Bioengineering Major Description

Introduction

Bioengineering/Biomedical Engineering (the terms are overwhelmingly used interchangeably) is perhaps the most rapidly expanding discipline in the USA and world-wide. Popularly it includes almost any mix of engineering and life sciences in any proportion to the point where most engineering programs embrace some form of bioengineering, but Bio/Biomedical engineering programs uniquely provide the depth at the intersection between life sciences and engineering expected for the 21st century workforce – industry, medicine, and research.

The UCSD Bioengineering Department has for decades been the national and international leader in bioengineering, establishing the Bioengineering Program, including an undergraduate degree in Bioengineering, in 1966, the original Bioengineering Major. The department was formed in 1994.

Since that time the department has created four distinct concentrations, each recognized as a separate undergraduate major, and has periodically updated and upgraded the Bioengineering curriculum. These offerings make it possible for us to offer highly focused and effective curricula to the advantage of our students.

Bioengineering: Bioengineering –short explanation with a little history

The redundant title came into being only when the other majors were added. We'll stick with "Bioengineering" for the rest of this document.

The UCSD Mechanical Engineering Department included a set of bioengineers with remarkable foresight, not only for world ground breaking research, but also for establishing the basics of education in the field of biomechanics. YC Fung was central to this effort, but in time Marcos Intaglietta, Shu Chien, Gert Schmid-Schoenbein, and David Gough complemented the efforts and established the Bioengineering program including the BS degree in Bioengineering. This degree had not only a decided biomechanics emphasis, but also a strong emphasis on physiology. The development with Mechanical Engineering (now the MAE Department) is evident from the strong inclusion of MAE courses in the curriculum.

The development of Bioengineering at UCSD from the Mechanical Engineering Department established a model copied by many other universities. Others developed in parallel but with emphases in electrical engineering (electronics and imaging oriented) and chemical engineering (drug delivery and materials oriented). More recently established or evolving departments include multiple of these themes, with biomechanics as perhaps the most common element.

Biomechanics can be subdivided into

- macro-scale mechanics – e.g. hip and knee implants, sports biomechanics
- tissue mechanics – how do tissues move under stress and deformation and how do they impart force
- fluid mechanics – beginning with the heart and the vascular system
- cellular mechanics – asking how mechanical stresses affect the properties and even growth of cells
- devices – there are a great many biomedical devices with a mechanical component
- mass transfer – how do heat, drugs, etc. move spatially within and without the body

Overview of the Curriculum

We break the curriculum down into these parts:

- preparation as a college graduate with a well-rounded education – your Humanities and Social Science Requirements
- preparation with mathematics and science needed for an Engineering undergraduate degree

- modern biology for engineers
- foci particular to the Bioengineering major that enhance the preparation for a variety of careers
- bioengineering coursework common to many if not most bioengineers in the USA
- senior design
- technical electives
- non-curricular opportunities

We elaborate on each below, followed by a year by year summary of the curriculum.

Well Rounded Education

At UCSD we have an exceptional and exceptionally strong system of academic and residential colleges and provide intellectual coherence to the breadth of your curriculum in the social sciences and humanities.

As a footnote we mention that all engineering programs must be accredited by ABET (Accreditation Board for Engineering and Technology) and that ABET demands that all engineering students have a solid liberal arts education. Your colleges exceed what ABET demands.

Never, ever, let someone claim that engineers are not well-rounded. You take more liberal arts courses than liberal arts majors take science and technology courses – and we are in an age where fluency in STEM (science, technology, math, engineering) is essential to being a fully engaged citizen.

Basic Engineering Preparation

There is no substitute for having a fundamental understanding of mathematics, physics, biology and chemistry. All engineers rely on this basic knowledge for their entire careers, long after they have forgotten the equations. These comprise the calculus (MATH 20ABCDE, 18), physics (PHYS 2ABC and sometimes D) and Chemistry (CHEM 6A, 6B, 7L) courses. While we agree less often on which computational courses (MAE 8 and MAE 170 for the Bioengineering major) should be required, it is clear that students, even in the liberal arts, should take as many CSE and related courses as their time and curriculum permit. Bioengineers are in a sense lucky in that biology is essential and built into the curriculum; some, but not nearly a majority, of universities require beginning biology of their engineering majors. With this solid science background, students are ready to pursue an engineering major.

Our Bioengineering majors receive additional engineering coursework in computer graphical design (MAE 3), circuits (MAE 40), experimental methods and computer aided design (MAE 170), all taught from a mechanical engineering perspective. These provide solid preparation for many projects. Students take two other basic but introductory engineering courses: circuits (MAE 40) and computer graphical design (MAE 3).

Beginning Biology in an Engineering Context

Bioengineering students in general are faced with a daunting task – learning enough basic biology at enough scales – in the very short period of time of their first two years. Our Bioengineering majors start with a basic biology class (BILD 1 The Cell). For them (and other majors) we most strongly emphasize Physiology (BENG 140A/B), a two quarter sequence that introduces all the major physiological systems. Students emerge with a new vocabulary – they can now discuss most human diseases with accuracy – as well as see how both research and the practice of medicine are organized. With their vocabulary and understanding greatly widened, students are ready for upper level courses, work in research labs and even in many summer internships.

The Bioengineering Department teaches its physiology courses in an “engineering aware” manner – more modeling, more measurements, more computation, more modeling than there would be in the corresponding biology classes. There is a difference between the quantitation that a bioengineer encounters and the qualitative understanding of the life scientist.

Uniquely Bioengineering

We expect our students to be especially strong in the understanding the mechanics of biological systems from the cellular to tissue to the large physiological system. This is accomplished in an excellent three quarter

sequence in Biomechanics (BENG 110, 112A, 112B) including materials at levels ranging from macro (whole or partial body) to tissues to fluids to cellular. Further, students take an intensive laboratory (BENG 172) that emphasizes the biomechanical and biophysical sides of physiology. They cap this with course in Mass Transfer (BENG 103B) and a Biomaterials course (BENG 186A), which helps them understand much better how the materials used for many biomedical applications, such as implants ranging from more traditional knees and hips to state-of-the-art tissues.

Engineering in a Bioengineering Context

Rounding out their Bioengineering education, our Bioengineers are exposed to many additional engineering topics, all taught in a "biology aware" manner. They share with other bioengineering majors the need for more experience applying engineering approaches to biomedical problems. They learn about mass transfer (BENG 110), the modeling of chemical and other kinetics (BENG 130), biomedical instrumentation (BENG 186B) and biomaterials (BENG 186A). They also learn advanced modeling techniques, largely linear, in BENG 122A (Biocontrol) and, largely non-linear, in BENG 125(Computational Bioengineering). They emerge with a solid understanding of many of the approaches used by other disciplines but with particular knowledge of the advantages and limitations of application to the biomedical field.

Senior Design for All Bioengineering Majors

The UCSD Bioengineering Senior Design course sequence has the philosophy of "Capstone" design courses, where students use a variety of their previously learned skills to solve a focused engineering problem. The course also serves to meet additional ABET Outcomes and Learning Objectives, including formal design and decision making processes, working in teams, and awareness of ethical and societal consequences.

This course sequence includes two components: BENG 187A/B/C/D, each a 1 credit hour lecture course, taken in the student's last four quarters (Spring/Fall/Winter/Spring); and two 3 credit hour project courses taken in Fall and Winter quarters. The goal of the entire experience is for students to gain experience with a formal design and reporting process, mostly through BENG 187, and to have hands-on experience with engineering design and implementation for biomedical applications through their project courses. They also gain brief introductions to FDA, animal and human subjects, ethics, and presentation skills.

Technical Electives for Bioengineers

Bioengineering majors must take 8 units (2 courses) of technical elective courses. These must be taken for a letter grade, be of upper division level, not required for the major. To meet accreditation requirements, at least one is to be an Engineering course (in the Jacobs School of Engineering), while the other may be a Science course. While BENG 199 Independent Study courses are highly encouraged in general, there are restrictions. Please discuss with UG Advising Staff or faculty.

Curriculum Beyond the Curriculum

A great many bioengineering students, including our Bioengineering majors, have very greatly enriched their education with experiences outside the classroom and outside the curriculum.

One of the greatest opportunities afforded by universities over the entire USA is the great range of opportunities beyond the classroom. Three simple looks illustrate tremendous sources of opportunities for UCSD Biosystems majors: (a) Bioengineering and related health sciences research opportunities on campus; (b) the Biotech corridor along North Torrey Pines Road; (c) the "mega" industrial complex which is San Diego.

Suggestions include:

BENG 191 – Senior Seminar in Bioengineering – please come! Do not worry about understanding most of the lecture – you should go with the goal of finding out why the lecturer is excited about what s/he does. There are lots of seminars in Bioengineering, other engineering departments and the medical school. Do not be intimidated.

Research Experiences – the majority of our students find opportunities in faculty research labs; many are with Bioengineering faculty, but there are also many opportunities in other departments, the UCSD School of Medicine, the Scripps Oceanographic Institute or the Salk Institute. These are enormously valuable.

Other on-campus experiences – some of our students find exceptional experiences in engineering project teams, including Global Ties and Engineering World Health.

Student professional societies provide exceptional opportunities for leadership experience and enhancements to your education. Please check out the BioMedical Engineering Society (BMES), the Engineering in Medicine and Biology Society (EMBS), the International Society for Pharmaceutical Engineering, SynBio, and the Undergraduate Bioinformatics Club.

Internships: many students have found summer jobs or internships which greatly augment their intellectual development. Please contact our internship office for help

Getting a great “beyond the curriculum” experience is part of why you pay tuition. But you have to hustle to take advantage.

Year by Year Summary of the Bioengineering: Bioengineering Major

(Abbreviated course titles are used. Most courses: 4 units of credit. 1* unit and 2** unit courses are marked.)

First Year

This year is dominated by traditional STEM courses that provide the intellectual ground work for all engineering majors: three terms of calculus (MATH 20A,20B,20C); two terms of Physics (mechanics and electricity and magnetism PHYS 2A,2B, 2BL (lab)); and chemistry (CHEM 6A, 6B). Students take their first life science course (BILD 1) which emphasizes how cells are organized, giving context to both molecular biology and macro physiology courses that follow next year. Finally BENG 1 gives students a hands on experience with bioengineering projects. Students also take Humanities and Social Science Courses that are required of all engineering majors, but customized to the requirements of their residential college.

Fall First Year
Humanities/Social Sciences
Humanities/Social Sciences
MATH 20A Calculus for Engrs I
CHEM 6A General Chemistry I

Winter First Year
Humanities/Social Sciences
MATH 20B Calculus for Engrs II
CHEM 6B General Chemistry II
PHYS 2A Physics Mechanics
BENG 1** Intro Bioengineering

Spring First Year
Humanities/Social Sciences
MATH 20C Calculus/Analytic Geometry
PHYS 2B / 2L** Electricity and Magnetism with Lab*
BILD 1 The Cell

Second Year

This year begins with the completion of foundational engineering courses and the transition to beginning and foundational Bioengineering courses. The math sequence finishes with differential equations (MATH 20D, foundational to circuits), vector calculus (MATH 20E, foundational to biomechanics) and linear algebra (MATH 18, foundational for many computational, modeling, and advanced statistical techniques). PHYS 2C (Fluids, waves, thermodynamics, optics) presages Bioengineering courses in multiple areas. CHEM 7L gives hands on chemistry lab experience. BENG 100 (Statistical Reasoning) provides the basis for a wide range of applications from probabilistic modeling to statistical evaluation of testing data. Most central for biomedical engineers is the BENG 140A/B sequence in physiology – at its simplest, this is what all parents need to know when their child is sick; at heart, however, is basic understanding of the body and how medical practitioners think about the biological basis of most of their profession. Students take three basic but introductory engineering courses: circuits (MAE 40), programming (MAE 8 Matlab), and computer graphical design (MAE 3), which will be complemented in Fall junior year with an experimental lab and more advanced computation. Students emerge well prepared for an intensive junior year in mechanically oriented biomedical engineering. Again, students also take Humanities and Social Science Courses that are required of all engineering majors, but customized to the requirements of their residential college.

Fall Second Year
Humanities/Social Sciences
MATH 20D Differential Equations
Phys 2C / 2L** Fluids, Waves, Optics, Thermo; with Lab
CHEM 7L General Chem Lab

Winter Second Year
Humanities/Social Sciences
MATH 18 Linear Algebra
BENG 140A BioE Physiology I
MAE 40 Linear Circuits
MAE 8 Matlab

Spring Second Year
MAE 3 Graphics
MATH 20E Vector Calculus
BENG 140B BioE Physiology II
BENG 100 Probability & Statistics

Third Year

This year very strongly emphasizes bioengineering courses that expand from fundamental mathematical, engineering and biological foundations to applications found throughout the bioengineering work and research world. As noted above, MAE 107 (Computational Methods) and MAE 170 (Experimental Techniques) give students a solid mechanically oriented background for medical devices and other studies. They take a three term biomechanics sequence: BENG 110/112A/112B (Continuum Mechanics, Tissue Biomechanics and Fluid/Cellular Biomechanics) and complement it with BENG 103B (Mass Transfer). They are now ready for a variety of projects (often in Senior Design) incorporating mechanical design into devices or perhaps modeling the biomechanics of movement or of tissues or fluids. Again, students take Humanities and Social Science Courses that are required of all engineering majors, but customized to the requirements of their residential college. They also begin the senior design sequence described below.

Fall Third Year
Humanities/Social Sciences
BENG 110 Foundation of Biomechanics
MAE 107 Comp. Methods
MAE 170 Exptl Techniques

Winter Third Year
Humanities/Social Sciences
BENG 112A Tissue Biomechanics
BENG 130 BioThermo/Kinetics
BENG 186B BioInstr. Lecture

Spring Third Year
BENG 103B Mass Transfer
BENG 112B Fluid and Cell Biomechanics
BENG 172 BioEng Lab
BENG 187A* Senior Design

Fourth Year

Senior year for Bioengineering majors is dominated by capstone courses. These include the classical Senior Design sequence described elsewhere, but also a Computational Bioengineering course (BENG 125). The Biomaterials course (BENG 186A) rounds out their knowledge of mechanics and materials for a variety of future applications. Students complete two technical electives in addition to the Senior Design project. Again, students take Humanities and Social Science Courses that are required of all engineering majors, but customized to the requirements of their residential college.

Fall Fourth Year
MAE 150 Computer Aided Design
BENG122A Biocontrol
BENG 187B and BENG 1XXA Senior Design

Winter Fourth Year
Humanities/Social Sciences
BENG 187C and BENG 1XXB Senior Design
Technical Elective

Spring Fourth Year
Humanities/Social Sciences
BENG 125 Computational Bioengineering
BENG 186A Biomaterials
BENG 187D* Senior Design
Technical Elective

Note: Humanities/Social Science and Technical Elective courses should be scheduled so as to balance workload and course offerings.