Biomedical Opportunities in the Undergraduate EE Curriculum

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Chair, Department of Electrical & Systems Engineering
The Eugene and Martha Lohman Professor of Electrical Engineering

www.ese.wustl.edu
Outline

• BSEE Pre-med Curriculum

• Imaging Sciences Pathway Program

• Example: ESE 489/589 Biological Imaging Technology

• Biomedical Undergraduate Research

• Bioimaging Study Abroad Program
BSEE Pre-med Curriculum
Pre-med Requirements

Two semesters of:

- Biology with lab
- Physics with lab
- General Chemistry with lab
- Organic Chemistry with lab
- Math to include differential equations

Each medical school has its own required and suggested courses listed in the “Medical School Admission Requirements,” published by the Association of American Medical Colleges (AAMC)
Students must complete a selection of courses for which the accumulated engineering topics is 45 units. Also certain restrictions apply about the total number of credits of ESE 400 (independent study) and ESE 497 (undergraduate research.)
**BSEE Curriculum**

### Year 1
- **Semester 1**
  - MATH 132 Calculus I (3 credits)
  - PHYS 117A General Physics I (4 credits)
  - CS Elective (CSE 131 or 125) (4 or 3 credits)
  - Elective Humanities or Soc. Sciences
  - ESE Elective (1 Credit)

- **Semester 2**
  - MATH 233 Calculus III (4 credits)
  - PHYS 118A General Physics II (4 credits)
  - Elective Free
  - Elective Humanities or Soc. Sciences
  - ESE 141 Intro. Robotics (1 Credit)

### Year 2
- **Semester 1**
  - MATH 217 Differential Equations (4 credits)
  - ESE 230 Intro to electrical principles (4 credits)
  - Elective Free
  - Elective Humanities or Soc. Sciences
  - ESE 231 Lab Electrical Circuits (3 credits)

- **Semester 2**
  - ESE 231 Lab Engineering Mathematics (4 credits)
  - ESE 232 Lab Electromagnetics Principles (3 credits)
  - Elective EE Breadth
  - Elective Free
  - ESE 231 Lab Numerical Analysis (3 credits)

### Year 3
- **Semester 1**
  - ESE 317 Lab Prob and Stats for Engineers (3 credits)
  - ESE 326 Lab Introduction to Digital Logic (3 credits)
  - Elective EE Breadth
  - Elective Free
  - Elective Free

- **Semester 2**
  - ESE 330 Lab Engineering Mathematics (4 credits)
  - EP 310 Lab Technical Writing (3 credits)
  - Elective EE Breadth
  - Elective Free
  - Elective Free

### Year 4
- **Semester 1**
  - ESE 400 Lab Senior Design Laboratory (3 credits)
  - ESE 498 Lab Senior Design Project (3 credits)
  - Elective EE Breadth
  - Elective Free
  - Elective Free

- **Semester 2**
  - ESE 400 Lab Senior Design Laboratory (3 credits)
  - ESE 498 Lab Senior Design Project (3 credits)
  - Elective Free
  - Elective Free
  - Elective Free

### Pre-med Sample Plan

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadth Elective</td>
<td>9</td>
</tr>
<tr>
<td>Free Electives</td>
<td>10 of 11</td>
</tr>
<tr>
<td>Non-ESE Engineering Elective</td>
<td>3</td>
</tr>
<tr>
<td>ESE 141 Intro. Robotics</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
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</tbody>
</table>
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<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>CHEM 112A, Gen. Chemistry 2</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 152, Gen. Chemistry 2 Lab</td>
<td>2</td>
</tr>
<tr>
<td>BIO 2960, Principles of Biology 1</td>
<td>4</td>
</tr>
<tr>
<td>BIO 2970, Principles of Biology 2</td>
<td>4</td>
</tr>
<tr>
<td>BIO 3058, Physiological Control Systems</td>
<td>2</td>
</tr>
<tr>
<td>CHEM 251, Organic Chemistry 1</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 252, Organic Chemistry 2</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 257, Organic Chemistry Lab</td>
<td>2</td>
</tr>
</tbody>
</table>

**Total:** 23 credits
## BSEE Pre-med

### Course Substitutions

<table>
<thead>
<tr>
<th>EE Curriculum Flexible Courses</th>
<th>Switch to</th>
<th>Pre-med Required Courses</th>
</tr>
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<tbody>
<tr>
<td>9 units of Breadth Electives</td>
<td></td>
<td></td>
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<tr>
<td>10 of 11 units of Free Electives</td>
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<td></td>
</tr>
<tr>
<td>1 unit ESE 141 Intro. Robotics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 units of non-ESE Engineering Electives</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Pre-med Required Courses (CHEM 111A, 151 are included in EE Curriculum)</th>
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<tbody>
<tr>
<td>• 3 units CHEM 112A Gen. Chemistry 2</td>
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<tr>
<td>• 3 units CHEM 251 Organic Chemistry 1</td>
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<td>• 4 units BIO 2960 Principles of Biology 1</td>
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<td>• 4 units BIO 2970, Principles of Biology 2</td>
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<td>• 2 units of BIO 3058 Physiological Control Systems</td>
</tr>
<tr>
<td>• 2 units of CHEM 152, Gen. Chemistry 2 Lab</td>
</tr>
<tr>
<td>• 2 units of CHEM 257, Org. Chemistry Lab</td>
</tr>
</tbody>
</table>

**Total Units** 23
Imaging Sciences Pathway Program
• Imaging sciences are multi-disciplinary, requiring knowledge of biology, chemistry, physics, engineering, and applied mathematics

• Washington University has many imaging resources and experts. It is nationally ranked in the top three of NIH funding for imaging sciences research

• Imaging Sciences Pathway emphasizes biomaging for undergraduate students in engineering, the physical and life sciences
Imaging Sciences Pathway Goals

• Educate “renaissance scientists” whose knowledge of the physical sciences, engineering, chemistry, and biology will allow them to explore new frontiers within the various and ever-expanding research domains of imaging sciences.

• Provide undergraduate students with extraordinary opportunities to carry out research with more than 60 leading investigators in the imaging sciences from more than 15 clinical and science departments.

• Provide undergraduate students in the physical and life sciences and engineering first-hand experience in this exciting area of biomedicine.
Consists of two parts:

- An introductory freshman/sophomore seminar introduces prospective Pathway students to the diverse imaging sciences research under way in Arts & Sciences, the School of Engineering & Applied Science, and the School of Medicine.

- Courses for juniors and seniors focus on chemistry, physics, computer science, engineering, and molecular cell biology as they relate to imaging sciences.
Core courses:

1) Seminar in Imaging Sciences (BIO 1810)

2) Introduction to Cell Biology (BIO 334)
   - Principles of Biology I (BIO 2960)
   - DNA Science: A Hands-On Workshop (BIO 280)
   - Biochemistry (BIO 4501/CHEM 456)

3) Principles & Applications of Biological Imaging (BIO 5146)

4) Contrast Agents for Biological Imaging (BIO/CHEM 5147)
   - Biological Imaging Technology (ESE 489/589/BME 494)

Students completing the ISP requirements receive a Milestone on their transcripts
Students choose two faculty mentors from different disciplines (e.g., engineering and biology), with one being the primary mentor.

Junior and senior Pathway students participate in an interdisciplinary imaging research project in the lab of the primary and/or secondary mentor.

Students can receive credit for independent research.

Students also participate in summer research internships between their junior and senior years; stipends are available through NIH R90 funds.
The Pathway makes extensive use of the University’s vast imaging resources, which cover the full spectrum from molecular microscopy to full body human imaging.

- Mallinckrodt Neuroimaging Laboratories
- WU Small Animal Imaging Resource
- Cardiovascular Imaging Laboratory
- Molecular Imaging Center
- Center for Clinical Imaging Research
- Electronic Systems & Signals Research Laboratory
- High-Resolution NMR Facility
- High Throughput Screening Robotics Core
- Deep-Etch Electron Microscopy Facility
- Center for Biomedical and Bioorganic
- Mass Spectrometry
- Bakewell Neuroimaging Laboratory
Imaging Sciences Pathway Plan

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<tr>
<td>EE Electives</td>
<td>3 of 15</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
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Department of Electrical & Systems Engineering

BSEE Curriculum
For 16 total units required for ISP with pre-requisites.

- Students participate in imaging research projects and can receive credits under ESE 497 Undergraduate Research.

- 20 available units in traditional curriculum consisting of free and breadth electives.
## BSEE Imaging Sciences Program

### Course Substitutions

<table>
<thead>
<tr>
<th>EE Curriculum Flexible Courses</th>
<th>ISP Required + Prerequisite Courses</th>
</tr>
</thead>
</table>
| **9 units of Breadth Electives** | **3 units CHEM 112A Gen. Chemistry 2**  
|                                | **2 units CHEM 152 Gen. Chemistry 2 Lab**  
|                                | **4 units BIO 2960 Principles of Biology 1**  |
| **4 of 11 units of Free Electives** | **1 unit BIO 1810 Seminar In Imaging Sciences**  
|                                | **3 units BIO 5146 Principles and Applications of Biological Imaging**  |
| **3 of 15 units of EE Electives** | **3 units ESE 489 Biological Imaging Technology**  |

**Total Units** 16

**3 units of ESE 497 Undergraduate Research on imaging research projects**
Example: ESE 489/589 Biological Imaging Technology
ESE 489/589 Biological Imaging Technology

• Course coordinators and modality experts:
  – J. A. O’Sullivan, ESE
  – J. P. Culver, Radiology
  – Y.-C. Tai, Radiology
  – J. Shimony, Radiology

Experts in EE, physics, biomedical physics, radiology.

• Textbook-based:

• Four lectures per modality:
  – Physics, mathematics, imaging
  – Lab tours and original literature critique

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**Modalities**

- Fundamentals
- Radiographic
- Nuclear
- Optical
- Ultrasound
- Magnetic Resonance

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Avanto 1.5 T MRI Scanner
Biological Imaging Technology

- Organ (e.g. CT, MRI, US)
- Tissue (e.g. Intrinsic optical imaging of cat visual cortex)
- Cells (e.g. fluorescence microscopy)
• State-of-the art CT and PET-CT imaging facilities

• Siemens equipment

SOMATOM Definition CT Scanner

Biograph 64/40: PET-CT scanner

CT (anatomical image)

Fused PET-CT

PET (functional image)

Data (PETCT-165) from R. Laforest and M. Mintun, Radiology
• Contrasting state-of-the-art facilities with foundational papers

• Siemens equipment


SOMATOM Definition CT Scanner
Contrasting state-of-the-art facilities with foundational papers

Siemens equipment

Biograph 64/40: PET-CT scanner

First PET machine, designed and built at Washington University in St. Louis

E. Hoffman, M. Phelps, N. A. Mullani, C. S. Higgins, and M. M. Ter-Pogossian, Instrumentations and Physics, 1976
Development of a High-Frequency Ultrasonic Imaging Platform
Amanda Virkus with R. Martin Arthur

Project: Ultrasound thermometry

Student contribution: Upgrade a 7.5 MHz pulse-echo system to work at 35 MHz

Configuration for automatic thermal image measurement from tissue samples during Hyperthermia

A 35-MHz ultrasound image of pig muscle
Project: Individualize heart models using a deformable model. Goal: compare normal with pathological electrical patterns on the same heart

Student contribution: Test suitability of candidate template hearts and quantify alignment errors

Visible Human heart model. Spherical harmonic approximation in red

Comparison of two deformed templates aligned at the apex of the heart
Bioimaging Study Abroad Program
Introduction to Multimodal Imaging

- **Host**: University of Tübingen MEG-Center, and the Max Planck Institute for Biological Cybernetics, Germany

- **Undergraduate students** from Electrical & Systems Engineering at Washington University will learn about medical imaging methods
Program

- May 11, 2009 – May 15, 2009
- One unit of credit, with the option to continue working on an independent study or undergraduate research course for a total of three units of credit
- Lectures, projects, lab visits, and social programs
- Final report
Lectures

- The physics of SQUID sensors
- Fetal magnetoencephalography (fMEG)
- MEG for basic research and clinical application
- Application of MEG to brain machine interfaces (BCI)
- Metabolic imaging with functional MRI (fMRI) and near infrared spectroscopy (NIRS)
- BCI in fMRI
- Transcranial magnetic stimulation (TMS) as a research tool
Research Projects

• Project 1: Fetal magnetoencephalography (fMEG) and magnetocardiography (MCG)
• Project 2: Brain computer interface (BCI) application of MEG
• Project 3: Visual processing of food related pictures with functional MRI (fMRI)
• Project 4: Transcranial magnetic stimulation (TMS)

• Lab visits:
  – Max-Planck Institute for biological Cybernetics
  – Laboratory for Preclinical Imaging and Imaging Technology of the Werner Siemens-Foundation, University Hospital Tübingen
Summary
Biomedical Opportunities in Undergraduate EE

- BSEE pre-med curriculum
- Imaging sciences pathway program
- Biomedical undergraduate research
- Bioimaging study abroad program
- Double major BSEE/BME
- BSEE/SSE curricula focused on bioelectricity, systems biology, bioinformatics, etc.
Thanks!