Biotechnology 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: 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.

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 Biotechnology 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 and sometimes 6C and 7L) courses. While we agree less often on which computational courses (MAE 8 for the several of the Bioengineering majors) should be required, it is clear that all university 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 some additional engineering coursework in computation, experimental methods and computer aided design, all taught from a mechanical engineering perspective. These provide solid preparation form many projects.

Beginning Biology in an Engineering Context

Bioengineering students in general are faced with a daunting task – learning enough basic biology at enough scales – in a very short period of time during their first two years. Our Biotechnology majors start with a basic biology class (BILD 1 The Cell) and add genetics (BICD 100).

Upper level Biotechnology courses can often be seen as more biology oriented (but taught in an "engineering aware" manner – more modeling, more measurements, more computation) or more engineering oriented (but taught in a "biology aware" manner – molecular, cellular and physiological application systems). Hence our Biotechnology students emerge with a distinct quantification/modeling approach in contrast to the more descriptive understanding of the life scientist.

Uniquely Biotechnology

Our Biotechnology students spend more time learning basic chemistry than almost all other engineers, getting superb preparation for their transition, during junior on into senior year, as they become Biotechnology majors. They take major coursework in biomolecular science and technology, including hands on laboratory exposure to state of the art technologies for analyzing, identifying and separating biomolecular components, as well as in the growth and genetic manipulation of cells in culture. Lecture work expands their knowledge to the cellular and tissue levels, including interaction with biomaterials, as well as the fundamentals of designing bioreactors used for commercial and research to grow microbial cultures to produce desired protein and other products.

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 103B), the modeling of chemical and other kinetics (BENG 130), and biomaterials (BENG 186A). They also learn advanced modeling techniques 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 biotechnology 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 Biotechnology majors

Biotechnology 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 – a large fraction of our students find opportunities in faculty research labs; many are 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: Biotechnology 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); and chemistry (CHEM 6A, 6B). Biotechnology majors, however, acquire a much stronger chemistry base with CHEM 6C plus lab CHEM 7L). 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 Electricity / Magnetism
CHEM 7L Lab
CHEM 6C General Chemistry III

Second Year

This year continues building the fundamental knowledge needed by Biotechnology majors, especially in the area of organic chemistry (CHEM 40A and 40B). Students finish solid basic sequences in mathematics (differential equations, needed for all engineering disciplines) and linear algebra and vector calculus which provide fundamentals for advanced engineering courses. The math sequence finishes with differential equations (MATH 20D, foundational to much of the next level in all fields of engineering), vector calculus (MATH 20E, foundational to biomechanics and fluids) and linear algebra (MATH 18, foundational for many computational, modeling, and advanced statistical techniques). PHYS 2C (Fluids, waves, thermodynamics, optics) presages multiple Biotechnology courses, as well as a number of other Bioengineering courses. BENG 100 (Statistical Reasoning) provides the basis for a wide range of applications from probabilistic modeling to statistical evaluation of testing data. Students gain essential but beginning programming competence (MAE 8 Matlab). Students emerge well prepared for an intensive junior year in biotechnology courses in the junior year. Again, students also take Humanities and Social Science Courses.

Fall Second Year
Humanities/Social Sciences
MATH 20D Differential Equations
BILD1 The Cell
CHEM 40A Organic Chem I

Winter Second Year
MATH 18 Linear Algebra
Phys 2C / 2L* Fluids, Waves, Optics, Thermo; with Lab
CHEM 40B Organic Chem II

Spring Second Year
MAE 8 Matlab
MATH 20E Vector Calculus
BENG 100 Probability & Statistics

Third Year

Fall of this year completes the basic engineering and science knowledge of the Biotechnology student: fluid mechanics (CENG 101A), hands on sensors/electronics oriented instrumentation lab (MAE 170), and a basic course in genetics (BICD 100). The winter and spring quarters are heavily biotechnology. Students learn in depth about molecular biology and recombinant DNA technologies (BENG 168), as well as the interaction of materials and the body from an engineering perspective. They learn thermodynamics (BENG 130) and mass transfer (BENG 103B) from the point of view of the biological reactions and phenomena. The take the first of two intensive laboratories, BENG 160, where they learn techniques for characterizing and separating biomolecular constituents – cells, protein, nucleic acids. BENG 123 shows use their quantitative understanding of biomolecular/chemical processes to construct computational models that, for instance, product yield in a biochemical system or degree of protein expression. 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. They also begin the senior design sequence described below.

Fall Third Year
Humanities/Social Sciences
CENG 101A Intro Fluid Mech.
BICD 100 Genetics
MAE 170 Exptl Techniques

Winter Third Year
BENG 123 Dynamic Simulation in Bioengineering
BENG 168 Biomolecular Engrg
BENG 130 Biotech Thermo-dynamics and Kinetics

Spring Third Year
Humanities/Social Sciences
BENG 103B Mass Transfer
BENG 160 Chem /Molecular Bioeng Techniques (lab)
BENG 186A Biomaterials
BENG 187A* Senior Design

Fourth Year

Senior year for Biotechnology majors is dominated by advanced biotechnology courses plus capstone courses. Students learn the design of bioreactors, such as are used for growing microbes and harvesting protein products, plus the genetic control of microbial and other systems, followed by product separation and recovery, such as might be used for commercial scaleup of biologically produced products; the Biotechnology Laboratory gives hands on experience with many of the techniques. The Cell and Tissue Engineering course builds on the Biomaterials course from junior year. The capstone courses include the classical Senior Design sequence described elsewhere, but also a Computational Bioengineering course (BENG 125). Students complete two technical electives in addition to the Senior Design project. Students complete their Humanities and Social Science Course requirements.

Fall Fourth Year
BENG 161A Bioreactor Engrg
BENG 162 Biotech Lab
BENG 166A Cell/Tissue Engrg
BENG 187B and BENG 1XXA Senior Design

Winter Fourth Year
Humanities/Social Sciences
BENG 161B Biochemical Engrg
BENG 187C and BENG 1XXB Senior Design
Technical Elective

Spring Fourth Year
Humanities/Social Sciences
BENG 125 Computational Bioengineering
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.