design; visits to the synchrotron radiation facilities SSRL and ALS; optional experiments. Offered in alternate years.—III. Cramer

280A-280B-280C. Plasma Physics and Controlled Fusion (3-3-3)

Lecture—3 hours. Prerequisite: course 234B or consent of instructor. Equilibrium plasma properties; single particle motion; fluid equations; waves and instabilities in a fluid plasma; plasma kinetic theory and transport coefficients; linear and nonlinear Vlasov theory; fluctuations, correlations and radiation; inertial and magnetic confinement systems in controlled fusion.—I, II, III. (I, II, III.) Luhmann, Hwang

285A. Physics and Technology of Microwave Vacuum Electron Beam Devices I (4)

Lecture—4 hours. Prerequisite: B.S. degree in physics or electrical engineering or the equivalent background. Physics and technology of electron beam emissions, flow and transport, electron gun design, space charge waves and klystrons. Offered in alternate years.—(III.) Luhmann

285B. Physics and Technology of Microwave Vacuum Electron Beam Devices II (4)

Lecture—4 hours. Prerequisite: 285A. Theory and experimental design of traveling wave tubes, backward wave oscillators, and extended interaction oscillators. Offered in alternate years.—(I.) Luhmann

285C. Physics and Technology of Microwave Vacuum Electron Beam Devices III (4)

Lecture—4 hours. Prerequisite: 285B. Physics and technology of gyrotrons, gyro-amplifiers, free electron lasers, magnetrons, crossfield amplifiers and relativistic devices. Offered in alternate years.—(II.) Luhmann

285D. Physics and Technology of Microwave Vacuum Electron Beam Devices IV (4)

Lecture—4 hours. Prerequisite: 285C. Computational models of vacuum electron beam devices. Offered in alternate years.—(III.) Luhmann

289A-N. Special Topics in Applied Science (1-5)

Lecture, laboratory, or combination. Prerequisite: graduate standing or permission of instructor. Special topics in the following areas: (A) Atomic, Molecular, and Optical Physics; (B) Chemical Physics; (C) Computational Physics; (D) Biophotonics/Biotechnology; (E) Materials Science; (F) Imaging Science and Photonics; (G) Nonlinear Optics; (H) Plasma/Fusion Energy Physics; (I) Quantum Electronics; (J) Condensed Matter/Statistical Physics; (K) Classical Optics; (L) Microwave and Millimeter-Wave Technology; (M) Synchrotron Radiation Science; (N) Space Physics. May be repeated for credit up to a total of five units per segment when topic differs.—I, II, III. (I, II, III.)

290. Seminar (1-2)

Seminar—1-2 hours. (S/U grading only.)

290C. Graduate Research Group Conference (1)

Discussion—1 hour. Prerequisite: consent of instructor. May be repeated for credit. (S/U grading only.)

298. Group Study (1-5)

(S/U grading only.)

299. Research (1-12)

(S/U grading only.)

Courses in Biophotonics (BPT)

Graduate Courses

280. Biophotonics Internship (7-12)

Internship—36 hours. Prerequisite: graduate standing; consent of instructor. Open only to students in the designated emphasis in Biophotonics. Research experience distinct from the student's dissertation topic at an industrial company, a national laboratory, or a cross-college laboratory for one quarter. (S/U grading only.)—I, II, III. (I, II, III.)

290. Biophotonics Seminar (1)

Seminar—1 hour. Prerequisite: graduate standing or consent of instructor. Presentation of current research in the area of biophotonics by experts in the field, followed by group discussions. May be repeated up to three times for credit. (S/U grading only.)—I, II, III (I, II, III.) Yeh

Engineering: Biological and Agricultural

(College of Engineering)

Raul H. Piedrahita, Ph.D., Chairperson of the Department

Department Office. 2030 Bainer Hall (530) 752-0102; *http://bae.engineering.ucdavis.edu*

Faculty

Michael J. Delwiche, Ph.D., Professor
Julia Fan, Ph.D., Assistant Professor
Fadi A. Fathallah, Ph.D., Professor
D. Ken Giles, Ph.D., Professor
Mark E. Grismer, Ph.D., Professor
(Land, Air and Water Resources)
Bruce R. Hartsough, Ph.D., Professor
Bryan M. Jenkins, Ph.D., Professor
Tina Jeoh, Ph.D., Assistant Professor
Kathryn McCarthy, Ph.D., Professor
(Food Science and Technology)
Michael J. McCarthy, Ph.D., Professor
(Food Science and Technology)
Nitin Nitin, Ph.D., Assistant Professor
(Food Science and Technology)
Ning Pan, Ph.D., Professor *(Textiles and Clothing)*
Raul H. Piedrahita, Ph.D., Professor
R. Paul Singh, Ph.D., Professor
David C. Slaughter, Ph.D., Professor
Shrinivasa K. Upadhyaya, Ph.D., Professor
Jean S. VanderGheynst, Ph.D., Professor
Stavros G. Vougioukas, Ph.D., Assistant Professor
Wesley W. Wallender, Ph.D., Professor
(Land, Air and Water Resources)
Ruihong Zhang, Ph.D., Professor

Emeriti Faculty

William J. Chancellor, Ph.D., Professor Emeritus
Pictiaw (Paul) Chen, Ph.D., Professor Emeritus
Roger E. Garrett, Ph.D., Professor Emeritus
John R. Goss, M.S., Professor Emeritus
David J. Hills, Ph.D., Professor Emeritus
John M. Krochta, Ph.D., Professor Emeritus
Miguel Mariño, Ph.D., Professor Emeritus
R. Larry Merson, Ph.D., Professor Emeritus
John A. Miles, Ph.D., Professor Emeritus
Stanton R. Morrison, Ph.D., Professor Emeritus
Richard E. Plant, Ph.D., Professor Emeritus
James W. Rumsey, M.S., Senior Lecturer Emeritus
Thomas A. Rumsey, Ph.D., Professor Emeritus
Verne H. Scott, Ph.D., Professor Emeritus
James F. Thompson, M.S., Extension Specialist Emeritus
Wesley E. Yates, M.S., Professor Emeritus

Affiliated Faculty

Atungulu, Griffiths, Ph.D., Associate Project Engineer
Dennis R. Heldman, Ph.D., Adjunct Professor
Larry Joh, Ph.D., Academic Coordinator
Zhongli Pan, Ph.D., Adjunct Professor
Mir S. Shafii, Ph.D., Lecturer
Martha Stiles, M.S., Academic Coordinator
Herbert B. Scher, Ph.D., Research Engineer

Mission. The Department of Biological and Agricultural Engineering is dedicated to the advancement of the discipline of Biological Engineering and to the conduction of research under its many diverse areas of application. Biological engineering (also called biological systems engineering) is the biology-based engineering discipline that integrates life sciences with engineering in the advancement and application of fundamental concepts of biological systems from molecular to ecosystem levels. Within this discipline, our faculty work in a range of research areas including agricultural production/natural resources, biotechnology engineering, and food engineering.

The mission of the department is to discover, develop, apply, and disseminate knowledge for the sustainable production, management, and use of biological materials, and to educate students for this work. Our goals are to advance the science, teach the principles and application, and disseminate the knowledge of engineering needed to produce, distribute, and process biological products such as food and fiber, while conserving natural resources, preserving environmental quality, and ensuring the health and safety of people.

Objectives. We educate students in the fundamentals of mathematics, physical and biological sciences, and engineering, balanced with the application of principles to practical problems. We teach students to develop skills for solving engineering problems in biological systems through use of appropriate analysis, synthesis, and engineering design techniques. We prepare students for entry into engineering practice and graduate education, as well as engagement in life-long learning. We foster the ability of our students to collaborate and communicate effectively, and provide an awareness of the importance of economics, professional responsibility, and the environment.

Students graduating with a B.S. degree in Biological Systems Engineering from UC Davis are prepared to:

- Apply life sciences in engineering at the biochemical, cellular, organismal, and macro levels,
- Solve biological systems engineering problems while employed in the private or public sector,
- Consider the environmental consequences of their engineering activities,
- Communicate effectively with professional colleagues and public constituencies,
- Act in an ethical manner, and
- Continue their education in a changing professional world.

The Biological Systems Engineering Undergraduate Program

Biological Systems Engineering is an engineering major that uses biology as its main scientific base. In the new age of biology and biotechnology, engineers are needed to work side by side with life scientists to bring laboratory developments into commercial production. Industries in plant and animal production, bioenergy, bioprocessing, biotechnology, food processing, aquaculture, agriculture, and forest production all need engineers with strong training in biology. Concern for environmental resources and their preservation creates many engineering opportunities as society strives to maintain a balance within the biosphere.

In the freshman and sophomore years, the Biological Systems Engineering major requires sequences of courses standard in all engineering programs, including mathematics, physics, chemistry, engineering science, and humanities. In addition, the Biological Systems Engineering major also requires courses in the biological sciences. In the junior and senior years, core courses are taken in the discipline of biological engineering, involving the integration of engineering with the life sciences.

Biological Systems Engineering Program

The Biological Systems Engineering program is accredited by the Engineering Accreditation Commission of ABET; *http://www.abet.org*.

Students are encouraged to carefully adhere to all prerequisite requirements. The instructor is authorized to drop students from a course for which stated prerequisites have not been completed.

Lower Division Required Courses

	UNITS
Mathematics 21A-21B-21C-21D	16
Mathematics 22A-22B	6
Physics 9A-9B-9C	15
Chemistry 2A-2B	10
Biological Sciences 2A-2B-2C	14
Engineering 6, 35, 17	12
Biological Systems Engineering 1, 75	8
University Writing Program 1	4
Communication 1 or 3	4
Minimum Lower Division Units	**89**

Upper Division Requirements:

In the junior and senior years, the Biological Systems Engineering major requires courses that cover the core discipline of biological engineering by integrating biology and physical sciences with engineering. Depending on your area of interest, you may select elective courses from one of three specializations, or you may develop your own specialization in consultation with your adviser. The areas of specialization are offered to help you select your electives, but it is not necessary for you to select or declare a specialization. If your career objective is a professional degree in the health sciences (e.g., medicine, veterinary medicine, or dentistry), you should consult with advisers from the appropriate school to plan for successful admission and to ensure that you take specific courses that may be required and that you have the necessary experience. The upper division requirements are listed following the areas of specialization:

- Biotechnology Engineering
- Agricultural and Natural Resources Engineering
- Food Engineering

Areas of Specialization

Biotechnology Engineering. Students specializing in biotechnology engineering integrate analysis and design with applied biology to solve problems in the production of energy from renewable biological resources, in transferring laboratory developments to large-scale biotechnical production, and in the development of biosensors and biomaterials. Students interested in biotechnology engineering may focus on the mechanisms and processes for the sustainable production and use of energy from renewable biological sources. Students may also focus on addressing the challenges in scaling up the production of genetically altered plants, plant materials and food products, production, packaging, and application of biocontrol agents for plant pests and diseases, microbial production of biological products, tissue culture, and bioremediation. Students may also focus on the development of biosensors for the detection of microorganisms or specific substances, or on the development of products based on biological processes and materials. The recommended electives provide students with strong training in genetics, biochemistry, microbiology, molecular biology, and plant production, in addition to engineering courses on topics such as process design and life-cycle analysis. Modern laboratory techniques in biochemistry are also included in the specialization to provide hands-on skills.

Biological engineers specializing in biotechnology engineering will be needed in the future to work within industrial, governmental, and academic settings in the U.S. and around the world.

Recommended biological science electives:

Biological Sciences 101, 102, 103

Microbiology 102

Molecular and Cellular Biology 120L

Plant Biology 113

Recommended engineering electives:

Biological Systems Engineering 161

Chemical Engineering 161B, 161C, 161L

Civil and Environmental Engineering 143, 148A, 149, 150, 153

Engineering 180

Mechanical Engineering 161, 162, 163

Suggested advisers. M. Delwiche, J. Fan, K. Giles, M. Grismer, B. Hartsough, B. Jenkins, T. Jeoh, N. Pan, J. VanderGheynst, N. Nitin, R. Zhang

Agricultural and Natural Resources Engineering. Students specializing in agricultural and natural resources engineering integrate analysis and design with applied biology to solve problems in producing, transporting and processing biological products leading to food, fiber, energy, pharmaceuticals and other human needs. Students may focus on automation of agricultural activities and on the biomechanics of humans and animals involved in agriculture. Students specializing in agricultural and natural resources engineering may also focus on engineering issues related to the sustainable use of natural resources, particularly water, but also land and air. Agricultural and natural resources engineers design machinery, processes, and systems for productive plant and animal culture, including managing nutrients and waste, while minimizing adverse environmental effects. The recommended electives provide students with the fundamental principles of agricultural production and a broad background in engineering and natural resources.

Depending on their specific interests, agricultural and natural resources engineers are employed as practicing professionals and managers with agricultural producers, equipment manufacturers, irrigation districts, food processors, consulting engineering firms, start-up companies and government agencies. Graduates with particular interests in biomechanics may go on to work on the design, evaluation, and application of human-centered devices and systems (e.g., medical devices), as well as on improving worker's health and safety.

Recommended biological science electives:

Animal Emphasis

Avian Sciences 100

Animal Science 143, 144, 146

Neurobiology, Physiology, and Behavior 101

Soil Science 100

Aquaculture Emphasis

Animal Science 118, 131, 136A

Applied Biological Systems Technology 163

Wildlife, Fish, and Conservation Biology 120, 121

Biomechanics Emphasis

Biological Sciences 102

Neurobiology, Physiology and Behavior 101

Exercise Biology 103

Cell Biology and Human Anatomy 101

Plant Emphasis

Entomology 100

Environmental Horticulture 102

Environmental Science and Policy 100

Environmental Toxicology 101

Hydrologic Sciences 124

Microbiology 120

Plant Biology 111

Soil Science 100

Plant Sciences 101, 110A, 114, 142

Recommended engineering electives:

Biological Systems Engineering 114, 120, 128, 145

Biomedical Engineering 109, 116, 126

Civil and Environmental Engineering 140, 141, 142, 144, 145, 148A, 171

Engineering 111, 121, 180

Additional recommended electives:

Applied Biological Systems Technology 150, 161, 165

Suggested Advisers. M. Delwiche, J. Fan, F. Fathallah, K. Giles, M. Grismer, B. Hartsough, B. Jenkins, R. Piedrahita, D. Slaughter, S. Upadhyaya, S. Vougioukas, J. VanderGheynst, W. Wallender, R. Zhang

Food Engineering. The food industry is the largest industrial sector of the U. S. economy. Students specializing in food engineering conceive, design, and operate food processes, equipment, and plants for the production of high quality, safe, and nutritious food with minimal impact on the environment. Students learn to apply engineering principles and concepts to handling, storing, processing, packaging, and distributing food and related products. In addition to engineering principles, the food engineering specialization is intended to provide an understanding of the chemical, biochemical, microbiological, and physical characteristics of foods. In the junior and senior years, students take courses that focus on the integration of biological and food science with engineering. Concepts of food refrigeration, freezing, thermal processing, drying, and other food operations are studied.

Depending on their specific interests, food engineers are employed as practicing engineers, scientists, and managers in the food industry.

Recommended biological sciences electives:

Biological Sciences 101, 102, 103

Environmental Science and Policy 110

Environmental Toxicology 101

Food Science and Technology 104, 104L, 119, 128

Plant Sciences 172

Recommended engineering electives:

Biological Systems Engineering 161

Chemical Engineering 157

Mechanical Engineering 171, 172

Suggested Advisers. K. McCarthy, M. McCarthy, N. Nitin, R. P. Singh, D. Slaughter

Upper Division Required Courses

	UNITS
Chemistry 8A or 118A	2 or 4
Chemistry 8B or 118B	4
Engineering 100, 102, 104 105, 106	18
Biological Systems Engineering 103, 125, 127, 130, 165, 170A, 170B, 170BL, 170C, 170CL	29
Biological Systems Engineering electives-Select a minimum of 4 units from all upper-division Biological Systems Engineering courses not otherwise required, with the exception of Biological Systems Engineering courses 189-199	4
Statistics 100	4
Engineering electives—Select a minimum of 3 units. All upper division courses offered by the College of Engineering may be taken as engineering electives with the exception of the following: Civil and Environmental Engineering 123, Computer Science Engineering 188, Engineering 103, 160, all courses numbered 190-197 and 199 (except Engineering 190, which may be taken for 2 units of engineering elective credit)	3
Biological science electives—All upper-division courses in the College of Biological Sciences (with the exception of Biological Sciences 132, Evolution and Ecology 175, Exercise Biology 102, 112, 115, 118 through 149L, Microbiology 100 and all courses numbered 190-199) may be used as biological science electives. The following courses may also be taken as biological science electives: Applied Biological Systems Technology 161; Animal Science 118, 143, 144, 146; Agricultural Management and	

Rangeland Resources 110A; Atmospheric Science 133; Avian Sciences 100; Cell Biology and Human Anatomy 101, 101L; Entomology 100; Environmental Horticulture 102; Environmental Science Policy and Management 120, 182, 185 (offered at UC Berkeley); Environmental Science and Policy 100, 110, 155; Environmental Toxicology 101, 112A, 131; Food Science and Technology 102A, 104L, 119, 120, 121, 128, 159; Infectious Diseases 141; Soil Science 100; Wildlife, Fish, and Conservation Biology 121. Students may choose other upper division courses with substantial biological content offered by the College of Agricultural and Environmental Sciences; consultation with a faculty adviser and approval by petition is required)........ 3
Upper Division Composition Requirement* one course from the following: University Writing Program 101, 102B, 102E, 102F, 102G, 104A, 104E, 104F 4
Minimum Upper Division Units............... 72

**The Upper-Division composition exam administered by the College of Letters and Sciences cannot be used to satisfy the upper-division composition requirement for students in the Biological Systems Engineering program.*

Minimum Units Required for Major..... 185

Master Undergraduate Adviser. M. Delwiche

Energy Minor Programs

There is an urgent need to develop and commercialize technologies for the sustainable conversion and use of energy. The goal of these minors is to prepare students for careers that require training in energy science and technology and energy policy. Clean-tech and green-tech markets including energy are some of the fastest growing in new investment, and well-trained individuals in all related fields are needed to provide the level of expertise required to advance technology and policy, and to satisfy state, national, and international objectives for greater energy sustainability. The minors are expected to accommodate persons of diverse background with educational interests in areas that may include engineering, science, policy, economics, planning, and management.

Energy Science and Technology Minor

All courses must be taken for a letter grade. Grade of *C-* or better required for all courses used to satisfy minor requirements with overall GPA in minor requirement courses of 2.000 or better.

Minor Requirements:

UNITS

Engineering 105 or Chemical Engineering 152B 4
Applied Science 188............................. 4
Select 12 units from: Biological Systems Engineering 162; Chemical Engineering 146, 158C, 161A, 161B, 161L, 166; Civil Engineering 125, 143, 162, 163; Mechanical Engineering 161; Agricultural and Resource Economics 175; Food Science and Technology 123; Applied Biological Systems Technology 182; Atmospheric Science 116; Plant Science 101; Environmental Science and Policy 167.. 12

Total Units for the Minor....................... 20

Minor Advisors. Bryan Jenkins *(Department of Biological and Agricultural Engineering)*, Karen McDonald *(Department of Chemical Engineering and Materials Science)*, Case van Dam *(Department of Mechanical and Aerospace Engineering)*

Energy Policy Minor

All courses must be taken for a letter grade. Grade of *C-* or better required for all courses used to satisfy minor requirements with overall GPA in minor requirement courses of 2.000 or better.

Minor Requirements:

UNITS

Applied Science 188 and Environmental Science and Policy................................ 8
Select 10 units from: Civil Engineering 125; Environmental Science and Policy 171, 163, 168A, 169B; Political Science 105, 109, 122, 164 143, 162, 164; ... 10

Total Units for the Minor....................... 18

Minor Advisors. Deb Niemeier *(Department of Civil and Environmental Engineering)*, Joan Ogden *(Environmental Science and Policy)*

The Graduate Program in Biological Systems Engineering

Integrated B.S./M.S, M.S., M.Engr., D.Engr., and Ph.D. in Biological Systems Engineering
Designated Ph.D. emphasis available in Biotechnology
http://bae.engineering.ucdavis.edu
(530) 752-0102

Graduate students in Biological Systems Engineering focus on finding economically and environmentally sustainable solutions to many of the most important global issues of our time-the safety, security and abundance of our food, detection of pathogens, development of bio-energy alternatives, control of insect-borne disease and damage, as well as the preservation of our land, air and water resources.

We enjoy the strategic advantage of being located in California, the national leader in agricultural production and crop diversity, and a major center for biotechnology. With the unique status of belonging to both the College of Engineering and the College of Agricultural and Environmental Sciences, collaboration is the rule. We interact with colleagues in both engineering and the life sciences to create multidisciplinary approaches to our teaching and research. Students benefit from this dynamic environment that combines the strengths of nationally ranked engineering, agricultural and environmental programs.

Financial support is available in the form of research assistantships, teaching assistantships, fellowships and financial aid.

Research Highlights:

- Bioenvironmental Engineering
- Renewable Energy
- Industrial Biotechnology
- Food Safety
- Biosensors
- Bioprocess Engineering
- Bioinstrumentation
- Ergonomics, Health and Safety
- Aquacultural Engineering
- Ecological Systems Engineering
- Food Engineering
- Forest and Fiber Engineering
- Postharvest Engineering
- Soil and Water Engineering
- Machine Systems and Precision Agriculture

Research Facilities and Partnerships:

- Agricultural Ergonomics Research Center
- GIS Visualization Lab
- Energy Institute
- Bodega Marine Lab
- Western Center for Agricultural Equipment
- California Biomass Collaborative

Complete Information on departmental website.

Courses in Engineering: Biological Systems (EBS)

Lower Division Courses

1. Foundations of Biological Systems Engineering (4)
Lecture—2 hours; laboratory—3 hours; project—3 hours. Restricted to students in Biological Systems Engineering. Introduction to engineering and the engineering design process with examples drawn from the field of biological systems engineering. Introduction to computer-aided design and mechanical fabrication of designs. Students work on a quarter-long group design project. GE credit: OL, QL, SE, SL, VL.—I. (I.) Jenkins, Piedrahita

75. Properties of Materials in Biological Systems (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Biological Sciences 1A; grade of C- or better in Physics 9B; Physics 9C (may be taken concurrently). Properties of typical biological materials; composition and structure with emphasis on the effects of physical and biochemical properties on design of engineered systems; interactions of biological materials with typical engineering materials. GE credit: SciEng | QL, SE, SL, VL, WE.—II. (II.) Jeoh, Slaughter

90C. Research Group Conference in Biological Systems Engineering (1)
Discussion—1 hour. Prerequisite: lower division standing in Biological Systems Engineering or Food Engineering; consent of instructor. Research group conference. May be repeated for credit. (P/NP grading only.) GE credit: SE.—I, II, III. (I, II, III.)

92. Internship in Biological Systems Engineering (1-5)
Internship. Prerequisite: lower division standing; project approval prior to period of internship. Supervised work experience in biological systems engineering. May be repeated for credit. (P/NP grading only.) GE credit: SE.

98. Directed Group Study (1-5)
Prerequisite: consent of instructor. Group study of selected topics; restricted to lower division students. (P/NP grading only.) GE credit: SE.

99. Special Study for Lower Division Students (1-5)
(P/NP grading only.) GE credit: SE.

Upper Division Courses

103. Fluid Mechanics Fundamentals (4)
Lecture—4 hours. Prerequisite: Physics 9B. Fluid mechanics axioms, fluid statics, kinematics, velocity fields for one-dimensional incompressible flow and boundary layers, turbulent flow time averaging, potential flow, dimensional analysis, and macroscopic balances to solve a range of practical problems. (Same course as Hydrologic Science 103N.) GE credit: QL, SE, VL.—II. (II.) Wallender

114. Principles of Field Machinery Design (3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: Engineering 102, 104. Traction and stability of vehicles with wheels or tracks. Operating principles of field machines and basic mechanisms used in their design. GE credit: QL, SE, VL, WE.—III. Rosa

115. Forest Engineering (3)
Lecture—3 hours. Prerequisite: Engineering 104, Biological Sciences 1C. Applications of engineering principles to problems in forestry including those in forest regeneration, harvesting, residue utilization, and transportation. GE credit: QL, SE, SL, VL.—(III.) Hartsough

120. Power Systems Design (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 17, 102, 103, 105. Design and performance of power devices and systems including combustion engines, electric generators and motors, fluid power systems, fuels, and emerging technologies. Selection of units for power matching and optimum performance. GE credit: QL, SE, SL, VL, WE.—I. (I.) Rosa

125. Heat Transfer in Biological Systems (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 103; Engineering 105; Biological Sciences 2A, 2B and 2C. Fundamentals of heat transfer with application to biological systems. Steady and transient heat transfer. Analysis and simulation of heat conduction, convection and radiation. Heat transfer operations. GE credit: OL, QL, SE, VL, WE.—III. (III.) Fan, Nitin

127. Mass Transfer and Kinetics in Biological Systems (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 125. Fundamentals of mass transfer and kinetics in biological systems. Molecular diffusion and convection. Thermodynamics and bioenergetics. Biological and chemical rate equations. Heterogeneous kinetics. Batch and continuous reaction processes. GE credit: QL, SE, VL, WE.—I. (I.) VanderGheynst, Zicari

128. Biomechanics and Ergonomics (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Statistics 100, Engineering 102. Anatomical, physiological, and biomechanical bases of physical ergonomics. Human motor capabilities, body mechanics, kinematics and anthropometry. Use of bioinstrumentation, industrial surveillance techniques and the NIOSH lifting guide. Cumulative trauma disorders. Static and dynamic biomechanical modeling. Emphasis on low back, shoulder, and hand/wrist biomechanics. GE credit: QL, SE, SL, VL, WE.—III. (III.) Fathallah

130. Modeling of Dynamic Processes in Biological Systems (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 75; Engineering 6 or Computer Science & Engineering 30; grade of C- or better in Mathematics 22B required for enrollment eligibility. Techniques for modeling processes through mass and energy balance, rate equations, and equations of state. Computer problem solution of models. Example models include package design, evaporation, respiration heating, thermal processing of foods, and plant growth. GE credit: OL, QL, SE, SL, VL.—II. (II.) K. McCarthy, Upadhyaya

135. Bioenvironmental Engineering (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: courses 125, 130. Biological responses to environmental conditions. Principles and engineering design of environmental control systems. Overview of environmental pollution problems and legal restrictions for biological systems, introduction of environmental quality assessment techniques, and environmental pollution control technologies. GE credit: QL, SE, SL, VL, WE.—I. (I.) Jenkins, Zhang

144. Groundwater Hydrology (4)
Lecture—4 hours. Prerequisite: Mathematics 16B or 21A; Hydrologic Science 103 or Engineering 103 recommended. Fundamentals of groundwater flow and contaminant hydrology. Occurrence, distribution, and movement of groundwater. Well-flow systems. Aquifer tests. Well construction operation and maintenance. Groundwater exploration and quality assessment. Agricultural threats to groundwater quality: fertilizers, pesticides, and salts. Same course as Hydrologic Science 144. GE credit: QL, SE, SL, VL.—I. (I.) Fogg

145. Irrigation and Drainage Systems (4)
Lecture—4 hours. Prerequisite: Engineering 103 or Hydrologic Science 103. Engineering and scientific principles applied to the design of surface, sprinkle and micro irrigation systems and drainage systems within economic, biological, and environmental constraints. Interaction between irrigation and drainage. (Same course as Hydrologic Science 115.) GE credit: QL, SE, SL, VL.—II. Grismer, Wallender

147. Runoff, Erosion and Water Quality Management in the Tahoe Basin (3)
Lecture/laboratory—30 hours; fieldwork—15 hours; discussion—10 hours; term paper. Prerequisite: Physics 7B or 9B, Mathematics 16C or 21C, Civil and Environmental Engineering 142 or Hydrologic Science 141 or Environmental and Resource Sciences 100. Five days of instruction in Tahoe City. Practical hydrology and runoff water quality management from Tahoe Basin slopes. Development of hillslope and riparian restoration concepts, modeling and applications from physical science perspectives including precipitation-runoff relationships, sediment transport, and detention ponds. (Same course as Hydrologic Science 147.) GE credit: QL, SE, SL.—Grismer

161. Kinetics and Bioreactor Design (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 127. Provide the basic principles of reactor design for bioprocess applications. This course emphasizes the following topics: 1) kinetics and reactor engineering principles; 2) bio-reaction kinetics; and 3) bioreactor design. GE credit: QL, SE, VL.—II. (II.) Fan, Zicari

165. Bioinstrumentation and Control (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 100. Instrumentation and control for biological production systems. Measurement system concepts, instrumentation and transducers for sensing physical and biological parameters, data acquisition and control. GE credit: QL, SE, SL, VL, WE.—I. (I.) Delwiche, Slaughter

170A. Engineering Design and Professional Responsibilities (3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: course 1, Engineering 102, 104. Engineering design including professional responsibilities. Emphasis on project selection, data sources, specifications, human factors, biological materials, safety systems, and professionalism. Detailed design proposals will be developed for courses 170B and 170BL. GE credit: OL, QL, SE, SL, VL, WE.—I. (I.) Giles, Zhang

170B. Engineering Projects: Design (2)
Discussion—2 hours. Prerequisite: course 170A; course 170BL required concurrently. Individual or group projects involving the design of devices, structures, or systems to solve specific engineering problems in biological systems. Project for study is jointly selected by student and instructor. GE credit: OL, QL, SE, SL, VL, WE.—II. (II.) Giles, Zhang

170BL. Engineering Projects: Design Laboratory (1)
Laboratory—3 hours. Prerequisite: course 170B required concurrently. Individual or group projects involving the design of devices, structures, or systems to solve specific engineering problems in biological systems. GE credit: OL, QL, SE, SL, VL, WE.—II. (II.)

170C. Engineering Projects: Design Evaluation (1)
Discussion—1 hour. Prerequisite: course 170B; required to enroll in course 170CL concurrently. Individual or group projects involving the fabrication, assembly and testing of components, devices, structures, or systems designed to solve specific engineering problems in biological systems. Project for study previously selected by student and instructor in course 170B. GE credit: OL, QL, SE, SL, VL, WE.—III. (III.) Giles, Zhang

170CL. Engineering Projects: Design Evaluation (2)
Laboratory—6 hours. Prerequisite: required to enroll in course 170C concurrently. Individual or group projects involving the fabrication, assembly and testing of components, devices, structures, or systems designed to solve specific engineering problems in biological systems. GE credit: OL, QL, SE, SL, VL, WE.—III. (III.)

175. Rheology of Biological Materials (3)
Lecture—3 hours. Prerequisite: Engineering 103 or Chemical Engineering 150A. Fluid and solid rheology, viscoelastic behavior of foods and other biological materials, and application of rheological properties to food and biological systems (i.e., pipeline design, extrusion, mixing, coating). GE credit: QL, SE, VL.—II. K. McCarthy

189A-G. Special Topics in Biological Systems Engineering (1-5)
Variable—3-15 hours. Prerequisite: upper division standing in engineering; consent of instructor. Special topics in: (A) Agricultural Engineering; (B) Aquacultural Engineering; (C) Biomedical Engineering; (D) Biotechnical Engineering; (E) Ecological Systems Engineering; (F) Food Engineering; and (G) Forest Engineering. May be repeated for credit when topic differs. GE credit: SE.—I, II, III. (I, II, III.)

190C. Research Group Conference in Biological Systems Engineering (1)
Discussion—1 hour. Prerequisite: upper division standing in Biological Systems Engineering or Food Engineering; consent of instructor. Research group conference. May be repeated for credit. (P/NP grading only.) GE credit: SE.—I, II, III. (I, II, III.)

192. Internship in Biological Systems Engineering (1-5)
Internship. Prerequisite: upper division standing; approval of project prior to period of internship. Supervised work experience in biological systems engineering. May be repeated for credit. (P/NP grading only.) GE credit: SE.

197T. Tutoring in Biological Systems Engineering (1-5)
Tutorial—3-15 hours. Prerequisite: upper division standing. Tutoring individual students, leading small voluntary discussion groups, or assisting the instructor in laboratories affiliated with one of the department's regular courses. May be repeated for credit if topic differs. (P/NP grading only.) GE credit: SE.

198. Directed Group Study (1-5)
Prerequisite: consent of instructor. (P/NP grading only.) GE credit: SE.

199. Special Study for Advanced Undergraduates (1-5)
(P/NP grading only.) GE credit: SE.

Graduate Courses

200. Research Methods in Biological Systems Engineering (2)
Lecture—2 hours. Prerequisite: graduate standing. Planning, execution and reporting of research projects. Literature review techniques and proposal preparation. Record keeping and patents. Uncertainty analysis in experiments and computations. Graphic analysis. Oral and written presentation of research results, manuscript preparation, submission and review.—I. (I.) Zhang, Giles

205. Continuum Mechanics of Natural Systems (4)
Lecture/discussion—4 hours. Prerequisite: Mathematics 21D and 22B, Physics 9B. Continuum mechanics of static and dynamic air, water, earth and biological systems using hydraulic, heat and electrical conductivity; diffusivity; dispersion; strain; stress; deformation gradient; velocity gradient; stretch and spin tensors. (Same course as Hydrologic Science 205.)—III. Wallender

215. Soil-Machine Relations in Tillage and Traction (3)
Lecture—3 hours. Prerequisite: course 114. Mechanics of interactions between agricultural soils and tillage and traction devices; determination of relevant physical properties of soil; analyses of stress and strains in soil due to machine-applied loads; experimental and analytical methods for synthesizing characteristics of overall systems. Offered in alternate years.—(II.) Upadhyaya

216. Energy Systems (3)
Lecture—3 hours. Prerequisite: Engineering 105. Theory and application of energy systems. System analysis including input-output analysis, energy balances, thermodynamic availability, economics, environmental considerations. Energy conversion systems and devices including cogeneration, heat pump, fuel cell, hydroelectric, wind, photovoltaic, and biomass conversion processes. Offered in alternate years.—II. Jenkins

218. Solar Thermal Engineering (3)
Lecture—3 hours. Prerequisite: course in heat transfer. Familiarity with FORTRAN language. Analysis and design of solar energy collection systems. Sun-earth geometry and estimation of solar radiation. Steady state and dynamic models of solar collectors. Modeling of thermal energy storage devices. Computer simulation. Offered in alternate years.—III. Jenkins

220. Pilot Plant Operations in Aquacultural Engineering (3)
Lecture—1 hour; laboratory—6 hours. Prerequisite: Civil Engineering 243A-243B or Applied Biological Systems Technology 161, 163. Topics in water treatment as they apply to aquaculture operations. Laboratory study of unit operations in aquaculture. Offered in alternate years.—(I.) Piedrahita

228. Occupational Musculoskeletal Disorders (3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: graduate standing and consent of instructor. Epidemiology and etiology of occupational musculoskeletal disorders (MSDs) with focus on low back and upper extremities disorders; anatomical and biomechanical functions of lower back and upper extremities; MSDs risk factors assessment and control; research opportunities related to MSDs.—III. (III.) Fathallah

231. Mass Transfer in Food and Biological Systems (3)
Lecture/discussion—3 hours. Prerequisite: graduate standing. Application of mass transfer principles to food and biological systems. Study of mass transfer affecting food quality and shelf life. Analysis of mass transfer in polymer films used for coating and packaging foods and controlling release of biologically active compounds. Offered in alternate years.—(II.) Krochta, K. McCarthy

233. Analysis of Processing Operations: Drying and Evaporation (3)
Lecture—3 hours. Prerequisite: course in food or process engineering, familiarity with FORTRAN. Diffusion theory in drying of solids. Analysis of fixed-bed and continuous-flow dryers. Steady-state and dynamic models to predict performance evaporators: multiple effects, mechanical and thermal recompression, control systems. Offered in alternate years.—(II.)

235. Advanced Analysis of Unit Operations in Food and Biological Engineering (3)
Lecture—3 hours. Prerequisite: course 132. Analysis and design of food processing operations. Steady state and dynamic heat and mass transfer models for operations involving phase change such as freezing and frying. Separation processes including membrane applications in food and fermentation systems.—(III.) Singh

237. Thermal Process Design (3)
Lecture—2 hours; discussion—1 hour. Prerequisite: course in heat transfer. Heat transfer and biological basis for design of heat sterilization of foods and other biological materials in containers or in bulk. Offered in alternate years.—III.

239. Magnetic Resonance Imaging in Biological Systems (3)
Lecture—3 hours. Prerequisite: graduate standing. Theory and applications of magnetic resonance imaging to biological systems. Classical Bloch model of magnetic resonance. Applications to be studied are drying of fruits, flow of food suspensions, diffusion of moisture, and structure of foods. Offered in alternate years.—I. M. McCarthy

240. Infiltration and Drainage (3)
Lecture—3 hours. Prerequisite: Soil Science 107, Engineering 103. Aspects of multi-phase flow in soils and their application to infiltration and immiscible displacement problems. Gas phase transport and entrapment during infiltration, and oil-water-gas displacement will be considered. Offered in alternate years.—II. Grismer

241. Sprinkle and Trickle Irrigation Systems (3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: course 145/Hydrologic Science 115. Computerized design of sprinkle and trickle irrigation systems. Consideration of emitter mechanics, distribution functions and water yield functions. Offered in alternate years.—III.

242. Hydraulics of Surface Irrigation (3)
Lecture—3 hours. Prerequisite: course 145, Hydrologic Science 115. Mathematical models of surface-irrigation systems for prediction of the ultimate disposition of water flowing onto a field. Quantity of runoff and distribution of infiltrated water over field length as a function of slope, roughness, infiltration and inflow rates. Offered in alternate years.—(III.) Wallender

243. Water Resource Planning and Management (3)
Lecture—3 hours. Prerequisite: Hydrologic Science 141 or the equivalent. Applications of deterministic and stochastic mathematical programming techniques to water resource planning, analysis, design, and management. Water allocation, capacity expansion, and reservoir operation. Conjunctive use of surface water and groundwater. Water quality management. Irrigation planning and operation models. (Same course as Hydrologic Science 243.) Offered in alternate years—(I.)

245. Waste Management for Biological Production Systems (3)
Lecture—3 hours. Prerequisite: graduate standing or consent of instructor. Characterization of solid and liquid wastes from animal, crop, and food production systems. Study of methods and system design for handling, treatment, and disposal/utilization of these materials.—II. (II.) Zhang

260. Analog Instrumentation (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 100. Instrument characteristics: generalized instrument models, calibration, and frequency response. Signal conditioning: operational amplifier circuits, filtering, and noise. Transducers: motion, force, pressure, flow, temperature, and photoelectric. Offered in alternate years.—II. Delwiche

262. Computer Interfacing and Control (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 100, course 165. Procedural and object-oriented programming in C++, analog and digital signal conversion, data acquisition and computer control. Offered in alternate years.—(III.) Delwiche

265. Design and Analysis of Engineering Experiments (5)
Lecture—3 hours; lecture/discussion—2 hours. Prerequisite: Statistics 100, Agricultural Systems and Environment 120, or an introductory course in statistics. Simple linear, multiple, and polynomial regression, correlation, residuals, model selection, one-way ANOVA, fixed and random effect models, sample size, multiple comparisons, randomized block, repeated measures, and Latin square designs, factorial experiments, nested design and subsampling, split-plot design, statistical software packages.—III. (III.) Upadhyaya, Plant

267. Renewable Bioprocessing (3)
Lecture—3 hours. Prerequisite: course 160, Biological Sciences 101 or Microbiology 102. Applications of biotechnology and bioprocess engineering toward the use of agricultural and renewable feedstocks for the production of biochemicals. Design and modeling of microbial- and plant-based production systems including associated fermentation, extraction, and purification processes. Offered in alternate years.—I. VanderGheynst

270. Modeling and Analysis of Biological and Physical Systems (3)
Lecture—3 hours. Prerequisite: familiarity with a programming language. Mathematical modeling of biological systems: model development; analytical and numerical solutions. Case studies from various specializations within biological and agricultural engineering. Offered in alternate years.—III. Upadhyaya

275. Physical Properties of Biological Materials (3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: consent of instructor. Selected topics on physical properties, such as mechanical, optical, rheological, and aerodynamic properties, as related to the design of harvesting, handling, sorting, and processing equipment. Techniques for measuring and recording physical properties of biological materials. Offered in alternate years.—III. Slaughter, Rosa

289A-K. Selected Topics in Biological Systems Engineering (1-5)
Variable—1-5 hours. Prerequisite: consent of instructor. Special topics in: (A) Animal Systems Engineering; (B) Aquacultural Engineering; (C) Biological Engineering; (D) Energy Systems; (E) Environmental Quality; (F) Food Engineering; (G) Forest Engineering; (H) Irrigation and Drainage; (I) Plant Production and Harvest; (J) Postharvest Engineering; (K) Sensors and Actuators. May be repeated for credit when topic differs.—I, II, III. (I, II, III.)

290. Seminar (1)
Seminar—1 hour. Prerequisite: graduate standing. Weekly seminars on recent advances and selected topics in biological systems engineering. Course theme will change from quarter to quarter. May be repeated for credit. (S/U grading only.)

290C. Graduate Research Conference (1)
Discussion—1 hour. Prerequisite: consent of instructor. Research problems, progress and techniques in biological systems engineering. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

298. Group Study (1-5)

299. Research (1-12)
(S/U grading only.)

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)

Kyriacos Athanasiou, Chairperson of the Department

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

Faculty

Kyriacos Athanasiou, Ph.D., Distinguished Professor *(Biomedical Engineering; Medicine: Orthopaedic Surgery)*
Ramsey Badawi, Ph.D., Associate Professor *(Biomedical Engineering; and Medicine: Radiology)*
Craig Benham, Ph.D., Professor *(Biomedical Engineering; Mathematics; and Genome Center: Bioinformatics)*
John Boone, Ph.D., Professor *(Biomedical Engineering; and Medicine: Radiology)*
Ye Chen-Izu, Ph.D., Assistant Professor *(Biomedical Engineering; Medicine: Pharmacology; and Internal Medicine)*
Simon Cherry, Ph.D., Professor *(Biomedical Engineering; and Medicine: Radiology)*