi). Units in motion control, sensors (light, temperature, humidity, UV/Vis absorbance), and actuation (pneumatics, gears, and motors) will provide students with functional knowledge to design and prototype their own experimental systems for laboratory-scale automation. Instructor Permission Required. Graduate/Undergraduate Equivalency: BIOE 521. Mutually Exclusive: Credit cannot be earned for BIOE 421 and BIOE 521.

BIOE 422 - GENE THERAPY
Short Title: GENE THERAPY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment limited to students with a class of Senior. Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CHEM 211 and (BIOS 201 or BIOC 201)
Description: This course will examine the gene therapy field, with topics ranging from gene delivery to vectors to ethics of gene therapy. The design principles for engineering improved gene delivery vectors, both viral and nonviral, will be discussed. The course will culminate in a design project focused on engineering a gene delivery device for a specific therapeutic application. Graduate/Undergraduate Equivalency: BIOE 522. Mutually Exclusive: Credit cannot be earned for BIOE 422 and BIOE 522.

BIOE 431 - BIOMATERIALS APPLICATIONS
Short Title: BIOMATERIALS APPLICATIONS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (CHEM 211 or CHEM 251) and BIOE 370
Description: Emphasis will be placed on issues regarding the design, synthesis, evaluation, regulation and clinical translation of biomaterials for specific applications. An overview of significant biomaterials engineering applications will be given, including topics such as ophthalmologic, orthopedic, cardiovascular and drug delivery applications, with attention to specific case studies. Regulatory issues concerning biomaterial will also be addressed. Assignments for this class will include frequent readings of the scientific literature with occasional homework assignments, one mid-term and cumulative final, a group project, a seminar report and individual presentations. Graduate/Undergraduate Equivalency: BIOE 631. Mutually Exclusive: Credit cannot be earned for BIOE 431 and BIOE 631.

BIOE 439 - APPLIED STATISTICS FOR BIOENGINEERING AND BIOTECHNOLOGY
Short Title: APPLIED STAT FOR BIOE BIOTECH
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 252 (may be taken concurrently)
Description: Course will cover fundamentals of probability and statistics with emphasis on application to biomedical problems and experimental design. Recommended for students pursuing careers in medicine or biotechnology. BIOE 439 and BIOE 440/STAT 440 cannot both be taken for credit. Prerequisite BIOE 252 may be taken concurrently. Graduate/Undergraduate Equivalency: BIOE 539. Mutually Exclusive: Credit cannot be earned for BIOE 439 and BIOE 440/BIOE 539/STAT 440.

BIOE 440 - STATISTICS FOR BIOENGINEERING
Short Title: STATISTICS FOR BIOENGINEERING
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 252 (may be taken concurrently)
Description: Course covers application of statistics to bioengineering. Topics include descriptive statistics, estimation, hypothesis testing, ANOVA, and regression. Offered first five weeks of the semester. BIOE 252 may be taken concurrently with BIOE 440. BIOE 440/STAT 440 and BIOE 439 cannot both be taken for credit. Cross-list: STAT 440. Mutually Exclusive: Credit cannot be earned for BIOE 440 and BIOE 439.
BIOE 442 - TISSUE ENGINEERING LAB MODULE
Short Title: TISSUE ENGINEERING LAB MODULE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (BIOE 342 or BIOC 320 or BIOS 320) and (BIOE 440 or STAT 440)
Description: Students design and conduct a series of tests to synthesize PLLA, characterize PLLA and PLGA, monitor PLLA and PLGA degradation, and assess the viability, attachment, and proliferation of HDF cells on PLLA films. The experiments include many of the basic types of experiments that would be required to do a preliminary investigation of a tissue engineered product. Sections 1 and 2 will be taught during the first half of the semester and sections 3 and 4 will be taught during the second half of the semester. In addition sections 1 and 3 will need to come into lab on 2-3 Fridays and sections 2 and 4 will need to come into lab on 2-3 Saturdays. Section sign-up is required by the instructor in Keck 108 during preregistration week.

BIOE 443 - BIOPROCESSING LAB MODULE
Short Title: BIOPROCESSING LAB MODULE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (BIOE 342 or BIOC 320 or BIOS 320) and (BIOE 440 or STAT 440)
Description: Students design and conduct a series of experiments to observe the growth of E. coli under different conditions, including agar plates, shake flasks, and a small-scale bioreactor. The E. coli has been transformed with a plasmid that produces beta-galactosidase. Engineering applications are emphasized. Some work “off hours” (early evening) is required. Sections 1 and 2 are taught in the first half of the semester and Sections 3 and 4 are taught in the second half of the semester. Section sign-up is required by the instructor in Keck 108 during preregistration week.

BIOE 444 - MECHANICAL TESTING LAB MODULE
Short Title: MECHANICAL TESTING LAB MODULE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 372 (may be taken concurrently) and (BIOE 440 or STAT 440)
Description: Students design and conduct a series of tests to elucidate the mechanical and material properties of animal tissue using the Instron. BIOE 372 may be taken concurrently with BIOE 444.

BIOE 445 - ADVANCED INSTRUMENTATION LAB MODULE
Short Title: ADVANCED INSTRUMENTATION LAB MODULE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 383 and BIOE 385 and (BIOE 440 or STAT 440)
Description: Students design and build a biomedical instrumentation device. Sign up is required in Keck 108 during preregistration week.

BIOE 446 - COMPUTATIONAL MODELING LAB
Short Title: COMPUTATIONAL MODELING LAB
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 391
Description: This course offers a hands-on application to systems biology modeling. Students will learn a range of modeling methods, and apply them directly in class to current bioengineering problems. Weekly tutorials will be offered, and a laptop is required (or can be loaned). Topics covered include in silico drug delivery and design studies, integrating multiscale models with high-resolution imaging, experimental design via computer modeling, and patient-specific simulations. Modeling methods include protein-protein interaction networks, biocircuits, stochastic differential equations, agent-based modeling, computational fluid dynamics, and finite element modeling.

BIOE 447 - DIGITAL DESIGN & VISUALIZATION
Short Title: DIG DES & VIS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: Students will acquire basic to intermediate-level digital design proficiency for bioengineering-related applications. Programs for the design of patient-specific therapies including image reconstruction, computer aided design, and parameter modeling will be used to create models. Section sign up is required during pre-registration week.

BIOE 449 - TROUBLESHOOTING WORKSHOP FOR CLINICALLY-RELEVANT BIOMEDICAL EQUIPMENT
Short Title: MED BIOENGINEERING WORKSHOP
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hour: 1
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 243
Description: Bioengineering course in the troubleshooting, repair, and maintenance of standard biomedical equipment used in hospitals in the developed and developing worlds. Cross-list: GLHT 449. Repeatable for Credit.
BIOE 454 - COMPUTATIONAL FLUID MECHANICS
Short Title: COMPUTATIONAL FLUID MECHANICS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 383 and BIOE 385 and (BIOE 332 or BIOE 372)
Description: Senior Bioengineering students will design devices in biotechnology or biomedicine. This project-based course covers systematic design processes, engineering economics, FDA requirements, safety, engineering ethics, design failures, research design, intellectual property rights, environmental impact, business planning and marketing. Students will be expected to compile documentation and present orally progress of their teams. BIOE 451 and 452 must be taken the same academic year. Instructor Permission Required.

BIOE 451 - BIOENGINEERING DESIGN I
Short Title: BIOENGINEERING DESIGN I
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 383 and BIOE 385 and (BIOE 332 or BIOE 372)
Description: Senior Bioengineering students will design devices in biotechnology or biomedicine. This project-based course covers systematic design processes, engineering economics, FDA requirements, safety, engineering ethics, design failures, research design, intellectual property rights, environmental impact, business planning and marketing. Students will be expected to compile documentation and present orally progress of their teams. BIOE 451 and 452 must be taken the same academic year. Instructor Permission Required.

BIOE 452 - BIOENGINEERING DESIGN II
Short Title: BIOENGINEERING DESIGN II
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 451
Description: Senior Bioengineering students will design devices in biotechnology or biomedicine. This project-based course covers systematic design processes, engineering economics, FDA requirements, safety, engineering ethics, design failures, research design, intellectual property rights, environmental impact, business planning and marketing. Students will be expected to compile documentation and present orally progress of their teams. BIOE 451 and 452 must be taken the same academic year. Instructor Permission Required.

BIOE 454 - COMPUTATIONAL FLUID MECHANICS
Short Title: COMPUTATIONAL FLUID MECHANICS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): MECH 371 (may be taken concurrently) or CEVE 363 (may be taken concurrently) or CHBE 401 (may be taken concurrently)
Description: Fundamental concepts of finite element methods in fluid mechanics, including spatial discretization and numerical integration in multidimensions, time-integration, and solution of nonlinear ordinary differential equation systems. Advanced numerical stabilization techniques designed for fluid mechanics problems. Strategies for solution of complex, real-world problems. Topics in large-scale computing, parallel processing, and visualization. Prerequisites may be taken concurrently. Cross-list: CEVE 454, MECH 454. Graduate/Undergraduate Equivalency: BIOE 554. Mutually Exclusive: Credit cannot be earned for BIOE 454 and BIOE 554.

BIOE 460 - BIOCHEMICAL ENGINEERING
Short Title: BIOCHEMICAL ENGINEERING
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 252
Description: Design, operation, and analysis of processes in the biochemical industries. Topics include enzyme kinetics, cell growth kinetics, energetics, recombinant DNA technology, microbial, tissue and plant cell cultures, bioreactor design and operation, and down stream processing. Cross-list: CHBE 460.

BIOE 464 - EXTRACELLULAR MATRIX
Short Title: EXTRACELLULAR MATRIX
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOS 341 or BIÖC 341
Description: This course will address the biology, organization, mechanics, and turnover of extracellular matrix. There will be an emphasis on cells and cell-matrix interactions, matrix distribution within and design of connective tissues and organs techniques for quantitative analysis of matrix, techniques for measurement and modeling of connective tissue biomechanics, changes with growth and aging and tissue/matrix degradation. Cross-list: BIÖC 464. Graduate/Undergraduate Equivalency: BIOE 524. Recommended Prerequisite and Corequisite: BIOE 372, BIÖC/BIOE 341. Mutually Exclusive: Credit cannot be earned for BIOE 464 and BIOE 524.

BIOE 470 - FROM SEQUENCE TO STRUCTURE: AN INTRODUCTION TO COMPUTATIONAL BIOLOGY
Short Title: FROM SEQUENCE TO STRUCTURE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 4
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: Contemporary introduction to problems in computational biology spanning sequence to structure. The course has three modules: the first introduces students to the design and statistical analysis of gene expression studies; the second covers statistical machine learning techniques for understanding experimental data generated in computational biology; and the third introduces problems in the modeling of protein structure using computational methods from robotics. The course is project oriented with an emphasis on computation and problem-solving. Cross-list: COMP 470, STAT 470. Recommended Prerequisite(s): COMP 280 and (STAT 310 or STAT 331).
BIOE 481 - COMPUTATIONAL NEUROSCIENCE AND NEURAL ENGINEERING
Short Title: COMP/NEUROSCIENCE/NEURAL ENGNR
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: An introduction to the anatomy and physiology of the brain. Includes basic electrophysiology of nerve and muscle. Develops mathematical models of neurons, synaptic transmission and natural neural networks. Leads to a discussion of neuromorphic circuits which can represent neuron and neural network behavior in silicon. Recommendation: Knowledge of electrical circuits, operational amplifier circuits; and ordinary differential equations. Mutually Exclusive: Credit cannot be earned for BIOE 481 and BIOE 583.

BIOE 482 - PHYSIOLOGICAL CONTROL SYSTEMS
Short Title: PHYSIOLOGICAL CONTROL SYSTEMS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: A study of the somatic and autonomic nervous system control of biological systems. Includes basic electrophysiology of nerve and muscle. Develops mathematical models of neurons, synaptic transmission and natural neural networks. Leads to a discussion of neuromorphic circuits which can represent neuron and neural network behavior in silicon. Cross-list: ELEC 481, NEUR 481. Graduate/Undergraduate Equivalency: BIOE 583. Knowledge of basic electrical and operational amplifier circuits; and ordinary differential equations. Mutually Exclusive: Credit cannot be earned for BIOE 482 and BIOE 582.

BIOE 483 - ECONOMICS OF HEALTHCARE
Short Title: ECONOMICS OF HEALTHCARE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Description: This course focuses on functional imaging modalities used specifically in nuclear medicine such as Gamma cameras, SPECT, and PET imaging. The course will introduce the basic principles of image acquisition, formation, and processing of several medical imaging modalities such as X-Ray, CT, MRI, and US that are used to evaluate the human anatomy. The course also includes visits to a clinical site to gain experience with the various imaging modalities covered in class. Cross-list: COMP 485, ELEC 485. Graduate/Undergraduate Equivalency: BIOE 591. Recommended Prerequisite(s): MATH 211 and MATH 212. Mutually Exclusive: Credit cannot be earned for BIOE 484 and BIOE 591.

BIOE 484 - BIOPHOTONICS INSTRUMENTATION AND APPLICATIONS
Short Title: BIOPHOTONICS INSTRUMENTATION
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 383
Description: This course is an introduction to the fundamentals of Biophotonics instrumentation related to coherent light generation, transmission by optical components such as lenses and fibers, and modulation and detection. Interference and polarization concepts and light theories including ray and wave optics will be covered. A broad variety of optical imaging and detection techniques including numerous microscopy techniques, spectral imaging, polarimetry, OCT and others will be covered. The course will guide through the principles and concepts used in a variety of optical instruments and point to special requirements for Biomedical applications with emphasis on principles and concepts used in a variety of optical instruments and point to special requirements for Biomedical applications with emphasis on principles and concepts used used in a variety of optical instruments and point to special requirements for bio-medical applications in optical sensing, diagnosis, and biomedical applications. Graduate/Undergraduate Equivalency: BIOE 512. Mutually Exclusive: Credit cannot be earned for BIOE 484 and BIOE 512.

BIOE 485 - FUNDAMENTALS OF MEDICAL IMAGING I
Short Title: FUND MEDICAL IMAGING I
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 383
Description: This course will introduce basic principles of image acquisition, formation and processing of several medical imaging modalities such as X-Ray, CT, MRI, and US that are used to evaluate the human anatomy. The course also includes visits to a clinical site to gain experience with the various imaging modalities covered in class. Cross-list: COMP 485, ELEC 485. Graduate/Undergraduate Equivalency: BIOE 591. Recommended Prerequisite(s): MATH 211 and MATH 212. Mutually Exclusive: Credit cannot be earned for BIOE 485 and BIOE 591.

BIOE 486 - FUNDAMENTALS OF MEDICAL IMAGING II
Short Title: FUND MEDICAL IMAGING II
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 483 or COMP 485
Description: This course focuses on functional imaging modalities used specifically in nuclear medicine such as Gamma cameras, SPECT, and PET imaging. The course will introduce the basic principles of image acquisition, formation, processing and the clinical applications of these imaging modalities and lays the foundations for understanding the principles of radiotracer kinetic modeling. A trip to a clinical site in also planned to gain experience with nuclear medicine imaging. Cross-list: COMP 486, ELEC 486. Graduate/Undergraduate Equivalency: BIOE 596. Mutually Exclusive: Credit cannot be earned for BIOE 486 and BIOE 596.
BIOE 490 - Intro Computational Systems Biology: Modeling & Design Principles of Biochem Networks
Short Title: Intro Systems Biology Modeling
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MATH 212 or MATH 213) and (BIOE 252 or CHBE 310) and BIOC 341 and CAAM 210
Description: The course summarizes techniques for quantitative analysis and simulations of basic circuits in genetic regulation, signal transduction and metabolism. We discuss engineering approaches adapted to computational systems biology and aim to formulate evolutionary design principles explaining organization of networks in terms of their physiological demands. We discuss biochemical simulation methodology and software as well as recent advances in the field. Topics include end-product inhibition in biosynthesis, optimality and robustness of the signaling networks and kinetic proofreading. Graduate/Undergraduate Equivalency: BIOE 552. Mutually Exclusive: Credit cannot be earned for BIOE 490 and BIOE 552.

BIOE 492 - Sensory Neuroengineering
Short Title: Sensory Neuroengineering
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Graduate level students may not enroll.
Course Level: Undergraduate Upper-Level
Prerequisite(s): BIOE 332
Description: This course will explore how bioengineering techniques and principles are applied to understand and model sensory systems, with a focus on the auditory, vestibular, and visual systems. The interaction between the electrical, mechanical and optical aspects of these systems, and ways to modulate these interactions, will be explored. The course will also cover the design of current auditory, visual and somatosensory neuropsychotics (i.e. cochlear implants, retinal implants and brain-machine interfaces), as well as emerging technologies for neural stimulation. Graduate/Undergraduate Equivalency: BIOE 592. Mutually Exclusive: Credit cannot be earned for BIOE 492 and BIOE 592.

BIOE 500 - Graduate Research
Short Title: Graduate Research
Department: Bioengineering
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Repeatable for Credit.

BIOE 501 - Graduate Research for Med-Intro-Grad Program
Short Title: Graduate Research
Department: Bioengineering
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Graduate Research for students participating in the HHMI Med-Intro-Grad program. Med-Into-Grad students should enroll in this course during summer internship. Department approval required for enrollment. Department Permission Required. Repeatable for Credit.

BIOE 502 - Physical Biology
Short Title: Physical Biology
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Basic introduction to a biophysical view of living systems, from the subcellular to the multicellular scales. Topics include: biomolecular dynamics, cellular biomechanics, cell motility and cell division, calcium signaling, action potential propagation, and tissue organization. Cross-list: SSPB 501.

BIOE 504 - First Year Graduate Student Lab Rotation
Short Title: Graduate Lab Rotation
Department: Bioengineering
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course provides students the opportunity to experience different research projects and assists first-year students in choosing an advisor and a lab for conduction thesis research. Students must successfully complete rotations in three labs to receive a satisfactory grade. All new BIOE PhD students must take this course during their first semester.

BIOE 506 - Graduate Independent Study
Short Title: Graduate Independent Study
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Independent Study
Credit Hours: 1-6
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Independent investigation of a specific topic in modern bioengineering research under the direction of a faculty member. Department Permission Required. Repeatable for Credit.
BIOE 507 - SYSTEMS BIOLOGY OF BLOOD VESSELS
Short Title: SYS BIOLOGY OF BLOOD VESSELS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): BIOE 252
Description: How blood vessels respond to hypoxia is a process critical to the progression of many diseases and conditions including cardiovascular disease, cancer, cerebrovascular disease, diabetes, obesity and arthritis. Physiological processes such as exercise, aging, and wound healing also depend on hypoxia-induced microvessel changes. This course introduces engineering concepts of hypoxic response, angiogenesis, and capillary remodeling - from the effects at the intracellular level to the whole body. Topics covered include computational systems biology modeling of hypoxia and angiogenesis, the use of angiogenesis in tissue engineering and regenerative medicine, imaging of blood vessel dynamics, capillaries of the brain, and the design of new blood vessels. Graduate students will be required to complete a term research project and present a related short seminar. Graduate/Undergraduate Equivalency: BIOE 307. Mutually Exclusive: Credit cannot be earned for BIOE 507 and BIOE 307.

BIOE 508 - SYNTHETIC BIOLOGY
Short Title: SYNTHETIC BIOLOGY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Design of biology at scales from molecules to multicellular organisms will be covered by lecture, primary literature, and student presentations. Students will write a research proposal at the end of the course. Cross-list: SSPB 503. Graduate/Undergraduate Equivalency: BIOE 408. Mutually Exclusive: Credit cannot be earned for BIOE 508 and BIOE 408.

BIOE 509 - POINT-OF-CARE DIAGNOSTICS
Short Title: POINT-OF-CARE DIAGNOSTICS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course provides an overview of diagnostic technologies that can be used at the point-of-care, including lateral flow assays, 2- and 3-D paper-based assays, and imaging based assays. Topics include the principles of assay design, validation and commercial development, with a focus on diagnostics for low-resource settings. The course includes a lecture and laboratory component, along with a team-based design project. Only graduate students may register for this course.

BIOE 512 - BIOPHOTONICS INSTRUMENTATION AND APPLICATIONS
Short Title: BIOPHOTONICS INSTRUMENTATION
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is an introduction to the fundamentals of Biophotonics instrumentation related to coherent light generation, transmission by optical components such as lenses and fibers, and modulation and detection. Interference and polarization concepts and light theories including ray and wave optics will be covered. A broad variety of optical imaging and detection techniques including numerous microscopy techniques, spectral imaging, polarimetry, OCT and others will be covered. The course will guide through the principles and concepts used in a variety of optical instruments and point to special requirements for Biomedical applications with emphasis on principles and concepts used in a variety of optical instruments and point to special requirements for Biomedical applications with emphasis on principles and concepts used in a variety of optical instruments and point out special requirements for biomedical applications in optical sensing, diagnosis, and biomedical applications. In addition to the undergraduate requirements in BIOE 484, graduate students will be required to complete more complex problems on both homework and tests. Graduate students will also be required to submit a research paper with oral presentations. Graduate/Undergraduate Equivalency: BIOE 484. Mutually Exclusive: Credit cannot be earned for BIOE 512 and BIOE 484.
BIOE 514 - INTRODUCTION TO BIOSTATISTICS
Short Title: INTRODUCTION TO BIOSTATISTICS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to students with a major in Bioengineering. Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Presents basic and advanced methods of statistics as applied to problems in bioengineering. Demonstrates techniques for data organization, exploration, and presentation. Foundations of statistical estimation, inference, and testing are reviewed. Optimal planning of experiments is explored. Advanced techniques include multiple regression, variable selection, logistic regression, analysis of variance, survival analysis, multiple measurements and measurements over time. Additional topics, such as Bayesian methods, will be discussed as time allows. Labs will use the statistical software JMP and/or R. Cross-list: STAT 514.

BIOE 516 - MECHANICS, TRANSPORT, AND CELLULAR SIGNALING
Short Title: MECHANICS/TRANSPORT/SIGNALING
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will cover the fundamental principles of mechanics, thermodynamics, and transport in the context of classical and contemporary bioengineering problems. An overall goal will be to expose students to the integrated approaches that are necessary to solve complex research problems. Topics covered will include membrane transport, cell signaling, and mechanotransduction. This course is intended for first year BIOE PhD students only.

BIOE 517 - INSTRUMENTATION AND MOLECULAR ANALYSIS
Short Title: INSTRUMENT/MOLECULAR ANALYSIS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will cover the basic principles of optics, optical instrumentation, microscopy and molecular detection technologies. Emphasis will be placed on the application of advanced microscopy techniques to imaging problems in biology and medicine. This course is intended for first year BIOE PhD students only.

BIOE 518 - INTRODUCTION TO COMPUTATIONAL BIOLOGY
Short Title: INTRO TO COMPUTATIONAL BIOLOGY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Provides students with the ability to use computational methods to understand and analyze biological data. This course will introduce students to advances in computational cell biology from an engineering perspective, and equip them with a suite of tools emerging from systems biology. Topics covered include computational cell engineering, high-throughput analysis, modeling of signaling pathways, network analysis, imaging coupled to modeling, and multi scale modeling. This course is intended for first year BIOE PhD students only.

BIOE 519 - BIOMATERIALS SYNTHESIS
Short Title: BIOMATERIALS SYNTHESIS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Biomaterials covers the design and synthesis of materials which interact with biologic phenomena such as cell-free, microbial, and mammalian systems. Topics covered include: surfaces and surface fractionalization, biomedical implants and them immune response, three dimensional cell culture systems, and regulatory hurdles (e.g., FDA clearance). The class will be rooted in a historical perspective, with a particular emphasis on the latest techniques in synthetic chemistry relating to biomaterials. This course is intended for first year BIOE PhD students only.

BIOE 521 - MICROCONTROLLER APPLICATIONS
Short Title: MICROCONTROLLER APPLICATIONS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): BIOE 385
Description: This class covers the usage of microcontrollers in a laboratory setting. We will start with basic electronics and, in the lab component, design, program, and build systems utilizing widely-available microcontrollers (e.g. Arduino, Raspberry Pi). Units in motion control, sensors (light, temperature, humidity, UV/Vis absorbance), and actuation (pneumatics, gears, and motors) will provide students with functional knowledge to design and prototype their own experimental systems for laboratory-scale automation. BIOE 521 students will be expected to complete a final research paper. Instructor Permission Required. Graduate/Undergraduate Equivalency: BIOE 421. Mutually Exclusive: Credit cannot be earned for BIOE 521 and BIOE 421.
BIOE 522 - GENE THERAPY
Short Title: GENE THERAPY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): CHEM 212 and (BIOS 201 or BIOC 201)
Description: This course will examine the gene therapy field, with topics ranging from gene delivery to vectors to ethics of gene therapy. The design principles for engineering improved gene delivery vectors, both viral and nonviral, will be discussed. The course will culminate in a design project focused on engineering a gene delivery device for a specific therapeutic application. Graduate/Undergraduate Equivalency: BIOE 422. Mutually Exclusive: Credit cannot be earned for BIOE 522 and BIOE 422.

BIOE 523 - BIOENGINEERING SYSTEMS AND CONTROL
Short Title: BIOENG SYSTEMS & CONTROLS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to basic principles of control theory and applications of these methods and tools to analyze the dynamics of biological systems with examples from metabolic pathway control, synthetic biology and physiological systems. Cross-list: CHBE 523.

BIOE 524 - EXTRACELLULAR MATRIX
Short Title: EXTRACELLULAR MATRIC
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will address the biology, organization, mechanics, and turnover of extracellular matrix. There will be an emphasis on cells and cell-matrix interactions, matrix distribution within and design of connective tissues and organs techniques for quantitative analysis of matrix, techniques for measurement and modeling of connective tissue biomechanics, changes with growth and aging and tissue/matrix degradation. Additional projects will be required of graduate level students. Cross-list: BIO 523. Graduate/Undergraduate Equivalency: BIOE 464. Recommended Prerequisite and Corequisite: BIOE 372, BIOC/BIOE 341. Mutually Exclusive: Credit cannot be earned for BIOE 524 and BIOE 464.

BIOE 525 - NANO BIOENGINEERING AND NANOMEDICINE
Short Title: NANO BIOENG AND NANOMEDICINE
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Covers broad range of topics in nanobioengineering and nanomedicine, including synthesis characterization and fractionalization of nanomaterials and nanostructures, nanoparticle-based molecular imaging probes, nanocarriers, for drug/gene delivery, and nanomachines for gene editing and regulation. Examples will be given to illustrate the applications of nanobioengineering and nanomedicine.

BIOE 526 - PRECISION GENOME EDITING
Short Title: PRECISION GENOME EDITING
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This is a course for graduate students who are interested in learning the emerging field of precision genome editing and its applications in biology and medicine. This is a lecture course consisting of classes that meet weekly for 3 hours; instruction is delivered both in a lecture setting and through projects.

BIOE 527 - MEDICAL TECHNOLOGY DESIGN 1
Short Title: MEDICAL TECHNOLOGY DESIGN 1
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Corequisite: BIOE 627
Description: This is the companion course to BIOE 627 and concurrent enrollment is required. Students will apply the principles learned in BIOE 627 in emerging-market design projects. Design projects are team-based, and each student will be involved in multiple projects at different levels of maturity. This course is limited to MBE-GMI students only. Instructor Permission Required.

BIOE 528 - MEDICAL TECHNOLOGY IMPLEMENTATION 1
Short Title: MEDICAL TECH IMPLEMENTATION 1
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Students focus on implementing strategies for manufacturing, regulatory, quality, and clinical trials with products that have already been through at least one cycle of design. Students are exposed to multiple projects at various levels of maturity in a team setting. This course is limited to MBE-GMI students only. Instructor Permission Required.
BIOE 529 - MEDICAL TECHNOLOGY DESIGN 2

Short Title: MEDICAL TECHNOLOGY DESIGN 2
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Corequisite: BIOE 629
Description: This is a companion course to BIOE 629 and concurrent enrollment is required. Students will apply the principles learned in BIOE 629 in emerging-market design projects. Design projects are team-based, and each student will be involved in multiple projects at different levels of maturity. This course is limited to MBE-GMI students only. Instructor Permission Required.

BIOE 530 - MEDICAL TECHNOLOGY IMPLEMENTATION 2

Short Title: MEDICAL TECH IMPLEMENTATION 2
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Corequisite: BIOE 630
Description: This is the companion course to BIOE 630 and concurrent enrollment is required. Students will apply the principles learned in BIOE 630 in emerging market design projects. Design projects are team-based, and each student will be involved in multiple projects at different levels of maturity. This course is limited to MBE-BMI students only. Instructor Permission Required.

BIOE 531 - MEDICAL INNOVATION I

Short Title: MEDICAL INNOVATION I
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment limited to students in the MBE program. Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will explore the front half of the medical innovation process through instruction in upstream marketing, finding and screening unmet clinical needs, and generating concepts and prototypes. Students will participate in a medical technology design project to apply the principles they are learning. Students in this course will be expected to continue their projects with BIOE 532 in the spring semester. Currently, the course is limited to MBE students. Department Permission Required.

BIOE 534 - INNOVATION LAB FOR MOBILE HEALTH

Short Title: INNOVATION LAB - MOBILE HEALTH
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will be an innovation lab for mobile health products. The students will organize themselves in groups with complementary skills and work on a single project for the whole semester. The aim will be to develop a product prototype which can then be demonstrated to both medical practitioners and potential investors. For successful projects with an operational prototype, the next steps could be applying for OWLspark (Rice accelerator program) or crowdsourcing (like Kickstarter) and/or work in Scalable Health Labs over summer. ELEC Juniors can also continue the project outcomes as a starting point for their senior design. Additional course work required beyond the undergraduate course requirements. Cross-list: ELEC 559. Graduate/Undergraduate Equivalency: BIOE 419. Mutually Exclusive: Credit cannot be earned for BIOE 534 and BIOE 419. Repeatable for Credit.
Course URL: www.ece.rice.edu/~ashu/ELEC419.html

BIOE 539 - APPLIED STATISTICS FOR BIOENGINEERING AND BIOTECHNOLOGY

Short Title: APPLIED STAT FOR BIOE BIOTECH
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Course will cover fundamentals of probability and statistics with emphasis on application to biomedical problems and experimental design. Recommended for students pursuing careers in medicine or biotechnology. Graduate/Undergraduate Equivalency: BIOE 439. Recommended Prerequisite(s): BIOE 252 Mutually Exclusive: Credit cannot be earned for BIOE 539 and BIOE 439.

BIOE 540 - INTRODUCTION TO SYSTEMS BIOLOGY AND SYSTEMS BIOTECHNOLOGY

Short Title: INTRO SYSTEMS BIO & BIOTECH
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Systems biology is an integrated experimental and mathematical approach to study the complex dynamic interactions between various components of a biological system. The course is designed to explore the basic concepts of systems biology. The course will introduce "systems" approaches based on genomics, transcriptomics, proteomics and metabolomics.
BIOE 543 - DNA BIOTECHNOLOGY, BIOPHYSICS, AND MODELING  
**Short Title:** DNA BIOTECHNOLOGY  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture/Laboratory  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** A semester-long course on fundamental properties of DNA, and their role in DNA biotechnology. Students will develop, analyze, and simulate simple biophysical models of DNA reactions, as well as learn and model methods of modern DNA biotechnology. Proficiency with MATLAB required.

BIOE 548 - MACHINE LEARNING AND SIGNAL PROCESSING FOR NEUROENGINEERING  
**Short Title:** NEURAL SIGNAL PROCESSING  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** The activity of a complex network of billions of interconnected neurons underlies our ability to sense, represent and store the details of experienced life, and enables us to interact with our environment and other organisms. Modern neuroscience techniques enable us to access this activity, and thus to begin to understand the processes whereby individual neurons enable complex behaviors. In order to increase this understanding and to design biomedical systems which might therapeutically interact with neural circuits, advanced statistical signal processing and machine learning approaches are required. This class will cover a range of techniques and their application to basic neuroscience and neural interfaces. Topics include latent variable models, point processes, Bayesian inference, dimensionality reduction, dynamical systems, and spectral analysis. Neuroscience applications include modeling neural firing rates, spike sorting, decoding, characterization of neural systems, and field potential analysis. Cross-list: ELEC 548.

BIOE 553 - SYSTEMS BIOLOGY AND NEUROENGINEERING  
**Short Title:** INTRO COMPUTATIONAL SYSTEMS BIOLOGY: MODELING & DESIGN PRINCIPLES OF BIOCHEM NETWORKS  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** The course summarizes techniques for quantitative analysis and simulations of basic circuits in genetic regulation, signal transduction and metabolism. We discuss engineering approaches adapted to computational systems biology and aim to formulate evolutionary design principles explaining organization of networks in terms of their physiological demands. We discuss biochemical simulation methodology and software as well as recent advances in the field. Topics include end-product inhibition in biosynthesis, optimality and robustness of the signaling networks and kinetic proofreading. Same as 490 but with more emphasis on recent advances in the field - paper reading and presentations. Cross-list: SSPB 502. Graduate/Undergraduate Equivalency: BIOE 490. Basic knowledge of biochemistry, cell biology, linear algebra, and ordinary differential equations is expected. Mutually Exclusive: Credit cannot be earned for BIOE 553 and BIOE 490.
BIOE 564 - BIOINFORMATICS: NETWORK ANALYSIS  
Short Title: BIOINFORMATICS: NETWORKS  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 1  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: This course covers computational aspects of biological network analysis, a major theme in the area of systems biology. The course addresses protein-protein interaction networks, signaling, and metabolic networks, and covers issues related to reconstructing, analyzing, and integrating various types of networks. Cross-list: BIOC 572, COMP 572.  
Course URL: www.cs.rice.edu/~nakheh/COMP572/  

BIOE 574 - CONTINUUM BIOMECHANICS  
Short Title: CONTINUUM BIOMECHANICS  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Prerequisite(s): BIOE 372  
Description: This course deals with elements of continuum mechanics relevant to bioengineering. The course covers important concepts in tensor calculus, kinematics, stress and strain, and constitutive theories of continua. Selected topics in bone, articular cartilage, blood and circulation, and cell biomechanics will be discussed to illustrate the application of continuum mechanics to bioengineering problems.  

BIOE 576 - FOUNDATIONS OF BIOTECHNOLOGY  
Short Title: FOUNDATIONS OF BIOTECHNOLOGY  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Seminar  
Credit Hour: 1  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  

BIOE 577 - FOUNDATIONS OF BIOTECHNOLOGY  
Short Title: FOUNDATIONS OF BIOTECHNOLOGY  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Seminar  
Credit Hour: 1  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Graduate level introduction to a wide range of research methods in biosciences and bioengineering. Individual faculty members from the Biosciences and Bioengineering will each present practices and techniques for their areas of expertise. A web-based methods database will be constructed, with student involvement, from the library of lectures. Cross-list: BIOC 577.  

BIOE 578 - BIOTECHNOLOGY PRACTICUM  
Short Title: BIOTECHNOLOGY PRACTICUM  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Internship/Practicum  
Credit Hour: 1  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: This course is part of the NIH Biotechnology Training Program and is limited to program participants. Students will receive exposure and training in cutting edge concepts and technologies. Cross-list: BIOC 578.  

BIOE 580 - PROTEIN ENGINEERING  
Short Title: PROTEIN ENGINEERING  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Prerequisite(s): BIOE 372  
Description: Manipulation of gene expression in prokaryotic and eukaryotic cells. Rational design and directed evolution for cell and protein engineering. Selection and screening technologies and process optimization. Synthetic Biology: engineering and application of gene circuits. Molecular biotechnology applications: Diagnosis, Therapeutics and Vaccines. Cross-list: BIO 580, CHBE 580. CHBE 310/510 or equivalent is highly recommended.  

BIOE 581 - CARDIOVASCULAR AND RESPIRATORY SYSTEM DYNAMICS  
Short Title: CARDIO - RESP SYSTEM DYNAMICS  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Autonomic nervous system control of the cardiovascular and respiratory systems. Development of models of neuron and cardiac cell activity; models of ventricular and vascular system mechanics; models of pulmonary mechanics and gas transport. Includes a study of instrumentation and techniques used in the cardiac catherization laboratory. Discussions of different types of ventricular assist devices is also included. The course serves as an introduction to engineering in cardiovascular and respiratory system diagnosis and critical care medicine. Cross-list: ELEC 581. Recommendation: Knowledge of ordinary differential equations; electricity and magnetism, and solid mechanics form elementary physics; linear control theory and elementary physiology of the cardiovascular and respiratory systems. Repeatable for Credit.
BIOE 582 - PHYSIOLOGICAL CONTROL SYSTEMS
**Short Title:** PHYSIOLOGICAL CONTROL SYSTEMS  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture/Laboratory  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** A study of the somatic and autonomic nervous system control of biological systems. Simulation methods, as well as, techniques common to linear and nonlinear control theory are used. Also included is an introduction to sensors and instrumentation techniques. Examples are taken from the cardiovascular, respiratory, and visual systems. Additional coursework required beyond the undergraduate course requirements.  
Cross-list: ELEC 582. Graduate/Undergraduate Equivalency: BIOE 482.  
Mutually Exclusive: Credit cannot be earned for BIOE 582 and BIOE 482.

BIOE 583 - COMPUTATIONAL NEUROSCIENCE AND NEURAL ENGINEERING  
**Short Title:** COMP/NEUROSCIENCE/NEURAL ENGR  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** An introduction to the anatomy and physiology of the brain. Includes basic electrophysiology of nerve and muscle. Develops mathematical models of neurons, synaptic transmission and natural neural networks. Leads to a discussion of neuromorphic circuits which can represent neuron and neural network behavior in silicon.  

BIOE 586 - RESPIRATORY SYSTEM MECHANICS  
**Short Title:** RESPIRATORY SYSTEM MECHANICS  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Mechanics of ventilation, respiratory muscle mechanics, rib cage mechanics, mechanical coupling between the respiratory muscles and the rib cage, and inferences on mechanics from respiratory muscle anatomy. The class will meet in the Pulmonary Division at Baylor College of Medicine in the Texas Medical Center. Cross-list: MECH 586.

BIOE 587 - OPTICAL IMAGING AND NANOBIPHOTONICS  
**Short Title:** OPTIC IMAGING/NANOBIPHOTONICS  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course focuses on diagnostic and therapeutic applications of photonics-based technologies with particular emphasis on nanotechnology enabled optical approaches. This course emphasizes biomedical applications of optics and complements BIOE 484 which introduces fundamental principles of optics to bioengineers.

BIOE 589 - COMPUTATIONAL MOLECULAR BIOENGINEERING/BIOPHYSICS  
**Short Title:** COMP MOLECULAR BIOENG/BIOPHYS  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This is a course designed for students in computationally-oriented biomedical and bioengineering majors to introduce the principles and methods used for the simulations and modeling of macromolecules of biological interest. Protein conformation and dynamics are emphasized. Empirical energy function and molecular dynamics calculations are described. Specific biological problems are discussed to illustrate the methodology. Classic examples such as the cooperative mechanism of hemoglobin and more frontier topics such as the motional properties of molecular motors and ion channels as well as results derived from the current literature are covered. Cross-list: BIOE 589. Recommended Prerequisite(s): MATH 212, (BIOS 301 or BIOC 301), BIOE 332.

BIOE 591 - FUNDAMENTALS OF MEDICAL IMAGING I  
**Short Title:** FUND MEDICAL IMAGING I  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course will introduce basic principles of image acquisition, formation and processing of several medical imaging modalities such as X-Ray, CT, MRI, and US that are used to evaluate the human anatomy. The course also includes visits to a clinical site to gain experience with the various imaging modalities covered in class. Additional coursework required beyond the undergraduate course requirements. Cross-list: ELEC 585. Graduate/Undergraduate Equivalency: BIOE 485.  
Mutually Exclusive: Credit cannot be earned for BIOE 591 and BIOE 485.
BIOE 596 - FUNDAMENTALS OF MEDICAL IMAGING II
Short Title: FUND MEDICAL IMAGING II
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course focuses on functional imaging modalities used specifically in nuclear medicine such as Gamma cameras, SPECT, and PET imaging. The course will introduce the basic principles of image acquisition, formation, processing and the clinical applications of these imaging modalities and lays the foundations for understanding the principles of radiotracer kinetic modeling. A trip to a clinical site in a planned to gain experience with nuclear medicine imaging. Additional coursework required beyond the undergraduate course requirements. Cross-list: ELEC 586. Graduate/Undergraduate Equivalency: BIOE 486. Mutually Exclusive: Credit cannot be earned for BIOE 596 and BIOE 486.

BIOE 592 - SENSORY NEUROENGINEERING
Short Title: SENSORY NEUROENGINEERING
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): BIOE 332 and BIOE 384
Description: This course will explore how bioengineering techniques and principles are applied to understand and model sensory systems, with a focus on the auditory, vestibular, and visual systems. The interaction between the electrical, mechanical and optical aspects of these systems, and ways to modulate these interactions, will be explored. The course will also cover the design of current auditory, visual and somato-sensory neuroprosthetics (i.e. cochlear implants, retinal implants and brain-machine interfaces), as well as emerging technologies for neural stimulation. Graduate/Undergraduate Equivalency: BIOE 492. Mutually Exclusive: Credit cannot be earned for BIOE 592 and BIOE 492.

BIOE 595 - MODELING TISSUE MECHANICS
Short Title: MODELING TISSUE MECHANICS
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Independent Study
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Independent study and seminar course which focuses on modeling the mechanical properties of biological tissues. Data from experiments will be used to refine the predictions of nonlinear mathematical computer models. Aimed at juniors, seniors, and graduate students. Laboratory work performed at Baylor College of Medicine, computer work at Rice University. Cross-list: MECH 595.

BIOE 600 - GRADUATE BIOENGINEERING INDUSTRY INTERNSHIP
Short Title: GRAD BIO INDUSTRY INTERNSHIP
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Internship/Practicum
Credit Hours: 3-6
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Students will participate in an industry internship or industry-sponsored project under the direction of Bioengineering faculty. This course may be taken in the summer for six credits or in the fall and spring for three credits each semester. Enrollment is limited to students in the Global Medical Innovation track of the MBE degree. Instructor permission is required. Instructor Permission Required. Repeatable for Credit.

BIOE 620 - TISSUE ENGINEERING
Short Title: TISSUE ENGINEERING
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Study of cell-cell interactions and the role of the extracellular matrix in the structure and function of normal and pathological tissues. Includes strategies to regenerate metabolic organs and repair structural tissues, as well as cell-based therapies to deliver proteins and other therapeutic drugs, with emphasis on issues related to cell and tissue. Cross-list: CHBE 620.
BIOE 621 - BIOVENTURES  
**Short Title:** BIOVENTURES  
**Department:** Bioengineering  
**Grade Mode:** Satisfactory/Unsatisfactory  
**Course Type:** Seminar  
**Credit Hours:** 2  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Corequisite:** BIOE 527 or BIOE 633  
**Description:** A hands-on immersion into life science entrepreneurship through practical lessons that are applied to students' group projects throughout the course. This practical course will provide the skills and resources to facilitate scientist-driven entrepreneurship in conceiving new life science ventures and translating research ideas into commercial ventures. This course will be taught in conjunction w/UTMB faculty on the Rice campus (BRC) and will meet from Feb 26 - April 30, 2015. To apply for the course, Rice students should fill out the online application located on the URL site listed above. Instructor Permission Required. Repeatable for Credit.  
**Course URL:** goo.gl/forms/pJ0UMeJitO (http://goo.gl/forms/pJ0UMeJitO)  

**BIOE 627 - MEDICAL TECHNOLOGY DESIGN SEMINAR 1**  
**Short Title:** MED TECH DESIGN SEMINAR 1  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 1.5  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Corequisite:** BIOE 527  
**Description:** Students will learn to discover unmet clinical needs that may benefit from a medical technology solution through disease state analysis, clinical observation, interviews, and market research. Screening of these needs will be done through market, stakeholder, competitive and intellectual property analyses. Students will participate in industry case studies and guest lectures from industry professionals. Instructor Permission Required.  

**BIOE 628 - MEDICAL TECHNOLOGY DESIGN SEMINAR 2**  
**Short Title:** MED TECH DESIGN SEMINAR 2  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 1.5  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Corequisite:** BIOE 528  
**Description:** Students will learn to address unmet clinical needs thru methodical design. Concept generation principles & proof-of-concept prototyping will be discussed. Screening techniques will be taught that not only weigh technical merit of a concept, but regulatory, reimbursement, IP & business strategies. Students will participate in industry case studies & guest lectures from industry professionals. Instructor Permission Required.  

**BIOE 631 - BIOMATERIALS APPLICATIONS**  
**Short Title:** BIOMATERIALS APPLICATIONS  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Emphasis will be placed on issues regarding the design, synthesis, evaluation, regulation and clinical translation of biomaterials for specific applications. An overview of significant biomaterials engineering applications will be given, including topics such as ophthalmologic, orthopedic, cardiovascular and drug delivery applications, with attention to specific case studies. Regulatory issues concerning biomaterial will also be addressed. Assignments for this class will include frequent readings of the scientific literature with occasional homework questions, one midterm, and cumulative final, a group project, a seminar report and individual presentations. In addition, graduate students in BIOE 631 will have additional exam problems and an additional research paper. Graduate/Undergraduate Equivalency: BIOE 431. Mutually Exclusive: Credit cannot be earned for BIOE 631 and BIOE 431.  

**BIOE 633 - LIFE SCIENCE ENTREPRENEURSHIP AND THE ROLES OF FOUNDERS AND VENTURE CAPITAL ON HIGH TECH STARTUP**  
**Short Title:** LIFE SCIENCE ENTREPRENEURSHIP  
**Department:** Bioengineering  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 1.5  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** The roles of physicians, scientists, engineers, and MBA's in biotech, medical device, and other life science companies will be described and characterized. The major trends and innovations driving the creation of new products in large established companies and venture-capital-backed startup companies are discussed. This pragmatic, experienced-based course describes the venture capital process, formation, and capitalization of high-tech companies, sources of technologies, role of tech transfer at universities and medical schools, startup operational issues, role of VCs and board members, execution time frames, liquidity process, IPOs and mergers, and payout prospects for founders and investors. Live, ongoing case studies are presented by guest entrepreneurs. These case studies of ongoing biotech, medical device, and healthcare informatics companies are presented by many notable M.D. and Ph.D. founders and CEOs. Rules of professional and ethical conduct of M.D.s, Ph.D.s, scientific advisory boards, clinical advisory boards, and boards of directors are reviewed. In the final classes, a high-tech, career-planning guide is discussed, plus a special lecture on leadership, intelligence, and entrepreneurship will be presented. Insider secrets and success stories from decades of highly successful VC practice in medical, biotech and infotech companies will be shared. Cross-list: MGMT 633. Repeatable for Credit.
**BIOE 643 - CELL MECHANICS, MECHANOTRANSDUCTION AND THE CELL MICROENVIRONMENT**

Short Title: MECHANOTRANSDUCTION  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Mechanotransduction is a fundamental process essential for living systems and plays a fundamental role in cell signaling, cancer metastasis and stem cell differentiation. Additionally, fundamental biological processes such as endocytosis cell fusion and cell migration are driven by a coordinated interplay of molecular interactions that drive membrane deformation. This course will survey the current understanding of mechanotransduction and the mechanical properties of cells and their microenvironment, including membrane and cytoskeletal mechanics. Experimental approaches for measuring and manipulating the material properties of cells and their environment; including optical, electrical and magnetic techniques will be covered. A variety of application will be covered, including manipulation in engineering of mechanotransduction pathways to drive cell migration and stem cell differentiation. Instructor Permission Required. Cross-list: BIOE 643, PHYS 643.

**BIOE 654 - ADVANCED COMPUTATIONAL MECHANICS**

Short Title: ADV COMPUTATIONAL MECHANICS  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Prerequisite(s): BIOE 554 or CEVE 554 or MECH 554 or BIOE 454 or CEVE 454 or MECH 454  

**BIOE 661 - ONCOLOGY FOR BIOENGINEERS: MOLECULES TO ORGANS**

Short Title: ONCOLOGY FOR BIOENGINEERS  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture/Laboratory  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Students will develop and work through patient cases that emphasize the informational needs of graduate bioengineering students interested in cancer-related translational research. The class will review and discuss the initial case, decide on relevant learning issues, gather information, present findings for further review and discussion, and submit a case-specific written assignment. Using the same model, each student will then develop and lead his/her own patient case for class study. Instructor Permission Required. Required: Admission to Med Into Grad Program.

**BIOE 680 - NANO-NEUROTECHNOLOGY**

Short Title: NANO-NEUROTECHNOLOGY  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: This course will review current nanofabricated technologies for measuring, manipulating, and controlling neural activity. The course will be based on reviewing current academic literature and topics will include nano-electronic, -photonic, -mechanical, and -fluidic neural devices. Cross-list: ELEC 680.

**BIOE 682 - SYSTEMS BIOLOGY OF HUMAN DISEASES**

Short Title: SYS BIO OF HUMAN DISEASES  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Introduction to concepts necessary for application of systems - Biology Approaches to Human Diseases. Topics include transcriptional and metabolic design principles, introduction to various regulatory network motifs in diseases and potential treatments using embryonic stem cells. Analysis of complex diseases using engineering concepts such as optimality, nonequilibrium thermodynamics, multiscale analysis and spatiotemporal transport. Cross-list: CHBE 682.

**BIOE 690 - PROFESSIONAL DEVELOPMENT FOR BIOENGINEERS**

Short Title: PROF DEVELOPMENT FOR BIOE  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Professional development topics relevant to academic careers including applying for faculty positions, interviewing, negotiating offers, building a lab, obtaining funding and balancing professional obligations. Designed for graduate students planning academic careers in research-intensive bioengineering departments.

**BIOE 698 - BIOENGINEERING COLLOQUIA**

Short Title: BIOENGINEERING COLLOQUIA  
Department: Bioengineering  
Grade Mode: Satisfactory/Unsatisfactory  
Course Type: Seminar  
Credit Hour: 1  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Recent research in bioengineering will be presented in this colloquium series. These colloquia provide an opportunity to learn about the research at other institutions, oftentimes in an area outside students’ specific dissertation specialty, and are an important part of graduate education. Graduate students in BIOE are expected to attend all regular Bioengineering colloquia. Repeatable for Credit.
BIOE 699 - BIOENGINEERING COLLOQUIA
Short Title: BIOENGINEERING COLLOQUIA
Department: Bioengineering
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Recent research in bioengineering will be presented in this colloquium series. These colloquia provide an opportunity to learn about the research at other institutions, oftentimes in an area outside students’ specific dissertation specialty, and are an important part of graduate education. Graduate students in BIOE are expected to attend all regular Bioengineering colloquia. Repeatable for Credit.

Description and Code Legend

Note: Internally the university uses the following descriptions, codes, and abbreviations for this academic program. The following is a quick reference:

Course Catalog/Schedule
- Course offerings/subject: BIOE

Department Description and Code
- Bioengineering: BIOE

Undergraduate Degree Description and Code
- Bachelor of Science in Bioengineering degree: BSBE

Undergraduate Major Description and Code
- Major in Bioengineering: BIOE

Graduate Degree Descriptions and Codes
- Master of Bioengineering degree: MBE
- Master of Science degree: MS
- Doctor of Philosophy degree: PhD

Graduate Degree Program Description and Code
- Degree Program in Bioengineering: BIOE