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 programs in bioengineering offer concentrations in 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 (https://ga.rice.edu/programs-study/departments-programs/engineering/bioengineering/bioengineering-mbe/)
- Master of Science (MS) Degree in the field of Bioengineering*

**Doctoral Program**

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

**Coordinated Program**

- 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
Michael W. Deem
Rebekah Anna Drezek
Kathryn Jane Grande-Allen
Oleg A. Igoshin
Jianpeng Ma
Antonios G. Mikos
Rebecca Richards-Kortum
Ka-Yiu San
Tomasz Tkaczyk

**Associate Professors**

Michael Diehl
Robert M. Raphael
Laura Segatori
Junghae Suh
Jeffrey J. Tabor
David Zhang

**Assistant Professors**

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

**Teaching Professor**

Z. Maria Oden
Bioengineering

**Associate Teaching Professors**
Renata Ramos
Matthew Wettergreen

**Lecturers**
Sabia Abidi
Bilal Ghosn
David Li

**Professors, Joint Appointments**
Benjamin J. Fregly
Fathi Ghorbel
Ramon Gonzalez
Naomi J. Halas
Jeffrey D. Hartgerink
C. Fred Higgs, III
Lydia Kavraki
Marek Kimmel
Marie Lynn Miranda
Kyriacos Zygourakis

**Associate Professors, Joint Appointments**
Matthew Bennett
Caleb Kemere
Ching-Hwa Kiang
Angel A. Marti-Arbona
Jacob Robinson
Jonathan J. Silberg

**Assistant Professors, Joint Appointments**
James Chappell
Xue Gao
Aryeh Warmflash
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
Andrew Sikora

**Adjunct Assistant Professors**
Lance Black
Stuart Corr
Daniel Harrington
Courtney Hodges
Robert Kencik
Rohith Malya
Aviva Presser Aiden
Amina Qutub
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)
To view the most recent semester’s course schedule, please see Rice’s Course Schedule (https://courses.rice.edu/admweb/!SWKSCAT.cat)

**Bioengineering (BIOE)**

**BIOE 202 - CAREERS IN BIOENGINEERING**
**Short Title:** CAREERS IN BIOENGINEERING
**Department:** Bioengineering
**Grade Mode:** Satisfactory/Unsatisfactory
**Course Type:** Seminar
**Credit Hour:** 1
**Restrictions:** 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, Seminar, Lecture, Laboratory
**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 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 Lower-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 BIOE 322 (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 332 if student has credit for BIOE 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): BIOE 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 BIOE 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.

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 BIOE 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 and submit a 250 statement to beyondtraditionalborders@rice.edu by Monday of preregistration. The minor and course prerequisite is waived for students majoring in Bioengineering. Instructor Permission Required. Cross-list: GLHT 360.
BIOE 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 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)
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 INSTRUMENTTION
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)
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 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 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 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.
CHBE 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
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 and (BIOE 332 or CHBE 411)
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 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 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 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 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 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 BIOE 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 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, 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, 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 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 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 or BIOE 484
Description: This course will address 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 524. 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 483
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 492 - SENSORY NEUROENGINEERING  
Short Title: SENSORY NEUROENGINEERING  
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 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 prosthetics (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 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.

BIOE 506 - 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 507 - 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: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Students take BIOE 507 as a Component I of research concentration of the MBE program. The class is 3 credit hours counting toward 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 other. Instructor Permission Required. Mutually Exclusive: Cannot register for BIOE 507 if student has credit for BIOE 307.

BIOE 508 - SYNTHETIC BIOLOGY
Short Title: SYNTHETIC BIOLOGY
Department: Bioengineering
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Design of biology at scales from molecules to multicellular organisms will be covered by lecture, primary literature, and student presentations. Students will write a research proposal at the end of the course. Cross-list: SSPB 503. Graduate/Undergraduate Equivalency: BIOE 408. Mutually Exclusive: 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 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. Instructor Permission Required. 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.  
*Course Level:* Graduate  
*Description:* Provides students with the ability to use computational methods to understand and analyze biological data. This course will introduce students to advances in computational cell biology from an engineering perspective, and equip them with a suite of tools emerging from systems biology. Topics covered include computational cell engineering, high-throughput analysis, modeling of signaling pathways, network analysis, imaging coupled to modeling, and multi scale modeling. This course is intended for first year BIOE PhD students only.

**BIOE 519 - BIOMATERIALS SYNTHESIS**  
*Short Title:* BIOMATERIALS SYNTHESIS  
*Department:* Bioengineering  
*Grade Mode:* Standard Letter  
*Course Type:* Lecture  
*Credit Hours:* 3  
*Restrictions:* Enrollment is limited to Graduate level students.  
*Course Level:* Graduate  
*Description:* Biomaterials covers the design and synthesis of materials which interact with biologic phenomena such as cell-free, microbial, and mammalian systems. Topics covered include: surfaces and surface fractionalization, biomedical implants and 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 first year BIOE PhD students only.

**BIOE 521 - MICROCONTROLLER APPLICATIONS**  
*Short Title:* MICROCONTROLLER APPLICATIONS  
*Department:* Bioengineering  
*Grade Mode:* Standard Letter  
*Course Type:* Lecture/Laboratory  
*Credit Hours:* 3  
*Restrictions:* Enrollment is limited to Graduate level students.  
*Course Level:* Graduate  
*Prerequisite(s):* BIOE 385  
*Description:* This class covers the usage of microcontrollers in a laboratory setting. We will start with basic electronics and, in the lab component, design, program, and build systems utilizing widely-available microcontrollers (e.g. Arduino, Raspberry Pi). Units in motion control, sensors (light, temperature, humidity, UV/Vis absorbance), and actuation (pneumatics, gears, and motors) will provide students with functional knowledge to design and prototype their own experimental systems for laboratory-scale automation. BIOE 521 students will be expected to complete a final research paper. Instructor Permission Required. Graduate/Undergraduate Equivalency: BIOE 421. Mutually Exclusive: 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.

BIOE 528 - MEDICAL ENGINEERING AND DESIGN LAB
Short Title: MED ENGINEERING & DESIGN 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 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 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:* This 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. Repeated for Credit.

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

BIOE 539 - APPLIED STATISTICS FOR BIOENGINEERING AND BIOTECHNOLOGY  
*Short Title:* APPLIED STAT FOR BIOE BIOTECH  
*Department:* Bioengineering  
*Grade Mode:* Standard Letter  
*Course Type:* Lecture  
*Credit Hours:* 3  
*Restrictions:* Enrollment is limited to Graduate level students.  
*Course Level:* Graduate  
*Description:* Course will cover fundamentals of probability and statistics with emphasis on application to biomedical problems and experimental design. Recommended for students pursuing careers in medicine or biotechnology. Graduate/Undergraduate Equivalency: BIOE 439. Recommended Prerequisite(s): BIOE 252 Mutually Exclusive: Cannot register for BIOE 539 if student has credit for BIOE 439.
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 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 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 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 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: BIOEbuquerque  
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 evolution for cell and protein engineering. Selection and screening technologies and process optimization. Synthetic Biology: engineering and application of gene circuits. Molecular biotechnology applications: Diagnosis, Therapeutics and Vaccines. 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 NANOBIOPHOTONICS  
**Short Title:** OPTIC IMAGING/NANOBIOPHOTONICS  
**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/BIOPHY  
**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:** Seminar  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Prerequisite(s):** BIOE 332 and BIOE 384  
**Description:** This course will explore how bioengineering techniques and principles are applied to understand and model sensory systems, with a focus on the auditory, vestibular, and visual systems. The interaction between the electrical, mechanical and optical aspects of these systems, and ways to modulate these interactions, will be explored. The course will also cover the design of current auditory, visual and somato-sensory prosthetics (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 in 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. Enrollment limited to students in a or Master of Bioengineering degrees.
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: 6
Restrictions: Students in the 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 6 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 BIOE 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 well 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: Study of cell-cell interactions and the role of the extracellular matrix in the structure and function of normal and pathological tissues. Includes strategies to regenerate metabolic organs and repair structural tissues, as well as cell-based therapies to deliver proteins and other therapeutic drugs, with emphasis on issues related to cell and tissue transplantation such as substrate properties, angiogenesis, growth stimulation, cell differentiation, and immunoprotection. Cross-list: CHBE 620.
BIOE 621 - BIOVENTURES  
**Short Title:** BIOVENTURES  
**Department:** Bioengineering  
**Grade Mode:** Satisfactory/Unsatisfactory  
**Course Type:** Seminar  
**Credit Hours:** 2  
**Restrictions:** Enrollment is limited to Graduate level students.

**Description:** A hands-on immersion into life science entrepreneurship through practical lessons that are applied to students’ group projects throughout the course. This practical course will provide the skills and resources to facilitate scientist-driven entrepreneurship in conceiving new life science ventures and translating research ideas into commercial ventures. This course will be taught in conjunction w/UTMB faculty on the Rice campus (BRC) and will meet from Feb 26 - April 30, 2015. To apply for the course, Rice students should fill out the online application located on the URL site listed above. Instructor Permission Required. Repeatable for Credit.  
**Course URL:** [goo.gl/forms/pJ0UMeJItO](http://goo.gl/forms/pJ0UMeJItO/)

**BIOE 627 - MEDICAL 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.

**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:** Lecture  
**Credit Hours:** 1.5  
**Restrictions:** Enrollment is limited to Graduate level students.

**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.

**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.

**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.

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

BIOE 677 - SPECIAL TOPICS  
Short Title: SPECIAL TOPICS  
Department: Bioengineering  
Grade Mode: Standard Letter  
Course Type: Laboratory, Lecture, Seminar, Internship/Practicum  
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: 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. Graduate/Undergraduate Equivalency: BIOE 348. Mutually Exclusive: Cannot register for BIOE 648 if student has credit for BIOE 348.

BIOE 699 - BIOENGINEERING COLLOQUIA  
Short Title: BIOENGINEERING COLLOQUIA  
Department: Bioengineering  
Course Level: Graduate  
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 690 - PROFESSIONAL DEVELOPMENT FOR BIOENGINEERS  
Short Title: PROF DEVELOPMENT FOR BIOE  
Department: Bioengineering  
Prerequisite(s): BIOE 517  
Description: Professional development topics relevant to academic careers including applying for faculty positions, interviewing, negotiating offers, building a lab, obtaining funding and balancing professional obligations. Designed for graduate students planning academic careers in research-intensive bioengineering departments.

BIOE 698 - BIOENGINEERING COLLOQUIA  
Short Title: BIOENGINEERING COLLOQUIA  
Department: Bioengineering  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
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 Degree Program Option Descriptions and Codes*
• Degree Program Option - Applied Bioengineering (MBE degree only): MBE
• Degree Program Option - Global Medical Innovation (MBE degree only): MBE-GMI

CIP Code and Description ¹
• BIOE Major/Program: 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/