Bioengineering

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DEPARTMENTAL FOCUS

Bioengineering is an interdisciplinary major in which the principles and tools of traditional engineering fields, such as mechanical, materials, electrical, and chemical engineering, are applied to biomedical and biological problems. Engineering plays an increasingly important role in medicine in projects that range from basic research in physiology to advances in biotechnology and the improvement of health-care delivery. By its very nature, bioengineering is broad and requires a foundation in the engineering sciences as well as in physiology and other biological sciences.

The overall mission of the Department of Bioengineering is to improve health and quality of life by applying engineering principles to scientific discovery and technology innovation and to train future leaders in bioengineering through inspiring education and dedicated mentorship.

The educational objectives of the Bioengineering program at UC San Diego are to produce graduates with a modern bioengineering education who will

- apply the central areas of bioengineering, its underlying sciences, and related technologies in a broad range of careers
- use strong communication, learning, and teamwork skills to facilitate bioengineering practice and continued professional advancement
- act professionally, ethically, and in a socially responsible manner

At the undergraduate level, the department offers several four-year engineering majors. One leads to a **B.S. degree in Bioengineering**. This major prepares students for careers in the biomedical device industry and for further education in graduate school. Students completing the B.S. degree in Bioengineering have a broad preparation in traditional topics in engineering, allowing for a variety of career pathways. This program addresses the bioengineering topics of biomechanics, biotransport, bioinstrumentation, bioelectricity, biosystems, and biomaterials, and the complementary fields of systems and integrative physiology. Education in these areas allows application of bioengineering and other scientific principles to benefit human health by advancing methods for effective diagnosis and treatment of disease, e.g., through development of medical devices and technologies.

The department also offers a **B.S. degree in Bioengineering: Biotechnology.** This major prepares students for careers in the biotechnology industry and for further education in graduate school. The curriculum has a strong engineering foundation with emphasis on biochemical process applications. This program addresses the bioengineering topics of biochemistry, metabolism, kinetics, biotransport, biosystems, bioreactors, bioseparations, tissue engineering, and the complementary fields of cellular physiology. Education in these areas allows application of bioengineering and physicochemical principles to cellular and molecular biology, with the applications that benefit human health.

Although the *Pre-Bioengineering: Premedical* premajor has been discontinued and the process has been initiated for the discontinuation and phase-out of the four-year major leading to a **B.S. degree in Bioengineering: Premedical**, all required courses will continue to be offered until students in the *Pre-Bioengineering: Premedical* pre-major who satisfy the requirements and transition into the *Bioengineering: Premedical* major and current students in the *Bioengineering: Premedical* major have graduated.

The department also offers a major leading to a B.S. degree in **Bioengineering: Bioinformatics.** Bioinformatics is the study of the flow of information (genetic, metabolic, and regulatory) in living systems to provide an understanding of the properties of cells and organisms. This major has been developed by the Departments of Bioengineering, Chemistry and Biochemistry, Computer Science and Engineering, and Division of Biological Sciences. Students wishing to major in bioinformatics may apply through any of these departments or the division. The *Bioinformatics* major in Bioengineering emphasizes systems engineering and model-based approaches to interpreting and integrating bioinformatics data. The *Bioinformatics* major prepares students for careers in the pharmaceutical, biotechnology, and biomedical software industries, and for further studies in graduate school.

The programs and curricula of Bioengineering emphasize education in the fundamentals of engineering sciences that form the common basis of all engineering subspecialties. Education with this emphasis is intended to provide students with an interdisciplinary engineering foundation for a career in which engineering practice may expand rapidly. In addition, elements of bioengineering design are incorporated at every level in the curricula. This is accomplished by integration of laboratory experimentation, computer applications, and exposure to real bioengineering problems throughout the program. In the *Bioengineering* and *Bioengineering: Biotechnology* majors, students also work in teams on a senior design project to design a solution to

a multidisciplinary bioengineering problem suggested by professionals in bioengineering industry, academia, or medicine.

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (EAC/ABET) is an organization with a mission of serving the public through promotion and advancement of education in fields including engineering, and ABET's strategic plans include accreditation of educational programs and promotion of quality and innovation in education http://www.abet.org). At UC San Diego, *Bioengineering* and *Bioengineering: Biotechnology* have a relatively heavy emphasis on engineering, whereas *Bioengineering: Bioinformatics* and *Bioengineering: Premedical* have a relatively heavy emphasis on biological, chemical, and physical sciences. The *Bioengineering* and *Bioengineering: Biotechnology* programs are accredited by EAC/ABET. The *Bioengineering: Bioinformatics* and *Bioengineering: Premedical* programs are not accredited by a Commission of ABET.

At the graduate level, specialized curricula lead to the **M.S., M.Eng. (Master of Engineering),** and **Ph.D.** degrees, as well as an integrated B.S./M.S. degree. In addition to the Ph.D. degree, the department offers a **Ph.D. degree with a specialization in Bioinformatics.** It is intended for students who have an interdisciplinary persuasion to work across computers, biology, medicine, and engineering. For further information on the specialization, please consult with the Student Affairs Office. The M.Eng. degree is a terminal professional degree whereas the M.S. and Ph.D. degrees are research programs. *(See section on master's degree programs.)* The graduate programs are characterized by strong interdisciplinary relationships with the other engineering departments and Departments of Physics, Mathematics, Biology, Chemistry and Biochemistry, Medicine, and others, as well as with campus organizations such as the Institute of Engineering in Medicine, Institute for Mechanics and Materials, and the School of Medicine.

THE UNDERGRADUATE PROGRAM

MAJOR REQUIREMENTS

Specific course requirements for each of the majors are outlined in tables below. In addition to the required technical courses specifically indicated, a suggested scheduling of humanities and social science courses (HSS) is included in the curricula for students to use to meet college general-education requirements. To graduate, students must maintain an overall GPA of at least 2.0, and obtain at least a C– grade in each course required for the major. All courses required for the major must be taken for a letter grade.

Deviations from the required programs of study must be approved by the Undergraduate Studies Committee *prior* to students taking alternative courses. In addition, students must obtain departmental approval of technical elective (TE) course selections *prior* to students taking the course. In the ABET-accredited programs, TE courses are restricted to those that meet ABET standards. Courses such as BENG 196, 197, and 198 are encouraged, but do not count as upper-division technical electives. BENG 195 and 199 can be used as technical electives under certain conditions. Policy information may be obtained from the Student Affairs Office.

Students with accelerated academic preparation at admission to the university may vary the scheduling of lower-division courses such as mathematics, physics, and chemistry, but must first consult the department. Most lower-division courses are offered more than once each year to permit students some flexibility in their program scheduling. However, most upper-division bioengineering courses are taught only once each year. **Deviations in the scheduling of upper-division Bioengineering courses are strongly discouraged, as such changes usually lead to a delay in graduation.** The curricula shown in the tables below are consistent with the current scheduling of classes.

Minors are not offered in Bioengineering, and double major options are restricted. Students interested in double majors should consult the Student Affairs Office as early as possible.

GENERAL-EDUCATION/COLLEGE REQUIREMENTS

For graduation, each student must satisfy general-education course requirements determined by the student's college, as well as the major requirements determined by the department. The six colleges at UCSD require different general-education courses, and the number of such courses differs from one college to another. Each student should choose his or her college carefully, considering the special nature of the curriculum and the breadth of general education.

The bioengineering programs allow for humanities and social science (HSS) courses so that students can fulfill their college requirements. In the bioengineering ABET-accredited programs, students must develop a program that includes a total of at least forty units in the arts, humanities, and social sciences, not including subjects such as accounting, industrial management, finance, or personnel administration. It should be noted, however, that some colleges require more than the ten HSS courses indicated in the *Bioengineering, Bioengineering: Premedical, Bioengineering: Biotechnology,* and *Bioengineering: Bioinformatics* curriculum tables. Accordingly, students in these colleges may take longer to graduate than the four years indicated in the schedule. Students must consult with their colleges to determine which HSS courses to take.

BIOENGINEERING

(ABET-Accredited Program)

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Math. 20B	Math. 20C
Chem. 6A	Chem. 6B	BILD 1
MAE 9 or 10	Phys. 2A	Phys. 2B/2BL
HSS4	BENG 12	HSS4
	HSS4	
SOPHOMORE YEAR		
Math. 20D	Math. 20F7	Math. 20E
Chem. 6BL1	MAE 1407	MAE 3
Phys. 2C/2CL	BENG 109	BENG 100
HSS4	HSS4	HSS4
JUNIOR YEAR		
BENG 101	BENG 112A	BENG 112B
BENG 110	BENG 186B	BENG 172
MAE 170	BENG 140A	BENG 140B
HSS4	HSS4	BENG 103B
		BENG 187A
SENIOR YEAR		
MAE 107	BENG 122A	BENG 125
BENG 187B	BENG 130	BENG 186A
DE6	BENG 187C	BENG 187D
TE3	DE6	TE3
HSS4	MAE 150	HSS4
	BENG 1915	

1 Chem. 6BL may be taken in any quarter within the first two years after completion of Chem. 6B.

2 BENG 1 may be taken in sophomore year.

3 Technical elective (TE) courses must be selected from a departmental approved list. Consult the Student Affairs Office.

4 Ten HSS courses are listed here; individual college requirements may be higher.

5 Recommended course, not required. For graduating seniors only.

6 Design elective (DE) courses must be selected from a two-quarter sequence, BENG 119AB, 126AB, 127AB, 128AB, 129AB, 139AB, 147AB, 148AB, 149AB, 169AB, 179AB.

7 Math. 20F and MAE 140 may be taken concurrently.

BIOENGINEERING: BIOTECHNOLOGY

(ABET-Accredited Program)

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Math. 20B	Math. 20C
Chem. 6A	Chem. 6B	Chem. 6BL1/6C
MAE 9 or 10	Phys. 2A	Phys. 2B
HSS4	BENG 12	HSS4
	HSS4	
SOPHOMORE YEAR		
Math. 20D	Math. 20F	Math. 20E
Chem. 140A	Phys. 2C/2CL	Chem. 140B
BILD 1	BENG 130	BENG 100
HSS4	HSS4	HSS4
JUNIOR YEAR		
BIBC 100	BENG 123	BENG 103B
CENG 101A	BIBC 102	BENG 160
MAE 170	BICD 100	BENG 168
HSS4	HSS4	BENG 187A
		HSS4
SENIOR YEAR		
BENG 161A	BENG 161B	BENG 125
BENG 187B	BENG 187C	BENG 187D
BENG 166A	DE6	BENG 186A
DE6	TE3	TE3
BENG 162	HSS4	
	BENG 1915	

1 Chem. 6BL may be taken concurrently with Chem. 6C or in any quarter within the first two years after completion of Chem. 6B.

2 BENG 1 may be taken in sophomore year.

3 Technical elective (TE) courses must be selected from a departmental approved list. Consult the Student Affairs Office.

4 Ten HSS courses are listed here; individual college requirements may be higher.

5 Recommended course, not required. For graduating seniors only.

6 Design elective (DE) courses must be selected from a two-quarter sequence, BENG 119AB, 126AB, 127AB, 128AB, 129AB, 139AB, 147AB, 148AB, 149AB, 169AB, 179AB.

BIOENGINEERING: PREMEDICAL‡

(Not accredited by a Commission of ABET.)

‡This major is being discontinued. Current students should follow the table of courses below.

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A*	Math. 20B*	Math. 20C*
Chem. 6A*	Chem. 6B	Chem. 6BL1/6C
MAE 9 or 10*	Phys. 2A*	Phys. 2B*/2BL
HSS4	BENG 12	HSS4
	HSS4	

SOPHOMORE YEAR		
Math. 20D	Math. 20F	Math. 20E
BILD 1	Chem. 140A	Chem. 140B
Phys. 2C/2CL	BENG 109	BENG 100
HSS4	HSS4	HSS4
JUNIOR YEAR		
BENG 110	BENG 112A	BENG 112B
Chem. 140C5	BICD 100	BIBC 100
Chem. 143A	MAE 140	MAE 170
BILD 2	HSS4	HSS4
SENIOR YEAR		
BIPN 140	BENG 186B	BENG 172
BIPN 100	BIPN 102	BENG 186A
BIBC 1023	TE3	TE3
HSS4	HSS4	

* Seven of the eight courses used to compute the performance index upon which Pre-Bioengineering: Premedical majors are admitted to the major at the end of the freshman year. The other course must be in engineering, science, or mathematics.

1 Chem. 6BL may be taken concurrently with Chem. 6C or in any quarter within the first two years after completion of Chem. 6B.

2 BENG 1 may be taken in sophomore year.

3 Technical elective (TE) courses must be selected from a departmental approved list. Consult the Student Affairs Office.

4 Ten HSS courses are listed here; individual college requirements may be higher.

5 Chem. 140C is not required for the major and can be used as a technical elective. Chem. 140C is a requirement for application to most medical schools.

BIOENGINEERING: BIOINFORMATICS

(Not accredited by a Commission of ABET.)

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 112	CSE 12	BILD 94
Chem. 6A	Chem. 6B	Chem. 6BL1/6C
Math. 20A	Math. 20B	Math. 20C
HSS4	HSS4	HSS4
SOPHOMORE YEAR		
BILD 1	BILD 2	BILD 3
Math. 20D	Chem. 140A	Chem. 140B
Phys. 2A	Phys. 2B	Phys. 2C
HSS4	HSS4	CSE 21/Math. 15B
JUNIOR YEAR		
BIBC 102/ Chem. 114B	BIMM 100/ Chem. 114C	BICD 110
BICD 100	CSE 101/ Math. 188	BIMM 101/ Chem. 112B
CSE 100/ Math. 176	Math. 20F	BENG 181
HSS4	Math. 186	HSS4
SENIOR YEAR		
BENG 182	BENG 130	BIMM 185
BENG 183	BENG 184	TE3
BIBC 103	TE3	TE3
HSS4	HSS4	HSS4

1 Chem. 6BL may be taken concurrently with Chem. 6C or in any quarter within the first two years after completion of Chem. 6B.

2 Students may take the slower paced version, CSE 8A-B, instead of CSE 11.

3 Technical elective (TE) courses must be selected from a departmental approved list. Consult the Student Affairs Office.

4 Ten HSS courses are listed here; individual college requirements may be higher.

POLICIES AND PROCEDURES

Transfer Student Admission into Bioengineering or Bioengineering: Biotechnology,

General advice: Transfer students are advised to complete the following courses for their major before enrolling at UC San Diego. Preparing well for the major helps students move efficiently toward graduation.

- Calculus I—for Science and Engineering (Math. 20A)
- Calculus II—for Science and Engineering (Math. 20B)
- Calculus and Analytic Geometry (Math. 20C)
- Differential Equations (Math. 20D)
- Linear Algebra (Math. 20F)
- Complete calculus-based physics series with lab experience (Physics 2A-B-C)
- Chemistry 6A (except Computer Science and Computer Engineering majors) **Note:** A total of ten quarter-units of general chemistry (including laboratory) are strongly recommended for students applying to **all** majors offered by the **Department of Bioengineering.**
- Highest level of introductory computer programming language course offerings at the community college

Admission to Bioengineering or Bioengineering: Biotechnology

Because of heavy student interest in the *Bioengineering* and *Bioengineering: Biotechnology* majors, and the limited resources available to accommodate this demand, maintenance of a high quality program makes it necessary to limit enrollments to the most qualified students.

Students admitted into an impacted major who transfer out of the impacted major may transfer back into it **one time** without meeting the full requirements for continuing student admission, **provided they are in good academic standing.**

Freshman Students

Freshman students who have excelled in high school and have declared *Bioengineering* or *Bioengineering: Biotechnology* on their UCSD application are eligible for direct admission into those majors.

Effective fall 2010 the UCSD Office of Admissions and Relations with Schools will calculate an admissions target number and admit the appropriate number of incoming freshmen into each impacted major using the "UCSD Comprehensive Review" score as a ranking method. (Visit "Undergraduate Admissions, Policies, and Procedures" and http://gort.ucsd.edu/admissions/ for detailed information concerning the "UCSD Comprehensive Review" score.) Students who meet the UCSD admission criteria will be admitted into their chosen impacted major, starting with the student having the highest "comprehensive review score," until the admission target number is reached. These students will be notified directly by the Office of Admissions and Relations with Schools whether they have been admitted into their chosen impacted major.

Freshman students who applied but were not admitted directly from high school into the impacted *Bioengineering* or *Bioengineering: Biotechnology* majors will be admitted into the major indicated as their "second choice" on the UC application (providing it is an "open" major).

Transfer Students

Effective fall 2010, the UCSD Office of Admissions and Relations with Schools will calculate an admissions target number and admit the appropriate number of incoming transfer students into each impacted major, based on the community college GPA. Additionally, transfer students should have completed courses equivalent to UCSD's Math. 20A-B-C; Physics 2A–B; and Chem. 6A–B. Students who meet the UCSD admission criteria will be admitted into their chosen impacted major, starting with the student having the highest community college GPA, until the admission target number is reached. (At least a 3.2 GPA in the community college transfer courses, and a 3.4 GPA in math., physics, and computer science courses, are likely to be needed to gain admission.) These students will be notified directly by the Office of Admissions and Relations with Schools whether they have been admitted into their chosen impacted major.

Transfer students who applied but were not admitted directly from community college into the impacted *Bioengineering* or *Bioengineering: Biotechnology* majors will be admitted into the major indicated as their "second choice" on the UC application (providing it is an "open" major).

Continuing Students

For the 2010–11 academic year, ten "open" slots will be available in each of the impacted *Bioengineering* and *Bioengineering: Biotechnology* majors for UCSD continuing students interested in applying.

Interested continuing students must not be past sophomore standing, as time to graduation would be delayed since departmental upper-division courses are currently offered only once a year.

Continuing students will be required to complete the following nine courses **prior** to applying: BILD 1; Chem. 6AB; MAE 9; Math. 20A-C; Physics 2AB. Upon completion of these courses, students will obtain an application from the Bioengineering Student Affairs Office**. Applications must be submitted to the Bioengineering Student Affairs Office by Friday of the first week of instruction.** Continuing students' applications will be ranked according to the GPA obtained in the nine required courses.

Applications to an impacted major will be approved, starting with the student having the highest GPA in the nine required courses, until the predetermined target number is reached. The Bioengineering Student Affairs Office will notify students who are successful in transitioning into an impacted major to "officially" declare the appropriate major online via the **Major/Minor** link under **Tools** at http://tritonlink.ucsd.edu.

Continuing students who apply and are unable to transition into an impacted major will also be notified of their status in a timely manner by the Bioengineering Student Affairs Office.

Academic Advising

Upon admission to a major, students are encouraged to seek advice from departmental staff in the Bioengineering Student Affairs Office, Room 141, Powell-Focht Bioengineering Hall, to plan a program of study. Students are expected to chart their progress within their major. As the department may make a small number of course and/or curricular changes every year, it is imperative that students check their e-mail for updates and consult a bioengineering undergraduate advisor on an annual basis.

To enroll in any courses required for a bioengineering major, a student must have satisfied prerequisite courses with a C– or better. (The department does not consider D or F grades as adequate preparation for subsequent material.) Also, the majority of bioengineering courses have enrollment restrictions and are open only to students who have been admitted to a bioengineering pre-major or major. Where these restrictions apply, the registrar will not enroll other students except by department approval. The department expects students to adhere to these policies and enroll in courses accordingly. Students are advised that they may be dropped from course rosters if prerequisites have not been met.

Bioengineering courses are typically offered only once a year and therefore should be taken in the recommended sequence. If courses are taken out of sequence, it may not always be possible to enroll in courses as desired or needed for timely graduation. If this occurs, students should seek immediate departmental advice.

Programmatic advice may be obtained from the Student Affairs Office. In addition, technical advice may be obtained from a specific bioengineering faculty advisor assigned to each student upon admission to the major.

Program Alterations, Exceptions to Requirements, and Special Programs

Exceptions to any program or course requirements are possible if approved by the Undergraduate Studies Committee before the courses in question are taken. Petitions may be obtained from the Bioengineering Student Affairs Office.

Capstone Design Course Sequence for Bioengineering and Bioengineering: Biotechnology

A capstone design course sequence is required for senior level students in the *Bioengineering* and *Bioengineering: Biotechnology* majors. The capstone design course sequence consists of a multiquarter upper-division sequence of courses that totals ten quarter-units and includes (1) a series of four one-unit courses on selection (BENG 187A), design (BENG 187B), implementation (BENG 187C), and presentation (BENG 187D) of design projects, with consideration of professional issues, and (2) a sequence of two three-unit laboratory design projects, offered in many of the primary areas of bioengineering, including biomechanics (BENG 119AB), systems bioengineering (BENG 127AB, 128AB, 129AB), nanoscale and molecular bioengineering (BENG 139AB), organ system bioengineering (BENG 147AB, 148AB, 149AB), tissue engineering and regenerative medicine (BENG 169AB), and bioinstrumentation (BENG 179AB). The design projects and presentations will be performed by student teams in the course sequence.

Independent Study for Undergraduates

Under the guidance of a bioengineering faculty member, lower- and upper-division level bioengineering students have opportunities to participate in independent study and research.

Upper-division bioengineering students may take BENG 199, Independent Study for Undergraduates. Lower-division bioengineering students may enroll in BENG 99, which is similar to BENG 199 except that less background in the curriculum is needed. These courses are taken as electives on a P/NP basis. Under certain conditions, a BENG 199 course may be used to satisfy upper-division technical elective course requirements for the major. Students interested in this alternative must identify a faculty member with whom they wish to work and propose a two-quarter research or study topic for *Bioengineering* and *Bioengineering: Biotechnology* majors, a one- or two-quarter research topic for *Bioengineering: Premedical* majors, and a one-quarter research topic for *Bioengineering: Bioinformatics* majors. Completion of two consecutive quarters of BENG 199 will satisfy both technical elective requirements in the *Bioengineering* and *Bioengineering: Biotechnology* majors. A *Bioengineering: Premedical* major may satisfy up to two of the three technical elective requirements in that major by completion of BENG 199 courses. Additionally, *Bioengineering: Bioinformatics* majors may also use a BENG 199 course to satisfy the major's one technical elective course requirement. After obtaining the faculty advisor's concurrence on the topic and scope of the study, the student must submit a *Special Studies Course Form* (each quarter) and a BENG 199 as *Technical Elective Contract* to the Undergraduate Studies Committee. These forms must be completed, approved, and processed prior to the beginning of the quarter in which the course is to be taken.

Teaching

Students interested in participating in the instructional activities of the department may take BENG 195, Undergraduate Teaching as an elective on a P/NP basis. Under certain conditions, it may be used to satisfy an upper-division technical elective in the *Bioengineering: Premedical* major. Policy in this regard may be obtained from the Student Affairs Office.

INDUSTRIAL INTERNSHIP PROGRAM AND GRADUATE INDUSTRIAL TRAINING PROGRAM

The Department of Bioengineering offers two industry-related programs: the **Industrial Internship Program** for undergraduates and the **Graduate Industrial Training Program** for graduate students. Both industrial programs are designed to complement the department's academic curriculum with practical industry experience. The Bioengineering Industrial Internship Office is located in 125 Powell-Focht Bioengineering Hall. Students interested in these programs should contact the office at bioengineering@ucsd.edu well in advance of the quarter in which they would like to start their internship.

The Industrial Internship Program is available to undergraduate students who have completed all lower-division course requirements. Academic credit under BENG 196, Bioengineering Industrial Internship, can be earned by spending ten weeks or more as interns in an industrial setting. The intern may be involved in a range of activities, including design, analysis, manufacturing, testing, regulatory affairs, etc., under the direction of a mentor in the workplace. At the completion of the internship experience, students are required to submit a brief report to the mentor and faculty advisor describing their activities.

The Graduate Industrial Training Program is designed for students in the Master of Engineering Degree Program. This program serves to significantly enhance the professional development of M.Eng. students in preparation for leadership in the bioengineering industry. Students will complete an independent industrial bioengineering project in a company setting under the direction of an industrial and faculty advisor.

THE GRADUATE PROGRAM

Admission to the M.Eng., M.S., and Ph.D., as well as to the Ph.D. with a specialization in bioinformatics programs, is in accordance with the general requirements of the graduate division. Applicants are required to have completed a B.S. and/or M.S. degree by time of admission in a branch of engineering, natural sciences, mathematics, or quantitative life sciences. M.S. and Ph.D. applicants must have a GPA of 3.4 or better in technical courses. M.Eng. applicants should have competitive grades (greater than a 3.02 GPA). All applicants must submit GRE General Test scores, as well as three letters of recommendation from individuals who can attest to their academic or professional competence and to the depth of their interest in pursuing graduate study. Attention will be paid to the background and statement of purpose to ensure that they are consistent with the goals of the program. For example, whereas undergraduate research experience and the intention to pursue a research career or advanced studies are qualifications and interests typically well suited to the M.S. program, industrial experience and the intention to pursue a professional career are better suited to the M.Eng. program.

A minimum score of 550 (paper based), 213 (computer based), or 80 (Internet based) on the Test of English as a Foreign Language (TOEFL) is required of all international applicants whose native language is not English and whose undergraduate education was conducted in a language other than English. Students who score below 600 on the TOEFL examination are strongly encouraged to enroll in an *English as a Second Language* program before beginning graduate work. (UC San Diego Extension offers an English language program during the summer as well as the academic year.) Admission to the M.S. or Ph.D. degree program is designated when

the applicants are judged to be appropriately qualified to pursue the degree requested at the time of application. Applicants are considered for admission for the fall quarter only.

A new graduate student who does not meet the prerequisites of required courses in the M.Eng., M.S., or Ph.D. curricula may have to take some basic courses to make up the deficiency. Thus, a student deficient in mathematics and mechanics may have to take Math. 110, CENG 101C or BENG 103B, and BENG 110, 122A in the first year and BENG 250A–B, 253 in the second year. A student deficient in biology and chemistry may have to take CHEM. 131 or BENG 130 and BIPN 100, 102 in the first year and BENG 230A-B-C in the second year.

Nonmatriculated students are welcome to seek enrollment in bioengineering courses via UC San Diego Extension's Concurrent Enrollment program. However, such enrollment in a bioengineering graduate course must be approved by the instructor.

INTEGRATED BACHELOR'S/MASTER'S DEGREE PROGRAM

An integrated program leading to a bachelor of science and a master of science degree in bioengineering is offered to undergraduate students who are enrolled in any of the major programs offered by the Department of Bioengineering. Students interested in obtaining the M.S. degree within one year following completion of the B.S. degree may apply to the department for admission to the program during the fourth quarter prior to the receipt of the B.S. degree. The program is open only to UCSD undergraduates.

To be eligible, students must have completed the first two quarters of their junior year in residence at UCSD and have an upper-division GPA of 3.5 or better and a 3.0 overall UC GPA. Twelve units of bioengineering graduate-level courses must be completed during the student's senior undergraduate year, *in addition* to the requirements for the bachelor's degree; these twelve units will count toward the requirements for the master's degree only and must be taken for a letter grade. It is the responsibility of the prospective B.S./M.S. student to select a bioengineering faculty member who is willing to serve as the student's advisor. The student will also arrange (with their faculty advisor's approval) a schedule of courses for the senior year that will fulfill the requirements for the B.S. degree while also serving the program planned for the M.S. degree. Students are expected to meet the requirements for the M.S. degree in one year (three consecutive academic quarters) from the date of the receipt of the B.S. degree.

MASTER OF SCIENCE DEGREE PROGRAMS

The **Master of Science (M.S.) Program** is intended to extend and broaden an undergraduate background and equip the graduates with fundamental knowledge in bioengineering. It is intended for those students wishing to gain experience in academic research, especially those considering continuing graduate studies at the doctoral level. The M.S. degree may be terminal or may be obtained while pursuing a doctorate. Doctoral degree students wishing to obtain the M.S. degree should refer to "Obtaining an M.S. Degree" under the section, "Doctoral Degree Program."

An individualized program is agreed upon by the student and a faculty advisor. The plan of study must involve both course work and research, culminating in the preparation of a thesis.

A total of **forty-eight** units of credit is required:

- **Thirty-six units in course work.** Nine courses, of which six are core courses in *Engineering Physics* and *Life Science* and three are elective courses to be selected from course offerings in Bioengineering, other engineering/science departments, and the School of Medicine as described below. The faculty advisor must approve the three elective courses.
- **Twelve units in research (S/U grading only).** Bioengineering Research (BENG 299) under the direction of the chosen faculty research advisor.

A thesis based on the research is written and subsequently reviewed by the thesis advisor and two other faculty members appointed by the dean of Graduate Studies. The oral defense of the thesis constitutes the departmental master's exam.

Required Core Courses for M.S. Degree Program

CORE COURSES (six required)

Engineering Physics

- BENG 221. Mathematical Methods for Bioengineering
- BENG 222. Continuum Mechanics and Transport Phenomena in Living Systems
- BENG 223. Thermodynamics, Statistical Mechanics, Interfacial Phenomena in Living Systems
- Life Science
- BENG 230A. Biochemistry
- BENG 230B. Cell and Molecular Biology
- BENG 231. Foundations of Physiology for Bioengineering

ELECTIVE COURSES (three required from any of the four categories)

Systems Biology

- BENG 202/CSE 282. Bioinformatics II: Introduction to Bioinformatics Algorithms
- BENG 203/CSE 283. Genomics, Proteomics, and Network Biology BENG 211. Systems Biology & Bioengineering I: Biological Components
- BENG 212. Systems Biology & Bioengineering II: Network Reconstruction
- BENG 213. Systems Biology & Bioengineering III: Building & Simulating Large-Scale In Silico Models

Regenerative Medicine and Imaging

BENG 230C. Cardiovascular Physiology

- BENG 230D. Respiratory and Renal Physiology
- BENG 241A. Foundations of Tissue Engineering
- BENG 280A. Principles of Biomedical Imaging
- BENG 280B. Comparative Biomedical Imaging

Multiscale Bioengineering

- BENG 209/MAE 209. Continuum Mechanics Applied to Medicine/Biology
- BENG 238/MED 238. Molecular Biology of the Cardiovascular System
- BENG 247A/ECE 247A. Advanced BioPhotonics
- BENG 247B/ECE 247B. BioElectronics
- BENG 247C/ECE 247C. BioNanotechnology
- BENG 250A. Biomechanics
- BENG 276/Chem. 276/Math. 276. Numerical Analysis in Multi-Scale Biology

Other Courses That Can Serve as Electives

BENG 207. Topics in Bioengineering

Course given at the discretion of the faculty on current topics of interest in bioengineering. *(The specific topics course must be approved by the Student Affairs Office.)* Graduate level courses must be approved by the assigned advisor (or thesis advisor if determined).

SEMINARS (required)

- BENG 281. Seminar in Bioengineering
- BENG 282. Seminar: Faculty Research

Restrictions to core course work requirements are as follows:

1. Units obtained in BENG 281, 299, or 501 may not be applied toward the course work requirement.
2. No more than a total of eight units of BENG 296 and 298 may be applied toward the course work requirement.
3. No more than twelve units of upper-division 100-level bioengineering courses may be applied toward the course work requirement.

Students must maintain at least a B average in the courses taken to fulfill the degree requirements.

Master's Time Limit Policy

Full-time M.S. students are permitted seven quarters in which to complete all requirements. While there are no written time limits for part-time students, the department has the right to set individual deadlines if necessary.

A strong effort is made to schedule M.S.-level course offerings so that students may obtain their M.S. degree in one year of full-time study or two years of part-time study *(see regulations on part-time study under "Graduate Studies")*. Entering students who do not meet the prerequisites of these core

courses may have to take some basic courses to make up the deficiency.

A candidate admitted for the M.S. degree who wishes to transfer to the Ph.D. program must consult the Student Affairs Office concerning the transfer before completion of the M.S. program.

Change of Degree Aim

Upon completion of the requirements for the M.S. degree, students are not automatically eligible for admission to the Ph.D. program.

M.S. candidates who wish to pursue a doctorate must submit an application for a change in status to the Graduate Studies Committee. The application must be approved and signed by a bioengineering faculty member who expects to serve as the student's Ph.D. advisor. Applications will be reviewed by an ad hoc faculty committee. If the committee recommends that the student has good potential for success in the doctoral program, the student will be given the opportunity to take an oral examination equivalent to the Ph.D. Departmental Qualifying Examination. At the time of that exam, an assessment will be made concerning admission to the Ph.D. program.

A change of status from a master's program to the doctoral program requires that the student meet the minimal grade-point average required by the department of doctoral candidates.

MASTER OF ENGINEERING DEGREE PROGRAM

The department offers a **master of engineering (M.Eng.) degree**. The purpose of this degree is to prepare design and project engineers for careers in the medical and biological engineering industries within the framework of the graduate program of the Department of Bioengineering. It is a terminal professional degree in engineering, which includes recognition of the importance of breadth in technical knowledge and sufficient electives to address job-specific interests and professional skills such as economics, management, and business. It is intended for students who are primarily interested in engineering design, development, manufacturing, and management within an industrial setting.

Students who may be interested in continuing to the Ph.D. program should apply to the M.S. program and not the terminal M.Eng. program.

The M.Eng. program is a flexible, course-intensive terminal professional degree, designed to be completed in one academic year of full-time study. It does not require a comprehensive exam. However, students must enroll for technical elective credit in BENG 295, *Bioengineering Design Project and Industrial Training*, under the direction of a faculty instructor. This is done by participating in the Graduate Industrial Training Program, which allows students to work in an industrial setting on bioengineering projects in order to gain practical experience. (See **"**Industrial Internship Program**"** and "Graduate Industrial Training Program**"** sections of this catalog.) BENG 295 course requirements include a written technical report.

In addition to enrolling in one to two quarters (four to eight units) of BENG 295, Bioengineering Design Project and Industrial Training, students must select six courses from the approved core areas, one to two courses from the approved technical elective course list, and three courses from the approved general elective course list. Such core courses and technical and general electives are described below. In selecting breadth courses, students must be mindful of the prerequisite requirements for some of the courses listed. The lists below are based on the current graduate course offerings of the bioengineering and other engineering departments. The Graduate Studies Committee will review the M.Eng. course lists annually and update them as course offerings change. M.Eng. students are required to complete course requirements with a grade of B or better.

Students must also enroll in BENG 291, Senior Seminar I: Professional Issues in Bioengineering. This course instills skills for personal and organizational development during lifelong learning. Students prepare portfolios and a model NIH small business research grant.

Required Core Courses for M.Eng. Degree Program

CORE COURSES (six required)

Engineering Physics

- BENG 221. Mathematical Methods for Bioengineering
- BENG 222. Continuum Mechanics and Transport Phenomena in Living Systems
- BENG 223. Thermodynamics, Statistical Mechanics, and Interfacial Phenomena in Living Systems

Life Science

- BENG 230A. Biochemistry
- BENG 230B. Cell and Molecular Biology
- BENG 230C. Cardiovascular Physiology
- BENG 230D. Respiratory and Renal Physiology
- BENG 231. Foundations of Physiology for Bioengineering
- Tissue Engineering
- BENG 241A. Foundations of Tissue Engineering Science
- BENG 241B. Methods in Tissue Engineering Science
- BENG 242/MATS 257. Polymer Science and Engineering

Imaging

- BENG 247A. Advanced Biophotonics
- BENG 280A. Principles of Biomedical Imaging
- BENG 280B. Comparative Biomedical Imaging
- Other approved core graduate courses taught by bioengineering faculty that satisfy the depth requirement of the M.Eng. degree as approved by the Graduate Studies Committee.

TECHNICAL ELECTIVE COURSES FOR M.ENG. DEGREE (three required, one of which must be BENG 295)

- BENG 202/CSE 282. Bioinformatics II: Introduction to Bioinformatics Algorithms
- BENG 203/CSE 283. Genomics, Proteomics, and Network Biology
- BENG 207. Neuromuscular Physiology and Biomechanics
- BENG 208. Topics in Bioengineering with Lab
- BENG 209/MAE 209. Continuum Mechanics Applied to Medicine/Biology
- BENG 211. Systems Biology and Bioengineering I. Biological Components
- BENG 212. Systems Biology and Bioengineering II. Network Reconstruction
- BENG 213. Systems Biology and Bioengineering III. Building and Simulating Large-Scale in Silico Models
- BENG 238/MED 238. Molecular Biology of the Cardiovascular System
- BENG 247B/ECE 247B. Bioelectronics
- BENG 247C/ECE 247C. Bionanotechnology
- BENG 250A. Biomechanics
- BENG 250B. Advanced Biomechanics
- BENG 253. Biomedical and Transport Phenomena
- BENG 260/BGGN 260. Neurodynamics
- BENG 267. Microcirculation in Health and Disease
- BENG 276/Chem. 276/Math. 276. Numerical Analysis in Multiscale Biology
- BENG 295. Bioengineering Design Project - **required**
- MAE 210A/CENG 210A. Fluid Mechanics I
- MAE 210B. Fluid Mechanics II
- MAE 210C. Fluid Mechanics III
- MAE 221/CENG 221AB. Heat and Mass Transfer
- MAE 229A/MATS 211A. Mechanical Properties
- MAE 231A. Solid Mechanics
- MAE 231B. Elasticity
- MAE 231C. Anelasticity
- MAE 280A. Linear Systems Theory
- MAE 293. Advanced Computer Graphics for Engineers and Scientists
- MATS 252/MAE 266. Biomaterials and Medical Devices
- MATS 253/MAE 267. Nanomaterials and Properties
- CSE 202. Algorithm Design and Analysis
- CSE 210. Principles of Software Engineering
- CSE 250A. Artificial Intelligence: Search and Reasoning

- ECE 235. Nanometer-Scale VLSI Devices
- ECE 251A. Digital Signal Processing I
- ECE 251B. Digital Signal Processing II

Examples of General Electives for M.Eng. (three required)

- BENG 225. BioBusiness: Biotech Company
- ENG 201. Venture Mechanics
- ENG 202. Enterprise Dynamics
- ENG 203. Applied Innovations
- ECE 254. Detection Theory
- IR/PS Management: IRGN 420, 434, 438, 439, 444, IRCO 420, 421, 490G
- IR/PS International Issues: IRCO 401, IRGN 407, 411, 413
- MAE 290A. Efficient Numerical Methods for Simulation, Organization, and Control
- Technical Elective courses may be taken for general elective credit

For other courses that address job-specific interests and professional skills such as economics, management, and business, consult with the Student Affairs Office.

SEMINAR (required)

BENG 291. Professional Issues in Bioengineering

Sample M.Eng. Degree Schedule

FALL	WINTER	SPRING
Core	Core	Core
Core	Core	Core
BENG 225 (GE)	BENG 295 (TE)	BENG 295 (TE)
Tech. Elec.	Gen. Elec.	Gen. Elec.
	BENG 291 (Seminar)	

DOCTORAL DEGREE PROGRAM

The **bioengineering Ph.D. program** is intended to prepare students for a variety of careers in research and teaching. Therefore, depending on the student's background and ability, research is initiated as soon as possible. Bioengineering students have specific course requirements and must maintain a minimum grade-point average of 3.4 in these courses. Students, in consultation with their advisors, develop course programs that will prepare them for the Departmental Qualifying Examination and for their dissertation research. These programs of study and research must be planned to meet the time limits established to advance to candidacy and to complete the requirements for the degree. Doctoral students who have passed the Departmental Qualifying Examination may take any course for an S/U grade with the exception of courses required by the Departmental or Senate Qualifying Examination Committee. It is recommended that all bioengineering graduate students take a minimum of two courses (other than research) per academic year after passing the Departmental Qualifying Examination. Details can be obtained from the Student Affairs Office.

Ph.D. in Bioengineering with Specialization in Multiscale Biology

As of winter 2009, the UCSD campus is offering a new Ph.D. specialization in Multiscale Biologythat will be available to doctoral candidates in participating programs that span four divisions: Biological Sciences, Physical Sciences, Jacobs School of Engineering, and Health Sciences at UCSD. The Ph.D. specialization is designed to allow students to obtain standard basic training in their chosen field within the Biological Sciences, Physical Sciences, Engineering and Health Sciences with training in integrative and quantitative analysis across multiple scales of biological organization from molecule to organism in health and disease into their graduate studies. It trains a new cadre of Ph.D. scientists and provides a unique interdisciplinary education at the interfaces between the biological, medical, physical, and engineering sciences.

The specific objectives of this program are

1. Focused collaboration across nine graduate degree programs train a new generation of cross-disciplinary scientist.
2. State-of-the-art interdisciplinary training through a new technology-centered hands-on graduate laboratory course curriculum.
3. Novel emphasis on research aimed at integrative and quantitative analysis across multiple scales of biological organization from molecule to organism in health and disease.

Prospective students must apply and be admitted into the Ph.D. program in bioengineering described previously. (For more information, see the Department of Bioengineering and/or the Graduate Interfaces Training Program administered within the Department of Chemistry and Biochemistry (4010 York Hall, Revelle College).

Doctoral Examinations

A bioengineering Ph.D. student is required to pass three examinations. The first is a Departmental Qualifying Examination, which must be taken during the spring quarter of the first year of study. The exam is designed to ensure that all successful candidates possess a firm command of the engineering and life science subjects that form the foundations of bioengineering research and their integration at a level appropriate for the doctorate. It is administered by a committee designated by the department, consisting of departmental faculty members and, in some cases, other faculty members from a related academic department (e.g., MAE, ECE, medicine). The scope of the oral examination includes the two broad areas that form the core first-year Ph.D. curriculum, namely *Engineering Physics* and *Life Science*. The purpose of the exam is not merely to recapitulate the content of first-year courses, but rather to establish that students are able to synthesize this knowledge and apply it to solve problems in contemporary bioengineering research.

Curriculum for First-Year Ph.D. Students

All bioengineering students are expected to enroll for letter grade credit in the core courses in *Engineering Physics* and *Life Sciences* tracks listed below. In addition they are required to take three electives for a letter grade from among the courses listed based on advice from the graduate advisor. Each incoming student will be assigned a bioengineering faculty advisor who will serve as a graduate advisor until the student chooses a thesis advisor. First-year students are also required to enroll in two one-credit seminars.

CORE COURSES (all six required)

Engineering Physics

- BENG 221. Mathematical Methods for Bioengineering
- BENG 222. Continuum Mechanics and Transport Phenomena in Living Systems
- BENG 223. Thermodynamics, Statistical Mechanics, Interfacial Phenomena in Living Systems

Life Science

- BENG 230A. Biochemistry
- BENG 230B. Cell and Molecular Biology
- BENG 231. Foundations of Physiology for Bioengineering

ELECTIVE COURSES (three required, from any of the four categories)

Systems Biology

- BENG 202/CSE 282. Bioinformatics II: Introduction to Bioinformatics Algorithms
- BENG 203/CSE 283. Genomics, Proteomics, and Network Biology
- BENG 211. Systems Biology and Bioengineering I: Biological Components
- BENG 212. Systems Biology and Bioengineering II: Network Reconstruction
- BENG 213. Systems Biology and Bioengineering III: Building and Simulating Large-Scale In Silico Models

Regenerative Medicine and Imaging

BENG 230C. Cardiovascular Physiology

- BENG 230D. Respiratory and Renal Physiology
- BENG 241A. Foundations of Tissue Engineering
- BENG 280A. Principles of Biomedical Imaging
- BENG 280B. Comparative Biomedical Imaging

Multiscale Bioengineering

- BENG 209/MAE 209. Continuum Mechanics Applied to Medicine/Biology
- BENG 238/MED 238. Molecular Biology of the Cardiovascular System
- BENG 247A/ECE 247A. Advanced Biophotonics
- BENG 247B/ECE 247B. Bioelectronics

- BENG 247C/ECE 247C. Bionanotechnology
- BENG 250A. Biomechanics
- BENG 276/Chem. 276/Math. 276. Numerical Analysis in Multiscale Biology

Other Courses That Can Serve as Electives

BENG 207. Topics in Bioengineering

Course is given at the discretion of the faculty on current topics of interest in bioengineering. (The specific topics course must be approved by the Student Affairs Office.)

Graduate level courses approved by the assigned advisor (or thesis advisor if determined).

SEMINARS (required)

- BENG 281. Seminar in Bioengineering
- BENG 282. Seminar: Faculty Research

In addition to the above mentioned breadth requirements, students must complete the following courses in their second and subsequent years of study:

- At least two four-unit courses from an approved list that includes the bioengineering graduate course sequences, other engineering/science course offerings, and School of Medicine courses. Students often take SOM courses to fulfill the second-year course requirements. The faculty advisor must approve the courses. Approved courses include BENG 203/CSE 283, BENG 207, BENG 230D, BENG 238/MED 238, BENG 247A-B-C, BENG 250B, MAE 207, MAE 210A-B-C, MAE 221A, MAE 231A-B-C, MAE 267/MATS 253, ECE 251A–B, and Chem. 211.
- One quarter of BENG 501. Teaching Experience

Courses comprising subject areas as well as subsequent requirements and composition of the examination committee, must be approved by the Graduate Studies Committee. Students are advised to seek such approval well in advance of their expected examination date, preferably while planning graduate studies.

Teaching experience is required of all bioengineering Ph.D. students prior to taking the Senate Qualifying Exam described below. Teaching experience is defined as service as a graduate student instructor in a course designated by the department. The total teaching requirement for new Ph.D. students is four quarters at 25 percent effort (ten hours per week). At least one quarter of teaching experience is required during the first year (prior to the departmental qualifying examination) and at least one quarter in the second year. Teaching experience can be fulfilled as a requirement for student support or taken as a course for academic credit (BENG 501). Students must contact the Student Affairs Office to plan for completion of this requirement.

The **Senate Qualifying Examination** is the second examination required of bioengineering Ph.D. students. In preparation for this examination, students must have completed the Departmental Qualifying Examination and the departmental teaching experience requirement, obtained a faculty research advisor, and identified a topic for their dissertation research and made initial progress. At the time of application for advancement to candidacy, a doctoral committee responsible for the remainder of the student's graduate program is appointed by the Graduate Council. The committee conducts the Senate Qualifying Examination, during which students must demonstrate the ability to engage in thesis research. This involves the presentation and defense of a plan for the thesis research project. Upon successful completion of this examination, students are advanced to candidacy and are awarded the Candidate in Philosophy degree (see "Graduate Studies" section in this catalog).

The **Dissertation Defense** is the final Ph.D. examination. Upon completion of the dissertation research project, the student writes a dissertation that must be successfully defended in a public presentation and oral examination conducted by the doctoral committee. A complete copy of the student's dissertation must be submitted to each member of the doctoral committee approximately four weeks before the defense. It is understood that this copy of the dissertation given to committee members will not be the final copy, and that the committee members may suggest changes in the text at the time of the defense. This examination must be conducted after completion of at least three quarters from the date of advancement to doctoral candidacy. Acceptance of the dissertation by the Office of Graduate Studies and the university librarian represents the final step in completion of all requirements for the Ph.D.

There is no formal foreign language requirement for doctoral candidates. Students are expected to master whatever language is needed for the pursuit of their own research.

Obtaining an M.S. Degree

Ph.D. students may obtain the M.S. degree by completing the course work requirements and by passing the Ph.D. departmental qualifying examination. Course work requirements include successful completion of a total of forty-eight units of credit comprising *Engineering Physics* and *Life Science* and two four-unit courses from an approved list taken during the second year of the Ph.D. degree *(*see details on course work requirements in the section "Doctoral Degree Program"*)*. Students should consult with the Student Affairs Office in advance of their second year of study concerning required paperwork and deadlines for conferral of the M.S. degree.

Ph.D. Time Limit Policy

Precandidacy status is limited to three years. Doctoral students are eligible for university support for six years. The defense and submission of the doctoral dissertation must be within seven years.

Evaluations

In the spring of each year, the faculty evaluate each doctoral student's overall performance in course work, research, and prospects for financial support for future years. A written assessment is given to the student after the evaluation. If a student's work is found to be inadequate, the faculty may determine that the student cannot continue in the graduate program.

Industrial Internship Program and Graduate Industrial Training Program

The Department of Bioengineering offers two industry-related programs: the **Industrial Internship Program** for undergraduates and the **Graduate Industrial Training Program** for graduate students. Both industrial programs are designed to complement the department's academic curriculum with practical industry experience. The Bioengineering Industrial Internship Office is located in 125 Powell-Focht Bioengineering Hall. Students interested in these programs should contact the office at bioengineering@ucsd.edu well in advance of the quarter in which they would like to start their internship.

The Industrial Internship Program is available to undergraduate students who have completed all lower-division course requirements. Academic credit under BENG 196, Bioengineering Industrial Internship, can be earned by spending ten weeks or more as interns in an industrial setting. The intern may be involved in a range of activities, including design, analysis, manufacturing, testing, regulatory affairs, etc., under the direction of a mentor in the workplace. At the completion of the internship experience, students are required to submit a brief report to the mentor and faculty advisor describing their activities.

The Graduate Industrial Training Program is designed for students in the Master of Engineering Degree Program. This program serves to significantly enhance the professional development of M.Eng. students in preparation for leadership in the bioengineering industry. Students will complete an independent industrial bioengineering project in a company setting under the direction of an industrial and faculty advisor.

COURSES

For course descriptions not found in the UC San Diego General Catalog, 2010–11, please contact the department for more information.

Note: The department will endeavor to offer the courses as outlined below; however, unforeseen circumstances sometimes mandate a change of scheduled offerings. Students are strongly advised to check with the department's Student Affairs Office. This is of particular importance in planning schedules to satisfy graduation requirements.

The following schedule is tentative for the academic year 2010–11 only. The quarter in which a course is scheduled may differ in subsequent academic years. Students should consult TritonLink and the Student Affairs Office to obtain current information.

Prerequisites are enforced when students register for courses. Students who have satisfied prerequisites at another institution or by AP credit need to be pre-authorized to register in these courses. If pre-authorization is necessary, students should contact the Student Affairs Office before the scheduled registration period.

Some courses require a course material fee.

LOWER-DIVISION

BENG 1. Introduction to Bioengineering (1)
An introduction to the central topics of bioengineering in a seminar format. The principles of problem definition, team design, engineering inventiveness, information access, communication, ethics, and social responsibility will be emphasized. P/NP grading only. **Prerequisite:** none. (W)

BENG 87. Freshman Seminar (1)
The Freshman Seminar Program is designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small seminar setting. Freshman seminars are offered in all campus departments and undergraduate colleges, and topics vary from quarter to quarter. Enrollment is limited to fifteen to twenty students, with preference given to entering freshmen. (F,W,S)

BENG 97. Internship/Field Studies (1–4)
An enrichment program available to a limited number of lower-division undergraduate students, which provides work experience with industry, government offices, and hospitals. The internship is coordinated through UCSD's Academic Internship Program under the supervision of a faculty member and an industrial, government, or hospital employee. **Prerequisites:** lower-division standing, completion of thirty units of UCSD undergraduate study, a minimum UCSD GPA of 3.0, and a completed and approved Special Studies form. (F,W,S)

BENG 98. Directed Group Study (1–4)
Directed group study on a topic or in a field not included in the regular department curriculum. (P/NP grades only.) **Prerequisites:** lower-division standing, completion of thirty units of undergraduate study at UCSD with a UCSD GPA of at least 3.0 and consent of a Bioengineering faculty member; completed and approved Special Studies form.

BENG 99. Independent Study for Undergraduates (4)
Independent reading or research by arrangement with a Bioengineering faculty member. (P/NP grades only.) **Prerequisites:** lower-division standing, completion of thirty units of undergraduate study at UCSD with a UCSD GPA of at least 3.0 and consent of a Bioengineering faculty member; completed and approved Special Studies form.

BENG 99R. Independent Study (1)
Independent study or research under direction of a member of the faculty. **Prerequisites:** student must be of first-year standing and a Regent's Scholar; approved Special Studies form.

UPPER-DIVISION

BENG 100. Introduction to Bioengineering Design (4)
A general introduction to bioengineering design, including examples of engineering analysis and design applied to representative topics in biomechanics, bioinstrumentation, biomaterials, biotechnology, and related areas. A review of technological needs, design methodology, testing procedures, statistical analysis, governmental regulation, evaluation of costs and benefits, quality of life, and ethical issues. **Prerequisites:** BENG 1; grade of C– or better in Math. 21C or Math. 20C and Math. 21D or Math. 20D, and Phys. 2C; majors only. (S)

BENG 101. Foundations of Biomedical Imaging (4)
An introduction to the principles and applications of biomedical imaging, with emphasis on the acquisition, processing, display of imagery, and design of imaging systems. Filtering, convolution, and Fourier methods. Microscopy, radiography, computed tomography, magnetic resonance, ultrasound, and nuclear imaging. **Prerequisites:** Grade of C– or better in BENG 100; majors only or consent of department. (F)

BENG 103B. Bioengineering Mass Transfer (4)
Mass transfer in solids, liquids, and gases with application to biological systems. Free and facilitated diffusion. Convective mass transfer. Diffusion-reaction phenomena. Active transport. Biological mass transfer coefficients. Steady and unsteady state. Flux-force relationships. (Credit not allowed for both CENG 101C and BENG 103B.) **Prerequisites:** grade of C– or better in CENG 101A or BENG 112A; majors only or consent of instructor. (S)

BENG 109. Bioengineering Statics and Dynamics (4)
Newton's Laws. Static resultant forces and moments. Conservation laws of dynamics. Muscle and joint loads. Human body dynamics, locomotion, and clinical applications. Bodies in contact: friction, momentum, and impulse; impact and injury. Work, power, and energy relationships. Bioengineering design problems. **Prerequisites:** grade of C– or better in Math. 21D or Math. 20D and Phys. 2C; majors only or consent of instructor. (W)

BENG 110. Continuum Mechanics (4)
An introduction to continuum mechanics of both living and nonliving bodies. The laws of motion and free-body diagrams. Stresses. Deformation. Compatibility conditions. Constitutive equations. Properties of common fluids and solids. Derivation of field equations and boundary conditions. Applications to bioengineering design. **Prerequisites:** grades of C– or better in Physics 2A, 2B, 2C, and BENG 109; majors only or consent of instructor. (F)

BENG 112A. Biomechanics (4)
Introduction to physiological systems, with emphasis on structure and function of major tissues and organs. Application of mechanics to understand the behavior of these tissues and organs at gross and microscopic levels. Bioelastic solids. Rigid body biomechanics. Biofluids. Bioengineering and medical design. **Prerequisites:** grade of C– or better in BENG 110; majors only or consent of instructor. (W)

BENG 112B. Biomechanics (4)
Biomechanics of living tissues with emphasis on continuum analysis of problems in biofluid and cell mechanics. Engineering design and problem solving in the biomechanics of mammalian tissues, especially those of the cardiovascular system. **Prerequisites:** grade of C– or better in BENG 112A; majors only or consent of instructor. (S)

BENG 119A. Design Development in Biomechanics (3)
Development of design project in biomechanics. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 119B. Design Implementation in Biomechanics (3)
Implementation of design project in biomechanics. **Prerequisites:** grade of C– or above in BENG 119A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 122A. Biosystems and Control (4)
Systems and control theory applied to bioengineering. Modeling, linearization, transfer functions, Laplace transforms, closed-loop systems, design and simulation of controllers. Dynamic behavior and controls of first and second order processes. PID controllers. Stability. Bode design. Features of biological controls systems. A simulation term project using MATLAB and an oral presentation are required. **Prerequisites:** grade of C– or better in MAE 140; majors only or consent of department. (W)

BENG 123. Systems Biology and Bioengineering (4)
Systems biology and bioengineering consists of (1) enumeration of biological components participating in a biological process, (2) reconstruction of interactions to form a network, (3) mathematical representation for analysis, interpretation, and prediction, (4) model validation and use in prospective design. **Prerequisites:** grade of C– or better in BIBC 100; majors only or consent of instructor. (W)

BENG 125. Modeling and Computation in Bioengineering (4)
Computational modeling of molecular bioengineering phenomena: excitable cells, regulatory networks, and transport. Application of ordinary, stochastic, and partial differential equations. Introduction to data analysis techniques: power spectra, wavelets, and nonlinear time series analysis. **Prerequisites:** grade of C– or better in BENG 122A or BENG 123; majors only or consent of instructor. (S)

BENG 126A. Design Development in Bioinformatics Bioengineering (3)
Development of design project in bioinformatics bioengineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 126B. Design Implementation in Bioinformatics Bioengineering (3)
Implementation of design project in bioinformatics bioengineering. **Prerequisites:** grade of C– or above in BENG 126A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 127A. Design Development in Molecular Systems Bioengineering (3)
Development of design project in molecular systems bioengineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 127B. Design Implementation in Molecular Systems Bioengineering (3)
Implementation of design project in molecular systems bioengineering. **Prerequisites:** grade of C– or above in BENG 127A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 128A. Design Development in Genetic Circuits Bioengineering (3)
Development of design project in genetic circuits bioengineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 128B. Design Implementation in Genetic Circuits Bioengineering (3)
Implementation of design project in genetic circuits bioengineering. **Prerequisites:** grade of C– or above in BENG 128A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 129A. Design Development in Cell Systems Bioengineering (3)
Development of design project in cell systems bioengineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 129B. Design Implementation in Cell Systems Bioengineering (3)
Implementation of design project in cell systems bioengineering. **Prerequisites:** grade of C– or above in BENG 129A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 130. Molecular Physical Chemistry (4)
An introduction to physical principles that govern biological matter and processes. Thermodynamic principles and their molecular origin, structural basis of life and physical and conceptual models to illustrate life phenomena. **Prerequisites:** grade of C– or better in Chem. 6B, Math. 20A, 20B, Physics 2A, 2B, 2C; majors only or consent of instructor. (W)

BENG 139A. Design Development in Molecular Bioengineering (3)
Development of design project in molecular bioengineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 139B. Design Implementation in Molecular Bioengineering (3)
Implementation of design project in molecular bioengineering. **Prerequisites:** grade of C– or above in BENG 139A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 140A. Bioengineering Physiology (4)
Introductory mammalian physiology for bioengineering students, with emphasis on control mechanisms and

engineering principles. Basic cell functions; biological control systems; muscle; neural; endocrine, and circulatory systems. Not intended for premedical bioengineering students. (Credit not allowed for both BIPN 100 and BENG 140A.) **Prerequisites:** grade of C– or better in Chem. 6A, 6B, Physics 2A, 2B, 2C, BILD 1; majors only or consent of instructor. (W)

BENG 140B. Bioengineering Physiology (4)
Introductory mammalian physiology for bioengineering students, with emphasis on control mechanisms and engineering principles. Digestive, respiratory, renal, and reproductive systems; regulation of metabolism, and defense mechanisms. (Credit not allowed for both BIPN 102 and BENG 140B.) **Prerequisite:** grade of C– or better in BENG 140A; majors only or consent of instructor. (S)

BENG 147A. Design Development in Neural Engineering (3)
Development of design project in neural engineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 147B. Design Implementation in Neural Engineering (3)
Implementation of design project in neural engineering. **Prerequisites:** grade of C– or above in BENG 147A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 148A. Design Development in Cardiac Bioengineering (3)
Development of design project in cardiac bioengineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 148B. Design Implementation in Cardiac Bioengineering (3)
Implementation of design project in cardiac bioengineering. **Prerequisites:** grade of C– or above in BENG 148A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 149A. Design Development in Vascular Bioengineering (3)
Development of design project in vascular bioengineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 149B. Design Implementation in Vascular Bioengineering (3)
Implementation of design project in vascular bioengineering. **Prerequisites:** grade of C– or above in BENG 149A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 160. Chemical and Molecular Bioengineering Techniques (4)
Introductory laboratory course in current principles and techniques of chemistry and molecular biology applicable to bioengineering. Quantitation of proteins and nucleic acids by spectrophotometric, immunological, and enzymatic methods. Separations and purification by centrifugation, chromatographic, and electrophoretic methods. Course material fee may apply. **Prerequisites:** grade of C– or better in BIBC 102, BICD 100, BENG 100, MAE 170; majors only or consent of instructor. (S)

BENG 161A. Bioreactor Engineering (4)
Engineering, biochemical, and physiological considerations in the design of bioreactor processes: enzyme kinetics, mass transfer limitations, microbial growth, and product formation kinetics. Fermentation reactor selection, design, scale-up, control. Quantitative bioengineering analysis and design of biochemical processes and experiments on biomolecules. **Prerequisites:** grade of C– or better in Chem. 114B or BIBC 102 (may be taken concurrently), BENG 122A or BENG 123, and BIBC 103 or BENG 160; majors only or consent of instructor. (F)

BENG 161B. Biochemical Engineering (4)
Commercial production of biochemical commodity products. Application of genetic control systems and mutant populations. Recombinant DNA and eucaryotic proteins in E. coli and other host organisms. Product recovery operations, including the design of bioseparation processes of filtration, adsorption, chromatography, and crystallization. Bioprocess economics. Human recombinant erythropoietin as an example, from genomic cloning to CHO cell expression, to bioreactor manufacturing and purification of medical products for clinical application. **Prerequisites:** grade of C– or better in BENG 161A; majors only or consent of instructor. (W)

BENG 161C. Metabolic Engineering (4)
Engineering systems analysis of metabolic and regulatory processes. Use of high-throughput data for network reconstruction. Formulation of the stoichiometric matrix and its uses to determine steady state flux distributions. Kinetics of individual enzymatic reactions. Computer simulations of metabolic networks, systemic sensitivity coefficients, bifurcations to study dynamic network functions. Temporal decomposition of metabolic processes into multiple time scales and the physiologic roles of metabolic events in each scale. **Prerequisites:** grade of C– or better in BENG 160B or BENG 161B; majors only or consent of instructor. (S)

BENG 162. Biotechnology Laboratory (4)
Laboratory practices and design principles for biotechnology. Culture of microorganisms and mammalian cells, recombinant DNA bioreactor design and operation. Design and implementation of biosensors. A team design-based term project and oral presentation required. Course material fee(s) may apply. **Prerequisites:** grade of C– or above in MAE 170; BIBC 102; BIBC 103 or BENG 160; majors only or consent of instructor. (F)

BENG 166A. Cell and Tissue Engineering (4)
Engineering analysis of physico-chemical rate processes that affect, limit, and govern the function of cells and tissues. Cell migration, mitosis, apoptosis, and differentiation. Dynamic and structural interactions between mesenchyme and parenchyme. The role of the tissue microenvironment including cell-cell interactions, extracellular matrix, and growth factor communication. The design of functional tissue substitutes including cell and material sourcing, scale-up and manufacturability, efficacy and safety, regulatory, and ethical topics. Clinical Applications. **Prerequisites:** grade of C– or better in BENG 103B or BENG 112B; senior standing; majors only or consent of department. (F)

BENG 167. Cell and Tissue Engineering Laboratory (4)
An introduction to contemporary methods and applications. Students will formulate and test hypotheses related to the design and production of functional tissue substitutes. Topics to be explored include tissue characterization, biomaterial scaffolds, cell migration, adhesion, and growth. **Prerequisite:** BENG 166A; majors only or consent of instructor. (S)

BENG 168. Biomolecular Engineering (4)
Basic molecular biology; recombinant DNA technologies; design and manufacture of recombinant proteins and genetically engineered cells; architecture and mechanism of molecular nano-machineries that perform gene regulation, energy conversion, enzymatic catalysis, and active transport. **Prerequisites:** grade of C– or better in BILD 1 and BENG 100; majors only or consent of instructor. (S)

BENG 169A. Design Development in Tissue Engineering (3)
Development of design project in tissue bioengineering. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 169B. Design Implementation in Tissue Engineering (3)
Implementation of design project in tissue engineering. **Prerequisites:** grade of C– or above in BENG 169A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 172. Bioengineering Laboratory (4)
A laboratory course demonstrating basic concepts of biomechanics, bioengineering design, and experimental procedures involving animal tissue. Sources of error and experimental limitations. Computer data acquisition, modeling, statistical analysis. Experiments on artery, muscle and heart mechanics, action potentials, viscoelasticity, electrocardiography, hemorheology. Course material fee may apply. **Prerequisites:** grade of C– or better in MAE 170; junior or senior standing in the major or consent of instructor. (S)

BENG 173. Bioengineering Project Laboratory (4)
Applications of bioengineering concepts to the solution of practical and research problems. Planning, design, and testing of prototype devices. Term project and oral presentation are required. **Prerequisites:** majors only; consent of instructor; BENG 112B, BENG 172. (Not offered in 2010–11.) (S)

BENG 179A. Design Development in Bioinstrumentation (3)
Development of design project in bioinstrumentation. **Prerequisites:** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 179B. Design Implementation in Bioinstrumentation (3)
Implementation of design project in bioinstrumentation. **Prerequisites:** grade of C– or above in BENG 179A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG/BIMM/CSE 181. Molecular Sequence Analysis (4)
(Cross-listed as BIMM 181 and CSE 181.) This course covers the analysis of nucleic acid and protein sequences, with an emphasis on the application of algorithms to biological problems. Topics include sequence alignments, database searching, comparative genomics, and phylogenetic and clustering analyses. Pairwise alignment, multiple alignment, DNA sequencing, scoring functions, fast database search, comparative genomics, clustering, phylogenetic trees, gene finding/DNA statistics. **Prerequisites:** CSE 100 or Math. 176, CSE 101 or Math. 188, BIMM 100 or Chem. 114C; Bioinformatics majors only. (S)

BENG/BIMM/CSE/Chem. 182. Biological Databases (4)
(Cross-listed as BIMM 182, CSE 182, and Chem. 182.) This course provides an introduction to the features of biological data, how those data are organized efficiently in databases, and how existing data resources can be utilized to solve a variety of biological problems. Object oriented databases, data modeling and description. Survey of current biological database with respect to above, implementation of database focused on a biological topic. **Prerequisites:** CSE 100 or Math. 176; Bioinformatics majors only. (F)

BENG 183. Applied Genomic Technologies (4)
Principles and technologies for using genomic information for biomedical applications. Technologies will be introduced progressively, from DNA to RNA to protein to whole cell systems. The integration of biology, chemistry, engineering, and computation will be stressed. Topics include: Technology for the Genome, DNA Chips, RNA Technologies, Proteomic Technologies, Physiomic and Phenomic Technologies, Analysis of Cell Function. **Prerequisites:** grade of C– or better in BIMM 100 or Chem. 114C; BICD 110; Bioinformatics majors only. (F)

BENG/BIMM/CSE/Chem. 184. Computational Molecular Biology (4)
(Cross-listed as BIMM 184, CSE 184, and Chem. 184.) This advanced course covers the application of machine learning and modeling techniques to biological systems. Topics include gene structure, recognition of DNA and protein sequence patterns, classification, and protein structure prediction. Pattern discovery, hidden Markov models/support vector machines/neural network/profiles, protein structure prediction, functional characterization of proteins, functional genomics/proteomics, metabolic pathways/gene networks. **Prerequisites:** BENG 181 or

BIMM 181 or CSE 181; BENG 182 or BIMM 182 or CSE 182 or Chem. 182; Bioinformatics majors only. (W)

BENG 186A. Principles of Biomaterials Design (4)
Fundamentals of materials science as applied to bioengineering design. Natural and synthetic polymeric materials. Materials characterization and design. Wound repair, blood clotting, foreign body response, transplantation biology, biocompatibility of materials, tissue engineering. Artificial organs and medical devices. Government regulations. Patenting. Economic impact. Ethical issues. A term project and oral presentation are required. **Prerequisites:** grade of C– or better in BENG 112B or senior standing in Bioengineering: Biotechnology major; majors only or consent of department. (S)

BENG 186B. Principles of Bioinstrumentation Design (4)
Biophysical phenomena, transducers, and electronics as related to the design of biomedical instrumentation. Potentiometric and amperometric signals and amplifiers. Biopotentials, membrane potentials, chemical sensors. Electrical safety. Mechanical transducers for displacement, force, and pressure. Temperature sensors. Flow sensors. Light-based instrumentation. **Prerequisites:** grade of C– or better in MAE 140 and MAE 170; majors only or consent of instructor. (W)

BENG 186C. Bioengineering Design (4)
Development of a bioengineering design described in a formal engineering report. Engineering analysis and application of methodology from applied sciences, biology, physiology, and biochemistry. Analysis of economic, environmental, manufacture, ethical, health and safety, social issues, and application of governmental regulations. **Prerequisites:** grade of C– or better in BENG 103B, BENG 106B, BENG 112B, BENG 186B, and MAE 130A; majors only or consent of instructor. (Not offered in 2010–11.) (W)

BENG 187A. Bioengineering Design Project: Planning (1)
General engineering design topics, including project planning and design objectives, background research, engineering needs assessment, and technical design specifications and requirements. Introduction to biomedical and biotechnology design projects. Majors must enroll in the course for a letter grade in order to count the sequence toward the major. No exceptions will be approved. **Prerequisites:** grade of C– or better in BENG 101 or BICD 100; BENG 112A or CENG 101A; BENG 140A or BIBC 102; BENG 186B or BENG 123; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (S)

BENG 187B. Bioengineering Design Project: Development (1)
Development of original bioengineering design to solution of problem in biology or medicine. Analysis of economic issues, manufacturing and quality assurance, ethics, safety, government regulations and patent requirements. Oral presentation and formal engineering reports. Majors must enroll in the course for a letter grade in order to count the sequence towards the major. No exceptions will be approved. Prerequisites: grade of C– or better in BENG 187A, MAE 170, and BENG 112B or BENG 123; concurrent enrollment in one of BENG 119A, BENG 126A, BENG 127A, BENG 128A, BENG 129A, BENG 139A, BENG 147A, BENG 148A, BENG 149A, BENG 169A, or BENG 179A; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 187C. Bio engineering Design Project: Implementation (1)
Approaches to implementation of senior design project, including final report. Teams will report on construction of prototypes, conduct of testing, collection of data, and assessment of reliability and failure. Majors must enroll in the course for a letter grade in order to count the sequence toward the major. No exceptions will be approved. **Prerequisites:** grade of C– or better in BENG 187B; concurrent enrollment in one of the following lab sections: BENG 119B, BENG 126B, BENG 127B, BENG 128B, BENG 129B, BENG 139B, BENG 147B, BENG 148B, BENG 149B, BENG 169B, or BENG 179B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 187D. Bioengineering Design Project: Presentation (1)
Oral presentations of design projects, including design, development, and implementation strategies and results of prototype testing. Majors must enroll in the course for a letter grade in order to count the sequence toward the major. No exceptions will be approved. **Prerequisites:** grade of C– or better in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (S)

BENG 191/291. Senior Seminar I: Professional Issues in Bioengineering (2)
(Conjoined with BENG 291.) Instills skills for personal and organizational development during lifelong learning. Student prepares portfolio of personal attributes and experiences, prepares for career interviews plus oral report of interviewing organizational CEO. Graduate students will prepare a NIH small business research grant. **Prerequisite:** consent of instructor. (W)

BENG 192. Senior Seminar in Bioengineering (1)
The Senior Seminar Program is designed to allow senior undergraduates to meet with faculty members in a small group setting to explore an intellectual topic in bioengineering (at the upper-division level). Senior seminars may be offered in all campus departments. Topics will vary from quarter to quarter. Senior seminars may be taken for credit up to four times with a change in topic and permission of the department. Enrollment is limited to twenty students, with preference given to seniors.

BENG 195. Teaching (2–4)
Teaching and tutorial assistance in a bioengineering course under supervision of instructor. Not more than four units may be used to satisfy graduation requirements. (P/NP grades only.) **Prerequisites:** B average in the major and departmental approval. (F,W,S)

BENG 196. Bioengineering Industrial Internship (1–4)
Under the joint supervision of a faculty advisor and industry mentor, the student will work at a bioengineering industrial site to gain practical bioengineering experience. No more than twelve units may be used to satisfy graduation unit requirements. (P/NP grades only.) **Prerequisites:** consent of department and completion of all lower-division course requirements, including general-science requirements; some laboratory experience; completion of ninety units with a 2.5 GPA; and consent of a bioengineering faculty coordinator. (F,W,S,Su)

BENG 197. Engineering Internship (1–4)
An enrichment program, available to a limited number of undergraduate students, which provides work experience with industry, government offices, hospitals, and their practices. Subject to the availability of positions, students will work in a local industry or hospital (on a salaried or unsalaried basis) under the supervision of a faculty member and industrial, government, or hospital employee. Coordination of the Engineering Internship is conducted through UCSD's Academic Internship Program. Time and effort to be arranged. Units may not be applied towards major graduation requirements unless prior approval of a faculty advisor is obtained and internship is an unsalaried position. **Prerequisites:** completion of ninety units with a 2.5 GPA and consent of a bioengineering faculty coordinator. (F,W,S,Su)

BENG 198. Directed Group Study (1–4)
Directed group study, on a topic or in a field not included in the regular department curriculum, by arrangement with a bioengineering faculty member. (P/NP grades only.) **Prerequisites:** upper-division standing, completion of ninety units of UCSD undergraduate study, a minimum UCSD GPA of 2.5, consent of instructor, and a completed and approved Special Studies form. (F,W,S)

BENG 199. Independent Study for Undergraduates (4)
Independent reading or research by arrangement with a bioengineering faculty member. May be taken for credit three times. (P/NP grades only.) **Prerequisites:** upper-division standing, completion of ninety units of UCSD undergraduate study, a minimum UCSD GPA of 2.5, consent of instructor, and a completed and approved Special Studies form. (F,W,S,Su)

GRADUATE

BENG 202/CSE 282. Bioinformatics II: Introduction to Bioinformatics Algorithms (4)
(Formerly BENG 202/CSE 257A.) Introduction to methods for sequence analysis. Applications to genome and proteome sequences. Protein structure, sequence-structure analysis. **Prerequisite:** Pharm. 201 or consent of instructor. (W)

BENG 203/CSE 283. Genomics, Proteomics, and Network Biology (4)
Annotating genomes, characterizing functional genes, profiling, reconstructing pathways. **Prerequisites:** Pharm. 201, BENG 202/CSE 282 or consent of instructor. (S)

BENG 207. Topics in Bioengineering (4)
Course given at the discretion of the faculty on current topics of interest in bioengineering. (F,W,S)

BENG 208. Topics in Bioengineering with Lab (4)
Course given at the discretion of the faculty on topics of current interest in engineering science. This course is intended to be a lecture and lab companion topics course. **Prerequisite:** consent of instructor. (S)

BENG 209/MAE 209. Continuum Mechanics Applied to Medicine/Biology (4)
Introduction to the basic definitions of Continuum Mechanics and their mathematical formulation at the graduate level with applications to problems in medicine and biology. This course is intended for students with little or no background in mechanics; it is an introduction to the Biomechanics courses BENG 250 A–B in the Department of Bioengineering and to Solid and Fluid Mechanics courses MAE 210A and MAE 231A in the Department of Mechanical and Aerospace Engineering. This course should *not* be taken concurrently with MAE 210A or MAE 231A. **Prerequisite:** consent of instructor. (F)

BENG 211. Systems Biology and Bioengineering I: Biological Components (4)
Components of biological systems, their biochemical properties and function. The technology used for obtaining component lists. Relationship within and integration of component lists. Structured vocabularies and component ontologies. Algorithms for comparative approaches in deciphering and mining component lists. **Prerequisite:** BENG 230A or BIMM 100 or consent of instructor. (F)

BENG 212. Systems Biology and Bioengineering II: Network Reconstruction (4)
This course will cover the process of reconstructing complex biological reaction networks. Reconstruction of metabolic networks, regulatory networks and signaling networks. Bottom-up and top-down approaches. The use of collections of historical data. The principles underlying high-throughput experimental technologies and examples given on how this data is used for network reconstruction, consistency checking, and validation. **Prerequisite:** BENG 211 or consent of instructor. (W)

BENG 213. Systems Biology and Bioengineering III: Building and Simulating Large-Scale In Silico Models (4)
Mathematical models of reconstructed reaction networks and simulation of their emergent properties. Classical kinetic theory, stochastic simulation methods and constraints-based models. Methods that are scalable and integrate multiple cellular processes will be emphasized. Existing genome-scale models will be described and computations performed. Emphasis will be on studying the genotype-phenotype relationship in an in silico model driven fashion. Comparisons with phenotypic data will be emphasized. **Prerequisite:** BENG 212 or consent of instructor. (S)

BENG 221. Mathematical Methods for Bioengineering (4)
Introduction of the foundations of engineering by teaching the mathematical methods that describe the engineering principles. Analytical and numerical approaches to solving the equations. **Prerequisite:** graduate standing in bioengineering or consent of instructor. (F)

BENG 222. Continuum Mechanics and Transport Phenomena in Living Systems (4)
Introduction to engineering problems from a physics and a problem-solving perspective. Important bioengineering problems in mechanics and transport will be discussed with case studies. **Prerequisite:** graduate standing in bioengineering or consent of instructor. (S)

BENG 223. Thermodynamics, Statistical Mechanics, Interfacial Phenomena in Living Systems (4)
Thermodynamics, statistical mechanics, and interfacial phenomena that emphasize the chemical natures of living systems. Topics include intermolecular and surface forces, calculation of energetic processes, computation of electrical forces and fields, and principles of physics in multiscale engineering and design. **Prerequisite:** graduate standing in bioengineering or consent of instructor. (W)

BENG 225. BioBusiness: Starting, Growing, and Harvesting a Biotech Company (4)
Biotech is a special breed of business, especially in the start-up and early phases. Whether you are considering joining a biotech start-up or want to be successful in a life science organization, it pays to understand this unique business model. In this course, you will study and analyze (1) start-up proposals (2) the genesis of the biotech industry (3) biotech categories and growth strategies (4) the process of spinning out viable product concepts from academia (5) financing techniques (6) business development (7) acquisition/IPO valuation methods and (8) potentially disruptive technologies. The format is highly interactive and learning is enhanced by means of exercises, team presentations, and case studies. **Prerequisite:** bioengineering M.Eng. degree student or consent of instructor. (S)

BENG 230A. Biochemistry (4)
A graduate course in biochemistry especially tailored to the requirements and background of bioengineering graduate students. It will cover the important macro- and small molecules in cells that are the major constituents, or that function as signaling molecules or molecular machineries. The structures, pathways, interactions, methodologies, and molecular designs using recombinant DNA technology will be covered. **Prerequisites:** BIPN 100 and 102 or consent of instructor. (F)

BENG 230B. Cell and Molecular Biology (4)
A general survey of structure-function relationships at the molecular and cellular levels. Emphasis on basic genetic mechanisms; control of gene expression; membrane structure, transport and traffic; cell signaling; cell adhesion; mechanics of cell division; and cytoskeleton. **Prerequisites:** BIPN 100, 102, and BENG 230A or consent of instructor. (W)

BENG 230C. Cardiovascular Physiology (4)
Physical concepts of behavior of heart, large blood vessels, vascular beds in major organs and the microcirculation. Physical and physiological principles of blood flow, blood pressure, cardiac work, electrophysiology of the heart. Special vascular beds, including their biological and hemodynamic importance. Integration through nervous and humoral controls. **Prerequisites:** BIPN 100,102, and BENG 230B or consent of instructor. (S)

BENG 230D. Respiratory and Renal Physiology (4)
Mechanics of breathing. Gas diffusion. Pulmonary blood flow. Stress distribution. Gas transport by blood. Kinetics of oxygen and carbon dioxide exchange. VA/Q relations. Control of ventilation. Glomerular and proximal tubule functions. Water metabolism. Control of sodium and potassium in the kidney. **Prerequisites:** BIPN 100, 102, and BENG 230C or consent of instructor. (F,W,S)

BENG 231. Foundations of Physiology for Bioengineering (4)
Introduction to human physiology emphasizing quantitative physiological principles and engineering applications to the study and understanding of physiological systems. The study of principal organ systems will be integrated with cell and molecular biology, biological control systems, and the physical sciences. **Prerequisite:** graduate standing in bioengineering or consent of instructor. (S)

BENG 238/MED 238. Molecular Biology of the Cardiovascular System (4)
An overview of heart, vascular development and associated diseases from a molecular biological perspective. Current approaches for generating mouse models of cardiovascular disease and recently developed technologies for physiological assessment in small animal models will be presented. (S)

BENG 241A. Foundations of Tissue Engineering Science (4)
Molecular and cell biological basis of tissue engineering science. Paracrine control of tissue growth and differentiation. Biomechanics and the molecular basis of cell-cell and cell-matrix interactions. Cell motility, mechanics of tissue growth and assembly, tissue repair. Mass transfer in tissues. Microcirculation of blood and lymph. **Prerequisite:** BENG 230A or consent of instructor. (F)

BENG 241B. Methods in Tissue Engineering Science (4)
Isolation of cells, cell and tissue culture systems. Fluorescence and confocal microscopy. Intracellular imaging. Mechanical testing of tissues. Micromechanical measurement and analysis of cell deformability and cell interaction. Methods in microcirculation and angiogenesis. **Prerequisite:** BENG 241A or consent of instructor. (S)

BENG 242/MATS 257. Polymer Science and Engineering (4)
Quantitative basic understanding of different branches of polymer science varying from polymer chemistry, characterization, thermodynamics, rheological properties, smart materials, self-assembly in biopolymers (natural) and synthetic polymers, and applications of polymers ranging from medicine to structure. **Prerequisite:** graduate standing in bioengineering or materials science or consent of instructor. (W)

BENG 247A/ECE 247A. Advanced Biophotonics (4)
Basic physics and chemistry for the interaction of photons with matter, including both biological and synthetic materials; use of photonic radiation pressure for manipulation of objects and materials; advanced optoelectronic detection systems, devices and methods, including time resolved fluorescent and chemiluminescent methods, fluorescent energy transfer (FRET) techniques, quantum dots, and near-field optical techniques; underlying mechanisms of the light sensitive biological systems, including chloroplasts for photosynthetic energy conversion and the basis of vision processes. **Prerequisite:** graduate standing. (F)

BENG 247B/ECE 247B. Bioelectronics (4)
Topics to be covered will include photolithographic techniques for high-density DNA microarray production, incorporation of CMOS control into electronic DNA microarrays, direct electronic detection technology used in microarrays and biosensor devices, and focus on problems related to making highly integrated devices (lab-on-a-chip, in vivo biosensors, etc.) form heterogeneous materials and components. **Prerequisite:** graduate standing. (W)

BENG 247C/ECE 247C. Bionanotechnology (4)
Topics include: nanosensors and nanodevices for both clinical diagnostics and biowarfare (bioterror) agent detection; nanostructures for drug delivery; nanoarrays and nanodevices; use of nanoanalytical devices and systems; methods and techniques for modification or functionalization of nanoparticles and nanostructures with biological molecules; nanostructural aspects of fuel cells and biofuel cells; potential use of DNA and other biomolecules for computing and ultra high-density data storage. **Prerequisite:** graduate standing. (S)

BENG 250A. Biomechanics (4)
An introduction to biomechanics and transport phenomena in biological systems at the graduate level. Biorheology, biosolid mechanics, muscle mechanics, mass transfer, momentum transfer, energy transfer. **Prerequisites:** CENG 101C, BENG 112B, and BENG 222 or consent of instructor. (W)

BENG 250B. Advanced Biomechanics (4)
Modern development of biomechanics at an advanced mathematical level. Selected topics in the dynamics of heart, pulsatile, blood flow, microcirculation, and muscle mechanics. **Prerequisite:** BENG 253 or consent of instructor. (S)

BENG 253. Biomedical Transport Phenomena (4)
Nonequilibrium thermodynamic analysis of transport phenomena. The osmotic effect. Diffusion and exchange in biological systems. **Prerequisite:** BENG 222 or consent of instructor. (W)

BENG 260/BGGN 260. Neurodynamics (4)
Introduction to the nonlinear dynamics of neurons and neural systems using bifurcation theory and chaotic motions, at different levels of abstraction, e.g., biophysical and "reduced" models for analysis of regularly spiking and bursting cells. Laboratory exercises will accompany the lectures. **Prerequisite:** graduate standing or consent of instructor.

BENG 267. Microcirculation in Health and Disease (4)
Structural and functional aspects of transport and blood-tissue exchange in key organs during circulatory shock, bacterial toxemia, hypertension. Physical and ultrastructural techniques used to analyze small-vessel dynamics. **Prerequisite:** consent of instructor. (S)

BENG 276/Chem. 276/Math. 276. Numerical Analysis in Multi-scale Biology (4)
Introduces mathematical tools to simulate biological processes at multiple scales. Numerical methods for ordinary and partial differential equations (deterministic and stochastic), and methods for parallel computing and visualization. Hands-on use of computers emphasized; students will apply numerical methods in individual projects. **Prerequisite:** consent of instructor. (F,W,S)

BENG 277/BIOM 287. Tissue Engineering Laboratory (4)
Students will learn to conduct tissue engineering and developmental biology experiments, microfabricate cell culture systems, engineer biopolymer materials, and develop and analyze quantitative models of transport, cell fate, and growth mechanics. The understanding and manipulation of multicellular processes that comprise development and growth involves specialized areas of biomechanics, developmental biology, biomaterials, and the tools of molecular biology, as well as the integration of theory and experiment. To fabricate functional tissues, it is important to establish underlying molecular and physical mechanisms and then control and integrate these. **Prerequisite:** consent of instructor. (S)

BENG 280A. Principles of Biomedical Imaging (4)
Fundamentals of Fourier transform and linear systems theory including convolution, sampling, noise, filtering, image reconstruction and visualization with an emphasis on applications to biomedical imaging. Examples from optical imaging, CT, MR, ultrasound, nuclear, PET, and radiography. **Prerequisite:** graduate standing. (F)

BENG 280B. Comparative Biomedical Imaging (4)
Application of biomedical imaging to the measurement of structure, function, and dynamics of organ systems from the microscopic to the organ level. Emphasis on detailed evaluation and comparison of specific imaging modalities. **Prerequisite:** consent of instructor. (W,S)

BENG 281. Seminar in Bioengineering (1)
Weekly seminars by faculty, visitors, postdoctoral research fellows, and graduate students concerning research topics in bioengineering and related subjects. May be repeated for credit. Course does not apply toward M.S. graduation requirements. (S/U grades only.) (F,W,S)

BENG 282. Seminar: Faculty Research (1)
Weekly seminars by bioengineering faculty presenting their research. May be repeated for credit. (S/U grades only.) (F,W,S)

BENG 283/Chem. 283/BIOM 283. Supramolecular Structure Determination Laboratory (4)
A laboratory course combining hands-on mass spectrometry and bioinformatics tools to explore the relationship between structure and function in macromolecules. Tools for peptide sequencing, analysis of post-translational modification, and fragmentation analysis by mass spectrometry are examples of experiments students will run. **Prerequisite:** consent of instructor.

BENG 290. Bioengineering Special Graduate Seminar (1–2)
Seminars by faculty, visitors, postdoctoral research fellows, and/or graduate students in selected topic(s) in bioengineering and/or related subjects. This course does not apply toward M.S. graduation requirements.

BENG 291/191. Senior Seminar I: Professional Issues in Bioengineering (2)
(Conjoined with BENG 191.) Instills skills for personal and organizational development during lifelong learning. Student prepares portfolio of personal attributes and experiences, prepares for career interviews plus oral report of interviewing organizational CEO. Graduate students will prepare a NIH small business research grant. **Prerequisites:** none. (W)

BENG 295. Bioengineering Design Project and Industrial Training (4)
Independent work by graduate students focused on design, applied research, and professional experience. **Prerequisites:** consent of instructor and departmental approval. (F,W,S)

BENG 296. Independent Study (4)
Prerequisite: consent of instructor. (F,W,S)

BENG 298. Directed Group Study (1–4)
Directed group study on a topic or in a field not included in regular department curriculum, by special arrangement with a faculty member. (S/U grades only.) **Prerequisite:** consent of instructor. (F,W,S)

BENG 299. Graduate Research (1–12)
Independent work by graduate students engaged in research and writing theses. (S/U grades only.) **Prerequisite:** consent of instructor. (F,W,S)

BENG 501. Teaching Experience (2 or 4)
Teaching experience in an appropriate bioengineering undergraduate course under direction of the faculty member in charge of the course. Lecturing one to two hours per week in either a problem-solving section or regular lecture. (S/U grades only.) **Prerequisites:** consent of instructor and departmental approval. (F,W,S)