

Professional Course

390. Supervised Teaching in Biological and Agricultural Engineering (1-3)

Laboratory—3 hours; tutorial—3-9 hours. Prerequisite: graduate standing; consent of instructor. Tutoring and teaching students in undergraduate courses offered in the Department of Biological and Agricultural Engineering. Weekly conferences with instructor; evaluation of teaching. Preparing for and conducting demonstrations, laboratories and discussions. Preparing and grading exams. May be repeated for a total of 6 units. (S/U grading only.)—I, II, III. (I, II, III.)

Engineering: Biomedical

(College of Engineering)

Simon Cherry, Chairperson of the Department

Department Office. 2303 Genome and Biomedical Sciences Facility; (530) 752-1033; <http://www.bme.ucdavis.edu>

Faculty

Craig Abbey, Ph.D., Adjunct Assistant Professor
Craig Benham, Ph.D., Professor (*Biomedical Engineering; Mathematics; and Genome Center: Bioinformatics*)

John Boone, Ph.D., Professor (*Biomedical Engineering; Medicine: Radiology*)

Simon Cherry, Ph.D., Professor

Fitz-Roy Curry, Ph.D., Professor (*Biomedical Engineering; and Medicine: Physiology and Membrane Biology*)

Katherine Ferrara, Ph.D., Professor

Volkmar Heinrich, Ph.D., Assistant Professor

Tonya Kuhl, Ph.D., Professor (*Biomedical Engineering; and Chemical Engineering & Materials Sciences*)

J. Kent Leach, Ph.D., Assistant Professor

Angelique Louie, Ph.D., Associate Professor

Laura Marcu, Ph.D., Associate Professor

Tingrui Pan, Ph.D., Assistant Professor

Anthony Passerini, Ph.D. Assistant Professor

Jinyi Qi, Ph.D., Associate Professor

Subhadip Raychaudhuri, Ph.D., Assistant Professor

Alexander Revzin, Ph.D., Assistant Professor

Leonor Saiz, Ph.D., Assistant Professor

Michael Savageau, Ph.D., Professor

Scott Simon, Ph.D., Professor

Julie Sutcliffe, Ph.D. Assistant Professor

(*Biomedical Engineering and Assistant Research Engineer CMGI*)

Soichiro Yamada, Ph.D., Assistant Professor

Yohei Yokobayashi, Ph.D., Assistant Professor

The Biomedical Engineering Major

Modern Biomedical Engineering is a diverse and interdisciplinary area of study that integrates knowledge drawn from engineering and the biomedical sciences. Biomedical Engineers work in systems ranging from medical imaging to the design of artificial organs. Some major recent research advances in Biomedical Engineering include the left ventricular assist device (LVAD), artificial joints, kidney dialysis, bioengineered skin, angioplasty, computed tomography (CT), and flexible endoscopes.

Students who choose Biomedical Engineering are interested in being of service to human health but do not routinely interact directly with patients. The mission of the BS degree program of the Department of Biomedical Engineering is to provide a cutting-edge, interdisciplinary, biomedical engineering education to students. To accomplish this, the Biomedical Engineering curriculum has been designed to provide a solid foundation in both engineering and the life sciences, and provide sufficient flexibility in the upper division requirements to encourage students to explore specializations within Biomedical Engineering.

The program produces highly qualified, interdisciplinary engineers who are well-prepared to pursue graduate or professional degrees and/or careers in industry, hospitals, academic research institutes, teaching, national laboratories, or government regulatory agencies. The Bureau of Labor Statistics projects that employment growth for Biomedical Engineering will be much faster than the average for all occupations through 2014. As a recently established program, the Biomedical Engineering program is not currently accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The program will pursue accreditation with ABET in the next accreditation cycle.

Objectives

Our teaching is designed to impart a strong foundation in mathematics, life and physical sciences, and engineering, as well as knowledge of contemporary issues at the forefront of biomedical engineering research. Students completing the program will: demonstrate their ability to conduct measurements on and interpret results from experiments involving living systems; design experiments, systems, devices, components, and processes to meet real-world challenges for solutions to problems in biomedical research and development; identify, formulate and solve engineering problems applied to questions in medicine and biology; work effectively in groups and communicate in oral, written, computer-based and graphical forms; have an understanding of the impact of engineering solutions in a global and societal context and a commitment to professionalism and ethical responsibility; be instilled with sense of need for life-long learning; use the techniques, skill, and modern engineering tools necessary for engineering practice and for successful pursuit of post-baccalaureate studies.

For information about the graduate degree options, see the [Biomedical Engineering \(A Graduate Group\)](#), on page 170.

Biomedical Engineering Program

Lower Division Required Courses

	UNITS
Mathematics 21A-21B-21C-21D	16
Mathematics 22A-22B	6
Physics 9A-9B-9C	15
Chemistry 2A-2B-2C, 8A-8B or 118A-118B	21
Engineering 6, 17	8
University Writing Program 1, or English 3, or Comparative Literature 1, 2, 3, or 4, or Native American Studies 5	4
Communication 1	4
Biological Sciences 2A	4
Biomedical Engineering 1, 20	5
General Education electives	8
Minimum Lower Division Units	91
* May not count in lower-division program and towards Engineering and Physical Science electives	

Upper Division Requirements:

Upper Division Required Courses

Engineering 100 or Electrical and Computer Engineering 100	3
Engineering 105, 190	7
Biomedical Engineering 116 or Neurobiology Physiology Behavior 101	5
Biomedical Engineering 105, 106, 107, 108, 109, 110A-110B, 111	30
Sciences electives	8
To be chosen according to specialization.	
Any graded upper division course in the Biological Sciences, Chemistry or Physics including Biological Sciences 2B, 2C, Biomedical Engineering 161A, 161S, 161L and Physics 9D, excluding courses for social science GE topical breadth credit.	
Engineering electives	20
Any graded upper division Biomedical Engineering course (except Biomedical Engineering 161A, 161S, 161L)	

Engineering 35, 45, 102, 103, 104, 106; Electrical and Computer Engineering 110A, 110B, 106, 114, 118, 130A, 130B, 140A, 140B, 150A, 150B, 151, 157A, 157B; Applied Science Engineering 108A, 108B, 161, 165, 166, 167, 169, 170, 171, 172; Biological Systems Engineering 128; Chemical Engineering 160, 161A, 161B, 161L, 170; Materials Science and Engineering 147, 160, 162, 162L, 164, 172, 172L, 174, 174L, 181, 182; Mechanical Engineering 150AB, 152, 154, 165.

General Education electives

16

Minimum Upper Division Units

89

Minimum Units Required for Major

Additional upper division elective policies:

- 2 units from Chemistry 118AB may be applied toward Sciences elective if 118AB are also used to satisfy lower division subject credit.
- 2 units from Electrical and Computer Engineering 100 may be applied toward Engineering elective if Electrical and Computer Engineering 100 is taken to satisfy upper division subject credit.
- 4 units of Biomedical Engineering 199 may be counted toward Engineering or Sciences elective with approval of Biomedical Engineering undergraduate committee.

Sciences electives and Engineering Electives are to be selected in consultation with a staff or faculty adviser.

Areas of Specialization

Because Biomedical Engineering is defined so broadly, a degree in Biomedical Engineering can mean many different things. Specializing in a subfield of engineering can help to provide more in-depth expertise in a focus area. You have the option to specialize in a subfield of Biomedical Engineering through judicious selection of your upper division electives in consultation with a staff or faculty adviser. One of the strengths of the UC Davis program is this flexibility to design your own emphasis. Biomedical Engineering includes a number of diverse areas of study:

Bioinstrumentation

Development of devices used in diagnosis and treatment of disease or in biomedical research. This area applies electronics principles and techniques and can involve computer hardware design.

Biomaterials and Tissue Engineering

The study of living materials or the development of implantable synthetic materials. In this field Biomedical Engineers design materials that are biocompatible or bioactive for use in the human body. This area draws heavily from knowledge in the chemical and biological sciences.

Biomechanics

A broad subfield that includes orthopedic/rehabilitation engineering (design of wheelchairs, prosthetics etc) and the study of mechanical forces produced by biological systems. For example, biomechanics allows a better understanding of the fluid dynamics of blood flow and forces acting on tissue in the artery, to allow design of better cardiovascular interventions. This field involves more intensive study of mechanics, dynamics and thermodynamics.

Medical Imaging

The visualization of living tissues for diagnosis of disease. An imaging scientist can work in areas ranging from developing instruments for imaging, to creating algorithms for three-dimensional reconstruction of imaging data, to generating new contrast agents for enhancing image quality. Depending upon the area of medical imaging of interest, this field can require more in depth study in electronics, signal processing, chemistry or computer programming.

Systems Engineering

Study of basic biological and physiological processes using engineering principles. Techniques and principles from engineering are applied to understand biological systems at a fundamental level. For example, stresses and strains are studied in cells to better understand how they propel themselves through tissues; modeling of biochemical processes allows engineers to mathematically describe chemical reactions occurring in cells in order to predict abnormalities that may lead to development of disease.

Premedical students

If you intend to apply to medical school you will need to fulfill additional coursework to meet admissions requirements for the various medical school programs. These courses will be in addition to the listed curricular requirements.

Courses in Biomedical Engineering (BIM)

Lower Division Courses

1. Introduction to Biomedical Engineering (1)

Lecture—1 hour. Introduction to the field of biomedical engineering with examples taken from the various areas of specialization within the discipline. Areas include cellular and molecular engineering; biomedical imaging; biofluids and transport; musculoskeletal biomechanics; and bioinstrumentation. (P/NP grading only.)—I. (I.)

20. Fundamentals of Bioengineering (4)

Lecture—4 hours. Prerequisite: Physics 9B; Mathematics 21D. Basic principles of mass, energy and momentum conservation equations applied to solve problems in the biological and medical sciences.—III. (III.) Yamada

99. Special Study for Undergraduates (1-5) (P/NP grading only.)

Upper Division Courses

102. Quantitative Cell Biology (4)

Lecture/discussion—4 hours. Prerequisite: Biological Sciences 2A; Physics 9B; Mathematics 22B; Chemistry 8B. Use of engineering principles to understand fundamental cell biology. Emphasis on physical concepts underlying cellular processes including protein trafficking, cell motility, cell division and cell adhesion. Current topics including cell biology of cancer and stem cells will be discussed. Only two units of credit for students who have previously taken Biological Sciences 104 or Molecular and Cellular Biology 143.—I. (I.) Yamada

106. Biotransport Phenomena (4)

Lecture—4 hours. Prerequisite: Neurobiology, Physiology, and Behavior 101 or equivalent, Physics 9B, Mathematics 22B. Principles of heat and mass transfer with applications to biomedical systems; emphasis on mass transfer across cell membranes and the design and analysis of artificial human organs, and basic fluid transport.—II. (II.)

105. Probability, Random Processes, and Statistics for Biomedical Engineers (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Mathematics 21D; upper division. Concepts of probability, random variables and processes, and statistical analysis with applications to engineering problems in biomedical sciences. Contents include discrete and continuous random variables, probability distributions and models, hypothesis testing, statistical inference and stochastic processes. Emphasis on BME applications. Limited to upper division standing.—I. (I.) Saiz

107. Mathematical Methods for Biological Systems (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Mathematics 22A and 22B. Restricted to upper division engineering. Essential mathematical and numerical techniques for engineering problems in medicine and biology. Contents include matrix algebra, linear transforms, ordinary and partial differen-

tial equations, probability and stochastic processes, and an introduction to Monte Carlo and molecular dynamics simulations.—II. (II.) Raychaudhuri

108. Biomedical Signals and Control (4)

Lecture—4 hours. Prerequisite: Mathematics 22B; Engineering 100 (may be taken concurrently). Restricted to upper division Engineering students. Systems and control theory applied to biomedical engineering problems. Time-domain and frequency-domain analyses of signals and systems, convolution, Laplace and Fourier transforms, transfer function, dynamic behavior of first and second order processes, and design of feedback control systems for biomedical applications. No credit for students who have taken Electrical and Computer Engineering 150A; 2 units of credit for students who have taken Mechanical Engineering 171.—III. (III.) Qi

109. Biomaterials (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: course 106. Mechanical and chemical properties of metallic, ceramic, and polymeric implant materials. Properties of bones, joints, and blood vessels. Cellular response to implants, including inflammation, blood coagulation, and wound and fracture healing. Biocompatibility of orthopaedic and cardiovascular materials.—III. (III.) Revzin

110A-110B. Capstone Biomedical Engineering Design (2-2)

Laboratory—3 hours; lecture/discussion—1 hour. Prerequisite: courses 107, 108, 109. Application of bioengineering theory and experimental analysis culminating in the design of a unique solution to a problem. The design may be geared towards current applications in applied biomechanics, biotechnology or medical technology. (Deferred grading only, pending completion of sequence.)—II, III. (II, III.)

111. Biomedical Instrumentation Laboratory (6)

Lecture—4 hours; laboratory—6 hours. Prerequisite: courses 107 and 108; Statistics 120, 131A, or equivalent; Engineering 100; Neurology, Physiology, & Behavior 101. Basic biomedical signals and sensors. Topics include analog and digital records using electronic, hydrodynamic, and optical sensors, and measurements made at cellular, tissue and whole organism level. Limited to upper division Biomedical Engineering majors.—II. (II.) Marcu, Pan

116. Research and Design Methods for Biomedical Engineers (5)

Lecture—2 hours; practice—3 hours; extensive writing. Prerequisite: Biological Sciences 1A; Mathematics 22B; Physics 9C. Introduction to the engineering research and design process as applied to biomedical devices and therapeutics. Small group design projects and presentations in interdisciplinary topics relating biomedical engineering to biology and medicine. GE Credit: Wrt.—I. (I.) Louie

117. Analysis of Molecular and Cellular Networks (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Biological Sciences 1A and Mathematics 22B. Network themes in biology, emphasizing metabolic, genetic, and developmental networks. Mathematical and computational methods for analysis of such networks. Elucidation of design principles in natural networks. Engineering and ethical issues in the design of synthetic networks.—III. (III.) Savageau

126. Tissue Mechanics (3)

Lecture—2 hours; laboratory/discussion—3 hours. Prerequisite: Exercise Science 103 and/or Engineering 45 and/or consent of instructor. Structural and mechanical properties of biological tissues, including bone, cartilage, ligaments, tendons, nerves, and skeletal muscle. (Same course as Exercise Science 126.)—II. (II.) Hawkins

140. Protein Engineering (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Biological Sciences 1A and Chemistry 8B. Restricted to upper division majors in sciences or engineering. Introduction to protein structure and function. Modern methods for designing, producing, and characterizing novel proteins and peptides. Design strategies, computer modeling, heterologous expres-

sion, in vitro mutagenesis. Protein crystallography, spectroscopic and calorimetric methods for characterization, and other techniques.—I. (I.) Sutcliffe-Goulden

141. Cell and Tissue Mechanics (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Physics 9C, Engineering 35, Neurobiology, Physiology, and Behavior 101. Mechanical properties that govern blood flow in the microcirculation. Concepts in blood rheology and cell and tissue viscoelasticity, biophysical aspects of cell migration, adhesion, and motility.—III. (III.) Simon

142. Biomedical Imaging: Basic Principles and Practice (4)

Lecture—3 hours; term paper. Prerequisite: Physics 9D and Mathematics 22B. Basic physics, engineering principles, and applications of biomedical imaging techniques including x-ray imaging, computed tomography, magnetic resonance imaging, ultrasound and nuclear imaging.—I. (I.) Chery

151. Mechanics of DNA (3)

Lecture—3 hours. Prerequisite: Biological Sciences 1A and Mathematics 22B. Structural, mechanical and dynamic properties of DNA. Topics include DNA structures and their mechanical properties, in vivo topological constraints on DNA, mechanical and thermodynamic equilibria, DNA dynamics, and their roles in normal and pathological biological processes. Offered in alternate years.—III. Benham

161A. Biomolecular Engineering (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Biological Sciences 1A; Chemistry 8B; upper division standing. Introduction to the basic concepts and techniques of biomolecular engineering such as recombinant DNA technology, protein engineering, and molecular diagnostics. Only three units of credit for students who have completed course 161S.—I. (I.) Yokobayashi

161L. Biomolecular Engineering Laboratory (2)

Laboratory/discussion—6 hours. Prerequisite: course 161A; upper division Biomedical Engineering major. Introduction to the basic techniques in biomolecular engineering. Laboratory and discussion sessions will cover basic techniques in DNA cloning, bacterial cell culture, protein expression, and data analysis. GE Credit: SciEng.—III. (III.) Yokobayashi

161S. Biomolecular Engineering: Brief Course (1)

Lecture—1 hour. Prerequisite: Biological Sciences 1A; Chemistry 8B; course 161L concurrently. Basic concepts and techniques in biomolecular analysis, recombinant DNA technology, and protein purification and analysis. Not open for credit to students who have completed Biomedical Engineering 161A. Not offered every year.—IV. Yokobayashi

162. Quantitative Concepts in Biomolecular Engineering (4)

Lecture—4 hours. Prerequisite: Mathematics 22B and Physics 9D. Introduction to fundamental physical mechanisms governing structure and function of biomacromolecules. Emphasis on a quantitative understanding of the nano- to microscale biomechanics of interactions between and within individual molecules, as well as of their assemblies, in particular membranes. Offered in alternate years.—II. Heinrich

167. Biomedical Fluid Mechanics (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: course 106 (may be taken concurrently) or Engineering 103. Basic biofluid mechanics, Navier Stokes equations of motion, circulation, respiration and specialized applications including miscellaneous topics such as boundary layer flow. Not open for credit to students who have completed Mechanical Engineering 167C.—I. (I.)

173. Cell and Tissue Engineering (4)

Laboratory/discussion—4 hours. Prerequisite: course 109. Engineering principles to direct cell and tissue behavior and formation. Cell sourcing, controlled delivery of macromolecules, transport within

and around biomaterials, bioreactor design, tissue design criteria and outcomes assessment.—I. (I.) Leach

189A-C. Topics in Biomedical Engineering (1-5)

Prerequisite: consent of instructor. Topics in Biomedical Engineering. (A) Cellular and Molecular Engineering (B) Biomedical Imaging (C) Biomedical Engineering. May be repeated if topic differs. Not offered every year.

190A. Upper Division Seminar in Biomedical Engineering (1)

Seminar—1 hour. Prerequisite: upper division standing. In depth examination of research topics in a small group setting. Question and answer session with faculty members. May be repeated for credit. (P/NP grading only.)—III. (III.) Louie

198. Directed Group Study (1-5)

Prerequisite: consent of instructor. May be repeated up to three times for credit. (P/NP grading only.)—I, II, III. (I, II, III.)

199. Special Study for Advanced Undergraduates (1-5)

Prerequisite: consent of instructor. (P/NP grading only.)

Graduate Courses

202. Cell and Molecular Biology for Engineers (4)

Lecture/discussion—4 hours. Prerequisite: Biological Sciences 104 or Molecular and Cellular Biology 121. Preparation for research and critical review in the field of cell and molecular biology for biomedical or applied science engineers. Emphasis on biophysical and engineering concepts intrinsic to specific topics including receptor-ligand dynamics in cell signaling and function, cell motility, DNA replication and RNA processing, cellular energetics and protein sorting. Modern topics in bioinformatics and proteomics.—II.

204. Physiology for Bioengineers (5)

Lecture—4 hours. Prerequisite: Biological Sciences 1A or equivalent; graduate standing or consent of instructor. Basic human physiology of the nervous, muscular, cardiovascular, respiratory, and renal systems and their interactions; Emphasis on the physical and engineering principles governing these systems, including control and transport processes, fluid dynamics, and electrochemistry.—I. (I.) Benham

209. Scientific Integrity for Biomedical Engineers (2)

Lecture—1 hour; discussion—1 hour. Scientific integrity and ethics for biomedical engineers, with emphasis and discussion on mentoring, authorship and peer review, use of humans and animals in biomedical research, conflict of interest, intellectual property, genetic technology and scientific record keeping. Biomedical Engineering majors only. (S/U grading only.)—III.

210. Introduction to Biomaterials (4)

Lecture—4 hours. Prerequisite: Engineering 45 or consent of instructor. Mechanical and atomic properties of metallic, ceramic, and polymeric implant materials of metallic, ceramic, and polymeric implant materials; corrosion, degradation, and failure of implants; inflammation, wound and fracture healing, blood coagulation; properties of bones, joints, and blood vessels; biocompatibility of orthopaedic and cardiovascular materials. Offered in alternate years.—(II.) Hazelwood

211. Design of Polymeric Biomaterials and Biological Interfaces (4)

Lecture—4 hours. Prerequisite: Engineering 45 or consent of instructor; upper division undergraduates or graduate students. Design, selection and application of polymeric biomaterials. Integration of the principles of polymer science, surface science, materials science and biology.—II. (II.) Revzin

212. Biomedical Heat and Mass Transport Processes (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Mechanical Engineering 165, Biological Systems Engineering 125, Chemical Engineering 153 or the

equivalent. Application of principles of heat and mass transfer to biomedical systems related to heat exchange between the biomedical system and its environment, mass transfer across cell membranes and the design and analysis of artificial human organs. (Same course as Mechanical and Aeronautical Engineering 212.) Offered in alternate years.—(II.) Alderidge

213. Principles and Applications of Biological Sensors (4)

Lecture—4 hours. Prerequisite: Chemistry 2C. Biological sensors based on principles of electrochemical, optical and affinity detection. Methods for integration of sensing elements (e.g. enzymes) into biosensors and miniaturization of biosensors.—I. (I.) Revzin

214. Blood Cell Biomechanics (4)

Lecture—4 hours. Prerequisite: Engineering 102. Mechanical properties that govern blood flow in the microcirculation and cell adhesion and motility. Constitutive equations of vasculature tissue and blood. Blood rheology and viscoelasticity. Red and white blood cell mechanics. Remodeling of blood vessels in disease and engineering of blood vessels and cells.—I. Simon

215. Biomedical Fluid Mechanics and Transport Phenomena (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Engineering 103 or Chemical Engineering 150B or Civil and Environmental Engineering 141. Application of fluid mechanics and transport to biomedical systems. Flow in normal physiological function and pathological conditions. Topics include circulatory and respiratory flows, effect of flow on cellular processes, transport in the arterial wall and in tumors, and tissue engineering. (Same course as Mechanical and Aeronautical Engineering 215.)—III. (III.) Barakat

216. Advanced Topics in Cellular Engineering (4)

Lecture—4 hours. Prerequisite: course 214 or consent of instructor. Advanced research strategies and technologies used in the study of immune function and inflammation. Static and dynamic measurements of stress, strain, and molecular scale forces in blood and vascular cells, as well as genetic approaches to the study of disease.—III. (III.) Simon

217. Mechanobiology in Health and Disease (4)

Lecture/discussion—4 hours. Prerequisite: course 106 or equivalent (e.g. Engineering 103), Biological Sciences 101 or equivalent, Neurology, Physiology, and Behavior 101 or equivalent. Principles by which biomechanical forces affect cell and tissue function to impact human health and disease. Emphasis on cardiovascular system: structure and function, biofluid mechanics and mechanotransduction, disease mechanisms and research methods. Cartilage, bone and other systems; current topics discussed.—III. (III.) Passerini

218. Microsciences (4)

Lecture/discussion—4 hours. Introduction to the theory of physical and chemical principles at the microscale. Scale effects, surface tension, microfluidic mechanics, micromechanical properties, intermolecular interactions and micro tribology.—I. (I.) Pan

223. Multibody Dynamics (4)

Lecture—4 hours. Prerequisite: Engineering 102. Coupled rigid-body kinematics/dynamics; reference frames; vector differentiation; configuration and motion constraints; holonomicity; generalized speeds; partial velocities; mass; inertia tensor/theorems; angular momentum; generalized forces; comparing Newton/Euler, Lagrange's, Kane's methods; computer-aided equation derivation; orientation; Euler; Rodrigues parameters. (Same course as Mechanical and Aeronautical Engineering 223.)—II. (II.) Eke, Hubbard

225. Spatial Kinematics and Robotics (4)

Lecture—3 hours; laboratory—3 hours. Prerequisite: C Language and course 222. Spatial kinematics, screw theory, spatial mechanisms analysis and syn-

thesis, robot kinematics and dynamics, robot workspace, path planning, robot programming, real-time architecture and software implementation. (Same course as Mechanical and Aeronautical Engineering 225.) Offered in alternate years.—II. Cheng

227. Research Techniques in Biomechanics (4)

Lecture—2 hours; laboratory—4 hours; term paper/discussion—1 hour. Prerequisite: consent of instructor, Mathematics 22B; Exercise Science 115 recommended. Experimental techniques for biomechanical analysis of human movement are examined. Techniques evaluated include data acquisition and analysis by computer, force platform analysis, strength assessment, planar and three-dimensional videography, data reduction and smoothing, body segment parameter determination, electromyography, and biomechanical modeling. (Same course as Mechanical and Aeronautical Engineering 227/Exercise Science 227.)—II. (II.) Williams, Hawkins

228. Skeletal Muscle Mechanics: Form, Function, Adaptability (4)

Lecture—4 hours. Prerequisite: basic background in biology, physiology, and engineering; Engineering 35 and 45, Mathematics 21D; Neurobiology, Physiology, and Behavior 101 recommended. Basic structure and function of skeletal muscle examined at the microscopic and macroscopic level. Muscle adaptation in response to aging, disease, injury, exercise, and disuse. Analytic models of muscle function are discussed. (Same course as Exercise Science 228.)—I. (I.) Hawkins

231. Musculo-Skeletal System Biomechanics (4)

Lecture—4 hours. Prerequisite: Engineering 102. Mechanics of skeletal muscle and mechanical models of muscle, solution of the inverse dynamics problem, theoretical and experimental methods of kinematic and kinetic analysis, computation of intersegmental load and muscle forces, applications to gait analysis and sports biomechanics. (Same course as Mechanical and Aeronautical Engineering 231.)—III. (III.) Hull

232. Skeletal Tissue Mechanics (3)

Lecture—3 hours; laboratory—1 hour. Prerequisite: Engineering 104B. Overview of the mechanical properties of the various tissues in the musculoskeletal system, the relationship of these properties to anatomic and histologic structure, and the changes in these properties caused by aging and disuse. The tissues covered include bone, cartilage and synovial fluid, ligament and tendon. (Same course as Mechanical and Aeronautical Engineering 232.)—III. (III.) Martin

239. Advanced Finite Elements and Optimization (4)

Lecture—4 hours. Prerequisite: Engineering 180 or Applied Science 115 or Mathematics 128C. Introduction to advanced finite elements and design optimization methods, with application to modeling of complex mechanical, aerospace and biomedical systems. Application of states of the art in finite elements in optimum design of components under realistic loading conditions and constraints. Offered in alternate years. (Same course as Mechanical Engineering 239.)—(II.) Sarigul-Klijn

240. Computational Methods in Nonlinear Mechanics (4)

Lecture—4 hours. Prerequisite: Applied Science Engineering 115 or Mathematics 128B or Engineering 180. Deformation of solids and the motion of fluids treated with state-of-the-art computational methods. Numerical treatment of nonlinear dynamics; classification of coupled problems; applications of finite element methods to mechanical, aeronautical, and biological systems. Offered in alternate years. (Same course as Mechanical and Aeronautical Engineering 240.)—II. Sarigul-Klijn

241. Introduction to Magnetic Resonance Imaging (3)

Lecture—3 hours. Prerequisite: Physics 9D, Mathematics 22B. Equipment, methods, medical applications of MRI. Lectures review basic, advanced pulse sequences, image reconstruction, display and tech-

Quarter Offered: I=Fall, II=Winter, III=Spring, IV=Summer; 2009-2010 offering in parentheses

General Education (GE) credit: ArtHum=Arts and Humanities; SciEng=Science and Engineering; SocSci=Social Sciences; Div=Social-Cultural Diversity; Wrt=Writing Experience

nology and how these are applied clinically. Lecture complements a more technical course. (course 246 can be taken concurrently.)—I. (I.) Buonocore

242. Introduction to Biomedical Imaging (4)

Lecture—4 hours. Prerequisite: Physics 9D and Electrical and Computer Engineering 106 or consent of instructor. Basic physics and engineering principles of image science. Emphasis on ionizing and nonionizing radiation production and interactions with the body and detectors. Major imaging systems: radiography, computed tomography, magnetic resonance, ultrasound, and optical microscopy.—I. (I.) Insana, Boone, Seibert

243. Radiation Detectors for Biomedical Applications (4)

Lecture/discussion—4 hours. Prerequisite: Physics 9D, Mathematics 21D, 22B. Radiation detectors and sensors used for biomedical applications. Emphasis on radiation interactions, detection, measurement and use of radiation sensors for imaging. Operating principles of gas, semiconductor, and scintillation detectors.—II. (II.) Chery

246. Magnetic Resonance Technology (3)

Lecture—3 hours. Prerequisite: Physics 9D, Mathematics 22B. Course covers MRI technology at an advanced level with emphasis on mathematical descriptions and problem solving. Topics include spin dynamics, signal generation, image reconstruction, pulse sequences, biophysical basis of T1, T2, RF, gradient coil design, signal to noise, image artifacts.—I. (I.) Buonocore

247. Current Concepts in Magnetic Resonance Imaging I (3)

Lecture—3 hours. Prerequisite: course 241 or 246 or consent of instructor. Modern pulse sequences, pulse sequence options, and biomedical/industrial applications; velocity encoded phase imaging and angiography, echo planar imaging, spiral imaging, computer simulation of MRI, fast spin echo, other topics.—II. (II.) Buonocore

248. Current Concepts in Magnetic Resonance Imaging II (3)

Lecture—3 hours. Prerequisite: course 247 or consent of instructor. Continuation of lecture coverage of modern pulse sequences, pulse sequence options, and biomedical/industrial applications: Control of tissue contrast by magnetization refocusing and spoiling, RF pulse design, diffusion and perfusion imaging, image artifact reduction methods, others.—III. (III.) Buonocore

250. Mathematical Methods of Biomedical Imaging (4)

Lecture—4 hours. Prerequisite: graduate standing or consent of instructor. Advanced mathematical techniques with emphasis on imaging systems. Matrices and vector spaces, Fourier analysis, integral transforms, signal representations, probability and random processes.—I. (I.) Insana

251. Medical Image Analysis (4)

Lecture—4 hours. Prerequisite: Electrical and Computer Engineering 106. Techniques for assessing the performance of medical imaging systems. Principles of digital image formation and processing. Measurements that summarize diagnostic image quality and the performance of human observers viewing those images. Definition of ideal observer and other mathematical observers that may be used to predict performance from system design features.—II. Insana

252. Computational Methods in Biomedical Imaging (4)

Lecture—4 hours. Prerequisite: course 108, Mathematics 22B, Electrical and Computer Engineering 106. Analytic tomographic reconstruction from projections in 2D and 3D; model-based image reconstruction methods; maximum likelihood and Bayesian methods; applications to CT, PET, and SPECT.—II. (II.) Qi

270. Biochemical Systems Theory (4)

Lecture—4 hours. Prerequisite: course 202 concurrently or consent of instructor. Systems biology at the biochemical level. Mathematical and computational methods emphasizing nonlinear representation, dynamics, robustness, and optimization. Case stud-

ies of signal-transduction cascades, metabolic networks and regulatory mechanisms. Focus on formulating and answering fundamental questions concerning network function, design, and evolution.—I. (I.) Savageau

271. Gene Circuit Theory (4)

Lecture—4 hours. Prerequisite: course 270 or 202 and consent of instructor. Analysis, design, and construction of gene circuits. Modeling strategies, elements of design, and methods for studying variations in design. Case studies involving prokaryotic gene circuits to illustrate natural selection, discovery of design principles, and construction of circuits for engineering objectives.—II. (II.) Savageau

272. Tissue Engineering (3)

Lecture/discussion—3 hours. Prerequisite: Biological Sciences 104 or Molecular and Cellular Biology 121. Based on morphogenetic signals, responding stem cells and extracellular matrix scaffolding. Design and development of tissues for functional restoration of various organs damaged/lost due to cancer, disease and trauma. Fundamentals of morphogenetic signals, responding stem cells and extracellular matrix scaffolding.—II. (II.) Reddi

273. Integrative Tissue Engineering and Technologies (4)

Lecture/discussion—4 hours. Prerequisite: courses 202 and 204 or similar; graduate standing; course 272 strongly encouraged, although not a prerequisite. Engineering principles to direct cell and tissue behavior and formation. Contents include controlled delivery of macromolecules, transport within and around biomaterials, examination of mechanical forces of engineered constructs, and current experimental techniques used in the field.—III. (III.) Leach

281. Acquisition and Analysis of Biomedical Signals (4)

Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 100, Statistics 130A. Basic concepts of digital signal recording and analysis; sampling; empirical modeling; Fourier analysis, random processes, spectral analysis, and correlation applied to biomedical signals.—III.

282. Biomedical Signal Processing (4)

Lecture—4 hours. Prerequisite: Electrical and Computer Engineering 150A, 150B. Characterization and analysis of continuous- and discrete-time signals from linear systems. Examples drawn from physiology illustrate the use of Laplace, Z, and Fourier transforms to model biological and bioengineered systems and instruments. Filter design and stochastic signal modeling. Genomic signal processing.—II. Insana

284. Mathematical Methods for Biomedical Engineers (4)

Lecture/discussion—4 hours. Prerequisite: Mathematics 22B, Statistics 130A, or consent of instructor; upper division biomedical engineering majors, and graduate students in sciences and engineering; priority given to Biomedical Engineering graduate students. Theoretical applications of linear systems, ordinary and partial differential equations, and probability theory and random processes that describe biological systems and instruments that measure them. Students will be introduced to numerical solution techniques in MATLAB.—(I.) Raychaudhuri

285. Computational Modeling in Biology and Immunology (4)

Lecture/discussion—4 hours. Prerequisite: graduate standing or consent of instructor. Essential computational modeling techniques in biology and immunology. Emphasis on applications of Monte Carlo methods in studying immune recognition and response. Introduction to Brownian dynamics and Molecular dynamics simulations as applied in molecular level diffusion and interactions.—III. (III.) Raychaudhuri

286. Nuclear Imaging in Medicine and Biology (4)

Lecture/discussion—4 hours. Prerequisite: course 243 or consent of instructor. Radioactive decay, interaction of radiation with matter, radionuclide

production, radiation detection, digital autoradiography, gamma camera imaging, single photon emission computed tomography, positron emission tomography and applications of these techniques in biology and medicine.—III. (III.) Chery

287. Concepts in Molecular Imaging (4)

Lecture—2 hours; lecture/discussion—2 hours; term paper. Prerequisite: Chemistry 2C, Mathematics 21C, Physics 9D, consent of instructor. Current techniques and tools for molecular imaging. Emphasis on learning to apply principles from the physical sciences to imaging problems in medicine and biology.—III. (III.) Louie, Sutcliffe-Goulden

289A-E. Selected Topics in Biomedical Engineering (1-5)

Variable. Prerequisite: consent of instructor. Selected topics in (A) Biinstrumentation and Signal Processing; (B) Biomedical Imaging; (C) Biofluids and Transport; (D) Orthopedic Biomechanics; (E) Analysis of Human Movement. May be repeated for credit.—I, II, III. (I, II, III.)

290. Seminar (1)

Seminar—1 hour. Seminar in biomedical engineering. (S/U grading only.)

290C. Graduate Research Conference (1)

Discussion—1 hour. Prerequisite: consent of instructor. Individual and/or group conference on problems, progress, and techniques in biomedical engineering research. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

299. Research (1-12)

(S/U grading only.)

Professional Course

396. Teaching Assistant Training Practicum (1-4)

Prerequisite: graduate standing. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

Engineering: Chemical Engineering and Materials Science

(College of Engineering)

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Faculty

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David E. Block, Ph.D., Associate Professor (*Chemical Engineering, Viticulture and Enology*)

Roger B. Boulton, Ph.D., Professor and Endowed Chair (*Chemical Engineering, Viticulture and Enology*)

Stephanie R. Dungan, Ph.D., Professor (*Chemical Engineering, Food Science and Technology*)

Nael El-Farra, Ph.D., Assistant Professor

Roland Fallor, Ph.D., Associate Professor

Bruce C. Gates, Ph.D., Distinguished Professor

Jeffery C. Gibeling, Ph.D., Professor

Joanna R. Groza, Ph.D., Professor

Brian G. Higgins, Ph.D., Professor

David G. Howitt, Ph.D., Professor

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Karen A. McDonald, Ph.D., Professor

Adam Moulé, Ph.D., Assistant Professor

Amiya K. Mukherjee, D.Phil., *Distinguished*

Professor, Academic Senate Distinguished Teaching Award, UC Davis Prize for Teaching

Quarter Offered: I=Fall, II=Winter, III=Spring, IV=Summer; 2009-2010 offering in parentheses

General Education (GE) credit: ArtHum=Arts and Humanities; SciEng=Science and Engineering; SocSci=Social Sciences; Div=Social-Cultural Diversity; Wrt=Writing Experience