Bioinformatics 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: Bioinformatics

Bioinformatics is the study of the structure and flow of information (genetic, metabolic, and regulatory) in living systems. The bioinformatics major emphasizes computation and model-based approaches to assembling, integrating, and interpreting biological information. This major has been developed by the Departments of Bioengineering, Chemistry and Biochemistry, Computer Science and Engineering, and the Division of Biological Sciences, and students may apply through any of these departments or the division. However, each department's version of Bioinformatics is customized to the philosophy and requirements of the home department. Here we detail the Bioengineering: Bioinformatics degree program and refer other students to the other departments.

The Bioinformatics major prepares students for careers in the pharmaceutical, biotechnology, and biomedical software industries, and for further studies in graduate or medical school. This includes the rapidly expanding field of Biomedical and Health Informatics.

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 Bioinformatics 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. They provide scholarship, identity, camaraderie , etc. We are exceptionally proud that they step up 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 Bioinformatics majors start with a basic biology class (BILD 1 The Cell) and add genetics (BICD 100).

Upper level Bioinformatics 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 Bioinformatics students emerge with a distinct quantification/modeling approach in contrast to the more descriptive understanding understanding of the life scientist.

Uniquely Bioinformatics

Our Bioinformatics students spend more time learning basic chemistry than almost all other engineers, getting superp preparation for their transition, during junior on into senior year, as they become Bioinformatics 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 Bioinformatics 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 Bioinformatics majors

Bioinformatics 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: Bioinformatics 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); one term of Physics (mechanics PHYS 2A); and chemistry (CHEM 6A, 6B). Bioinformatics majors, however, acquire a much stronger base in computation as they complete the CSE majors' courses in beginning programming (with Java) and data structures. Students also take Cell Biology (BILD 1) – the cell is the basic biological structure that gives context to the most important genomics and bioinformatics inquiries.. 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
MATH 20A Calculus for Engrs I
CHEM 6A General Chemistry I
CSE 11 Intro CS / Java

Winter First Year
Humanities/Social Sciences
MATH 20B Calculus for Engrs II
CHEM 6B General Chemistry II
CSE 12 Data Structures / Object Oriented Design
BENG 1* Intro Bioengineering

Spring First Year
Humanities/Social Sciences
MATH 20C Calculus/Analytic Geometry
PHYS 2A Mechanics
BILD 1 The Cell

Second Year

This year has three scientific themes, plus continuation of humanities and social science courses. First is a continuation of the basics underlying much of engineering: MATH 20D, foundational to much of the next level in all fields of engineering), vector calculus (MATH 20E, foundational especially to mechanics and fluids oriented fields), plus PHYS 2B (electricity and magnetism) and PHYS 2C (fluids/waves/optics). Second is development of their sophistication in computer and data handling which will be fundamental to advance bioinformatics study: CSE 100 (advanced data structures), CSE 21 (the math for analyzing algorithms), and BENG 185 (bioinformatics computational laboratory). The third area is the development of biological knowledge emphasizing the identification of structural components at multiple scales: BILD 3 (organismic/evolutionary biology); BENG 102 (the structures within cells and of important biomolecules) and BENG 120 (organic chemistry), and BILD 4 (introductory biology lab).

BENG 100 (Statistical Reasoning) provides the basis for a wide range of applications from probabilistic modeling to statistical evaluation of testing data. Students emerge well prepared for an intensive junior year in Bioinformatics courses in the junior year.

Fall Second Year
Humanities/Social Sciences
MATH 20D Differential Equations
BILD 3 Organism /Evolution Biology
CSE 21 Math for Algorithms and Systems
PHYS 2B Electricity/Magnetism

Winter Second Year
Humanities/Social Sciences
MATH 20E Vector Calculus
Phys 2C Fluids, Waves, Optics, Thermo
BILD 4 Intro Biology Lab
BENG 120 Organic Chem

Spring Second Year
CSE 100 Advanced Data Structures
BIMM 185 Bioinformatics Lab
BENG 102 Cellular/Molecular Structures
BENG 100 Probability & Statistics

Third Year

Bioinformatics students enhance their knowledge base for bioinformatics including genetics (BICD 100) and a molecular biology course focusing on genes and transcription (BIMM 100). They add a second course in handling biological databases (BENG 182). CSE 101 teaches the design of efficient algorithms for applications including bioinformatics data base searching. Again, students take Humanities and Social Science Courses. They also begin the senior design sequence described below.

Fall Third Year
Humanities/Social Sciences
MATH 18 Linear Algebra
CSE 101 Algorithms
BICD 100 Genetics

Winter Third Year
BENG 181 Molecular Sequence Analysis
BENG 130 Biotech Thermo-dynamics and Kinetics
BIMM 100 Molecular Biology

Spring Third Year
Humanities/Social Sciences
BENG 182 Biological Databases
BENG 187A* Senior Design

Fourth Year

Bioinformatics students round out their concentration with three courses. In Applied Genomic Technologies (BENG 183) they learn how DNA, RNA, protein and other biomolecules are extracted from samples. In BENG 168, biomolecular engineering, they learn more of how biomolecules function – including decoding genomes, converting energy, enzymatic activity. In Math they learn how approach probability and statistics in decidedly large but ill-behaved biological systems and data bases. The capstone courses include the classical Senior Design sequence described elsewhere, as well as a Computational Bioengineering course (BENG 125) where students model dynamic non-linear biological systems such as transcriptomes. Students complete two technical electives in addition to the Senior Design project. Students complete their Humanities and Social Science Course requirements.

Fall Fourth Year
Humanities/Social Sciences
BENG 183 Applied Genomic Technologies
BENG 187B and BENG 1XXA Senior Design
Technical Elective

Winter Fourth Year
Humanities/Social Sciences
Math 186 Probability/Statistics for Bioinformatics
BENG 168 Biomolecular Engrg
BENG 187C and BENG 1XXB Senior Design

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.