

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

Engr Field	2012	2017
■ AgE	3.0	1.3
■ BME	4.5	3.0
■ ChemE	4.6	3.1
■ MechE	12.7	9.7
■ Materials	18.9	13.4
■ Aero	19.5	16.2
■ EE	23.5	17.0
■ Petroleum	34.8	18.3
■ Mining	33.9	20.9
■ Environ.	32.0	22.8
■ Civil	21.3	25.1
■ Nuclear	29.0	29.5
■ CS	256.0	133.0

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

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Shu Chien-Gene Lay Department of Bioengineering

Sources: 2017, 2012 ASEE <https://www.asee.org/documents/papers-and-publications/publications/college-profiles/2017-Engineering-by-Numbers-Engineering-Statistics.pdf> 2017, 2013 Bureau of Labor Statistics http://www.bls.gov/oes/current/oes_nat.htm#15-0000

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)

References: 1. M. Schneider. (2013). Why the S in STEM is overrated. *The Atlantic*. [Online]. Available: <http://www.theatlantic.com/business/archive/2013/09/why-the-s-in-stem-is-overrated/279931/>. 2. B. Alberts, M. W. Kirschner, S. Tilghman, and H. Varmus. Rescuing U.S. biomedical research from its systemic flaws. *Proc. Nat. Acad. Sci. United States Amer.* [Online]. Available: www.pnas.org/cgi/doi/10.1073/pnas.1404402111. 3. U.S. National Institutes of Health, "Biomedical Research Workforce Working Group Report," Bethesda, MD, 2012.

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?

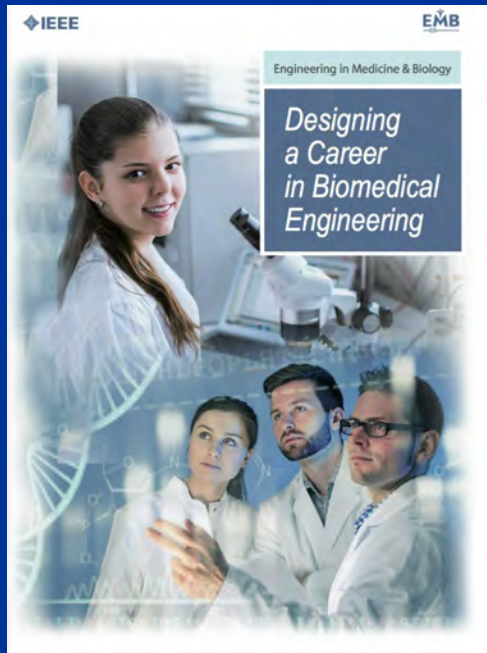
2019 Starting and Mean Salaries for Engineers

	Starting	Mean
■ BME:	\$61k	\$95k
■ Aero:	\$	\$115k
■ AgE:	\$	\$77k
■ Civil:	\$56k	\$93k
■ CompE hardware:	\$71k	\$118k
■ CompE software:	\$68k	\$114k
■ ChemE:	\$65k	\$114k
■ EE:	\$65k	\$101k
■ Environmental:	\$56k	\$92k
■ Geo/Mining:	\$62k	\$98k
■ Materials:	\$66k	\$97k
■ MechE:	\$62k	\$93k
■ Petroleum:	\$	\$137k

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/>

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So You Want to Become a Biomedical Engineer

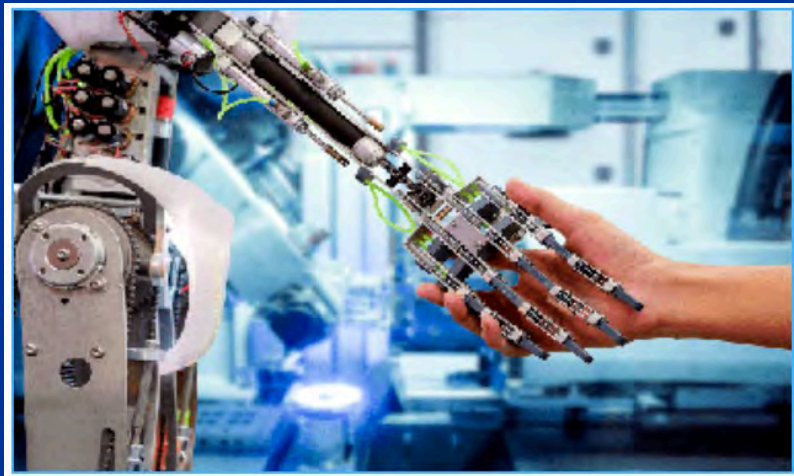
MOOC (Massive Online Open-access Course)

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

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IEEE Fellow
AAAS Fellow



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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

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

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

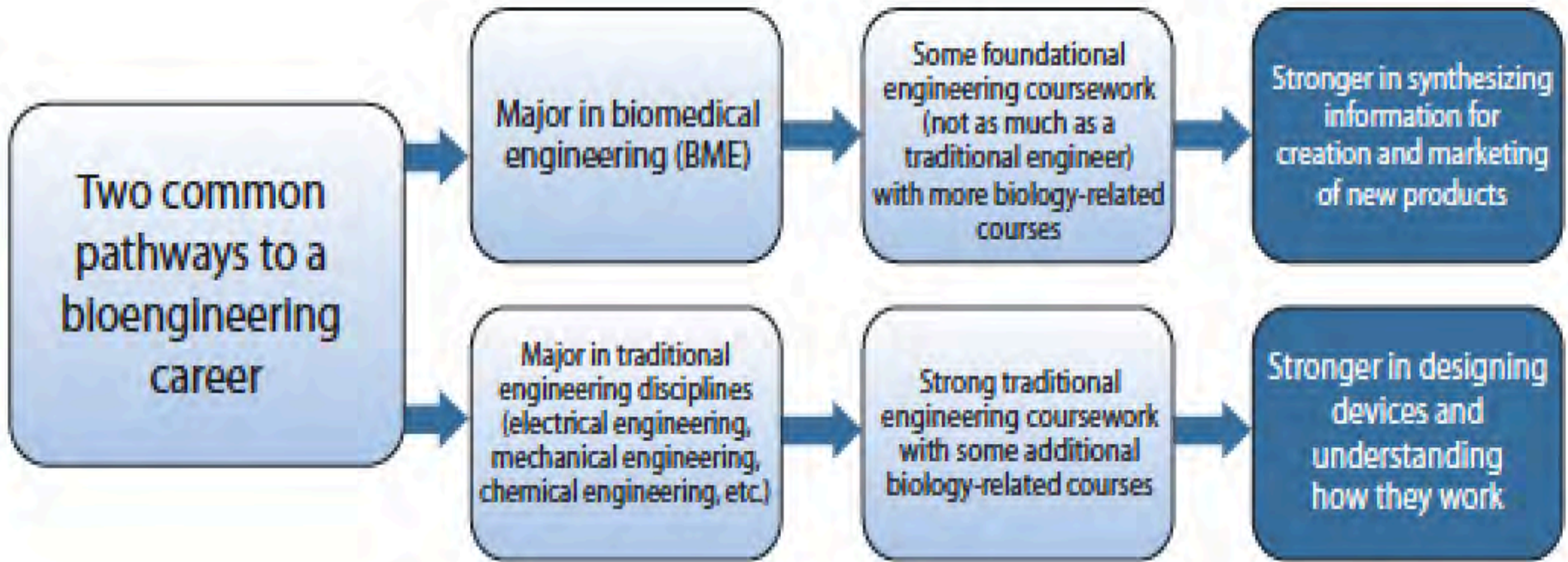
Elias Zerhounis, former NIH Director:

- 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

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