

Thoughts On Graduate School in Bioengineering

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- Disclaimer:
- Some arguments are ... *well* ... argumentative
 - *If you are skeptical, you should ask for 2nd opinions*

Outline

- Simple rationale for BS/MS/PhD/Postdoc
- Economics of higher ed, emphasizing graduate programs
- *Making Sausage!* – *the compromises/inconsistencies, yet the whole system works well*
- **Part 1: PhD programs – this talk**
 - Advice on choosing a PhD program
 - How candidates are chosen by the university
 - Student support
- *Part 2: Masters Programs – the next talk*
 - *Categories of MS programs -- examples*
 - *What you should think about in choosing one*
 - *What do MS programs in other majors look like?*

Thoughts On Graduate School in Bioengineering

... from the 30,000 foot level ...

- Graduate Education in the USA is the best in the world
- Research is the best in the world
- The technology created drives the world's economies
- Like anything that really, really works – you have to look at "*how the sausage is made*" – economics, etc. of grad school
- The USA produces more PhD's in the life sciences than exist appropriate job openings (bio-oriented BioE PhDs included)
- Great expansion of the pharmaceutical / molecular biology industries is improving employment

Intellectual Rationale for BS/MS/PhD

- BS: can answer well defined questions
- MS: can answer poorly defined questions
- PhD: can pose the questions that need answering
- PostDoc: further specific training, principal researchers
- Distinctions apply to Engineering, Biology, ... English, Communications, Public Health,
 - *I have a good friend with a PhD in Philosophy*
 - *She is better at analytical analysis than almost all engineers*
 - *Political scientists pose questions as well as anyone*

Reasons for Getting a PhD

- Personal pride – self-recognition that you are an elite who knows something better than anyone else in the world
 - my motivation #1 - an internal basic pride ...
- Research – you are a scientist at heart; you love problems
- Applications – a PhD is needed to get a position to attack important societal or scientific problems
 - my motivation #2 – bring engineering to neuroscience
- Job in academia -- my motivation #3
- Job in research in industry ... start a company?
- Job at the FDA

Classical Pathways in Engrg vs Biology

- Engineers
 - MEng for terminal project-oriented degree (1 to 1.5 years)
 - MS for potential PhD students, thesis required (1.5 to 2 years)
 - PhD **after doing MS**
 - Postdocs – not so common
- Biologists (and much of academia)
 - Most enter PhD programs directly (**no MS**)
 - MS is for: (a) HS teachers; (b) consolation prize
 - Postdoc – mandatory for academia and many industry jobs
- Bioengineering across USA
 - **Most have adopted the biology model**

Economics of Higher Education (STE but not M*)

A Highly Selective View

- UG: tuition plus state support (private schools are different)
 - The reason the universities exist
- MS: students pay, no state support
- PhD: funding comes from NIH, NSF, industry
 - Med/Bio/Beng – mostly NIH
 - Other Engineering: mostly NSF, industry
 - Industry overall – surprisingly small
 - Fellowships: great (e.g. NSF) but modest part of student support
 - How about TA's? Redistribution of teaching funds

* Why not Math? Most Math grad students are TA's, just like English; not on research grants

Economics of Higher Education

A Highly Selective View

- Ironic? Cynical?
 - When the money leaves Sacramento ...
... it is for Susie and Johnny in the classroom.
 - When the money arrives in SD (Berkeley, LA, ...) it is for research
 - Applies to Springfield and Urbana, Tallahassee and Gainesville
- Existence of the University depends on UG Education
- Reputation of the University depends on two things
 - The Football Team
 - Research

Making Sausage Part I: Simple Economics

Growth in MS – across the Nation

- We are tapped out on UG tuition from parents/state
- PhD programs lose money – grants don't cover all the expenses
- MS programs -- the new money maker
 - Students will pay
 - Instruction can only be done by advanced faculty; it is beyond capability of junior colleges or most 4 year schools
- I have seen the economics often:
 - Cornell as a grad student -- 1974-80! – Bell Labs paid for 30 MEng/year in EE
 - Illinois as BioE Head – 2003-7 – Coast Guard paid Civil E for MS
 - Florida as BME Chair – 2008-15 – active discounting to maximize MS revenue in Engineering
 - UCSD as faculty – 2015 to present – tremendous growth in MS programs

Grants: Who Competes to Get the Money

The Business of Research

- Faculty! But you knew that
- Pragmatically:
 - Research-1 universities are business operations
 - NIH, NSF, DARPA, industry
 - sources of funds
 - have mandates to get ideas generated for technologies, improved health, improved warfare preparedness, ...
 - Faculty are trained to
 - create ideas, technologies, improve health, improve warfare preparedness, ...
 - we do what NIH etc. ask – and we do it very well!

Grants: What is the Money For

- Grants are Contracts:
 - Promise of good faith effort to investigate important problem
 - Remarkable! – the deliverable is “I tried”
 - Penalty for non-delivery – no more grants
 - Reward – more grants, papers, fame ... maybe social impact
 - Audited expenditures for people, supplies, overhead
- Reinterpreted
 - Professor creates idea, organizes, hires people, writes reports
 - Research staff (students, postdocs) implement experiments
 - Admin staff perform the accounting, personnel ...
- Some universities; testing etc. contracts ... Different performance rules

Grants: Where is the Grad Student in All This

- As a contract employee:
 - Student is a paid employee following directions
- As a student:
 - Student is a learner who pays the professor for instruction on how to do research
- Compromise
 - Student gets a stipend, doesn't pay tuition (paid by NIH etc.)
 - "gets a free education"
 - Student's research has to be close to the proposed work
- Generally, a pretty good compromise

Making Sausage Part II

- The funding of PhD students compromises many things
 - They aren't worth their pay at the beginning
 - They are more than worth their pay at the end
 - They can't just work on their own great idea
- Compromise on research topic
 - If work only on the professor's great idea, the system breaks down
 - We need new knowledge from professor and grad student
 - Grad student goes to new career with new knowledge
- Overall it works great
- There are tensions

Don't Universities Make Money From Grants?

- No, no, and again no! -- They make Fame!
 - Lots of money-making opportunities -- Recruiting, Alumni donations
 - Startup companies are possible/encouraged
- Typical grant requires substantial work by professor that is not directly paid for by grant
 - UCSD faculty mostly are on 9 month UCSD salary – i.e. from state/UG tuition; summer – depends on grants
 - But perhaps 70% of effort is for research during academic year – who is paying?
- Compare “soft money”: many Med Schools: entire salary comes from NIH; MD researchers – 1/2 support from clinic
- Special resources are almost always subsidized – animal quarters, microfab facilities, ...

Indirect Costs (IDC)

- The Federal Government enables universities to charge for indirect costs (an audited percentage). This is called Indirect Cost Recovery, referred to as IDC – legit expenses
 - Lights, facilities, accounting, animal quarters, microfab, ...
- Most universities allow individual departments and faculty to take part of the IDC recovery ... !
 - At Illinois I got 5% of the IDC to use as I chose for research
 - At Florida, the BME Dept got 30% of IDC for dept needs
 - These were incentives to do more funded research
 - Makes it easier for faculty/departments to carry out their mission
 - Money is made up from other sources (state?)

Making Sausage Part III

- UG students
 - Student tuition subsidizes research active faculty
 - But ... UG education is advanced ... state of the art
 - UG Research experience (~75% of UCSD BioE UG students)
- Indirect Cost Recovery
 - Much goes to places other than Indirect Costs
 - Incentive for doing better work
 - Funds make it easier for faculty/departments to do things
- Companies
 - Don't pay for the basic research that underlies their products
 - Don't pay for the training of their workforce
- Society
 - Gains tremendously from research (COVID tests/vaccines!!!)
 - Only indirectly pays for the costs of research

Making Sausage Part III*

- California is 5th largest economy in the world
 - It may soon surpass Germany
- We are all part of this engine
 - Growth, wealth ... driving all of the USA
 - We have problems
 - Inequality, homeless ...
 - Environment, climate change
- * We all have responsibilities

Choosing a PhD Program

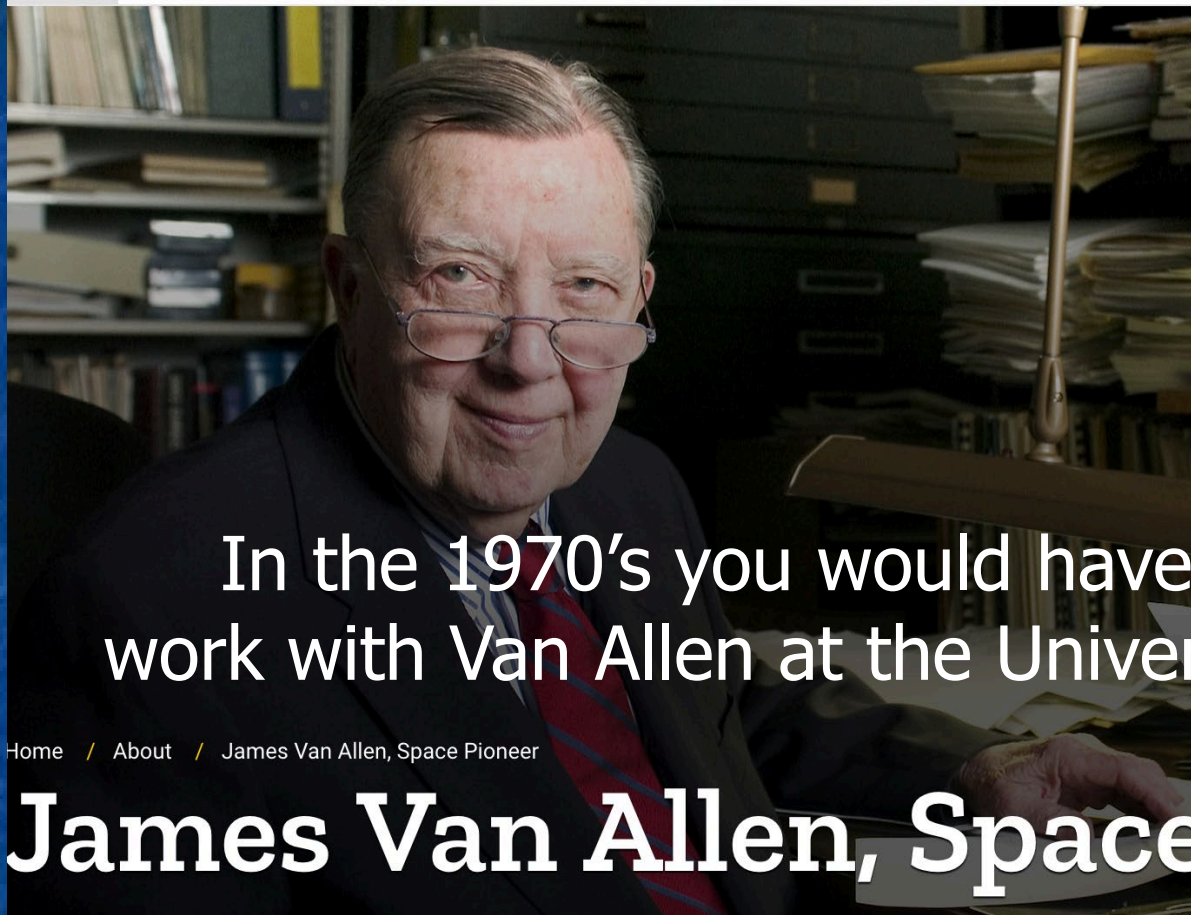
- Most important:
 - the science / engineering area or problem you might work on
- Next: the advisor
- Next: the university
- Of course, great universities attract great advisors who work on great problems
- But ... it is not always true
 - Great advisor, great question ... but ... wrong problem after all!
 - You are making a bet – sometimes it works great, sometimes not
 - You'll know 20 years later

Two Examples from the Fly-Over States Make Sure You Are Looking !

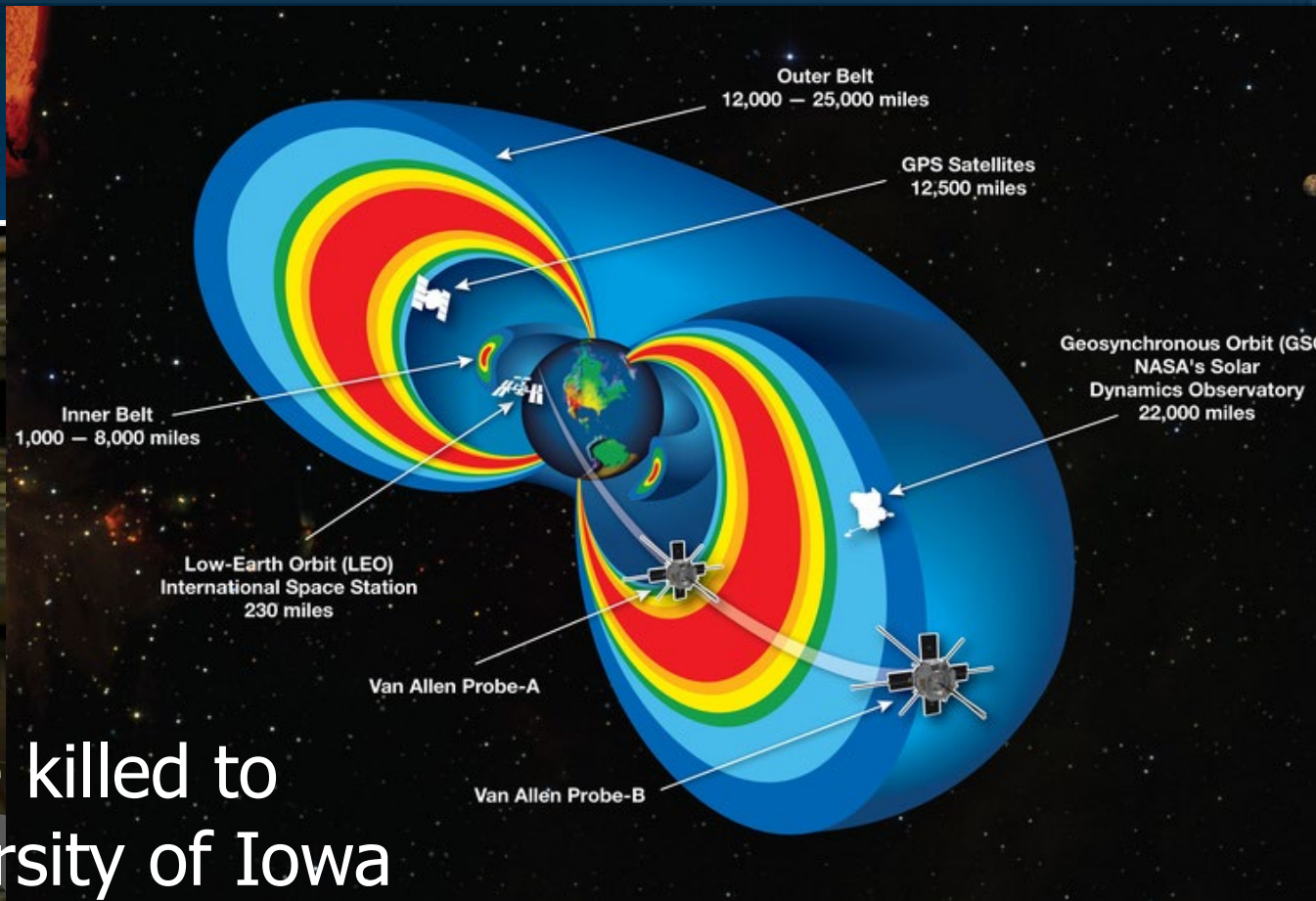
- You know the universities in California (and even U Dub)
- You can guess that Boston has some pretty good ones
- The Midwest? Atlantic Coast? Atlanta?

- UCSD has a great bioengineering research program, but
 - You should look for other possibilities
 - ... there is much more east of the Sierras

Every heard of the Van Allen Belts



In the 1970's you would have killed to work with Van Allen at the University of Iowa



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James Van Allen, Space Pioneer

Iowa is a great university.
California residents have a hard time relating.
Iowa has great Bioengineers.

By [Jeni Bushman](#) | Published on Oct. 27, 2022



(From left): Mark Anastasio, a professor of bioengineering; Stephen Boppart, a professor of electrical and computer engineering and bioengineering; and Rohit Bhargava, a professor of bioengineering, will use funding from the National Institute of Biomedical Imaging and Bioengineering at the National Institutes of Health to establish the Center for Label-free Imaging and Multi-scale Biophotonics, known as CLIMB.

NIBIB establishes the Center for the Label-free Imaging and Multiscale Biophotonics at the University of Illinois

UC San Diego

JACOBS SCHOOL OF ENGINEERING

Shu Chien-Gene Lay Department of Bioengineering

Flying over Illinois
you will miss these stars:
my successor, my student,
my first BioE hire

If you think biophotonics
is in your future, think
Illinois ... and UC Irvine
Beckman Laser Institute
(whose previous director
is now Director of NIBIB)

Generally

... the USA and the World have great Research/Faculty

Maybe you should consider

... ETH Zurich; EPFL Lausanne

... University College London, Oxford

... Tsinghua, Beijing

... Seoul National, KAIST, Korea

... Tokyo U., Kyoto

... Karolinska, Stockholm; Katholieke, Belgium; Heidelberg ...

... Pontifical Catolica Universidad del Peru

and many other regionally influential universities

and many others

How to Universities Decide Who to Admit?

- Leading Factors (rough order of importance)
 - GPA
 - UG University
 - Interest Area
 - Research Experience
 - Reference Letters
 - Faculty of Interest
 - Other \$\$ Support (anecdote)
 - Soft Skill/Personality
- Big Faculty Concerns
 - All the things on the left
 - Interest matches my grant(s)?
- Wild Card
 - “Your Prof calls Their Prof” with recommendation

A Note

- You are often asked to suggest multiple potential advisors
- Rationale
 - Your application is routed to each to take a closer look
 - Don't count on anyone to notice you if you don't speak up
 - What happens if you go to there and it doesn't work out?
 - \$\$\$ Personality conflicts ...
 - From your side -- do you still want to stay there?
 - From the university's side – how can we find another lab for her/him?

Campus Visits

- Wealthier schools will have campus visits
 - Subsidized (maybe completely) transportation
 - Housing – typically with current grad students
- Who is invited?
 - Intent is to make an offer to everyone who comes (usually)
 - But this is a final check on compatibility
- Event
 - Often there is a symposium: poster session + guest speaker
 - It is 80% a recruiting event, 20% an evaluation event.
- Interviews – BEGS does a great job of helping you
- Big Opportunity to talk to current grad students

Rotations and Student Support

- Rotations – generally
 - Students work in several labs over the course of a semester or year
 - Matching: students choose lab, lab chooses student
- Money: during rotation tuition/stipend can't be paid by grants
 - student is not an employee working on the project
- Where does the money come from? possibly ...
 - TA positions
 - IDC Funds to the Department and/or Faculty Member
 - State/University budget to support beginning grad students
- Great idea, but it takes money
 - Rich departments can do it, poor ones can't

How Long Before a Student Commits to a Lab?

- UCSD BioE – we support for up to one year
- UC Santa Barbara -- Materials Science (2000's) – one quarter
- U Michigan – anecdotes
 - Students approaching me at Illinois ECE as UM ECE admitted lots of students; not enough money to support them
 - New UM Dean
 - made departments promise 4 years of support
 - Impact – UM BME turned down excellent students
 - My great Florida UG BME student
 - turned down until they learned he had an NSF Fellowship
- Illinois – at start of BioE – 5 year guarantee; we didn't know for sure where the money would come from

Simple Summary

- BME is a great and expanding area
 - The science possibilities range from obvious to unbelievable
 - The job opportunities range from ... great to disappointing
- PhDs offer entrance to the elite of our emergent technologies
- Choose wisely – you can go wrong, but much more likely you will go right