

BIOENGINEERING

Contact Information

Bioengineering

<https://bioe.rice.edu/>

BioScience Research Collaborative

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Gang Bao

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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 students 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 studies in bioengineering include areas such as biomaterials, biofabrication, and mechanobiology; biomedical imaging and instrumentation; cellular and molecular engineering and synthetic biology; and computational and theoretical bioengineering and biophysics. Research areas include biomechanics, biological systems modeling, bioinformatics, cellular and molecular engineering, controlled release technologies, metabolic engineering, spectroscopy, statistical mechanics, synthetic biology, systems engineering and instrumentation, thrombosis, tissue engineering, and transport processes.

Bachelor's Program

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

Master's Programs

- Master of Bioengineering (MBE) Degree
 - and a Major Concentration in Applied Bioengineering (<https://ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/bioengineering-mbe-concentration-applied-bioengineering/>)
 - and a Major Concentration in Global Medical Innovation (<https://ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/bioengineering-mbe-concentration-global-medical-innovation/>)
- Master of Science (MS) Degree in the field of Bioengineering*

Doctoral Program

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

Dual Degree Programs

- **Master of Bioengineering (MBE) Degree / Doctor of Medicine (MD) Degree with UT Health Science Center** (<https://ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/bioengineering-mbe-md/>)
- **Doctor of Philosophy (PhD) Degree in the field of Bioengineering / Doctor of Medicine (MD) Degree with Baylor College of Medicine** (<https://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

Gang Bao

Professors

Gang Bao
 Rebekah Anna Drezek
 Kathryn Jane Grande-Allen
 Oleg A. Igoshin
 Antonios G. Mikos
 Rebecca Richards-Kortum
 Ka-Yiu San
 Tomasz Tkaczyk

Associate Professors

Michael Diehl
 Robert M. Raphael
 Jeffrey J. Tabor
 David Zhang

Assistant Professors

Caleb Bashor
 Isaac Hilton
 George Lu
 Kevin McHugh
 Jordan Miller
 Jerzy Szablowski

Omid Veisesh

Teaching Professor

Z. Maria Oden

Associate Teaching Professors

Renata Ramos

Matthew Wettergreen

Assistant Research Professors

Buhle Moyo

Qingbo Zhang

Lecturers

Sabia Abidi

Bilal Ghosn

David Li

Irena Petsche

Adjunct Lecturers

Lance Black

Meghan Bond

Richard Schwarz

Professors, Joint Appointments

Caroline Ajo-Franklin

Benjamin J. Fregly

Fathi Ghorbel

Naomi J. Halas

Jeffrey D. Hartgerink

C. Fred Higgs, III

Lydia Kavradi

Marek Kimmel

Peter Lillhoj

Angel A. Martí-Arbona

Jonathan Silberg

Kyriacos Zygorakis

Associate Professors, Joint Appointments

Matthew Bennett

Caleb Kemere

Ching-Hwa Kiang

Jacob Robinson

Aryeh Warmflash

Chong Xie

Assistant Professors, Joint Appointments

James Chappell

Xue Gao

Lan Luan

Akane Sano

Ross Thyer

Han Xiao

Adjunct Professors

Sharmila Anandasabapathy

James Bankson

Maria Elena Bottazzi

Suneet Chauhan

Margaret Shun Cheung

Elizabeth Cosgriff-Hernandez

Miguel Cruz

Mary E. Dickinson

Cindy Farach-Carson

Ann M. Gillenwater

Ramon Gonzalez

Peter Jay Hotez

Raghu Kalluri

Chester Koh

Herbert Levine

Anirban Maitra

David R. Piwnica-Worms

Ann Saterbak

Konstantin Sokolov

Mark Wong

Adjunct Associate Professors

Catherine G. Ambrose

Jean Bismuth

M. Waleed Gaber

Irina Larina

Stephen H. Little

Joseph A. Ludwig, IV

Mehdi Razavi

Adjunct Assistant Professors

Stuart Corr

Daniel Harrington

Courtney Hodges

Robert Krencik

Rohith Malya

Sarah Sartain

Rachael Sirianni

Farzad Soleimani

Andrew Yee

Simon Young

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) (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) (<https://courses.rice.edu/admweb!/SWKSCAT.cat>).

Bioengineering (BIOE)

BIOE 123 - BIAS AND MEDICAL DEVICE DESIGN: EXPLORING THE HIDDEN BIASES BEHIND MEDICAL PRODUCTS AND DEVICES

Short Title: BIAS AND MEDICAL DEVICE DESIGN

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Lecture

Credit Hour: 1

Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

Course Level: Undergraduate Lower-Level

Description: This course explores the hidden biases that exist in product design with a focus on the tradeoffs entrepreneurs and innovators face when making decisions on how to design, build, and test their medical products and devices. Through the lenses of failed medical devices, poorly designed clinical trials, lack of stakeholder understanding, and interpretation bias students will discuss opportunities to proactively increase diversity of users that can lead to a more impactful, inclusive design. Assessments will consist of in and out of class exercises, reflections and a group project. Cross-list: BUSI 224.

BIOE 202 - CAREERS IN BIOENGINEERING

Short Title: CAREERS IN BIOENGINEERING

Department: Bioengineering

Grade Mode: Satisfactory/Unsatisfactory

Course Type: Seminar

Credit Hour: 1

Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

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 238 - SPECIAL TOPICS

Short Title: SPECIAL TOPICS

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Internship/Practicum, Laboratory, Lecture, Seminar, Independent Study

Credit Hours: 1-4

Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

Course Level: Undergraduate Lower-Level

Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

BIOE 252 - BIOENGINEERING FUNDAMENTALS

Short Title: BIOENGINEERING FUNDAMENTALS

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Lecture

Credit Hours: 4

Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

Course Level: Undergraduate Lower-Level

Prerequisite(s): (MATH 101 or MATH 105) and (MATH 102 or MATH 106) and MATH 211 (may be taken concurrently) and (CHEM 112 or CHEM 122) and (CAAM 210 or CMOR 220) 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 302 - SYSTEMS PHYSIOLOGY

Short Title: SYSTEMS PHYSIOLOGY

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Lecture

Credit Hours: 3

Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

Course Level: Undergraduate Upper-Level

Prerequisite(s): BIOC 201 and (PHYS 101 and PHYS 102) or (PHYS 125 and PHYS 126)

Description: This course will teach the fundamentals of human physiology with a specific focus on the nervous, cardiovascular, respiratory, and urinary systems. Basic introductory engineering principles will be applied to the study of physiological systems. The course is aimed to be accessible to students with non-engineering backgrounds. Students may receive credit for only one of BIOE 302, BIOE 322, and BIOC 332. Mutually Exclusive: Cannot register for BIOE 302 if student has credit for BIOE 322.

BIOE 320 - SYSTEMS PHYSIOLOGY LAB MODULE

Short Title: SYSTEMS PHYSIOLOGY LAB MODULE

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Laboratory

Credit Hour: 1

Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

Course Level: Undergraduate Upper-Level

Prerequisite(s): BIOE 252 and (BIOC 332 or BIOE 322 (may be taken concurrently) or BIOC 332 (may be taken concurrently))

Description: Exploration of physiologic systems through measurement of biologic signals. EEG, ECG, EMG pulmonary function tests, etc. are performed and analyzed. Students will explore physiologic concepts through computer simulations, data collection, and analysis. Enrollment in or completion of BIOE 322/BIOC 332 is expected and maybe taken the same semester as BIOE 320. For students intending to major in Bioengineering. Instructor Permission Required.

BIOE 321 - CELLULAR ENGINEERING**Short Title:** CELLULAR ENGINEERING**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOE 252**Description:** Introduction to engineering principles and modeling regulation and circuitry at the cellular level. Topics include genetic metabolic networks and cell surface interactions.**BIOE 322 - FUNDAMENTALS OF SYSTEMS PHYSIOLOGY****Short Title:** FUND OF SYSTEMS PHYSIOLOGY**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Distribution Group:** Distribution Group III**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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: Cannot register for BIOE 322 if student has credit for BIOC 332/BIOE 302.**BIOE 330 - BIOREACTION ENGINEERING****Short Title:** BIOREACTION ENGINEERING**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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 and statistical mechanics. Advanced topics will include transcription factor-DNA binding, nucleic acid hybridization, translation initiation and genetic circuits. The course will cover the role that thermodynamics plays in molecular engineering and synthetic biology.**BIOE 333 - MOLECULAR BIOTECHNOLOGY****Short Title:** MOLECULAR BIOTECHNOLOGY**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOC 201 and BIOE 252**Description:** This course will introduce the students to modern biotechnology. The course will cover fundamental technologies with emphasis on modern genome engineering, sequencing and bioinformatics, molecular diagnostics, design of therapeutics, and recombinant microorganisms for industrial and environmental applications. The course includes discussion of bioethical issues, societal impact, and intellectual properties.**BIOE 341 - CELL AND MOLECULAR BIOLOGY FOR ENGINEERS****Short Title:** CELL & MOL BIOL FOR ENGINEERS**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOE 252 and (BIOC 201 or BIOS 201)**Description:** Understanding the behaviors of cells and biomolecules in health and disease is a prerequisite to appropriately applying modern bioengineering principles. In this course, students will learn the fundamentals of cell and molecular biology and how transformative new technologies permit measuring and engineering these alterations to improve human health and uncover biological insights. Graduate/ Undergraduate Equivalency: BIOE 541. Mutually Exclusive: Cannot register for BIOE 341 if student has credit for BIOE 541.

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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOE 440 or STAT 440 or BIOC 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.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** (BIOC 341 or BIOE 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. Graduate/Undergraduate Equivalency: BIOE 648. Mutually Exclusive: Cannot register for BIOE 348 if student has credit for BIOE 648.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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. The minor and course prerequisite is waived for students majoring in Bioengineering. Instructor Permission Required. Cross-list: GLHT 360.**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:** Enrollment limited to students with a class of Senior. Enrollment is limited to students with a major in Bioengineering. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOE 252 and CHEM 211 and (MECH 202 (may be taken concurrently) or MECH 211 (may be taken concurrently) 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 or MECH 202 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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOE 252 and MATH 212 and (MECH 202 or MECH 211 or CEVE 211)**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. Graduate/Undergraduate Equivalency: BIOE 572. Mutually Exclusive: Cannot register for BIOE 372 if student has credit for BIOE 572.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141) and (PHYS 102 or PHYS 112 or PHYS 126 or PHYS 142) and (COMP 140 or CAAM 210 or CMOR 220)**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.**BIOE 383 - BIOMEDICAL ENGINEERING INSTRUMENTATION****Short Title:** BIOMED ENGINEER INSTRUMENTATION**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** MATH 211 and ELEC 243 and (BIOC 201 or BIOS 201) and (PHYS 102 or PHYS 126 or PHYS 112)**Corequisite:** BIOE 385**Description:** This is an introductory level course on fundamentals of biomedical engineering instrumentation and analysis. Topics include measurement principles; fundamental concepts in electronics including circuit analysis, data acquisition, amplifiers, filters and A/D converters; Fourier analysis; temperature, pressure, and flow measurements in biological systems.**BIOE 385 - BIOMEDICAL INSTRUMENTATION LAB****Short Title:** BIOMEDICAL INSTRUMENTATION LAB**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Laboratory**Credit Hour:** 1**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Corequisite:** BIOE 383**Description:** Students will gain hands on experience with building biomedical instrumentation circuits and systems. Students will learn the basics of lab view programming and signal analysis. Instructor Permission Required.**BIOE 391 - NUMERICAL METHODS****Short Title:** NUMERICAL METHODS**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOE 252 and (CAAM 210 or CMOR 220) 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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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 400 - ENGINEERING UNDERGRADUATE RESEARCH****Short Title:** ENGINEERING UG RESEARCH**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Research**Credit Hours:** 1-4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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. Department Permission Required. Repeatable for Credit.**BIOE 403 - ADVANCES IN BIONANOTECHNOLOGY****Short Title:** ADVANCES IN BIONANOTECHNOLOGY**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Seminar**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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 405 - MACROMOLECULAR ASSEMBLIES****Short Title:** MACROMOLECULAR ASSEMBLIES**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** There is increasing attention on the biological phenomena and engineering opportunities at the mesoscopic scale, which is between the size of a single protein and that of the large organelles. This course will cover a range of these phenomena, such as viral particles, ribosomes, bacterial microcompartments, amyloid fibrils, gas vesicles, and membraneless condensates. Additionally, the course will aim to formulate physical principles behind these phenomena, describe the experimental and computational approaches to study them, and discuss how to engineer these assemblies. Graduate/Undergraduate Equivalency: BIOE 505.**BIOE 406 - TISSUE ENGINEERING****Short Title:** TISSUE ENGINEERING**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** This course will review the fundamental elements of the tissue engineering paradigm, that is biomaterials, biomolecules, and cells. Topics covered will include synthetic biomaterials, calcium phosphates, engineered protein biomaterials, signal expression in engineered tissues, pluripotent stem cells, hematopoietic and mesenchymal stem cells, nanobiomaterials and nanotechnology strategies, and biomimetic approaches. The course will further explore the enabling engineering technologies that are harnessed to recreate the structure and function of native tissue microenvironments. Additional topics covered will include mechanical conditioning, micropatterning, drug delivery, gene therapy, cell encapsulation, co-culture systems, 3D printing and bioprinting, bioreactors and shear forces, vascularization of engineered tissues, biomedical imaging of engineered tissues, and multiscale modeling. Finally, the course will conclude with a discussion of the applications of tissue engineering and cover topics related to interfacial tissue engineering and tumor tissue engineering. Cross-list: CHBE 406. Graduate/Undergraduate Equivalency: BIOE 620.**BIOE 408 - SYNTHETIC BIOLOGY****Short Title:** SYNTHETIC BIOLOGY**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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: Cannot register for BIOE 408 if student has credit for 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. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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: Cannot register for BIOE 419 if student has credit for BIOE 534. Repeatable for Credit.**Course URL:** www.ece.rice.edu/~ashu/ELEC419.html (<http://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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** MATH 211 and MATH 212 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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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: Cannot register for BIOE 421 if student has credit for 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. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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: Cannot register for BIOE 422 if student has credit for BIOE 522.**BIOE 431 - BIOMATERIALS APPLICATIONS****Short Title:** BIOMATERIALS APPLICATIONS**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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 questions, one midterm and cumulative final, a group project, a seminar report and individual presentations. Graduate/Undergraduate Equivalency: BIOE 631. Mutually Exclusive: Cannot register for BIOE 431 if student has credit for BIOE 631.**BIOE 432 - BIOMANUFACTURING, SUSTAINABILITY, AND BIOECONOMY****Short Title:** BIOEMANUFACTURING, SUS. & ECON**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** The climate crisis, the need for sustainable energy sources, the manufacturing of commodities with low carbon emissions, and the scalable manufacturing of biomedicines are some of the grand challenges of the 21st century. Biotechnology and synthetic biology can offer innovative solutions to many of these challenges. This course will survey the current frontier of research on these topics, explore the future of the bioeconomy, and brainstorm novel strategies to address these challenges. Graduate/Undergraduate Equivalency: BIOE 532. Mutually Exclusive: Cannot register for BIOE 432 if student has credit for BIOE 532.

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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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: Cannot register for BIOE 439 if student has credit for 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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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. 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: Cannot register for BIOE 440 if student has credit for 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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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 vial 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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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. Instructor Permission Required.

BIOE 448 - MICROCONTROLLERS FOR MEDICAL DEVICE DESIGN**Short Title:** MICROCONTROLLERS - MED DEVICE**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Laboratory**Credit Hour:** 1**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOE 385

Description: In this laboratory course, students will learn to design, build, and test basic devices powered by microcontrollers. Students will work in groups to complete a series of laboratory modules to learn basic applications in sensing and actuation. Additionally, students will learn standard conventions for creating and maintaining a code repository. The modules in this course will culminate in a multi-week, open-ended final project, where students will identify a desired task of moderate complexity that can be accomplished with a microcontroller. Instructor Permission Required.

BIOE 449 - TROUBLESHOOTING WORKSHOP FOR CLINICALLY-RELEVANT BIOMEDICAL EQUIPMENT**Short Title:** MED BIOENGINEERING WORKSHOP**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Laboratory**Credit Hour:** 1**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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 451 - BIOENGINEERING DESIGN I**Short Title:** BIOENGINEERING DESIGN I**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture/Laboratory**Credit Hours:** 4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** MECH 371 (may be taken concurrently) or MECH 444 (may be taken concurrently) or CEVE 363 (may be taken concurrently) or CHBE 401 (may be taken concurrently) or BIOE 420 (may be taken concurrently) or CHBE 420 (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: Cannot register for BIOE 454 if student has credit for BIOE 554.**BIOE 464 - EXTRACELLULAR MATRIX****Short Title:** EXTRACELLULAR MATRIX**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** BIOS 341 or BIOC 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. Graduate/Undergraduate Equivalency: BIOE 524. Recommended Prerequisite(s): BIOE 372, BIOC/BIOE 341. Mutually Exclusive: Cannot register for BIOE 464 if student has credit for BIOE 524.**BIOE 477 - SPECIAL TOPICS****Short Title:** SPECIAL TOPICS**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Internship/Practicum, Seminar, Lecture, Laboratory**Credit Hours:** 1-4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.**BIOE 484 - 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 Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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 in a variety of optical instruments and point out special requirements for bio-medical applications in optical sensing, diagnosis, and biomedical applications. Graduate/Undergraduate Equivalency: BIOE 512. Mutually Exclusive: Cannot register for BIOE 484 if student has credit for 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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**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: Cannot register for BIOE 485 if student has credit for 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:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** ELEC 485 or BIOE 485 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 is also planned to gain experience with nuclear medicine imaging. Cross-list: COMP 486, ELEC 486. Graduate/Undergraduate Equivalency: BIOE 596. Mutually Exclusive: Cannot register for BIOE 486 if student has credit for BIOE 596.**BIOE 492 - SENSORY NEUROENGINEERING****Short Title:** SENSORY NEUROENGINEERING**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**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 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 592. Mutually Exclusive: Cannot register for BIOE 492 if student has credit for BIOE 592.**BIOE 493 - BUILDING LIFE SCIENCES, BIOMEDICAL AND BIOTECHNOLOGY STARTUPS****Short Title:** BIOTECH STARTUP**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** This semester-long course aims to provide entrepreneurial students with a hands-on experience in building a high-tech company based on novel biomedical technologies being developed at Rice University and in the Texas Medical Center. Students will form teams of 2-4, and identify a promising biomedical technology, perform intellectual property landscape analysis, identify a minimum viable product, build a business plan, construct 1 year and 5 year financial projections, conduct voice of customer interviews, and present a fundraising "pitch." Students are expected to spend 8-10 hours per week outside the classroom to complete tasks assigned during lectures, and will summarize their findings every 2 weeks in a 7-minute presentation. Graduate/Undergraduate Equivalency: BIOE 593. Mutually Exclusive: Cannot register for BIOE 493 if student has credit for BIOE 593.**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 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: BIOS 505, 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 505 - MACROMOLECULAR ASSEMBLIES**Short Title:** MACROMOLECULAR ASSEMBLIES**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

Description: There is increasing attention on the biological phenomena and engineering opportunities at the mesoscopic scale, which is between the size of a single protein and that of the large organelles. This course will cover a range of these phenomena, such as viral particles, ribosomes, bacterial microcompartments, amyloid fibrils, gas vesicles, and membraneless condensates. Additionally, the course will aim to formulate physical principles behind these phenomena, describe the experimental and computational approaches to study them, and discuss how to engineer these assemblies. Graduate/Undergraduate Equivalency: BIOE 405.

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 - GRADUATE RESEARCH COMPONENTS I**Short Title:** GRADUATE RESEARCH COMPONENTS I**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Research**Credit Hours:** 2**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

Description: Students take BIOE 507 as a Component I of the research concentration of the MBE program. The class is 2 credit hours counting toward an MBE degree. The project may vary depending on the mentor's group focus and range from lab assay work, material studies, design, and assembly of biomedical devices, simulations, and many others. Instructor Permission Required.

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: Cannot register for BIOE 508 if student has credit for 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 510 - SEMINAR IN TROPICAL MEDICINE**Short Title:** SEMINAR IN TROPICAL MEDICINE**Department:** Bioengineering**Grade Mode:** Satisfactory/Unsatisfactory**Course Type:** Seminar**Credit Hour:** 1**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

Description: 8 week lecture series on topics in global health. The theme for this offering is one health; integrating efforts to obtain optimal health for humans, animals, and the environment. Offered in conjunction with the new National School of Tropical Medicine, the course will feature lectures by various experts on the public health issues most pressing in poor populations in the world today. Course open to all undergraduates and graduate students. Cross-list: GLHT 510. Repeatable for Credit.

BIOE 511 - MBE RESEARCH DESIGN AND TECHNOLOGY SEMINAR**Short Title:** MBE RESEARCH DESIGN TECHNOLOGY**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Seminar**Credit Hours:** 2**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

Description: The purpose of the seminar course is to provide foundational knowledge about working in science and engineering with the focus on biomedical and bioengineering research. The course prepares students with information on experimental design and good lab citizenship, a big picture overview of common and cutting-edge technologies that are widely used in bioengineering research, and a brief introduction to the regulatory ethics that govern research commercialization. Therefore, the seminar allows for improving knowledge and understanding useful in laboratory projects and also builds a foundation for further career development in continuing graduate education or industry.

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 bio-medical 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: Cannot register for BIOE 512 if student has credit for BIOE 484.

BIOE 513 - STRATEGIC CAREER PREPAREDNESS FOR INDUSTRY JOBS**Short Title:** CAREER PREP FOR INDUSTRY**Department:** Bioengineering**Grade Mode:** Satisfactory/Unsatisfactory**Course Type:** Lecture**Credit Hours:** 1.5**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

Description: This course is designed for MBE candidates and PhD students planning to graduate within the year who are interested in industry careers. The course will help students design a resume, cover letter, and other career development tools to strategically identify and market their skills to bioengineering industry partners.

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 515 - ENGINEERING DRUG DELIVERY SYSTEMS**Short Title:** ENGINEERING DRUG DELIVERY SYS.**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 focus on the application of innovative engineering approaches to enhance drug efficacy and/or reduce toxicity. Topics of emphasis include, but are not limited to, routes of administration, bioavailability, biodistribution, pharmacokinetics, pharmacodynamics, therapeutic drug windows, patient compliance, immunogenicity, the foreign body reaction, and solubility enhancement. A wide array of device types will be discussed, such as biodegradable microspheres, self-assembled lipid nanoparticles, microneedles, and osmotic pumps. Students will be expected to quantitatively evaluate drug release from complex devices and determine drug distribution and clearance using multi-compartment models. An additional project will be required of graduate level students.

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 advance 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 COMPUTATION BIOLOGY**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students. Enrollment limited to students in a Doctor of Philosophy degree. Enrollment limited to students in the Bioengineering department.**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. Enrollment limited to students in a Doctor of Philosophy degree. Enrollment limited to students in the Bioengineering department.**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 their 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 BIOE PhD students only. Recommended Prerequisite(s): BIOE 516 and BIOE 517**BIOE 520 - CANCER BIOENGINEERING: TECHNOLOGY FOR UNMET CLINICAL NEEDS****Short Title:** CANCER BIOENGINEERING**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** In this course, students will be introduced to the current states of bioengineering research and clinical practice in cancer diagnosis, treatment and survivorship. Through direct interaction with pathologists, radiologists, oncologists and surgeons at the Texas Medical Center, students will learn about technologies used and needed in the clinic. By the end of the course, students will build critical communication and observation skills to identify unmet needs and design clinically translatable solutions. Instructor Permission Required.**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: Cannot register for BIOE 521 if student has credit for 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**Description:** Gene therapy suffered from major clinical setbacks in the late 1990's, putting the entire field of genetic medicine at a standstill. However, through perseverance and strategic re-thinking of how viruses and cells could be used as therapeutics, the field is currently experiencing a biotechnological revolution. In December of 2017, a virus-based gene therapy drug was approved by the FDA, making it the first of its kind for the treatment of an inherited disease. This landmark achievement is just the beginning of a new era of human therapeutics. This class will discuss the gene therapy field – where it was and where it is now. Clinically important vectors currently under human testing, and opportunities for the next generation of improved gene delivery vectors will be presented. The biological and physiological barriers to efficient gene delivery will be investigated in order to spur new ideas for improving vector efficiency and specificity. Graduate/Undergraduate Equivalency: BIOE 422. Mutually Exclusive: Cannot register for BIOE 522 if student has credit for 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 MATRIX**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. Graduate/Undergraduate Equivalency: BIOE 464. Recommended Prerequisite(s): BIOE 372, BIOC/BIOE 341. Mutually Exclusive: Cannot register for BIOE 524 if student has credit for BIOE 464.

BIOE 525 - NANOBIOENGINEERING AND NANOMEDICINE**Short Title:** NANOBIOENG 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 - ADVANCES IN GENOME EDITING AND ENGINEERING**Short Title:** ADVANCES IN 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 - HEALTHCARE INNOVATION AND ENTREPRENEURSHIP**Short Title:** HEALTHCARE INNOV & ENTREPREN**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 designed for healthcare entrepreneurs who want to build innovative medical technologies. During the course, students will learn how to identify customers, key stakeholders, and the market opportunity for a clinical need; apply design thinking, including low-fidelity prototyping, to quickly test and iterate on a concept; assess regulatory, reimbursement, and clinical trial requirements; identify key assumptions and develop a business model; create a financial model based on business model assumptions; determine capital requirements and funding sources for their venture; understand and evaluate term sheets; create a pitch presentation for investors. Instructor Permission Required.

BIOE 528 - MEDICAL ENGINEERING AND DESIGN LAB**Short Title:** MED ENGINEERING & DESIGN LAB**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Laboratory**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

Description: In this studio-based lab, students apply technical engineering and prototyping skills to medical design projects. Participants are taught and apply a range of topics including engineering design processes, medical materials, biocompatibility, design for manufacturing, rapid prototyping, medical equipment, sterility, manufacturing techniques, and quality system implementation.

BIOE 529 - HEALTHCARE INNOVATION AND ENTREPRENEURSHIP LAB**Short Title:** INNOV & ENTREPRENEURSHIP LAB**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: In this follow-on experiential Lab course, students work on refining and completing the plan for the venture they created in Health Innovation and Entrepreneurship. Teams receive guidance and Mentoring from faculty and mentors to develop the next steps of their business. The Lab takes place in the Liu Idea Lab for Innovation and Entrepreneurship, a purpose built state-of-the-art incubator and co-working space on the Rice campus.

BIOE 530 - MEDICAL ENGINEERING & DESIGN LAB 2**Short Title:** MED ENGIN & DESIGN LAB 2**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**Prerequisite(s):** BIOE 528

Description: In this studio-based lab, students apply technical engineering and prototyping skills to medical design projects. Participants are taught and apply a range of topics including engineering design processes, medical materials, biocompatibility, design for manufacturing, rapid prototyping, medical equipment, sterility, manufacturing techniques, and quality system implementation. This course is intended for only those students in Bioengineering.

BIOE 532 - BIOMANUFACTURING, SUSTAINABILITY, AND BIOECONOMY**Short Title:** BIOMANUFACTURING, SUS. & ECON**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Course Level:** Graduate

Description: The climate crisis, the need for sustainable energy sources, the manufacturing of commodities with low carbon emissions, and the scalable manufacturing of biomedicines are some of the grand challenges of the 21st century. Biotechnology and synthetic biology can offer innovative solutions to many of these challenges. This course will survey the current frontier of research on these topics, explore the future of the bioeconomy, and brainstorm novel strategies to address these challenges. Graduate/Undergraduate Equivalency: BIOE 432. Mutually Exclusive: Cannot register for BIOE 532 if student has credit for BIOE 432.

BIOE 533 - FUNDAMENTALS OF SYSTEMS PHYSIOLOGY**Short Title:** FUND. OF SYSTEMS PHYSIOLOGY**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 aspects of medical physiology from an engineering viewpoint. Physiological systems will be analyzed at the molecular, cellular, tissue, and organism levels. Graduate students will have an extra submission in their PBL report – 3-5 page Pitfalls and Alternatives Section detailing how the proposed design can fail and the alternative strategies that will be employed to achieve success.

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 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. Additional course work required beyond the undergraduate course requirements. Cross-list: ELEC 559. Graduate/Undergraduate Equivalency: BIOE 419. Mutually Exclusive: Cannot register for BIOE 534 if student has credit for BIOE 419. Repeatable for Credit.

Course URL: www.ece.rice.edu/~ashu/ELEC419.html (<http://www.ece.rice.edu/~ashu/ELEC419.html>)

BIOE 535 - ENGINEERING CELL-BASED THERAPEUTICS FOR THE TREATMENT OF DISEASE**Short Title:** CELL-BASED THERAPEUTICS**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

Description: Once the stuff of science fiction, there is increasing attention on using engineered living cells as therapeutic agents. We will discuss how application of synthetic biology, genetic engineering, and systems biology can endow cells with the ability to detect and treat disease, identifying breakthroughs, challenges, and long-term possibilities for this exciting new field. Recommended Prerequisite(s): BIOE 321.

BIOE 536 - FRONTIERS IN IMMUNOENGINEERING**Short Title:** IMMUNOENGINEERING**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 immunology concepts from an engineering perspective and covers various immune responses including to pathogens, self, allergens, cancer, and biomaterials. Using principles of engineering we will perform an in-depth analysis of these responses and the latest advances on the development of novel therapeutics. Topics include systems immunology, nanotechnology, hydrogels, biomaterials, vaccines, cancer immunotherapy, autoimmunity, tissue engineering, stem cells, viruses, and the microbiome.

BIOE 537 - GENETIC AND EPIGENETIC CONTROL**Short Title:** GENETIC AND EPIGENETIC CONTROL**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

Description: All human diseases are driven by alterations in genetic sequences, cellular transcription, and/or chromatin structure. In this course, students will learn how transformative new technologies permit measuring and manipulating these alterations, and how bioengineers can leverage these innovative tools to combat human diseases and catalyze advances in biotechnology.

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: Cannot register for BIOE 539 if student has credit for BIOE 439.

BIOE 541 - CELL AND MOLECULAR BIOLOGY FOR ENGINEERS**Short Title:** CELL & MOLECULAR 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: Understanding the behaviors of cells and biomolecules in health and disease is a prerequisite to appropriately applying modern bioengineering principles. In this course, students will learn the fundamentals of cell and molecular biology and how transformative new technologies permit measuring and engineering these alterations to improve human health and uncover biological insights. Graduate/Undergraduate Equivalency: BIOE 341. Mutually Exclusive: Cannot register for BIOE 541 if student has credit for BIOE 341.

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: 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 NEURO ENGINEERING**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 552 - 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:** 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. The class is based on MATLAB, with a brief refresher provided at the beginning. We discuss engineering approaches adapted to computational systems biology and aim to formulate evolutionary design principles explaining the organization of networks in terms of their physiological demands. Topics include end-product inhibition in biosynthesis, optimality and robustness of the signaling networks, and kinetic proofreading. The topics covered include modeling of enzyme kinetics, biochemical reaction networks, gene regulation, stochasticity of gene expression, and evolutionary and epidemiological population dynamics. The final project focuses on modeling synthetic biology circuits. Instructor Permission Required. Cross-list: SSPB 502. Recommended Prerequisite(s): Basic knowledge of biochemistry, cell biology, linear algebra, and ordinary differential equations is expected. Experience with MATLAB or Python programming is highly recommended. Mutually Exclusive: Cannot register for BIOE 552 if student has credit for BIOE 490.

BIOE 553 - SYSTEMS BIOLOGY AND NEUROENGINEERING**Short Title:** SYS BIOLOGY & NEUROENGINEERING**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 students to advances in computational biology relevant to neuroengineering, and equip them with a suite of tools emerging from systems biology to student neurological processes. Example class topics include: decoding multineuron activity, models for optogenetic control, and optimization of neuro-generative therapies.**BIOE 554 - COMPUTATIONAL FLUID MECHANICS****Short Title:** COMPUTATIONAL FLUID 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):** MECH 371 (may be taken concurrently) or MECH 444 (may be taken concurrently) or CEVE 363 (may be taken concurrently) or CHBE 401 (may be taken concurrently) or BIOE 420 (may be taken concurrently) or CHBE 420 (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. Additional work required. Cross-list: CEVE 554, MECH 554. Graduate/Undergraduate Equivalency: BIOE 454. Mutually Exclusive: Cannot register for BIOE 554 if student has credit for BIOE 454.**BIOE 555 - PROTOTYPING AND FABRICATION OF MEDICAL DEVICES****Short Title:** PROTOTYPING & FABRICATION**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** Students will learn the technical fundamentals, industrial applications, and practical skills of physical and digital prototyping of medical devices. Students will operate machines and apply relevant techniques to produce physical objects that demonstrate best practices. Fabricated objects will be considered from the perspective of design for manufacturing for medical devices, including production cost models, part redesign for high volume production, and materials selection for scale up. Students will train with the instructor and learn by doing with other students. Work will be completed individually and in pairs, with a strong emphasis on collaboration fostering creativity and increased proficiency.**BIOE 558 - INTRODUCTION TO GENOME EDITING AND ENGINEERING****Short Title:** GENOME EDITING AND 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:** This course provides an introduction to the recent advances in the genome editing and engineering field. Past and current stages of genome-editing technologies, the fundamental mechanisms of different classes of genome-editing proteins, and cutting-edge strategies for engineering novel genome-editing agents and their applications in synthetic biology and therapeutics. Cross-list: CHBE 558.**BIOE 564 - BIOINFORMATICS: NETWORK ANALYSIS****Short Title:** BIOINFORMATICS: 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:** This course covers computational aspects of biological network analysis, a major theme in the area of systems biology. The course discusses protein-protein interaction, signaling, metabolic, and functional networks, and covers issues related to constructing, analyzing various types of networks, as well as how they can be used for downstream applications. Cross-list: COMP 572.**BIOE 567 - NEEDS FINDING IN CLINICAL CONTEXT****Short Title:** NEEDS FINDING CLINICAL CONTEXT**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Laboratory**Credit Hour:** 1**Restrictions:** Enrollment limited to students in the MBE-GMI program.

Enrollment is limited to Graduate level students.

Course Level: Graduate**Description:** Needs Finding in a Clinical Context is an experiential course that serves to expose Biomedical Engineering Graduate students to the clinical environment. It is critical for engineers to understand the context in which the devices they will design and develop are well suited to the users and use environment. By spending time observing the clinical setting, students will also become more aware of unmet needs in healthcare. The course will focus on important constraints within the healthcare fields as they relate to medical device development, as well as the global landscape of healthcare.

BIOE 571 - PRINCIPLES OF VISUAL DESIGN**Short Title:** VISUAL DESIGN**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 instruct participants in conceptual and technical approaches for effective visual communication of data, technical information, and engineering / science concepts, and will develop strategies for improving presentation of materials from participants own research. Knowledge and skills will be developed through short lectures, in-class studio instruction, design assignments, presentations, and a final design project.

BIOE 572 - BIOMECHANICS**Short Title:** BIOEMECHANICS**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 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. Mutually Exclusive: Cannot register for BIOE 572 if student has credit for BIOE 372. Graduate/Undergraduate Equivalency: BIOE 372. Mutually Exclusive: Cannot register for BIOE 572 if student has credit for BIOE 372.

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 mechanism to bioengineering problems.

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.

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

Description: Manipulation of gene expression in prokaryotic and eukaryotic cells. Rational design and directed solutions 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: CHBE 580. Recommended Prerequisite(s): CHBE 310/510 or equivalent is highly recommended.

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. Instructor Permission Required. 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: Cannot register for BIOE 591 if student has credit for BIOE 485.

BIOE 592 - SENSORY NEUROENGINEERING**Short Title:** SENSORY NEUROENGINEERING**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 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 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: Cannot register for BIOE 592 if student has credit for BIOE 492.

**BIOE 593 - BUILDING LIFE SCIENCES, BIOMEDICAL, AND
BIOTECHNOLOGY STARTUPS****Short Title:** BIOTECH STARTUP**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 semester-long course aims to provide entrepreneurial students with a hands-on experience in building a high-tech company based on novel biomedical technologies being developed at Rice University and in the Texas Medical Center. Students will form teams of 2-4, and identify a promising biomedical technology, perform intellectual property landscape analysis, identify a minimum viable product, build a business plan, construct 1 year and 5 year financial projections, conduct voice of customer interviews, and present a fundraising "pitch." Students are expected to spend 8-10 hours per week outside the classroom to complete tasks assigned during lectures, and will summarize their findings every 2 weeks in a 7-minute presentation. Graduate/Undergraduate Equivalency: BIOE 493. Mutually Exclusive: Cannot register for BIOE 593 if student has credit for BIOE 493.

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 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 is also 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: Cannot register for BIOE 596 if student has credit for BIOE 486.

BIOE 600 - GRADUATE BIOENGINEERING INDUSTRY INTERNSHIP**Short Title:** GRAD BIOE INDUSTRY INTERNSHIP**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Internship/Practicum**Credit Hours:** 6**Restrictions:** Enrollment limited to students in the MBE-GMI program.

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 is taken in the summer for six credits. Enrollment is limited to students in the Global Medical Innovation track of the MBE degree. Instructor permission is required. Instructor Permission Required.**BIOE 607 - RESEARCH CONCENTRATION – COMPONENT II****Short Title:** RES CONCENTRATION COMPONENT II**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Research**Credit Hours:** 5**Restrictions:** Students in the MBE-GMI program may not enroll.

Enrollment is limited to Graduate level students. Enrollment limited to students in a Master of Bioengineering degree.

Course Level: Graduate**Prerequisite(s):** BIOE 507**Description:** Students take BIOE 607 as a Component II of research concentration of the MBE program. The class is 5 credit hours counting toward MBE degree. The project focuses on research project defined within Component I and its results. Results will be presented to open forum of students and faculty. The grade for this class is awarded based on the report and presentation.**BIOE 610 - METHODS OF MOLECULAR SIMULATION****Short Title:** METHODS OF MOLECULAR SIMUL**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):** CHBE 611 or BIOC 589 or BIOE 589 or BIOS 589 or CHEM 520 or PHYS 526**Description:** Modern simulation techniques for classical atomistic systems. Review of statistical mechanical systems. Monte Carlo and molecular dynamics simulation techniques. Extensions of the basic methods to various ensembles. Applications to simulations of large molecules such as proteins. Advanced techniques for simulation of complex systems, including constraint satisfaction, cluster moves, biased sampling, and random energy models. Cross-list: PHYS 610.**BIOE 615 - BIOENGINEERING AND CARDIAC SURGERY****Short Title:** BIOENGINEERING/CARDIAC SURGERY**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 biomaterials and medical devices relevant to cardiac and vascular surgery and interventional cardiology in adult and pediatric patients. Mechanical and design considerations, notable successes and failures, and ethical issues will also be discussed, as will differences in cardiac disease and care due to health disparities.**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:** This course will review the fundamental elements of the tissue engineering paradigm, that is biomaterials, biomolecules, and cells. Topics covered will include synthetic biomaterials, calcium phosphates, engineered protein biomaterials, signal expression in engineered tissues, pluripotent stem cells, hematopoietic and mesenchymal stem cells, nanobiomaterials and nanotechnology strategies, and biomimetic approaches. The course will further explore the enabling engineering technologies that are harnessed to recreate the structure and function of native tissue microenvironments. Additional topics covered will include mechanical conditioning, micropatterning, drug delivery, gene therapy, cell encapsulation, co-culture systems, 3D printing and bioprinting, bioreactors and shear forces, vascularization of engineered tissues, biomedical imaging of engineered tissues, and multiscale modeling. Finally, the course will conclude with a discussion of the applications of tissue engineering and cover topics related to interfacial tissue engineering and tumor tissue engineering. Cross-list: CHBE 620. Graduate/Undergraduate Equivalency: BIOE 406.**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.**Course Level:** Graduate**Prerequisite(s):** MGMT 633 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/pJOUmeJItO (<http://goo.gl/forms/pJOUmeJItO/>)

BIOE 627 - MEDICAL INNOVATION INDUSTRY SEMINAR

Short Title: MED. INNOVATION INDUSTRY SEM.

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Seminar

Credit Hours: 1.5

Restrictions: Enrollment is limited to Graduate level students.

Course Level: Graduate

Description: This course exposes participants to the wide variety of career paths in the medical technology industry including large to mid sized companies, consulting, biotech, pharma, diagnostics, hospital administration and more through guest lectures, case studies, and informational interviews. Additional topics include: Resume and LinkedIn refinement, Job Application Process, Interview Skills, Delivering Oral Presentations

BIOE 628 - MEDICAL TECHNOLOGY DESIGN SEMINAR 2

Short Title: MED TECH DESIGN SEMINAR 2

Department: Bioengineering

Grade Mode: Standard Letter

Course Type: Seminar

Credit Hours: 1.5

Restrictions: Enrollment is limited to Graduate level students.

Course Level: Graduate

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.

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: Cannot register for BIOE 631 if student has credit for BIOE 431.

BIOE 633 - ROLES OF PHYSICIANS, SCIENTISTS, ENGINEERS AND MBA'S IN HIGH-TECH STARTUPS

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: This pragmatic course combines core lectures on entrepreneurship with special guest presentations by notable life science entrepreneurs. It explores the roles that physicians, scientists, engineers, and MBA's play in biotech, medical device, and healthcare companies, as well as major trends in Angel and Venture Capital Financings of Startups. Lectures on entrepreneurial team building, leadership and career planning are included. Cross-list: MGMT 633.

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: PHYS 643.

BIOE 648 - MOLECULAR TECHNIQUES IN BIOENGINEERING

Short Title: MOLECULAR TECHNIQUES IN BIOENG

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 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. A research paper on new advancements on a technique/technology of their choice based on the ones covered. Instructor Permission Required. Graduate/Undergraduate Equivalency: BIOE 348. Mutually Exclusive: Cannot register for BIOE 648 if student has credit for BIOE 348.

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**Description:** Advanced topics in computational mechanics with emphasis on finite element methods and fluid mechanics. Stabilized formulations. Fluid-particle and fluid-structure interactions and free-surface and two-fluid flows. Interface tracking and interface-capturing techniques, space-time formulations, and mesh update methods. Enhanced discretization and solution techniques. Iterative solution methods, matrix-free computations, and advanced preconditioning techniques. Cross-list: CEVE 654, MECH 654.**BIOE 677 - SPECIAL TOPICS****Short Title:** SPECIAL TOPICS**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Independent Study, Internship/Practicum, Laboratory, Lecture, Seminar, Activity Course, Intensive Learning Experience, Lecture/Laboratory, Research, Studio**Credit Hours:** 1-4**Restrictions:** Enrollment is limited to Graduate or Visiting Graduate level students.**Course Level:** Graduate**Description:** Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.**BIOE 680 - NANO-NEUROTECHNOLOGY****Short Title:** NANO-NEUROTECHNOLOGY**Department:** Bioengineering**Grade Mode:** Standard Letter**Course Type:** Seminar**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 695 - TRANSFER - FOUNDATIONS OF MEDICAL SCIENCE****Short Title:** TRANSFER - FOUNDATIONS MED SCI**Department:** Bioengineering**Grade Mode:** Transfer Courses**Course Type:** Transfer**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** This course is used for transfer credit from UTHSC-McGovern Medical School, and specifically for those students admitted and participating in the coordinated inter-institutional MD/MBE Dual Degree program.**BIOE 696 - TRANSFER - DOCTORING 1: HISTORY AND PHYSICAL EXAM****Short Title:** TRANSFER - DOCTORING 1**Department:** Bioengineering**Grade Mode:** Transfer Courses**Course Type:** Transfer**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** This course is used for transfer credit from UTHSC-McGovern Medical School, and specifically for those students admitted and participating in the coordinated inter-institutional MD/MBE Dual Degree program.**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

Graduate Major Concentration Descriptions and Codes

- Major Concentration in Applied Bioengineering (attached to the MBE degree): BAPB
- Major Concentration in Global Medical Innovation (attached to the MBE degree): BGMI

CIP Code and Description ¹

- **BIOE** Major/Program: CIP Code/Title: 14.0501 - Bioengineering and Biomedical Engineering
- **BAPB** Major Concentration: CIP Code/Title: 14.0501 - Bioengineering and Biomedical Engineering
- **BGMI** Major Concentration: CIP Code/Title: 14.0501 - Bioengineering and Biomedical Engineering

* *Systems Use Only: this information is used solely by internal offices at Rice University (such as OTR, GPS, etc.) and primarily within student information systems and support.*

¹ Classification of Instructional Programs (CIP) 2020 Codes and Descriptions from the National Center for Education Statistics: <https://nces.ed.gov/ipeds/cipcode/>