BME Careers
A Deeper Look

Prof Bruce Wheeler
BME Enrollment and Employment

Sources: American Institute of Medical and Biological Engineering [http://navigate.aimbe.org], Bureau of Labor Statistics, American Society for Engineering Education

Good News

- 20,100 BME jobs in US (AIMBE: 21,300 in 2016; others up to 27,000)
- 7% growth rate to 2026
- $92,970 annual salary average (Bureau of Labor Statistics)
- 1008 PhDs in 2017

Not So Good News (ASEE and Bureau Labor Statistics)

- 6,725 grads/yr = 33% of current total BME job market
- 34,060 current BME BS students = 70% greater than total BME job market
- 4,025 current BME MS students = 20% of total BME job market
- 6,730 current BME PhD students = 33% of total BME job market
<table>
<thead>
<tr>
<th>Engr Field</th>
<th>2012</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgE</td>
<td>3.0</td>
<td>1.3</td>
</tr>
<tr>
<td>BME</td>
<td>4.5</td>
<td>3.0</td>
</tr>
<tr>
<td>ChemE</td>
<td>4.6</td>
<td>3.1</td>
</tr>
<tr>
<td>MechE</td>
<td>12.7</td>
<td>9.7</td>
</tr>
<tr>
<td>Materials</td>
<td>18.9</td>
<td>13.4</td>
</tr>
<tr>
<td>Aero</td>
<td>19.5</td>
<td>16.2</td>
</tr>
<tr>
<td>EE</td>
<td>23.5</td>
<td>17.0</td>
</tr>
<tr>
<td>Petroleum</td>
<td>34.8</td>
<td>18.3</td>
</tr>
<tr>
<td>Mining</td>
<td>33.9</td>
<td>20.9</td>
</tr>
<tr>
<td>Environ.</td>
<td>32.0</td>
<td>22.8</td>
</tr>
<tr>
<td>Civil</td>
<td>21.3</td>
<td>25.1</td>
</tr>
<tr>
<td>Nuclear</td>
<td>29.0</td>
<td>29.5</td>
</tr>
<tr>
<td>CS</td>
<td>256.0</td>
<td>133.0</td>
</tr>
</tbody>
</table>

**Not So Good News:**

**Ratios:**

**Total USA Jobs**

**Current BS Grads**

Notes:
- Job totals for all who are working, not new openings;
- BS grads are those graduating in 2017

Enrollments are increasing faster than jobs.

STEM recruitment in middle/high school increases number of BS grads.

Limits of STEM – it’s Really TE

2013 starting salary data for BS grads:
- English majors - $32k
- TE: Engineering/CS - $50k
- S: Biology - $25k
- S: Chemistry – a little better than English majors
- M: Math – between Chem and Engineering

Associate’s Level
- Bio and Chem majors ~ barista
- Eng / CS tech – twice as much

NIH recognizes oversupply of biology PhD’s
- (still happening today)

BME in Between
Engineering and Biology

- The more like an engineer …
  - Higher pay, more jobs, but … is it as interesting?
- The more like a biologist …
  - Lower pay, fewer jobs, but … is it as interesting?
- But … the Big But …
- Life is more than calculating odds for getting a job
- The exciting stuff is “right down the middle” -- both bio and engineering
- Where are you going to bet your life?
# 2019 Starting and Mean Salaries for Engineers

<table>
<thead>
<tr>
<th>Field</th>
<th>Starting</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME:</td>
<td>$61k</td>
<td>$95k</td>
</tr>
<tr>
<td>Aero:</td>
<td>$</td>
<td>$115k</td>
</tr>
<tr>
<td>AgE:</td>
<td>$</td>
<td>$77k</td>
</tr>
<tr>
<td>Civil:</td>
<td>$56k</td>
<td>$93k</td>
</tr>
<tr>
<td>CompE hardware:</td>
<td>$71k</td>
<td>$118k</td>
</tr>
<tr>
<td>CompE software:</td>
<td>$68k</td>
<td>$114k</td>
</tr>
<tr>
<td>ChemE:</td>
<td>$65k</td>
<td>$114k</td>
</tr>
<tr>
<td>EE:</td>
<td>$65k</td>
<td>$101k</td>
</tr>
<tr>
<td>Environmental:</td>
<td>$56k</td>
<td>$92k</td>
</tr>
<tr>
<td>Geo/Mining:</td>
<td>$62k</td>
<td>$98k</td>
</tr>
<tr>
<td>Materials:</td>
<td>$66k</td>
<td>$97k</td>
</tr>
<tr>
<td>MechE:</td>
<td>$62k</td>
<td>$93k</td>
</tr>
<tr>
<td>Petroleum:</td>
<td>$</td>
<td>$137k</td>
</tr>
</tbody>
</table>

Source: Michigan Tech: [https://www.mtu.edu/engineering/outreach/welcome/salary/](https://www.mtu.edu/engineering/outreach/welcome/salary/)

An Overview of the Biomedical Engineering Field

It’s All Super Exciting!!

Which UCSD majors are best prepared for each subfield?

Extrapolated from Designing a Career in Biomedical Engineering

Available for free download at https://www.embs.org/about-biomedical-engineering/designing-a-career-in-biomedical-engineering/
So You Want to Become a Biomedical Engineer

MOOC (Massive Online Open-access Course)
From EdX and UCSD
4 week course / 2 hours per week
But it is really just advice and it is free

https://www.edx.org/course/so-you-want-to-be-a-biomedical-engineer

Career Advice Aimed at Early College Students

Free! Certificate is Extra

Meet the Instructor
Bruce C. Wheeler
Adjunct Professor, Bioengineering
University of California, San Diego
IEEE Fellow
AAAS Fellow
PRACTICAL APPLICATIONS

- **Clinical Engineering** – managing technology in hospitals
  - Bioengineering, Biosystems; ECE, MAE
  - Certificates: American College of Clinical Engineering – there is no clinical engineering UG degree! business skills a plus
  - Now known as Healthcare Technology Management

- **Diagnostic & Therapeutic Systems** – improve instrumentation, lab clinical, physiological, data
  - Bioengineering, Biosystems; ECE, MAE
  - Includes clinical decision making support
  - Industry – not an academic discipline

- **Rehabilitation Engineering** – augmentative technologies
  - Bioengineering, Biosystems; ECE; MAE; Rehabilitation specialty programs
  - Will need to work/study in Rehabilitation facilities
  - Growing use of Smart Houses and Fit-Bit devices; wheelchairs
  - Performance Enhancement?
STARTING FROM PHYSIOLOGY

- **Cardiac Bioengineering** – cardiovascular disease modeling and imaging; therapeutics
  - *Bioengineering, Biotechnology; MAE; ECE*
  - Multiscale modeling; increasing emphasis on imaging; device technologies (valves, artificial hearts) are sophisticated; move toward biomolecular & tissue
  - Very strong research at UCSD

- **Neural Engineering** – imaging, brain-computer interface
  - *Bioengineering, Biosystems; ECE; CSE; Neuroscience*
  - Neuroscience is a huge area and exceptional at UCSD

- **Physiological System Modeling** – all other systems
  - *Bioengineering, Biosystems; Physiology; CompSci*
ELECTRONICS TECHNOLOGY AND INSTRUMENTATION

- **Instrumentation Sensors and Measurement**
  - **Biosystems, Bioengineering; ECE; CSE; Nano; BChem**
  - Powerful enabler of much of medical technology
  - A real plus if you add Biotechnology and bio/chemical/molecular sensing

- **Bio-signal Processing**
  - **Biosystems; ECE; CSE**
  - Common to much of instrumentation

- **Wearable Biomedical Sensors**
  - **Biosystems; ECE; CSE; Bioengineering; MAE; NanoE**
  - Explosion of electronics technology coupled with mostly physiologic measurements
BIOMEDICAL IMAGING

- **Biomedical Imaging** – MR, CT, Ultrasound, Nuclear Med
  - **Biosystems, Bioengineering; ECE; CSE; Physics**
  - Major Medical Modalities: Ultrasound, MRI, CT
  - **THE MOST IMPORTANT ENGINEERING CONTRIBUTION TO MEDICINE**

- **Biomedical Image Processing**
  - **Biosystems, Bioengineering; ECE; CSE; Physics**
  - You can do the processing independent of building the device

- **Radiology** – especially radioactive modalities
  - **Physics, Nuclear Engineering; Bioengineering**
  - Xray, Radiation Therapy, Positron Emission Tomography

- **Microscopies; Molecular Imaging**
  - **Biotechnology, Bioengineering; Biological Sciences; Physics; Biochem; Chem**
  - Tremendous innovation in physical microscopy technologies
  - Great growth in use of innovative biomolecules to augment images

UC San Diego

JACOBS SCHOOL OF ENGINEERING
Shu Chien-Gene Lay Department of Bioengineering
MOLECULAR BIOLOGY MEETS COMPUTERS / INFORMATION

- **OMICS, OMICS, OMICS ... fundamentals of how biology does information processing**
  - **Genomics** -- DNA is principal carrier of information
  - **Transcriptomics** -- DNA to RNA
  - **Functional Genomics** -- dynamics of gene and protein interactions
  - **Proteomics** -- structure and large scale composition of proteins
  - **Metabolomics** -- chemical processes within a cell – good match for computationally intensive modeling

- **Knowledge / Skill Base**
  - **Molecular Biology / Biochemistry / Computer Science**

- **Who**
  - **Bioinfo (taught by BioE, CSE, Biology); Data Science**
  - Big area of growth

UCSanDiego

JACOBS SCHOOL OF ENGINEERING
Shu Chien-Gene Lay Department of Bioengineering
MEDICINE MEETS COMPUTERS

- Medical and Health Informatics
  - Bioinformatics, Biosystems; CSE; ECE; Data Science
  - Largest/fastest growing of all biomedical engineering areas – perhaps 50% of all BME jobs
  - Data mining, analysis of all kinds of medical data

- Information Technology – wireless, wearables, analytics
  - Bioinformatics, Biosystems; CSE; ECE; Data Science
  - Also Artificial intelligence, ”Big Data”, Patient Health Care Records

- Telemedicine – “telehealth” or “e-health”
  - Biosystems, Bioengineering; CSE; ECE
  - Remote delivery in third world countries; remote doc at urgent care clinics
MECHANICS MEETS BIOLOGY AND MEDICINE

- **Biomechanics**
  - Bioengineering; BTech; MAE; Materials Science
  - Orthopedics, knee/hip implants; artificial hearts; blood circulation
  - Tremendous need to mix biomechanics and biomaterials

- **Robotics in Surgery**
  - Bioengineering, Biosystems; MAE; CSE; ECE
  - Includes heavy reliance on imaging and artificial intelligence

- **Biorobotics**
  - Bioengineering; Biosystems; ECE; MAE; CSE
  - Biomimetic Devices (e.g. exoskeletons)
  - Rehabilitation Assist Devices
MATERIALS GO VERY SMALL

- **Micro / Nano Technology**
  - **Nano Engineering; ECE; MechE**
  - The fabrication of devices that are of the same scale as cells and large biomolecules

- **BioMEMS = Bio Micro Electro Mechanical System**
  - **Nano Engineering; ECE; Biotechnology; Bioengineering**
  - Integration of micro/nano technology and biotechnology
  - Microfluidics; many “Lab on Chip” reactions come from biotechnology

- **Biomaterials**
  - **Biotechnology; Materials Science; Nano Engineering**
  - Customizing materials to promote tissue responses (or to be inert); sutures
  - Essential to all kinds of medical products; **HUGELY IMPORTANT FIELD**
CHEMICAL ENGINEERING APPROACHES

- **Biotechnology**
  - Biotechnology; Chemical Engineering; Nano Engineering
  - Using microbial organisms to produce products (insulin, yeast, alcohol, commercial non-biological chemicals)
  - Novel DNA engineering techniques to correct genetic defects

- **Drug Delivery**
  - Biotechnology; Chemical Engineering; Nano Engineering
  - Integration of micro/nano technology and biotechnology
  - Microfluidics, “Lab on Chip”
  - Many “Lab on Chip” reactions come from biotechnology

- **Biofuels**
  - BTech; Agriculture Ag Engr; ChemE; Chemistry
  - Wouldn’t it be wonderful to ”grow your gasoline”
BIOLOGY GOES ENGINEERING

- **Tissue Engineering**
  - Biology; BTech; Bioeng; Chem E; Nano
  - Growing new tissues and organs
  - Very Exciting science
  - Exceptionally compelling applications (replace your damaged cartilage! and more!)
  - Industry is still developing

- **Cellular and Molecular Biomechanics**
  - BTech; Bioeng; Biology; Chem E; Nano E
  - Mechanical properties of cells and substrates have tremendous impact on cell behavior and phenotype
  - Can we harness this?
  - Still a science and not an industry
**ENGINEERING THE NEW BIOLOGY**

- Genetic Engineering and Synthetic Biology
  - Biotechnology; Molecular Biology
  - The MOST SPECTACULAR AREA of BIOTECHNOLOGY
  - Beginning to impact many other areas – genetic diseases, crop production, anti-cancer drugs
  - Is it engineering or is it molecular biology? Or how soon will BS level Bioengineers be employed to do genetic engineering designs?
BME Careers -- perspectives and options
A View from NIH

Elias Zerhounis, former NIH Director:

- The nation is very capable of creating teams of engineers and medical / life scientists
- We also need a critically cross-trained workforce

Translation to Education:

- biomedical engineering is right for a growing population of students
Opportunity or Challenge?
Blurred Lines between Biology and Engineering

- Do you want to be an engineer?
- Do you want to be a biologist?
- A biologist who is called an engineer?
- An engineer who is called a biologist?
- ...
Two common pathways to a bioengineering career

- Major in biomedical engineering (BME)
  - Some foundational engineering coursework (not as much as a traditional engineer) with more biology-related courses
  - Stronger in synthesizing information for creation and marketing of new products

- Major in traditional engineering disciplines (electrical engineering, mechanical engineering, chemical engineering, etc.)
  - Strong traditional engineering coursework with some additional biology-related courses
  - Stronger in designing devices and understanding how they work
Career Paths

- **BS/MS/MEng** - previous slides
  - Masters is very helpful
- **MD** – competitive but now accepting of bioengineers
- **PhD** – research, academic, advanced positions in industry
- **JD** – many, many legal issues
- **MBA** – rapid industrial growth
- **Specialized training** – regulatory especially
What Do Employers Want?
Employer Survey
Ranked Characteristics of Potential Hires for New BS BME

Most Important
- Problem Solving
- Communication
- Industry Exposure
- Team Project Experience
- Design Experience
- Technical Writing
- Technical Presentation
- Advance Engrg Coursework

Less Cited
- Health Care Econ
- Design Simulation
- Adv. Programming
- Stats Software
- Prototyping
- Lab Inst & Software
- Clinical Needs Awareness
- Life Sci Courses
- Research Experience

Reported at the Council of Chairs BME Curriculum Meeting, Cleveland, June 2019
Translation

- Employers assume generalized Engineering Analytical and Design Skills
- They look for productive, interactive, team-players who can communicate

Otherwise

- Employers do not hire BME’s to do design or development engineering
So What Kinds of Engineering Jobs Are Our BME Students Finding?

Many, many jobs in biomedical industries, but the job titles do not say “biomedical engineering”

Hence, the BME employment data is severely undercounted
Job Titles throughout biomedical industries

- Patent Agent / Regulatory
- Project Management (with Certifications)
- Product Management
- Quality Control
- Design and Test
- Marketing Engineering
- Field Engineering
Patent Agent

Need:

- Increasing number of patents at the bio/engineering interface;
- Limited number of qualified people

Requirements: Citizen, STEM BS degree

Exam: detailed knowledge of US Patent Office procedures; preparation courses exist

Need to market yourself

Patent Lawyer = Patent Agent w/ Law Degree

Salaries ~$90k
Project Management Certification

Project Management Institute (non-profit)

- Certifies multiple levels of proficiency in project management; each requires
  - Specified educational background, both general (e.g. BS degree) and specific (project management coursework)
  - Experience

- Creates ISO standards for people and processes, many of which are recognized by, for instance, FDA

- Notes:
  - No BS degree program teaches this
  - Advantage to the individual: higher salary and responsibility
  - Applies to BME related manufacturing
Product Management Engineering

- Responsible for All Aspects of Production of a Product
- Example: Dialysis Bag at Baxter (near Chicago)
  - Responsible for
    - Materials contract implementation
    - Quality control of materials on arrival
    - Oversight of manufacturing
    - Quality assurance of exiting product
    - Shipping of product to customer
  (one of my Illinois UG bioengineers)
Field Engineering

- Work with clients on-site
- Plan and design products
- Possible Biomed Applications
  - Assist in surgeries with complex product
  - Plan sensor outlay for pharmaceutical plant
Design and Test Engineering

BME Examples:

- Design surgical support devices (mechanics knowledge is a plus)
- Test/Validate new hip implant design (need materials, biocompatibility, mechanics knowledge)
Marketing Engineering

BME Examples:

- Provide technical information regarding a product (stent, ablation tool, implant, …)
- Provide cost information for planning
- Work with field engineer for sales
- Help marketing craft its message
Other Job Titles of Possible Relevance

- Accounting, finance, contracts
- Compliance Engineer
- Component Engineer
- Computer applications
- Cost Engineer
- Environmental Compliance Engineer
- Equipment Manager
- Facilities Engineer
- Health engineer
- HR - hiring more BMEs
- Industrial Engineer
- Licensing Engineer
- Manufacturing
- Materials Qualification
- Materials Selection
- Modeling
- Operations Engineer
- Packaging Engineer
- Planning Engineer
- Process Control
- Process Control
- Process Design
Other Job Titles of Possible Relevance

- Production, operations, maintenance
- Proposal Engineering Coordinator
- Public Relations, Customer Service
- Quality Assurance Engineer
- Quality Management
- Reliability Engineer
- Safety Engineer
- Sales Engineer
- System Engineer
- Technical Writing
- Validation Engineer

Dialog: ”These aren’t really Bioengineering Jobs”
Answer: “These really are Bioengineering Jobs”

“Do you think a business major can evaluate an engineering product?”
”How well can an ME evaluate effectiveness of a sterilization process?”
… or a hundred other questions for products in biomed market-place
"Conventional" BME Wisdom

BME grads are weaker at design engineering. However …

- Their breadth makes them much better suited for many industry positions
  - Team/Product/Process Management
  - Sandia Example:
    - EE PhD with neuroscience application PhD thesis
    - Hired to lead pressure sensor initiative. Why?
    - Because he “could talk to anyone” and Sandia needed this
- Much more likely to go to Grad or Med School
- World-Tech is rapidly becoming more Bio
  - Best suited are: BME; Other Engineers with Molecular Biology Minor
Why ABET Demands What it Does

Accreditation Board for Engineering and Technology
Responsible for Accrediting Almost All Engineering BS programs in USA

- Dynamics of Jobs for Our Students
  - Most will work for multiple employers
  - Most will not work in BME but in science/engrg
  - Technology will change multiple times during career
  - Must rapidly learn to work with new people
  - Directly or indirectly … design and implementation
  - Responsibility to the level of ethics

- Therefore …
  - Need: excellence in science, engineering, humanities
  - Teamwork, lifelong learning, design and solution approach, ethics

- Matches Well with What Employers Say They Want
Final Prognosis

- MedTech and BioTech applications and industry are changing America and the world.
- Lots of jobs! But other areas are also booming and intersecting BME (e.g. Data Science, Pharma, Wearables).
- Competitors for jobs include other engineering majors and biology majors.
- Most jobs are managerial/organizational.
Final Prognosis

You have to hustle to get the job you want – it won’t come to you.

Choose Wisely, but make sure you look at careers that do what you love and ethically find most rewarding!
- bioengineer/molecular science
- medical devices
- pharmaceutical quality control
- … well, hundreds of others!
Final Prognosis

You soon will be on a great career path!
Congratulations from everyone in BioE at UCSD