Bioengineering

Mail Code: 94305-5444
Student Services Phone: Graduate students: (650) 736-2254;
Undergraduates: (650) 724-5314
Web Site: http://bioengineering.stanford.edu

Courses offered by the Department of Bioengineering are listed under the subject code BIOE on the Stanford Bulletin’s ExploreCourses web site. Bioengineering is jointly supported by the School of Engineering and the School of Medicine. The facilities and personnel of the Department of Bioengineering are housed in the James H. Clark Center, the William F. Durand Building for Space Engineering and Science, the William M. Keck Science Building, the Jerry Yang and Akiko Yamazaki Environment and Energy Building, and the Richard M. Lucas Center for Magnetic Resonance Spectroscopy and Imaging.

The departmental headquarters is in the James H. Clark Center for Biomedical Engineering and Sciences, along with approximately 600 faculty, staff, and students from more than 40 University departments. The Clark Center is also home to Stanford’s Bio-X program, a collaboration of the Schools of Engineering, Medicine, Humanities and Sciences, and Earth Sciences.

Courses in the teaching program lead to the degrees of Master of Science and Doctor of Philosophy. The department collaborates in research and teaching programs with faculty members in Chemical Engineering, Mechanical Engineering, Electrical Engineering, and departments in the School of Medicine. Quantitative biology is the core science base of the department. The research and educational thrusts are in biomedical computation, biomedical imaging, biomedical devices, regenerative medicine, and cell/molecular engineering. The clinical dimension of the department includes cardiovascular medicine, neuroscience, orthopedics, cancer care, neurology, and environment.

Mission of the Undergraduate Program in Bioengineering

The mission of the Department of Bioengineering is to create a fusion of engineering and the life sciences that promotes scientific discovery and the development of new biomedical technologies and therapies through research and education. The Bioengineering (BioE) major enables students to embrace biology as a new engineering paradigm and apply engineering principles to medical problems and biological systems. Students who major in BioE obtain a solid background in the basic sciences (chemistry, physics, and biology) and mathematics. They take three engineering fundamentals courses including an introductory bioengineering course and computer programming. Starting in the sophomore year, BioE students take six core classes to gain essential knowledge to pursue a career in bioengineering and then have the opportunity to pursue elective courses suited to their own interests. The major prepares students to continue on to graduate or medical school; work in the biotechnology, medical device, medical imaging, or other medical and non-medical industries; or pursue advanced degrees in business or law.

The department offers an undergraduate major in Bioengineering (BIOE) leading to the B.S. degree in Engineering. An undergraduate major in Biomechanical Engineering and an undergraduate major in Biomedical Computation, both of which lead to the B.S. degree in Engineering, are available through the School of Engineering. For further information, see the Handbook for Undergraduate Engineering Programs at http://ughb.stanford.edu .

Learning Outcomes (Graduate)

The purpose of the master’s program is to provide students with the knowledge and skills necessary for a professional career or doctoral studies. This is done through course work with specialization in an area of the field, including biomedical computation, regenerative medicine and tissue engineering, molecular and cell bioengineering, biomedical imaging, and biomedical devices.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research. Through course work and guided research, the program prepares students to make original contributions in Bioengineering and related fields.

Graduate Programs in Bioengineering

The University’s requirements for the M.S. and Ph.D. degrees are outlined in the “Graduate Degrees (http://exploredegrees.stanford.edu/archive/2012-13/graduatedegrees) ” section of this bulletin.

Admission

Students are expected to enter with a series of core competencies in mathematics, biology, chemistry, physics, computing, and engineering. Students entering the program are assessed by the examination of their undergraduate transcripts and research experiences. Specifically, the department requires that students have completed mathematics through multivariable calculus and differential equations, completed a series of undergraduate biology courses (equivalent to the BIO 41 Genetics, Biochemistry, and Molecular Biology, BIO 42 Cell Biology and Animal Physiology series) and completed physics, chemistry, and computer sciences courses required of all undergraduate majors in engineering. Qualified applicants are encouraged to apply for predoctoral national competitive fellowships, especially those from the National Science Foundation. Applicants to the Ph.D. program should consult with their financial aid officers for information and applications.

The deadline for receiving applications is December 3, 2012.

Further information and application forms for all graduate degree programs may be obtained from Graduate Admissions, the Registrar’s Office, http://gradadmissions.stanford.edu .

Bachelor of Science in Engineering (Bioengineering)

The department offers an undergraduate major in Bioengineering (BioE) leading to the B.S. degree in Engineering. For additional information, see the Handbook for Undergraduate Engineering Programs at http://ughb.stanford.edu .

Bioengineering (BioE)

Completion of the undergraduate program in Bioengineering leads to the conferral of the Bachelor of Science in Engineering. The subplan "Bioengineering" appears on the transcript and on the diploma.
Mission of the Undergraduate Program in Bioengineering

The Stanford Bioengineering (BioE) major enables students to combine engineering and the life sciences in ways that advance scientific discovery, healthcare and medicine, manufacturing, environmental quality, culture, education, and policy. Students who major in BioE earn a fundamental engineering degree for which the raw materials, underlying basic sciences, fundamental toolkit, and future frontiers are all defined by the unique properties of living systems. Students will complete engineering fundamentals courses, including an introduction to BioE and computer programming. A series of core BioE classes beginning in the second year leads to a student-selected depth area and a capstone senior BioDesign project. The department also organizes a summer Research Experience for Undergraduates (REU) program. BioE graduates are well prepared to pursue careers and lead projects in research, medicine, business, law, and policy.

Requirements

Mathematics (28-29) 1
28 units minimum required, see Basic Requirement 1)

MATH 41 Calculus 10
&MATH 42 and Calculus (or AP Calculus)
CME 100 Vector Calculus for Engineers 5
CME 102 Ordinary Differential Equations for Engineers 5
CME 104 Linear Algebra and Partial Differential Equations for Engineers 5
CME 106 Introduction to Probability and Statistics for Engineers 3-4

Science (26) 2
26 units minimum:

CHEM 31X Chemical Principles (or CHEM 31A and 31B) 4
CHEM 33 Structure and Reactivity 4
BIO 41 Genetics, Biochemistry, and Molecular Biology 5
BIO 42 Cell Biology and Animal Physiology 5
PHYSICS 41 Mechanics 4
PHYSICS 43 Electricity and Magnetism 4

Technology in Society (3)
One course required; see Basic Requirement 4

BIOE 131 Ethics in Bioengineering 3

Engineering Fundamentals (12-14)

ENGR 70A Programming Methodology (same as CS 106A) 5
ENGR 80 Introduction to Bioengineering 4
Fundamentals Elective; see UGHB Fig. 3-4 for approved course list; may not use ENGR 70B or ENGR 70X 3-5

Bioengineering Core (36)

BIOE 41 Physical Biology of Macromolecules 4
BIOE 42 Physical Biology of Cells 4
BIOE 44 Fundamentals for Engineering Biology Lab 4
BIOE 51 Anatomy for Bioengineers 4
BIOE 101 Systems Biology 4
BIOE 103 Systems Physiology and Design 4
BIOE 123 Optics and Devices Lab 4
BIOE 141A Biodesign Project I 4
BIOE 141B Biodesign Project II 4

Bioengineering Depth Electives (12)
Four courses, minimum 12 units: 12

1 It is strongly recommended that CME 100 Vector Calculus for Engineers, CME 102 Ordinary Differential Equations for Engineers, and CME 104 Linear Algebra and Partial Differential Equations for Engineers) be taken rather than MATH 51 Linear Algebra and Differential Calculus of Several Variables, MATH 52 Integral Calculus of Several Variables, and MATH 53 Ordinary Differential Equations with Linear Algebra. CME 106 Introduction to Probability and Statistics for Engineers should be taken rather than STATS 110 Statistical Methods in Engineering and the Physical Sciences or STATS 141 Biostatistics

2 Science must include both Chemistry (CHEM 31A Chemical Principles I and CHEM 31B Chemical Principles II) or CHEM 31X Chemical Principles I and ENGR 31 Chemical Principles with Application to Nanoscale Science and Technology) and calculus-based Physics, with two quarters of course work in each, in addition to two courses of BIO core. CHEM 31A Chemical Principles I and CHEM 31B Chemical Principles II are considered one course even though given over two quarters. Premeds should take Chemistry, not ENGR 31 Chemical Principles with Application to Nanoscale Science and Technology

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://exploredegrees.stanford.edu/schoolofengineering/bioengineering/http://ughb.stanford.edu). Students pursuing a premed program need to take additional courses; see the UGHB, BioE Premed 4-Year Plan.

Coterminal B.S./M.S. Program in Bioengineering

This option is available to outstanding Stanford undergraduates who wish to work simultaneously toward a B.S. in another field and an M.S. in Bioengineering. The degrees may be granted simultaneously or at the conclusion of different quarters, though the bachelor’s degree cannot be awarded after the master’s degree has been granted. The University minimum requirements for the coterminal bachelor’s/master’s program are 180 units for the bachelor’s degree plus 45 unduplicated units for the master’s degree. Students may apply for the coterminal B.S. and M.S. program after 120 undergraduate units have been completed, and they must be accepted into our program one quarter before receiving the B.S. degree. Students should apply directly to the Bioengineering Student Service Office by December 3, 2012. Students interested in the coterminal degree must take the Graduate Record Examination (GRE); applications may be obtained at http://www.gre.org. Prospective applicants should
The seminar units should be fulfilled through:

3. Seminars (4 units)

Students are required to take at least one course in some area of device or provide a cohesive degree program in a bioengineering focus area. They should be chosen in concert with the bioengineering courses to statistics, engineering, physical science, life science, and medicine. These units must be selected from graduate courses in mathematics, cohesive course of study that provides depth and breadth.

The following courses are required:

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>BIOE 300A</td>
<td>Molecular and Cellular Bioengineering</td>
<td>3</td>
</tr>
<tr>
<td>BIOE 300B</td>
<td>Physiology and Tissue Engineering</td>
<td>3</td>
</tr>
<tr>
<td>BIOE 301A</td>
<td>Molecular and Cellular Engineering Lab</td>
<td>2</td>
</tr>
<tr>
<td>BIOE 301B</td>
<td>Clinical Needs and Technology</td>
<td>1</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

These courses, together with the approved technical electives, should form a cohesive course of study that provides depth and breadth.

2. Approved Technical Electives (26 units)

These units must be selected from graduate courses in mathematics, statistics, engineering, physical science, life science, and medicine. They should be chosen in concert with the bioengineering courses to provide a cohesive degree program in a bioengineering focus area. Students are required to take at least one course in some area of device or instrumentation. Up to 9 units of directed study and research may be used as approved electives.

3. Seminars (4 units)

The seminar units should be fulfilled through:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOE 390</td>
<td>Introduction to Bioengineering Research</td>
<td>2</td>
</tr>
<tr>
<td>BIOE 393</td>
<td>Bioengineering Departmental Research Colloquium</td>
<td>1</td>
</tr>
<tr>
<td>MED 255</td>
<td>The Responsible Conduct of Research</td>
<td>1</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Other relevant seminar units may also be used with the approval of the faculty adviser. One of the seminar units must be MED 255 The Responsible Conduct of Research.

4. Unrestricted Electives (6 units).

Students are assigned an initial faculty adviser to assist them in designing a plan of study that creates a cohesive degree program with a concentration in a particular bioengineering focus area. These focus areas include, but are not limited to: Biomedical Computation, Regenerative Medicine/Tissue Engineering, Molecular and Cell Bioengineering, Biomedical Imaging, and Biomedical Devices.

To ensure that an appropriate program is pursued by all M.S. candidates, students who first matriculate at Stanford at the graduate level must:

1. submit an adviser-approved Program Proposal for a Master’s Degree form to the student services office during the first month of the first quarter of enrollment
2. obtain approval from the M.S. adviser and the Chair of Graduate Studies for any subsequent program change or changes.

It is expected that the requirements for the M.S. in Bioengineering can be completed within approximately one year. There is no thesis requirement for the M.S.

Due to the interdisciplinary nature of Bioengineering; a number of courses are offered directly through the Bioengineering Department, but many are available through other departments. See respective ExploreCourses for course descriptions.

Doctor of Philosophy in Bioengineering

A student studying for the Ph.D. degree must complete a master’s degree (45 units) comparable to that of the Stanford M.S. degree in Bioengineering. Up to 45 units of master’s degree residency units may be counted towards the degree. The Ph.D. degree is awarded after the completion of a minimum of 135 units of graduate work as well as satisfactory completion of any additional University requirements. Students admitted to the Ph.D. program with an M.S. degree must complete at least 90 units of work at Stanford. The maximum number of transfer units is 45.

On the basis of the research interests expressed in their application, students are assigned an initial faculty adviser who assists them in choosing courses and identifying research opportunities. The department does not require formal lab rotations, but students are encouraged to explore research activities in two or three labs during their first academic year.

Prior to being formally admitted to candidacy for the Ph.D. degree, the student must demonstrate knowledge of bioengineering fundamentals and a potential for research by passing a qualifying oral examination.

Typically, the exam is taken shortly after the student earns a master’s degree. The student is expected to have a nominal graduate Stanford GPA of 3.25 to be eligible for the exam. Once the student’s faculty sponsor has agreed that the exam is to take place, the student must submit an application folder containing items including a curriculum vitae, research project abstract, and preliminary dissertation proposal to the student services office. Information about the exam may be obtained from the student services office.

In addition to the course requirements of the M.S. degree, doctoral candidates must complete a minimum of 15 additional units of approved formal course work (excluding research, directed study, and seminars).

Dissertation Reading Committee

Each Ph.D. candidate is required to establish a reading committee for the doctoral dissertation within six months after passing the department’s Ph.D. qualifying exams. Thereafter, the student should consult frequently...
with all members of the committee about the direction and progress of the dissertation research.

A dissertation reading committee consists of the principal dissertation adviser and at least two other readers. Reading committees in Bioengineering may include faculty from another department. It is expected that at least one member of the Bioengineering faculty be on each reading committee. The initial committee, and any subsequent changes, must be officially approved by the department Chair.

**University Oral and Dissertation**

The Ph.D. candidate is required to take the University oral examination after the dissertation is substantially completed (with the dissertation draft in writing), but before final approval. The examination consists of a public presentation of dissertation research, followed by substantive private questioning on the dissertation and related fields by the University oral committee (four selected faculty members, plus a chair from another department). Once the oral has been passed, the student finalizes the dissertation for reading committee review and final approval. Forms for the University oral scheduling and a one-page dissertation abstract should be submitted to the department student services office at least three weeks prior to the date of the oral for departmental review and approval.

**Ph.D. Minor in Bioengineering**

Doctoral students pursuing a Ph.D. degree in a major other than Bioengineering may apply for the Ph.D. minor in Bioengineering. A minor is not a requirement for any degree, but is available when agreed upon by the student and the major and minor department. Application forms, including the University’s general requirements, can be found at [http://registrar.stanford.edu/shared/forms.htm](http://registrar.stanford.edu/shared/forms.htm).

A student desiring a Ph.D. minor in Bioengineering must have a minor program advisor who is a regular Bioengineering faculty member. This advisor must be a member of the student’s reading committee for the doctoral dissertation, and the entire reading committee must meet at least one year prior to the date of the student’s dissertation defense. The Ph.D. minor program must include at least 20 units of course work in Stanford Bioengineering or Bioengineering cognate courses at or above the 200 level. Of these 20 units, no more than 10 can be in cognate courses. All courses listed to fulfill the 20-unit requirement must be taken for a letter grade and the GPA must be at least 3.25. Courses used for a minor may not be used to also meet the requirements for a master’s degree.

**M.D./Ph.D. Dual Degree Program**

Students interested in a career oriented towards bioengineering and medicine can pursue the combined M.D./Ph.D. degree program. Stanford has two ways to do an M.D./Ph.D. U.S. citizens and permanent residents can apply to the Medical Scientist Training Program and can be accepted with funding from both M.D. and Ph.D. programs for stipend and tuition. They can then select a bioengineering laboratory for their Ph.D. Students not admitted to the Medical Scientist Training Program must apply to be admitted separately to the M.D. program and the Ph.D. program of their choice.

The Ph.D. is administered by the Department of Bioengineering. To be formally admitted as a Ph.D. degree candidate in this combined degree program, the student must apply through normal departmental channels and must have earned or have plans to earn an M.S. in bioengineering or other engineering discipline at Stanford or another university. The M.S. requires 45 units of course work which consists of core bioengineering courses, technical electives, seminars, and 6-unrestricted units. Students must also pass the Department of Bioengineering Ph.D. qualifying examination.

For students fulfilling the full M.D. requirements who earned their master’s level engineering degree at Stanford, the Department of Bioengineering waives the normal departmental requirement of 15 units applied towards the Ph.D. degree beyond the master’s degree level through formal course work. Consistent with the University Ph.D. requirements, the department accepts 15 units comprised of courses, research, or seminars approved by the student’s academic adviser and the department chair. Students not completing their M.S. engineering degree at Stanford are required to take 15 units of formal course work in engineering-related areas as determined by their academic adviser.

**Joint Degree Programs in Bioengineering and the School of Law**

The School of Law and the Department of Bioengineering offer joint programs leading to either a J.D. degree combined with an M.S. degree in Bioengineering or to a J.D. degree combined with a Ph.D. in Bioengineering.

The J.D./M.S. and J.D./Ph.D. degree programs are designed for students who wish to prepare themselves intensively for careers in areas relating to both law and bioengineering. Students interested in either joint degree program must apply and gain entrance separately to the School of Law and the Department of Bioengineering and, as an additional step, must secure permission from both academic units to pursue degrees in those units as part of a joint degree program. Interest in either joint degree program should be noted on the student’s admission applications and may be considered by the admission committee of each program. Alternatively, an enrolled student in either the Law School or the Bioengineering Department may apply for admission to the other program and for joint degree status in both academic units after commencing study in either program.

Joint degree students may elect to begin their course of study in either the School of Law or the Department of Bioengineering. Faculty advisers from each academic unit will participate in the planning and supervising of the student’s joint program. Students must be enrolled full time in the Law School for the first year of law school, and, at some point during the joint program, may be required to devote one or more quarters largely or exclusively to studies in the Bioengineering program regardless of whether enrollment at that time is in the Law School or in the Department of Bioengineering. At all other times, enrollment may be in the graduate school or the Law School, and students may choose courses from either program regardless of where enrolled. Students must satisfy the requirements for both the J.D. and the M.S. or Ph.D. degrees as specified in the Stanford Bulletin or elsewhere.

The Law School shall approve courses from the Bioengineering Department that may count toward the J.D. degree, and the Bioengineering Department shall approve courses from the Law School that may count toward the M.S. or Ph.D. degree in Bioengineering. In either case, approval may consist of a list applicable to all joint degree students or may be tailored to each individual student’s program. The lists may differ depending on whether the student is pursuing an M.S. or a Ph.D. in Bioengineering.

In the case of a J.D./M.S. program, no more than 45 units of approved courses may be counted toward both degrees. In the case of a J.D./Ph.D. program, no more than 54 units of approved courses may be counted toward both degrees. In either case, no more than 36 units of courses that originate outside the Law School may count toward the law degree. To the extent that courses under this joint degree program originate outside of the Law School but count toward the law degree, the law school credits permitted under Section 17(1) of the Law School Regulations shall be reduced on a unit-per-unit basis, but not below zero. The maximum number of law school credits that may be counted toward the M.S. or Ph.D. in Bioengineering is the greater of: (i) 15 units; or (ii) the maximum number of units from courses outside of the department that M.S. or Ph.D. candidates in Bioengineering are permitted to count toward the applicable degree under general departmental guidelines or in the case of a particular student’s
individual program. Tuition and financial aid arrangements will normally be through the school in which the student is then enrolled.

Chair: Norbert J. Pelc


Associate Professors: Kwabena Boahen, Karl Deisseroth, Christina D. Smolke

Assistant Professors: Zev David Bryant, David B. Camarillo, Jennifer R. Cochran, Markus Willard Covert, Andrew Endy, Kerwyn C. Huang, Jin Hyung Lee, Michael Lin, Manu Prakash, Ingmar Riedel-Kruse, Fan Yang

Courtesey Professors: Daniel S. Fisher, Sanjiv Sam Gambhir, Stuart B. Goodman, Thomas Krummel, Craig Levin, Michael T. Longaker, Stefanos Zenios, Paul J. Wang, Stefanos Zenios

Courtesey Associate Professors: Jeffrey A. Feinstein, Garry E. Gold, Kim Butts Pauly, Marc E. Levenston, Sakti Srivastava

Student Services: Clark Center, Room S-165

Cognate Courses

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<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>BIOC 218</td>
<td>Computational Molecular Biology</td>
<td>3</td>
</tr>
<tr>
<td>BIOMEDIN 210</td>
<td>Modeling Biomedical Systems: Ontology, Terminology, Problem Solving</td>
<td>3</td>
</tr>
<tr>
<td>BIOMEDIN 217</td>
<td>Translational Bioinformatics</td>
<td>4</td>
</tr>
<tr>
<td>CHEMENG 450</td>
<td>Advances in Biotechnology</td>
<td>3</td>
</tr>
<tr>
<td>EE 369A</td>
<td>Medical Imaging Systems I</td>
<td>3</td>
</tr>
<tr>
<td>EE 369B</td>
<td>Medical Imaging Systems II</td>
<td>3</td>
</tr>
<tr>
<td>ME 280</td>
<td>Skeletal Development and Evolution</td>
<td>3</td>
</tr>
<tr>
<td>ME 287</td>
<td>Mechanics of Biological Tissues</td>
<td>3</td>
</tr>
<tr>
<td>ME 381</td>
<td>Orthopaedic Bioengineering</td>
<td>3</td>
</tr>
<tr>
<td>ME 382A</td>
<td>Biomedical Engineering in Research and Development</td>
<td>4</td>
</tr>
<tr>
<td>RAD 226</td>
<td>In Vivo Magnetic Resonance Spectroscopy and Imaging</td>
<td>3</td>
</tr>
</tbody>
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