Biomedical Engineering
Undergraduate Handbook

Academic Year: 2013-2014
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BME Department Administration for Undergraduate Programs

Department Chair:
David Kaplan, Professor and Chair
Office: 251 SciTech
Tel: (617) 627-3251
E-mail: david.kaplan@tufts.edu

Undergraduate Program Director:
Sergio Fantini, Professor
Office: 247 SciTech
Tel: (617) 627-4356
Fax (617) 627-3231
E-mail: sergio.fantini@tufts.edu

Undergraduate Design/Research Coordinator:
Fiorenzo Omenetto, Professor
Office: 241 SciTech
Tel: (617) 627-4972
Fax (617) 627-3231
E-mail: fiorenzo.omenetto@tufts.edu

BME Department Faculty

<table>
<thead>
<tr>
<th>Faculty member</th>
<th>Office</th>
<th>Telephone</th>
<th>E-mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>David Kaplan</td>
<td>251 SciTech</td>
<td>617-627-3251</td>
<td><a href="mailto:david.kaplan@tufts.edu">david.kaplan@tufts.edu</a></td>
</tr>
<tr>
<td>Lauren Black</td>
<td>232 SciTech</td>
<td>617-627-4660</td>
<td><a href="mailto:lauren.black@tufts.edu">lauren.black@tufts.edu</a></td>
</tr>
<tr>
<td>Mark Cronin-Golomb</td>
<td>246 SciTech</td>
<td>617-627-4355</td>
<td><a href="mailto:mark.cronin-golomb@tufts.edu">mark.cronin-golomb@tufts.edu</a></td>
</tr>
<tr>
<td>Sergio Fantini</td>
<td>247 SciTech</td>
<td>617-627-4356</td>
<td><a href="mailto:sergio.fantini@tufts.edu">sergio.fantini@tufts.edu</a></td>
</tr>
<tr>
<td>Irene Georgakoudi</td>
<td>243 SciTech</td>
<td>617-627-4353</td>
<td><a href="mailto:irene.georgakoudi@tufts.edu">irene.georgakoudi@tufts.edu</a></td>
</tr>
<tr>
<td>Catherine K. Kuo</td>
<td>245 SciTech</td>
<td>617-627-4321</td>
<td><a href="mailto:catherine.kuo@tufts.edu">catherine.kuo@tufts.edu</a></td>
</tr>
<tr>
<td>Fiorenzo Omenetto</td>
<td>241 SciTech</td>
<td>617-627-4972</td>
<td><a href="mailto:fiorenzo.omenetto@tufts.edu">fiorenzo.omenetto@tufts.edu</a></td>
</tr>
<tr>
<td>Qiaobing Xu</td>
<td>236 SciTech</td>
<td>617-627-4322</td>
<td><a href="mailto:qiaobing.xu@tufts.edu">qiaobing.xu@tufts.edu</a></td>
</tr>
<tr>
<td>Bree Aldridge</td>
<td>Boston Campus</td>
<td>617-636-6703</td>
<td><a href="mailto:bree.aldridge@tufts.edu">bree.aldridge@tufts.edu</a></td>
</tr>
<tr>
<td>Alessandra Balduini</td>
<td>140 Sci Tech</td>
<td>617-627-3607</td>
<td><a href="mailto:alessandra.balduini@tufts.edu">alessandra.balduini@tufts.edu</a></td>
</tr>
<tr>
<td>Barbara Brodsky</td>
<td>125 SciTech</td>
<td>617-627-0447</td>
<td><a href="mailto:barbara.brodsky@tufts.edu">barbara.brodsky@tufts.edu</a></td>
</tr>
<tr>
<td>Bruce Panilaitis</td>
<td>140 SciTech</td>
<td>617-627-3607</td>
<td><a href="mailto:bruce.panilaitis@tufts.edu">bruce.panilaitis@tufts.edu</a></td>
</tr>
<tr>
<td>Angelo Sassaroli</td>
<td>238 SciTech</td>
<td>617-627-4970</td>
<td><a href="mailto:angelo.sassaroli@tufts.edu">angelo.sassaroli@tufts.edu</a></td>
</tr>
<tr>
<td>Hu (Tiger) Tao</td>
<td>124 Sci Tech</td>
<td>N/A</td>
<td><a href="mailto:hu.tao@tufts.edu">hu.tao@tufts.edu</a></td>
</tr>
<tr>
<td>Xiaoqin Wang</td>
<td>200 Boston Ave</td>
<td>N/A</td>
<td><a href="mailto:xiaoqin.wang@tufts.edu">xiaoqin.wang@tufts.edu</a></td>
</tr>
<tr>
<td>Anthony Barry</td>
<td>N/A</td>
<td>N/A</td>
<td><a href="mailto:anthony.b.barry@pfizer.com">anthony.b.barry@pfizer.com</a></td>
</tr>
<tr>
<td>Bernardo Perez-Ramirez</td>
<td>N/A</td>
<td>N/A</td>
<td><a href="mailto:bernardo.perez-ramirez@genzyme.com">bernardo.perez-ramirez@genzyme.com</a></td>
</tr>
<tr>
<td>Martin Hunter</td>
<td>235 SciTech</td>
<td>617-627-4604</td>
<td><a href="mailto:martin.hunter@tufts.edu">martin.hunter@tufts.edu</a></td>
</tr>
<tr>
<td>Gregory Sonek</td>
<td>N/A</td>
<td>N/A</td>
<td><a href="mailto:gregory.sonek@tufts.edu">gregory.sonek@tufts.edu</a></td>
</tr>
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Overview of undergraduate programs

Biomedical engineering involves a synergistic combination of the techniques and practices of a number of disciplines (including mathematics, statistics, biology, chemistry, physics, chemical engineering, mechanical engineering, electrical engineering, and computer science), brought together and focused toward the goal of creating more effective tools, applications, and treatments in areas such as regenerative medicine, tissue engineering, medical instrumentation and devices, patient aids, and robustly engineered medical practices.

The department offers instruction leading to a bachelor of science in biomedical engineering (BSBME) for students in the School of Engineering. Furthermore, the department offers second major programs for engineering and liberal arts students. By careful selection of course work, students who follow these curricula can satisfy admission requirements for professional schools of medicine, dentistry, business, or law.
Bachelor of Science in Biomedical Engineering (BSBME)

The bachelor of science in biomedical engineering is a degree program that combines intensive training in design and research methods, techniques, and practical skills, with a solid math, science, and engineering curriculum to provide education with breadth and depth in the field. A key aspect of biomedical engineering is its interdisciplinary nature; introductory courses in mathematics, statistics, biology, chemistry, and physics, together with foundation/concentration engineering courses build the basis for creating the synergy among these disciplines that is required in the practice of biomedical engineering.

The curriculum leading to the bachelor of science degree in biomedical engineering is intended to prepare students to continue with graduate study either in biomedical engineering or medicine, or to enter professional practice as an engineer or designer of biomedical systems. The curriculum includes intensive instruction in math, sciences and engineering disciplines, as well as a unique integrated design and research experience covering sophomore to senior years, in which each student participates in interdisciplinary design/research teams to learn about open-ended biomedical engineering problems, and design approaches, research techniques, and testing methods to propose, implement, and evaluate solutions to these problems.

The program leading to the BSBME degree is accredited by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET).

Application Procedures for the BSBME Program

Those students who are interested in applying for the Bachelor of Science in Biomedical Engineering must, by the end of their first term of their freshman year, take and complete for a grade at Tufts the following set of five courses:

1. ES 93.
2. One of Math 32, Math 36, or Math 42.
3. One of Phys 11, Phys 12, or any Physics course with Phys 12 as a prerequisite.
4. One of Chem 1, Chem 2, or any Chemistry course with Chem 2 as a prerequisite.

The applicant must take and complete one course in each category even if the applicant has previously earned Advanced Placement (AP) credit in that category via the appropriate placement examination. For example, a student with two AP credits in Chemistry may not count those credits as satisfying the requirement, but may use that placement to enroll in Chemistry 31 (Physical Chemistry) or 51 (Organic Chemistry). Students must submit an application (available online at http://engineering.tufts.edu/docs/BSBME_Application_Form.pdf) for admission into the BSBME program before December 1st of their freshman year. Admission to the program is merit-based. Of the students that will apply, 20 students will be admitted into the program according to the following merit criteria:

- **The 15 students** obtaining the top first-semester grade point average, adjusted by including a grade of A for each course in points 2-4 above for which the applicant has received AP credit and has enrolled in a more advanced course in the same discipline in the first term (in this case students must submit a copy of their AP scores with the application to the BSBME program).
- Among the students who enroll in ES93-10 (Introduction to Biomedical Engineering) the 5 students obtaining the top grades in ES93-10 (excluding the 15 students already admitted into the BSBME program on the basis of the adjusted first-semester grade point average). For equal grades in ES93-10, the adjusted cumulative grade point average will serve as a tie breaker.

The department will notify students of their acceptance into the program during the winter break of their freshman year. **Students who are admitted into the program are required to formally confirm their intention to enroll into the program by notifying the department in writing by**
February 15th of their freshman year. In case one or more students decline admission into the program, they may be replaced by the student(s) achieving the top adjusted cumulative grade point average among the applicants who were not originally admitted into the program.

Mission
The mission of the bachelor of science degree in biomedical engineering is to provide students with undergraduate educational experiences that provide a sound basis for professional practice in biomedical engineering, life-long learning, and leadership roles in the biomedical engineering field.

Student Outcomes
The student outcomes of the Bachelor of Science in Biomedical Engineering specify that, by the time of graduation, all graduates will be able to:
- Apply fundamental knowledge of mathematics, statistics, physical sciences, biology, physiology, and engineering for the solution of problems at the interface of engineering and biology;
- Make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems;
- Communicate effectively, work as part of a multidisciplinary team, and have an awareness of professional and ethical responsibilities to have a positive impact on society;
- Recognize the importance of life-long learning in order to expand one’s knowledge base;
- Participate in creative and integrative design projects and independent research projects.

Program Educational Objectives
The BSBME Program Educational Objectives specify that graduates of the program will:
- Be successful in tackling open-ended biomedical engineering problems in a quantitative and systematic fashion;
- Be motivated to continuously expand their knowledge, be creative and innovative in their contributions to the field of biomedical engineering;
- Perform, manage, or lead original engineering design and research projects in an ethical and professional manner; carry this out at the highest levels in private industry, research laboratories, medical school, graduate and professional schools.

Curriculum
Successful completion of the BSBME program requires that students complete the 38-credit curriculum reported below:

**Introductory (9 Credits) – No Pass/Fail**
Math 11 or 32 – Calculus I
Math 12 or 36 – (Applied) Calculus II
Math 13 or 42 – Calculus III
Math 38 or 51 – Differential Equations
Physics 11 – General Physics I with Lab
Physics 12 – General Physics II with Lab
Chemistry 1 – Chemical Fundamentals with Lab
Chemistry 2 – Chemical Principles with Lab
Biology 13 – Cells and Organisms with Lab

**Introductory First-Year Engineering (2 Credits) – No Pass/Fail**
ES 93 – Introductory Engineering elective
ES 2 – Introduction to Computing
**Humanity/Art/Social Science (6 Credits)****

- English 1 – Expository Writing (No Pass/Fail) OR English 3 – Reading, Writing, Research
- Humanity Elective
- Social Science Elective
- Humanity/Art/Social Science Elective
- Humanity/Art/Social Science Elective
- Humanity/Art/Social Science Elective

**Free Elective (1 Credit)**

Free elective

**Foundation (8 Credits) – No Pass/Fail**

- ES 3 – Introduction to Electrical Engineering with Lab
- ES 5 – Applied Mechanics
- ES 7 – Thermodynamics
- ES 8 – Fluid Mechanics
- Biology 41 – General Genetics
- Probability and Statistics Selected Elective *
- BME 121 – Quantitative Physiology OR Biology 115/116 – General Physiology I/II

**Concentration (12 Credits) – No Pass/Fail**

- BME 3 (0.5 Credits) – Sophomore Design and Research I
- BME 4 (0.5 Credits) – Sophomore Design and Research II
- BME 5 (0.5 Credits) – Junior Design and Research I
- BME 6 (0.5 Credits) – Junior Design and Research II
- BME 7 – Senior Design and Research I
- BME 8 – Senior Design and Research II
- BME 50 – Introduction to Biomedical Engineering
- BME 51 (formerly BME 101) – Introduction to Biophotonics
- BME 62 – Molecular Biotechnology
- BME 100 – Medical Instrumentation
- BME 153 Biomaterials and Regenerative Medicine OR BME 154 Tissue Engineering and Regenerative Medicine (formerly BME 164)
- BME 131 – Principles of Medical Imaging OR BME 165 – Principles of Drug Delivery

**Notes:**

* Bio 132 (Biostatistics), Math 162 (Statistics), ES 56 (Probability and Statistics), EE 104 (Probabilistic Systems Analysis), BME 141 (Analytical Tools for Biomedical Engineering), CD 140 (Problems of Research: Statistics), PSY 31 (Statistics for Behavioral Science)

** Chem 31 (Physical Chemistry I), Chem 32 (Physical Chemistry II), Chem 51 (Organic Chemistry I)

*** Any BME course from the approved engineering list (use iSIS - Must be BME courses wish attribute value: SoE-Engineering). Also, one Concentration Elective may be chosen from any BME course or from Bio 46 (Cell Biology), Bio 102 (Human Genetics), Bio 105 (Molecular Biology), Bio 152 (Biochemistry and Cellular Metabolism), Bio/Chem 171 (Biochemistry I), Chem 51 (Organic Chemistry I), Chem 52 (Organic Chemistry II), Phy 31 or Phy 115 (Optics and Wave Motion).
**** Use iSIS – Must be courses with attribute value: SoE-HASS. Courses selected must include a minimum of one credit in each area of Humanities (H) and Social Sciences (SS). In addition, at least two HASS courses must be taken in the same department.

The recommended course schedule is as follows:

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<th>Fall – 1st Year (4.0 Credits)</th>
<th>Spring – 1st Year (4.0 Credits)</th>
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<tr>
<td>ES 93</td>
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<tr>
<td>Math 32</td>
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<tr>
<td>Phys 11</td>
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<td>Math 42</td>
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<tr>
<td>Bio 13</td>
<td>Chem 2/Phys 12</td>
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<tr>
<td>ES 3</td>
<td>ES 7</td>
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<td>ES 5</td>
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<td>HASS</td>
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<tr>
<td>Bio 41</td>
<td>BME 51</td>
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<tr>
<td>ES 8</td>
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<tr>
<td>Probability and Statistics</td>
<td>BME 100</td>
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<td>BME 121</td>
<td>HASS</td>
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<td>Foundation Elective</td>
<td>BME 6 (0.5)</td>
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<td>BME 5 (0.5)</td>
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<td>BME 165/Concentration</td>
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<tr>
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<td>Soc.Sci. Elective</td>
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<tr>
<td>HASS</td>
<td>Free Elective</td>
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<tr>
<td>BME 7</td>
<td>BME 8</td>
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**Degree Checklist**

If intending to graduate in May, students must file a degree sheet with the University the previous November. The Degree Checklist for the BSBME program is available online at [http://engineering.tufts.edu/academics/undergradprograms/degreesmajors.htm#BSBME](http://engineering.tufts.edu/academics/undergradprograms/degreesmajors.htm#BSBME). In this process, the student’s advisor and the Department Chair assist the student in verifying that all academic requirements will be satisfied based on the projected coursework. After the fall term, a degree audit is completed by Student Services with the Associate Dean of Undergraduate Education, and a final audit is done at the end of the spring term.
Academic meetings and events for BSBME students

BSBME orientation for first-year applicants. In early December, the department holds an orientation session for all first-year students who have submitted an application for the BSBME program. This orientation aims at describing the curriculum of the BME major, as well as other undergraduate programs and research opportunities offered by the BME department.

Annual BSBME meeting. In April, the department holds an annual meeting for all classes of BSBME students as an opportunity for them to interact with each other, exchange information on the program, and provide feedback to the faculty. These meetings are also used to announce updates on the program, provide information of general interest to the students, and cover specific topics such as bioethics, contemporary issues relevant to biomedical engineering, societal and global impact of engineering solutions, etc.

Undergraduate design day. At the end of the spring semester, the department organizes a one-day event devoted to all student projects in the department. In particular, sophomore and juniors present their design and research projects in a technical poster session, while seniors present their senior projects in an oral presentation session. All BME students and faculty attend this research day event.

Thesis Honors Program

The Thesis Honors Program allows students to pursue a program of independent study involving extensive design or research activities that lead to a senior thesis and an oral defense. Admission to the Thesis Honors Program is restricted to students whose names have appeared on the Dean’s List at least two times before their senior year. The student is responsible for identifying an advisory committee consisting of the principal advisor (who must be a full-time faculty member in the BME department) and at least one additional committee member that must be a full-time Tufts faculty member. Admission to the program requires formation of an advisory committee, consent of the student’s advisor, and approval of the BME department. The membership of the advisory committee and the title of the thesis must be registered with the Academic Resource Center. The committee will direct the student’s design and research work and will guide the student in preparing the thesis and oral defense.

The Thesis Honors Program requires two one-semester course credits, namely BME 89 (fall term) and BME 90 (spring term). The thesis should be of quality comparable to a paper publishable in a peer-reviewed journal. The completed thesis will be presented for consideration no later than two weeks before the last day of classes of the student’s final semester. After the defense, a final copy of the thesis, in electronic form, should be submitted to the Tisch Library archive.

The advisory committee is empowered to determine the level of thesis honors to be awarded, basing its recommendation on an evaluation of the thesis. Degrees are designated bachelor of science with highest thesis honors, with high thesis honors, or with thesis honors (thesis honors will be indicated on the student’s transcript, but not on the diploma). Students who, in the judgment of the advisory committee, have not attained the standard required for a thesis honor designation may be withdrawn from the BME 89 and BME 90 courses.

After the defense, a final copy of the thesis should be submitted electronically to Digital Collections and Archives (DCA). Please contact the DCA (http://dca.tufts.edu/) for more information on how to submit the thesis.
Study Abroad

Many Tufts students take the opportunity to broaden their college experience by studying abroad during their junior year. This is possible also for students enrolled in the BSBME program. However, because the requirements associated with the design/research course sequence may not be fulfilled at an institution other than Tufts, it is important that students interested in studying abroad begin to make plans well in advance of their junior year. Specifically, as part of their planning for studies abroad, students need to make specific plans to fulfill the requirements of BME 5 and/or BME 6 with the respective instructors.
Second Major in Biomedical Engineering (BED)

The second major in biomedical engineering is offered to engineering students. Students must enroll in conjunction with another engineering undergraduate departmental major. For the second major in biomedical engineering, students are required to complete ten courses. No more than five of these courses may be used to fulfill the concentration requirement of the first major. All ten courses must be taken for a letter grade. The ten credits required for the second major in biomedical engineering as follows:

1. Biology 13 or Engineering Science 11
2. Physics 12 or Chemistry 2
3. Probability and Statistics Elective*
4. Engineering Science 3 or Engineering Science 5
5. Engineering Elective**
6. Biomedical Engineering 50
7. Biomedical Engineering 62 or Biomedical Engineering 100
8. Biomedical Engineering 153 or Biomedical Engineering 131
9. Biomedical Engineering elective***
10. Biomedical Engineering elective***

** Engineering Elective Courses: Any course in CEE, BME, ChBE, EE, ENP, ME, or COMP 11 and beyond.
*** BME Elective Courses: Any BME course.

The degree checklist for the BED program is available online at http://engineering.tufts.edu/bme/academics/undergraduate/bed.asp.
Second Major in Biomedical Sciences (BES)

The second major in biomedical engineering sciences is offered to liberal arts students. Students must enroll in conjunction with another undergraduate departmental major. For the second major in biomedical engineering sciences, students are required to complete ten courses. No more than five of these courses may be used to fulfill the concentration requirement of the first major. All ten courses must be taken for a letter grade. The ten credits are required for the second major in biomedical engineering are as follows:

1. Biomedical Engineering 50
2. Biomedical Engineering 62
3-5. Three Biomedical Engineering elective courses *
6-10. Five elective courses related to biomedical sciences, including independent studies, research, and design projects **

* BME elective courses for BES: Any one-credit courses with BME designation.
** Elective courses for BES: Any one-credit courses related to biomedical sciences, including independent studies, research, and design projects, may be counted toward electives by consent of the Advisor. A partial list of acceptable elective courses is the following:

- Any course with BME designation
- BIO 115 - General Physiology I
- BIO 116 - General Physiology II
- BIO 132 - Biostatistics
- Chem 135 - Biophysical Chemistry
- Chem 157 - Medicinal Chemistry
- Chem 171/172 - Biochemistry I/II
- COMP 171 - Human Computer Interaction
- ENP120 – Project Study in Human Systems
- ENP 161 - Human Factors in Product Design
- ENP 162 - Man-Machine System Design
- ENP 166 – Computer Interface Design
- MATH 150 - Math. Models in Biology
- ME 121 - Biomaterials
- ME 152 - Biomechanics
- OTS 105 - Assistive Technology
- PHIL 124 – Bioethics
- PHY 25 - Biophysics
- PHY 31 – Optics and Wave Motion
- PSY 31 - Statistics for Behavioral Sciences

The degree checklist for the BES program is available online at http://engineering.tufts.edu/bme/academics/undergraduate/bes.asp.