Cornell Bioengineering

Looking to the Future

The Cornell ECC Bioengineering Task Force

Team 1 – Cornell Today

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Team 2 – External Trends

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Cornell ECC Bioengineering Task Force Charge

Provide strategic counsel about enhancement of bioengineering research, teaching and interdisciplinary engagement across the College and the University

- Define the aspirational objectives for bioengineering at Cornell
- Identify how to strengthen the bioengineering discipline at Cornell
  - What are the gaps that limit reaching our aspirations?
  - How can we strengthen the connections between the many Cornell and external entities that are needed to reach our aspiration?

Bioengineering Task Force Approach

Phase 1

- Map Bioengineering at Cornell today
- Define requirements for the future
- Identify gaps and priorities for action
- Map plan for building action plan (phase 2)

Phase 2

- Develop plans for key gap areas
- Define resources needed
- Execute operational pilot projects where appropriate
- Deliver an integrated plan for Cornell Bioengineering

Phase 3

- Set goals and responsibilities for elements of the plan
- Launch the overall plan for enhancing bioengineering at Cornell
- Define metrics and initiate tracking of initiative

April ECC: Current state
Vision for the Future
Gaps and action plan

Fall ECC: Integrated Plan
Resources Requirements
Prospective implementation

Phase 1 Goals of Bioengineering Task Force

1. Map the current state of bioengineering at Cornell across the involved areas of the university

2. Evaluate macro trends and develop perspectives on how they will impact Bioengineering

3. Apply this lens to the academic approach to the field to determine the implications for Cornell's Bioengineering strategy

4. Identify Cornell's strengths and gaps against our projected future requirements and suggest ideas for phase 2 to explore ways to extend Cornell's leadership position in the field

Our Approach to Phase 1

Divided our team in two

- External Team: Review of macro trends and how they will impact the field
- Internal Team: Map current state of Bioengineering at Cornell

Full team meeting to combine views and discuss recommendations

- Recommendations for ECC Phase 1
- Ideas for Phase 2

Summary Conclusions – Initial Perspectives

Cornell is starting from a position of strength in Bioengineering

- 83 faculty across 24 research areas
- 7 engineering departments involved

The recent progress made in many areas is well documented

- Success with faculty recruitment, awards, funding
- Rapid growth of biomedical engineering in particular

Our task force recommendations seek to build on this strength by incorporating a stronger strategic focus, informed by trends outside of Cornell

- We don't have a full view of all that is happening at Cornell
- Putting life into these recommendations will require broad input from the faculty, the engineering school, and the University

Summary Conclusions – University Level

1. There are broad areas of strength across the University in Bioengineering, but little unified strategy for the field

2. The University should create a central place to capture comprehensive data and metrics on the Cornell's Bioengineering efforts to enable it to monitor and continually assess progress and identify areas where additional funding and resources are needed

3. Cornell can build on its leadership in the field in many ways, but will need to both make choices in its areas of focus, and then define strategies and investments needed to establish a leadership position

4. While not necessary for success, Cornell can build on its leadership position by defining a broad mission or objective for its bioengineering efforts

Summary Conclusions – Field Level

1. Areas of focus for bioengineering should better integrate future requirements resulting from our rapidly changing global ecosystem into their research planning

2. A strong and continuously refreshed set of relations with relevant industry, venture and government players should be established and maintained (with assigned responsibility) for each area of focus

3. Access to supporting tools from outside the field (and possibly the University) should be established to support integrated research efforts

Summary Conclusions – Faculty / Program Level

1. Faculty should be given training and support to help them evaluate the relevancy of their research and the requirements it must meet to successfully drive impact

2. Programs should be evaluated, and then supported, to identify, build toward appropriate funding, and ultimately drive societal use of their discoveries (venture, corporation, government)

3. Regular review of programmatic investments should be the norm to assess relevance in a rapidly changing environment

Summary Conclusions – Student Level

1. Limited bioengineering companies are coming on campus or recruiting through the online “Handbook” platform to hire bioengineering students

2. Placement strategies could be enhanced by conducting an annual review of students career interests so career service activities can be tailored to student’s career objectives
    - Career services should have a strong target list of companies to pursue for recruiting graduates

Summary Recommendations for Phase 2

We have developed a set of four recommendations for phase 2

1. A University level strategic dialog about priorities and themes for bioengineering
2. An Engineering College level initiative to consider how to properly target efforts in priority areas
3. A set of pilot programs to bring strategic focus in two or three core areas and develop the tools for a broader rollout
4. An administrative project to develop the metrics and tools to map and monitor our progress in bioengineering

This subcommittee is committed to support the University in phase 2

- But it will require significant Cornell resource
- And attention at senior levels

Cornell Bioengineering Today

Team 1: Mapping the Ecosystem of Bioengineering

Team 1
Cornell Bioengineering today

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Team 2
The world we are moving towards

→

Methodology
Interviews, data analysis

→

April 13th ECC
- Current state of bioengineering
- Aspirational vision
- Gaps we need to fill

Process	Focus Areas - Funding	Focus Areas - Faculty	Focus Areas - Patents	Students	Challenges

Our Process for Mapping the Ecosystem of Bioengineering Today

	What is Bioengineering at Cornell?		How do we measure?
Who	**Faculty**	→	• Tenure and funding • Professional ranking
	Students	→	• Accepts / Declines • Placements and Salary
What	**Infrastructure**	→	• Teaching and Research Space • Incubator and collaboration space
	Key Research Areas	→	• Funding and Priority • Publications and Patents
Reach	**Industry Ties**	→	• Depth / Breadth of Relationships • Level of funding
	Government	→	• Amount and Source of funding • “perceived” quality of funding
	Start-ups and Patents	→	• Incubation and startup history • IP developed

Refining our Project Scope

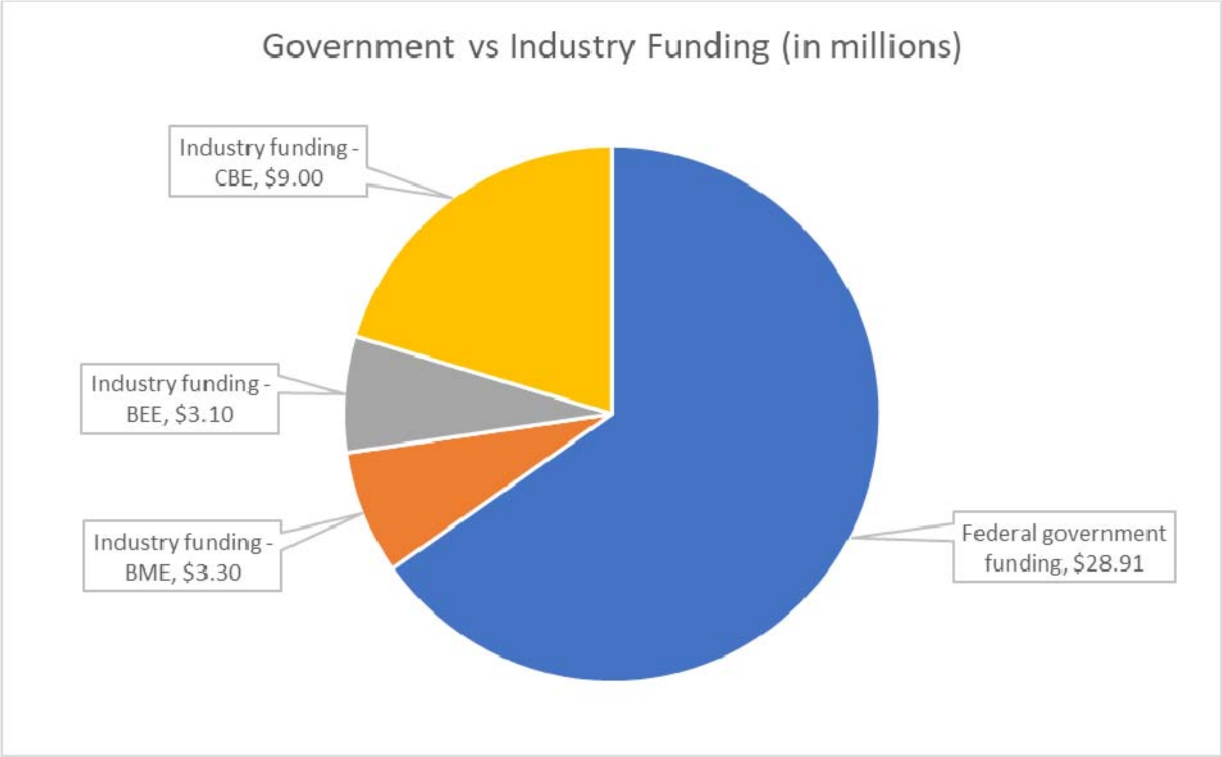
What is our operational definition of Bioengineering?

<u>Assumption 1</u>: To be categorized in the field of bioengineering, the activity must be at the confluence of biology and a complex system approachable with engineering techniques

<u>Assumption 2</u>: Areas of the field (meeting the above criteria) can be found in a broad range of applied research, and can be roughly categorized in three areas:

1. Biomedical Engineering
2. Biological and Environmental Engineering
3. Biomolecular Engineering

Bioengineering receives significant funding from the federal government but industry and foundation funding could be stronger



Cornell Bioengineering has 24 research focus areas that overlap within several departments, the groupings below were used for further analyses

BEE

- Molecular and Cellular Engineering
- Computational Mechanics

BME

- Biomechanics and Mechanobiology
- Tissue Engineering and Biomaterials
- Imaging and Instrumentation
- Microfluidics and Microsystems
- Computational and Systems Biology
- Drug Delivery and Nanomedicine
- Biotechnology
- Signal and Image Processing
- Systems and Synthetic Biology

CBE

- Materials Synthesis and Processing
- Microfluidics
- Mechanics of Biological Materials
- Molecular Biotechnology
- Nanotechnology
- Fluid Dynamics and Rheology
- Nanobio Applications

Other*

- Computer Aided Diagnosis
- Biosignal and Biosystems
- Bioinspired Materials and Systems
- Biosensors and Medical Devices
- Biomedical Technology
- Biophysics

***Other: MechE, ECE, AEP, MatSci, CEE**

Cornell Bioengineering has 24 research focus areas with various levels of government funding

BEE
- Molecular and Cellular Engineering (>$10M)
- Computational Mechanics (Limited Funding)

BME
- Biomechanics and Mechanobiology ($0-5M)
- Tissue Engineering and Biomaterials ($0-5M)
- Imaging and Instrumentation ($0-5M)
- Microfluidics and Microsystems ($0-5M)
- Computational and Systems Biology ($0-5M)
- Drug Delivery and Nanomedicine ($0-5M)
- Biotechnology ($0-5M)
- Signal and Image Processing (Limited Funding)
- Systems and Synthetic Biology (Limited Funding)

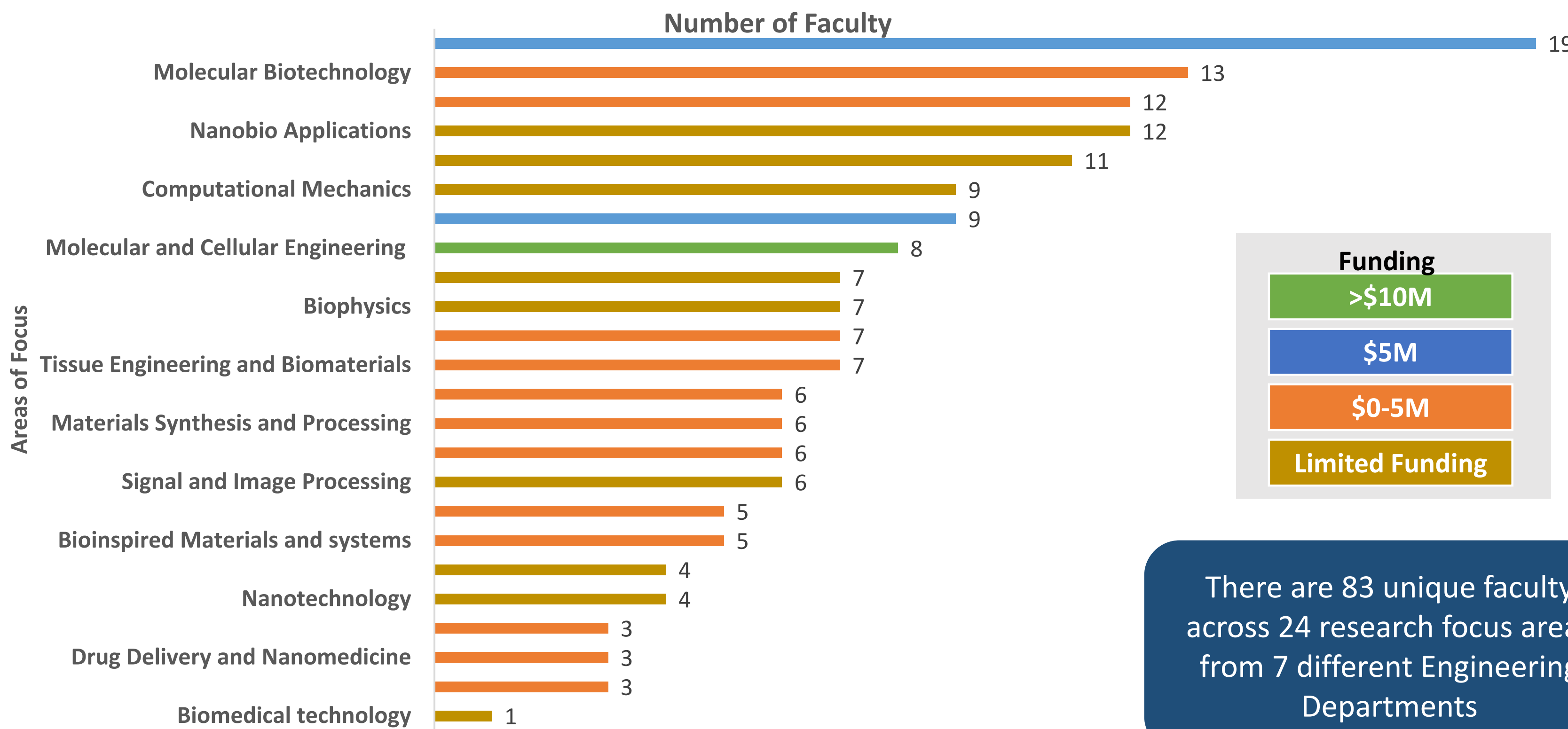
CBE
- Materials Synthesis and Processing ($0-5M)
- Microfluidics ($0-5M)
- Mechanics of Biological Materials ($0-5M)
- Molecular Biotechnology ($0-5M)
- Nanotechnology (Limited Funding)
- Fluid Dynamics and Rheology (Limited Funding)
- Nanobio Applications (Limited Funding)

Other*
- Computer Aided Diagnosis ($0-5M)
- Biosignal and Biosystems ($0-5M)
- Bioinspired Materials and Systems ($0-5M)
- Biosensors and Medical Devices (Limited Funding)
- Biomedical Technology (Limited Funding)
- Biophysics (Limited Funding)

Funding
- >$10M
- $5M
- $0-5M
- Limited Funding

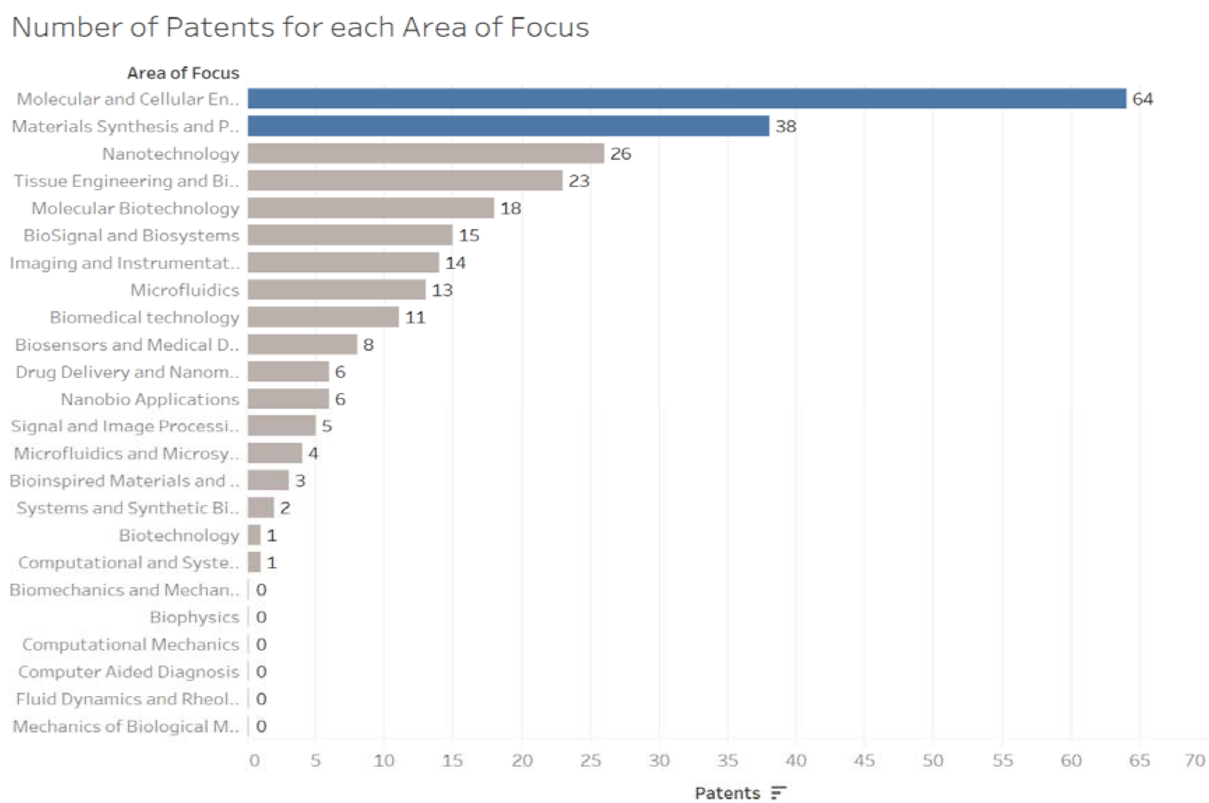
*Other: MechE, ECE, AEP, MatSci, CEE

Coordination across field areas and departments is difficult and it is unclear how focus areas evolve while adapting to constantly changing external needs



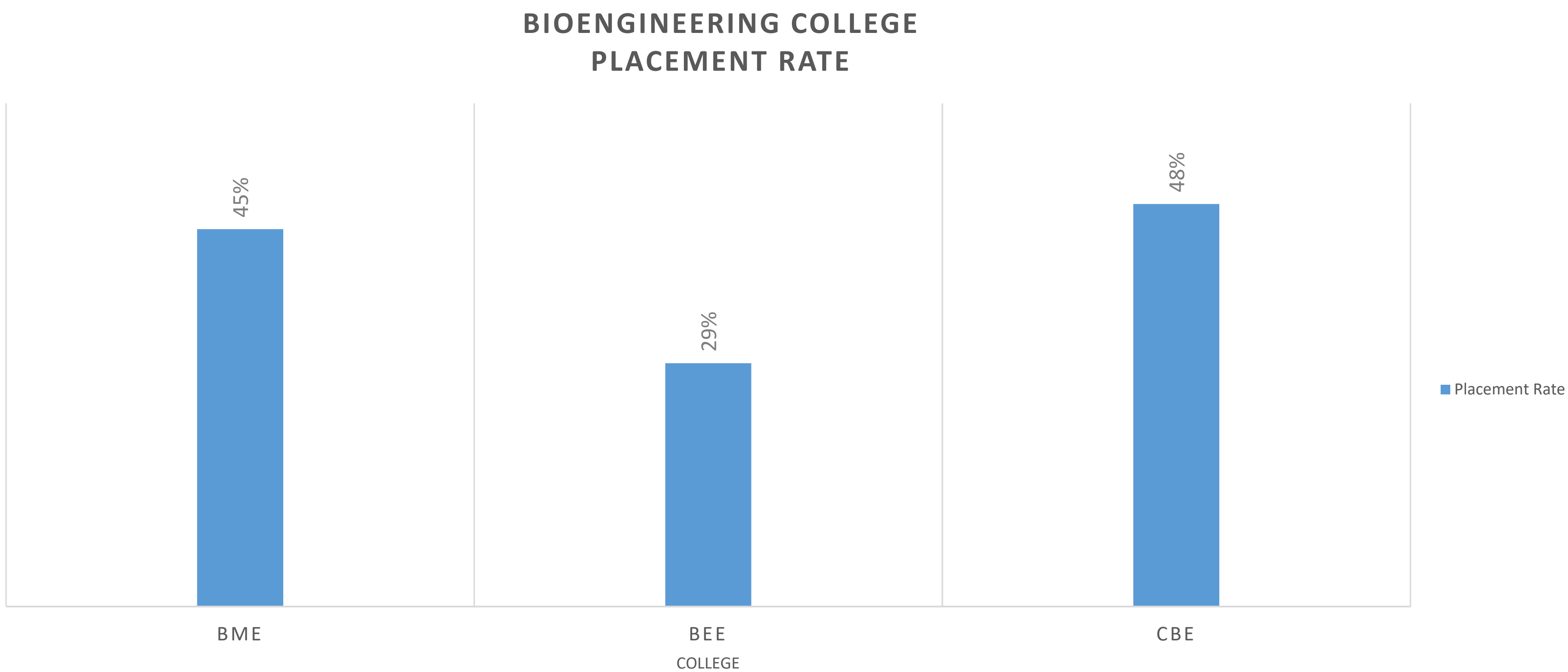
There are 83 unique faculty across 24 research focus areas from 7 different Engineering Departments

Intellectual property from Molecular and Cellular Engineering and Materials Synthesis research dominated the bioengineering IP landscape

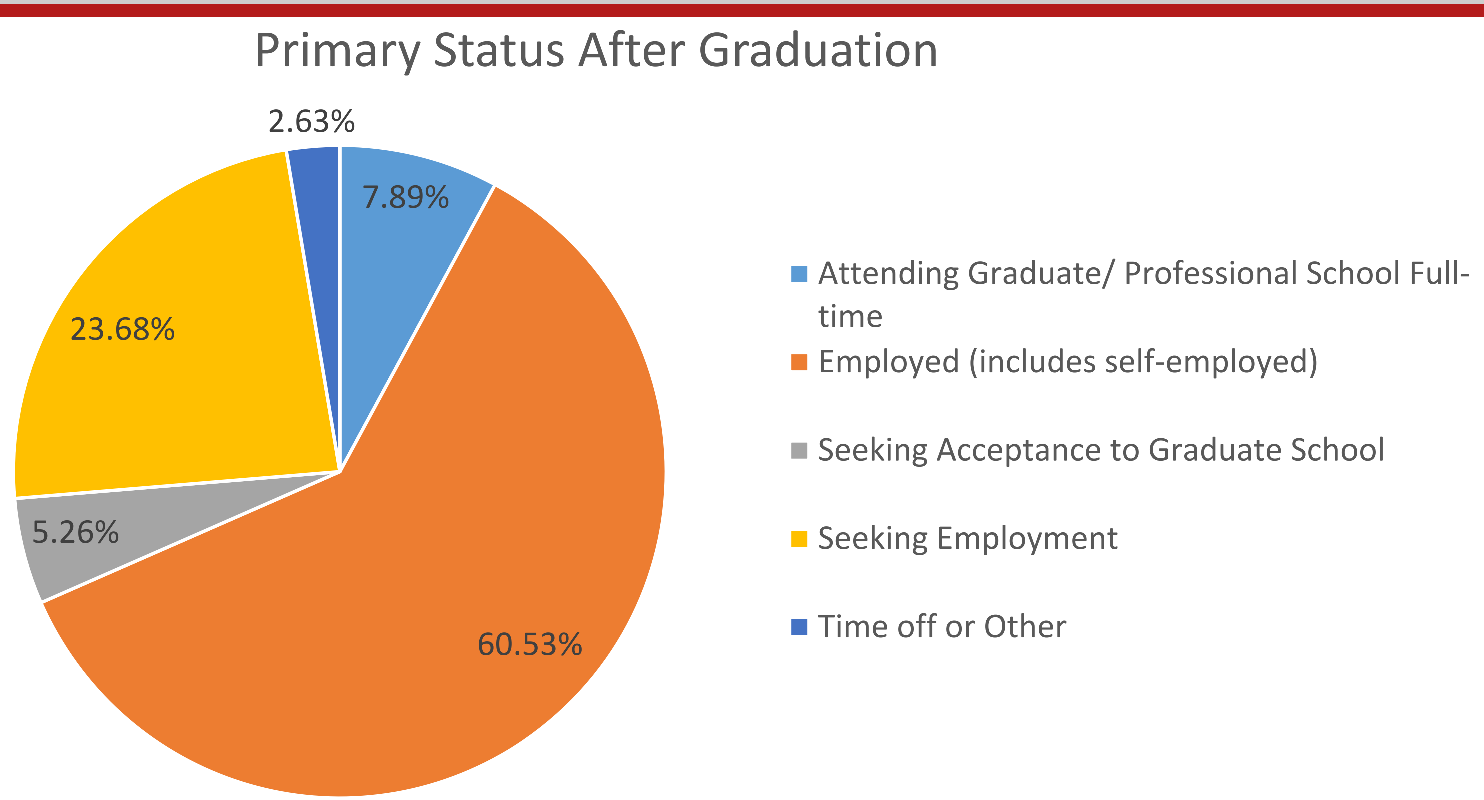


Data from 2003 - 2018

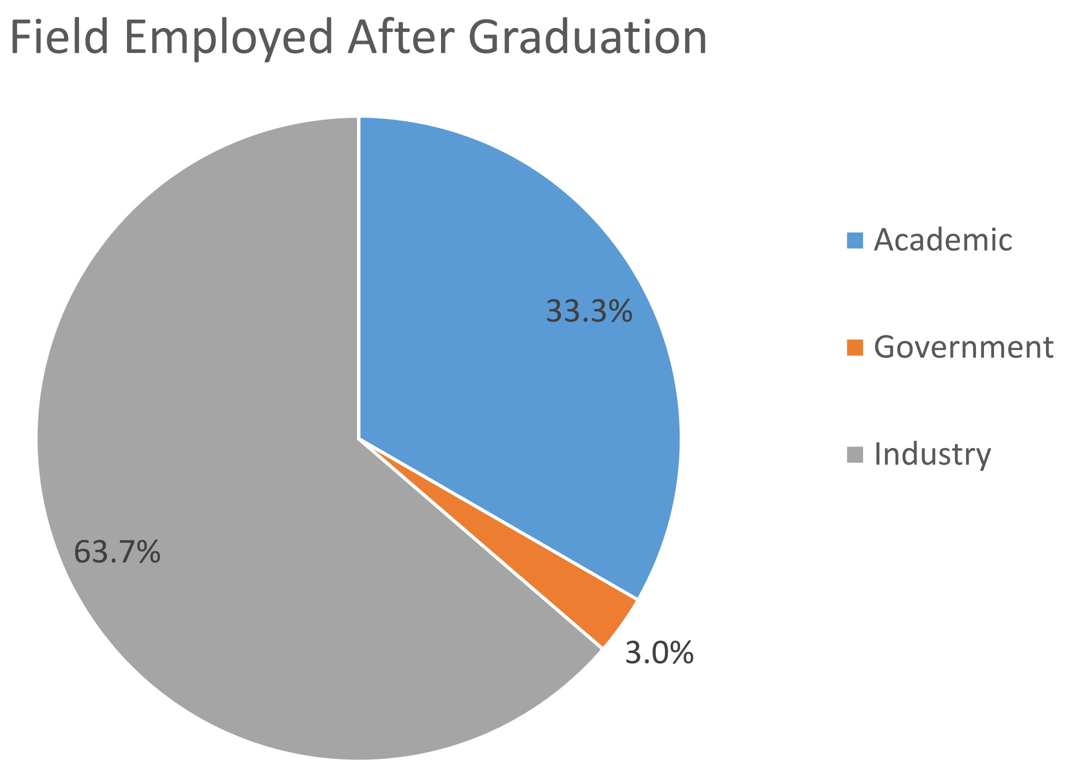
Placement rate for the BME is commensurate with CBE, but over 15% higher than BEE



About 1 in 4 biomedical engineering Mater of Engineering students from the Class 2016 were still seeking employment 12 months after graduation



The majority of biomedical M. Eng. students currently working are employed in industry as compared to academia or government



Space is a big issues with the growth of Biomedical Engineering

- Bioengineering spans spaces in the Engineering Quad to Riley Robb to Weill Hall (Home of BME)
- Entrepreneurship and Incubator support for Bioengineering:
  - McGovern Family Center for Venture Development in the Life Sciences
  - PhD Commercialization Fellows Program

Kevin M. McGovern Family Center for Venture Development in the Life Sciences
Cornell University

Additionally, several other challenges were identified based on this analysis

Very difficult to find data overall. There is need for better tracking mechanisms to measure and evaluate Bioengineering as a whole

Opportunity for more connections with Ithaca-based Bioengineering and NYC-based Weill Cornell Medicine and Cornell Tech

There is no central site or platform that captured start ups developed out of Cornell Bioengineering as a whole

Macro Trends and Their Implications

Team 2: Understanding the Macro Trends Impacting Bioengineering

Team 1

Cornell Bioengineering today

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Team 2

The world we are moving towards

→

Methodology
Interviews, data analysis

→

April 13th ECC

- Current state of bioengineering
- Aspirational vision
- Gaps we need to fill

Biomedical Engineering Trends

Biomedical Engineering at Cornell off to a Strong Start

The investments the college has made in the past decade have created a foundation for a world class presence in the field

- Strong, widely recognize faculty (existing and recently recruited) form the core of the effort
- Rapid growth in both faculty and students (and the addition of an undergraduate major) have cemented it as a leading area of the engineering school
- Have already chosen cellular imaging and micro / nano biotechnology as areas to drive to number one status
  - Other areas of strength include: biomaterials and drug delivery; molecular, cellular and tissue engineering; and soft tissue biomechanics

Biomedical Engineering Ecosystem

Funding Sources

Patients

Materials
- Nanotechnology
- Engineered materials
- Biomaterials

Regulation and Patents

Support Technology
- Sensors
- Delivery Technology
- Diagnostics

Data
- Data access
- Data mining tools
- AI decisions support

Cornell Biomedical Engineering

Engineered Therapy
- Replacement Joints
- Assist devices

Tools
- 3D Printing
- Robotics
- Delivery technology

Economic Value

Emerging Fields
- Regenerative Medicine
- Bioelectronics
- Microbiome

Collaborators

Industry

Bio Med Competitive Landscape – Universities

Most University Biomedical Engineering "BME" programs are focused solely on research:

- Faculty accolades and facilities/technology are key differentiators between programs
- Not many Universities incorporate an innovation or a corporate connection to their BME research centers

Innovation programs are strongest in Universities with high BME education rankings:

- Most of these Universities offer co-op internships for their students
    - Corporate partners provide early exposure to students due to their co-op experiences

The Wallace Coulter Foundation partners with 13 Universities to fund BME startups:

- Most partner Universities are ranked in top 20 for BME education
- Startups receive up to $200,000 with office/lab space and mentoring

Leading University Biomedical Engineering Programs

University	Program Name	Notes
Georgia Institute of Technology	Center for Pediatric Innovation	Ranked as the #1 BME school by U.S. News & World Report. Partners with Emory University to share facilities and encourage research collaboration.
Johns Hopkins University	Carnegie Center for Surgical Innovation	Identifies clinical needs, develops new technology, and transitions research into clinical use. Also offers programs such as BME Design Day to encourage student innovation.
Massachusetts Institute of Technology	Center for Biomedical Innovation	Connects government, academia, and industry together to focus on BME advancements. MIT offers 30+ research centers for specific BME concentrations.
Duke University	Bioengineering Research initiative to Develop Global Entrepreneurs (BRiDGE)	Provides office/lab space, funding, and mentoring to startups founded by Duke BME faculty, PhD, and alumni.
Stanford University	Byers Center for Biodesign	Has launched 45 companies, helped almost one million patients, and trains 300+ fellows a year.
Rice	Rice 360 Institute for Global Health	Partners with clinics, schools, and organizations working in developing countries. Trains students to advance their research to a global health clinical application. Also has a Global Medical Innovation track for students to focus on research.
Yale	Center for Biomedical Innovation and Technology	Fosters greater innovation in medical technology through education, clinical immersion, corporate partnerships, and startup funding.
USC University of Southern California	Alfred Mann Institute	Helps transition BME research to commercially successful medical products to prove/save lives. USC spends nearly $700mm in research expenditures every year, and has the largest graduate STEM program of all private universities.

Healthcare Delivery is Undergoing a Dramatic Evolution

Healthcare systems - Dramatic changes in how care is delivered based on technology advances, competition, and ability to pay

Healthcare Demand – Demand increases driven by aging population, advanced living standards, and discretionary procedures

Healthcare Economics – Value chain is evolving, with cost effective solutions expected

- Purchasers of healthcare consolidating, driving prices down
- Governments are reaching limits in percent of public funds spent on care
- Increasing shift of payment burden to patients will increase cost sensitivity

These System Changes will Drive Changes in Competitive Dynamics for Companies Providing Products for Healthcare

Global Competition – Increasing access to capital and living standards ex-US will drive technology investments globally

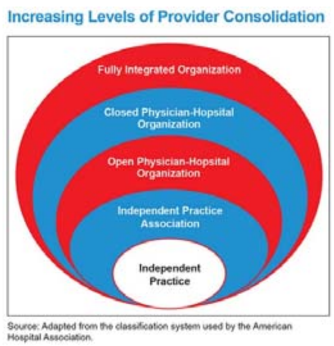
Lower Product Pricing – The changing healthcare delivery sector and increased buying power will result in lower margins for products

Consolidation and New Competitors

- Traditional competitors will consolidate to gain access to cost savings, global scale, and technology
- New "disruptive" competitors from the tech industry will accelerate market changes
- Strategic focus will begin to migrate to wellness maintenance and access to private pay

Recent Examples of Industry Changes in the Biomedical Field

Provider Consolidation

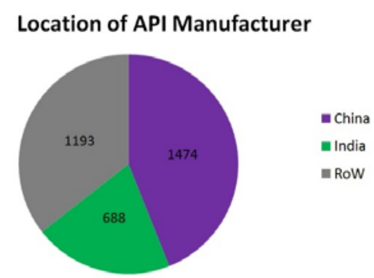


Channel Integration

Care Delivery Changes

URGENT
CARE
CLINIC

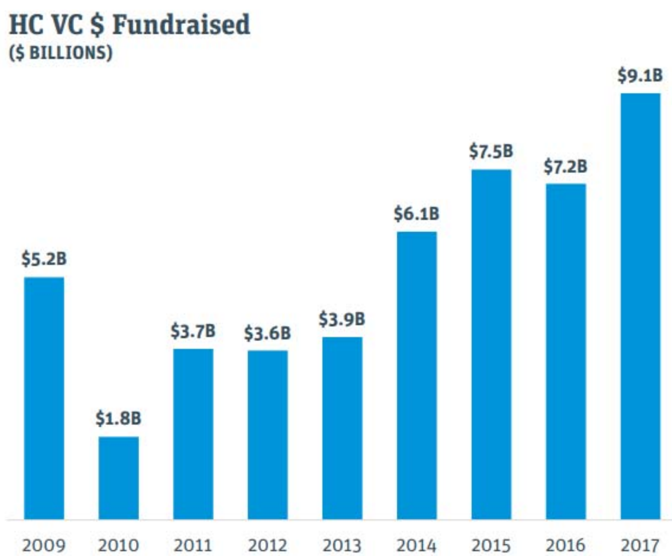
Globalization



Venture funding of Healthcare Startups Accelerating

Healthcare Fundraising Reaches New Heights

U.S. Healthcare Venture Fundraising*, 2009 – 2017



Healthcare venture funding hit a new high in 2017. The increase started in 2014 when fundraising jumped 50% over the previous year. This has led to a large pool of capital available to invest in venture-backed companies.

Venture healthcare investors have recently focused on biopharma and Dx/Tools. As Dx/Tools companies integrate computational methods such as artificial intelligence, we see tech investors, many new to healthcare, starting to invest in these deals.

Over the past few years, traditional VCs scaled back medical device investments. This trend reversed in 2017.

Looking ahead, we anticipate fundraising will continue to be strong, but will decline to the $6B-7B range in 2018.

svb

*SVB estimates the dollars allocated to healthcare by all U.S. venture funds.
Source: PitchBook and SVB proprietary data

Trends in Healthcare Investments and Exits 2018

Key Trends Affecting Biomedical Engineering

Terra Trends
• *Aging Population*
  • By 2030, the global population over 60 (1.4B) will outnumber children age 0 – 9
• *Obesity*
  • Statistics from 2104 indicate ~2B adults are overweight (600M morbidly obese)
• *Urbanization*
  • Globally, over 60% of the population will live in urban settings by 2030
• *Rise of Millennials*
  • The first "digital generation" is reshaping the cultural landscape
  • Will control 30% of retail spend by 2020
	Econo Trends
	• *Global Competition Increasing*
	  • Companies are investing more in R&D and talent to survive
	• *Value migration to service businesses*
	  • Service sector accounts for over 2/3 of global GDP (over $50T)
	• *Capital flows increasing to developing countries*
	  • Capital inflows to developing countries more than doubled in the past 10 yrs (>$.5T)
	• *Rise in E-commerce*
	  • Retail e-commerce sales expected to pass $4T by 2020

Tech Trends
• *Internet driven change accelerates*
  • Driven by increasingly unrestricted bandwidth and ubiquitous mobile technology
  • Continued change driver for social, economic and scientific interaction
• *Rise of Nanotechnology*
  • Dramatically increasing the ability to engineer at very small scale
• *Accelerating discovery of new engineered materials*
  • Potential to disrupt many industries
• *Powerful new data mining opportunities emerging*
  • Driven by computing power, access to vast data sets, and emergence of AI
	Meta Trends
	• *Rising Security Risks*
	  • Privacy, personal financial security and well as safety all more at risk
	  • Driven by increased connectivity across people and "things"
	• *Fabric of Society Evolving*
	  • Internet enabling new communities to form
	  • Increased polarization across the societal spectrum
	• *Globalization increasing*
	  • Instant information exchange
	  • Global migrations and global disease risk
	  • Financial systems highly linked

Products from Biomedical Engineering: What to Expect

Advances in the standard of care will still be important, but evidence of cost savings and avoidance of future care will be critical

Technology advances will continue to accelerate, resulting in faster product replacement

Market dynamics will require careful analysis of relevant patient segments

- Many new products and techniques will be limited to small subsets of patients
- Ability to segment and screen patients based on genetics or other health factors will be critical to drive use
- Risk based contracting based on patient outcome may offer higher revenue opportunity

Impact on Biomedical Engineering Field

Evolving Science Priorities

- Increasing focus on wellness and early intervention
- Technologies that reduced cost of healthcare will be prioritized
- Access to rapidly evolving tool technologies critical
  - Nanotechnology and new materials
  - Information sciences and data mining
  - Robotics and 3D printing

Evolving Customer Base

- Consolidation and purchasing consortiums are driving more purchasing power, driving lower prices
- Cost pressures at Federal and State level pushing aggressive tactics to restrict high cost care and resist high prices through regulation
- Emerging care models driven by technology (remote diagnosis and care) and employers (employee healthcare management) will increasingly impact field
- Private pay by patients will be an important element of value for some technologies due to growing global middle class

Evolving Funding Model

- Science will increasingly be sourced globally as industry and academia work across traditional boundaries
- Critical projects will increasingly be seen as cross disciplinary and will require coordinated efforts to attract funding
- Economic potential (value and cost savings as well as market potential) will become central elements of project selection and evaluation for ongoing funding

Evolving Industry / Governmental Participation

- Industry participation
  - Increased need for innovative products in more aggressive global market
  - Prices likely under pressure as higher demand attracts competition and regulation
  - Will likely invest in academic ideas, but with short time horizon
- Government participation
  - Domestic governmental funding will likely shift focus to drive cost effective therapies as high healthcare cost increasingly pressure budgets
  - Internationally, governments likely to continue to increase investments to help build leading positions for local companies (China, India)

Implications for Cornell Biomedical Engineering

University Level

- Selecting priority areas for investment will be critical to develop and maintain leading positions in the field
    - May conflict with academic independence at some levels
- Global focus and capabilities of the University will be important for the Biomedical engineering in the future as funding becomes more international
- Flexibility around IP and a willingness to work with corporate priorities may be necessary for some attractive funding sources, policy will be critical

Field Level

- Biomedical Engineering should prioritize areas it wishes to lead in and identify a road map to attain leadership in each area
- Strategy to access critical tools (data mining, materials, fabrication technologies) should be considered across biomedical engineering
- Evaluation tools should be developed to help faculty understand economic value of their ideas early in research

Faculty / Program Level

- For each program area, an understanding of the industrial as well as academic space should be developed to inform the research
- Look for best academic and industrial partners to access adjacent tools and technologies (Inside of and outside of Cornell)
- Review each program for viability regularly (technology is moving very fast and ideas could be obsolete before they emerge from a lab)

Key Take-Aways for Cornell Biomedical Engineering

1. For all key programs, it will be important to factor the requirement of the changing ecosystem into research plans
2. Funding sources will shift, and Biomedical Engineering should prepare
   - Access to corporate investments will require global view, and may be from unexpected sources such as tech companies
   - Government funding may become much more focused on cost saving technologies
3. Biomedical Engineering has some of the most advanced thinking in how they want to focus, may be a good area to pilot new strategies

Ag-Biotech Engineering Trends

Ag Bio Competitive Landscape – Universities

University Ag Biotech programs are fairly recent:

- Most Universities placing increased emphasis on Ag Biotech
  - Some Universities have colleges dedicated to Agriculture & Biology Technology ("ABE" or "BAE")

Leading Ag Biotech programs are in states with strong agricultural economies:

- These states are funding their public Universities for research to improve their state's agricultural practices
- Some Universities have strong relationships with large agriculture companies, resulting in additional funding

Most university programs are focused solely on research:

- Some programs have started to focus on commercial objectives, however there is no clear market leading program
- Most Universities do not offer an agricultural startup incubator for their students

Leading University Ag Biotech Programs

University	Program Name	Notes
The Ohio State University	OBIC Bioproducts Innovation Center	Founded in 2014. Provides client services, research studies, and undergraduate incubator.
NC State University	Cooperative Extention	Collaboration between NC State and NC A&T. Cites $1.5bn impact on rural NC. Generated more than $25mm in licensing revenue since 2011.
The University of Georgia	Institute of Plant Breeding, Genetics and Genomics	Mission is to develop improved plant cultivars from agronomic and horticultural species. Faculty train graduate students in modern plant breeding and conduct research on genetics.
Wisconsin University of Wisconsin–Madison	Crop Innovation Center	Founded in 1981. Current building through a gift by Monsanto. Services include Maize, Soybean, and Sorghuim Transformation. Also has phenotyping and molecular technology capabilities.,
University of Nebraska	Center for Biotechnology	Focuses on bioinformatics, flow cytometry, microscopy, plant transformation, and metabolomics. Provides scholarships and fellowships.
UC Davis University of California	Seed Biotechnology Center	Founded in 1999. Famous for sequencing the genomes of 100 indigenous African plant species
Iowa State University	Seed Science Center	Offers two programs: Seed Science Center focuses specifically on seed sample testing and Biotechnology Outreach Center for agricultural education.

Animal Bio - Competitive Landscape – Universities

Animal Biotechnology is a mix of technology and engineering:

- Assisted reproductive technologies refers to the distribution of genetics beyond natural mating
- Cloning is the rapid distribution of desirable traits
- Genetic Engineering introduces/modifies genes to add new traits

Most American universities do not offer a Animal Biotechnology Major:

- However, a few universities offer a "Animal" concentration in their Biotechnology Master Degree

Most centers focused on Animal Biotechnology are located in flagship International Universities :

- National governments provide funding for research for livestock innovation

Leading University Animal Biotechnology Programs

University	Country	Notes
Oklahoma State University		Offers Animal Biotechnology as an undergraduate concentration for Animal Science majors and offers student organizations with corporate partnerships.
Texas A&M University		Center for Animal Biotechnology and Genomics focuses on the development of management and clinical therapies to increase reproductive health, and enhance reproductive efficiency in humans and domestic animals.
University of Nebraska		Offers Animal Biotechnology as an undergraduate concentration for Animal Science majors and offers student organizations with corporate partnerships.
UOH University of Hyderabad		National Institute of Animal Biotechnology conducts research on livestock breeding and functions as an incubator for startups.
The University of Melbourne		Centre for Animal Biotechnology (CAB) was established in 1990 to apply discoveries to practical methods of livestock management, develop links with companies for testing, and encourage entry of scientists into the field.
KU Konkuk University		Department of Animal Biotechnology has been a world leader since 1962 and is one of the few universities to offer a Animal Biotechnology undergraduate major. Research focuses on control of animal diseases, development of new medicines using animal cells, and cloning.

Ag Bio Competitive Landscape – Institutions

Private corporations are spending large amounts on Ag Biotech R&D:

- Most corporations do not publicly share their research due to its proprietary nature
- Monsanto has the most public approach out of the major Ag Biotech players

While there are many programs for agricultural innovation, few are dedicated to Ag Biotech:

- Most nonprofits do not have a dedicated department to Ag Biotech, but many focus on holistic agriculture
- Many large nonprofits are starting to focus on Ag Biotech due to its potential value to society

Leading Ag Biotech Institutions

Institutions	Notes
AgBio[sphere]®	Funded by the North Carolina Biotech Center. Provides thought leadership sharing and funding for agriculture startups.
Donald Danforth Plant Science Center	Independent research facility with 267 employees, including 193 scientists. Focuses on bioinformatics, microscopy, phenotyping, plant growth, and tissue culture. 2017 Operating budget: $30mm. 45% from grants, 40% endowment, 15% annual gifts
Monsanto *(University of Illinois Collaboration)*	Opened an agricultural innovation center at the University of Illinois in 02/18. Employs 24+ students across different colleges.
McKinsey & Company	Center for Agricultural Transformation offers private sector engagement strategy, data analytics, and aids in fundraising. 1890 agricultural projects to date in 69 countries from 371 clients.
World Economic Forum	Research team concentrates on health and agrictulture biotech. WEF collaborates with the best scientists/researchers in the world.

Key Trends Driving Ag-Tech

- **Growing global population – feed 10B by 2050**
- **Urbanization – 50% of the world's population live in urban areas**
- **Climate change**
- **Consumer preferences – demands for transparency, healthy food, sustainability**

DRIVING

- **Yield (there is 30% room for improvement) and reduction of value chain loss (33% on average, as a percentage of initial production)**
- **Vertical farming**
- **Better water management and better seeds**
- **Organic and healthy products, fewer pesticides**

Ag-Tech – Broad category which includes: Farm Management, Sensing, IoT, Robotics, and Ag-Biotech. We are focusing on *Ag-Biotech*

Key Trends Affecting Ag-Biotech Engineering

Evolving Science Priorities

Bio-Agriculture Engineering – known as ***Ag-Biotech***

- Plant Ag-Biotech: new approaches to driving top-line value for the grower
  - Small-molecule discovery platforms -eg. 'shape shifting' boron to produce pesticides to combat pesticide resistant organisms
  - Biologicals – eg. engineered microbes that provide 'organic' pesticides
- Food tech: artificial meat, plant based meat
- Animal Ag-Biotech: new approaches to alternative therapies for animal health, advanced genetic engineering

Evolving Market Dynamics

Turbulence ahead for big 6 (BASF, Bayer, Dupont, Dow Chemical Company, Monsanto, and Syngenta)

- key products in seed and chemistry have come off patent, the change imperative for the Big 6 has only strengthened
- Organic disruption unlikely, so expect heavy acquisition activity – presenting great opportunities for startups to be acquired for big $$s

Evolving Funding Model

Investments in ag-tech accelerating

- Global – agriculture and food technology companies - $10.1 billion in investments in 2017, up 29 percent from 2016, according to an annual report from food and agriculture investment platform AgFunder 2017.
- Of that, ***Ag biotechnology investments - $670 million***
- Corporate venture capital activity in the sector has expanded, with more than 30 active funds, joining the agtech-focused funds like Khosla, Fall Line, Finistere, Innovation Endeavors and S2G, among others
- Even players like Softbank, Amazon, Google getting into the food game with major investments and funds dedicated for agriculture innovation

Evolving Industry / Governmental Participation

Water and GMO Regulations

- GMO labeling bill passed in July 2017 - Action on GMO ingredients is in early stages and likely take 2 years to complete
- If not implemented carefully could undercut innovation
- Will heighten consumer sensitivity

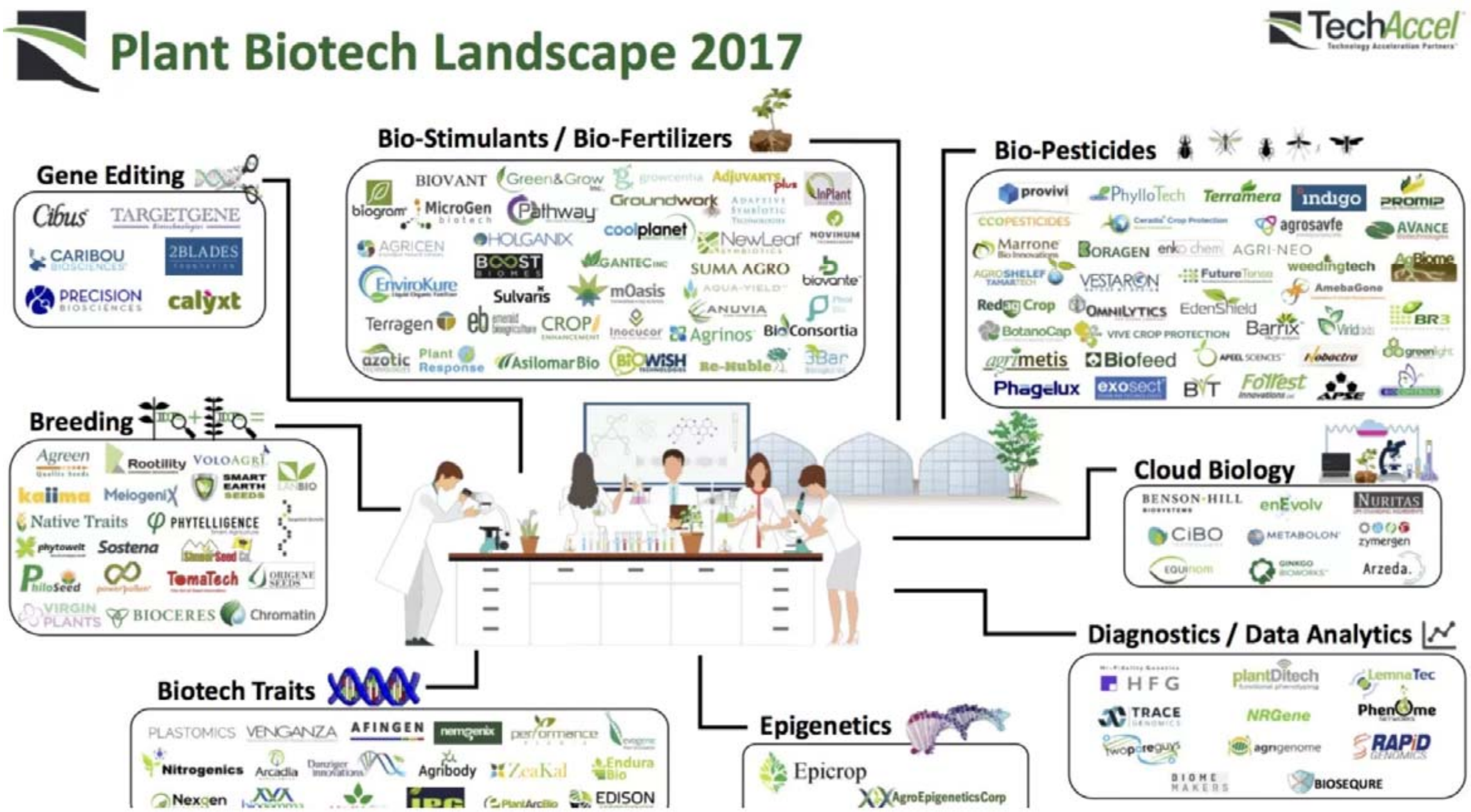
Immigration reform

- Undocumented workers make up 16% of the workforce – pressures on the workforce will drive innovation in labor (think robots)

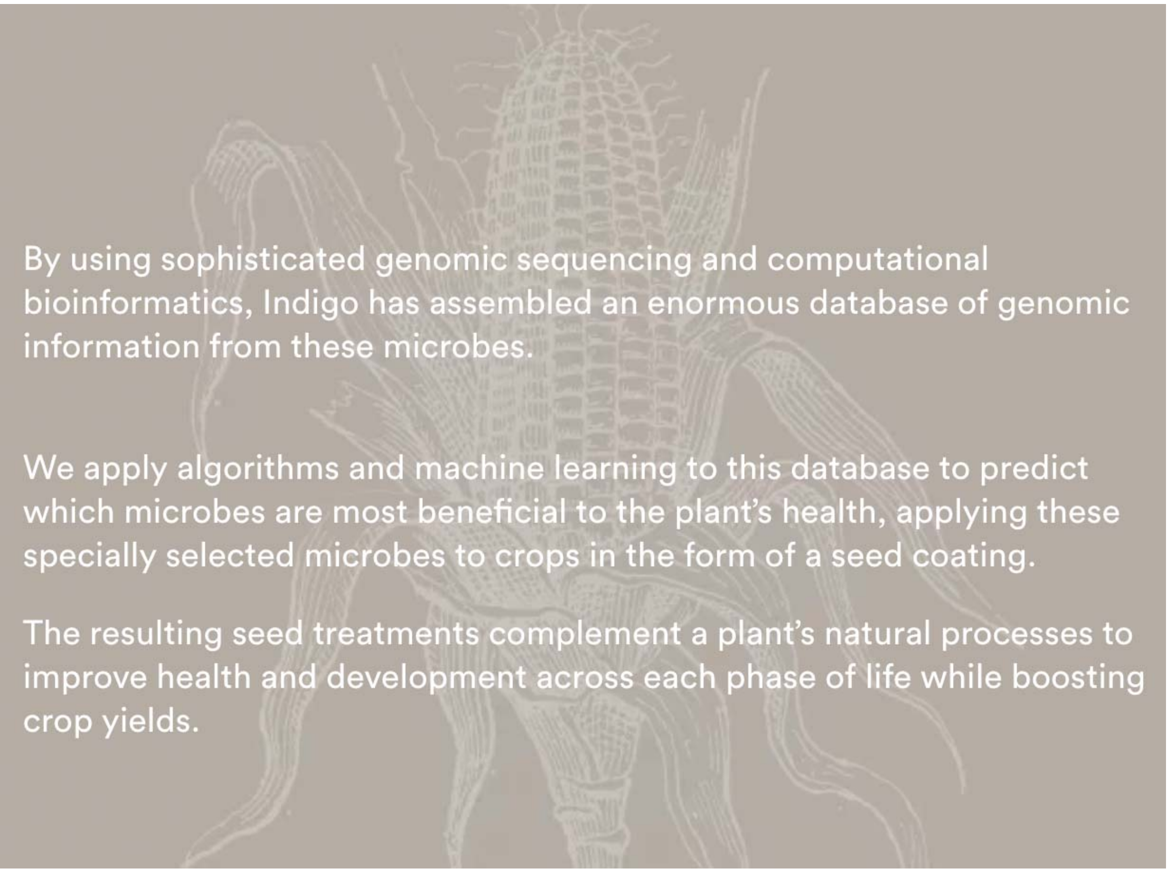
Government investment in Ag Biotech

- Eg: Dubai sovereign fund investment of $205M in Indigo

Evolving Science Priorities – Plant Bio-Tech Landscape



Evolving Science Priorities – Indigo Case

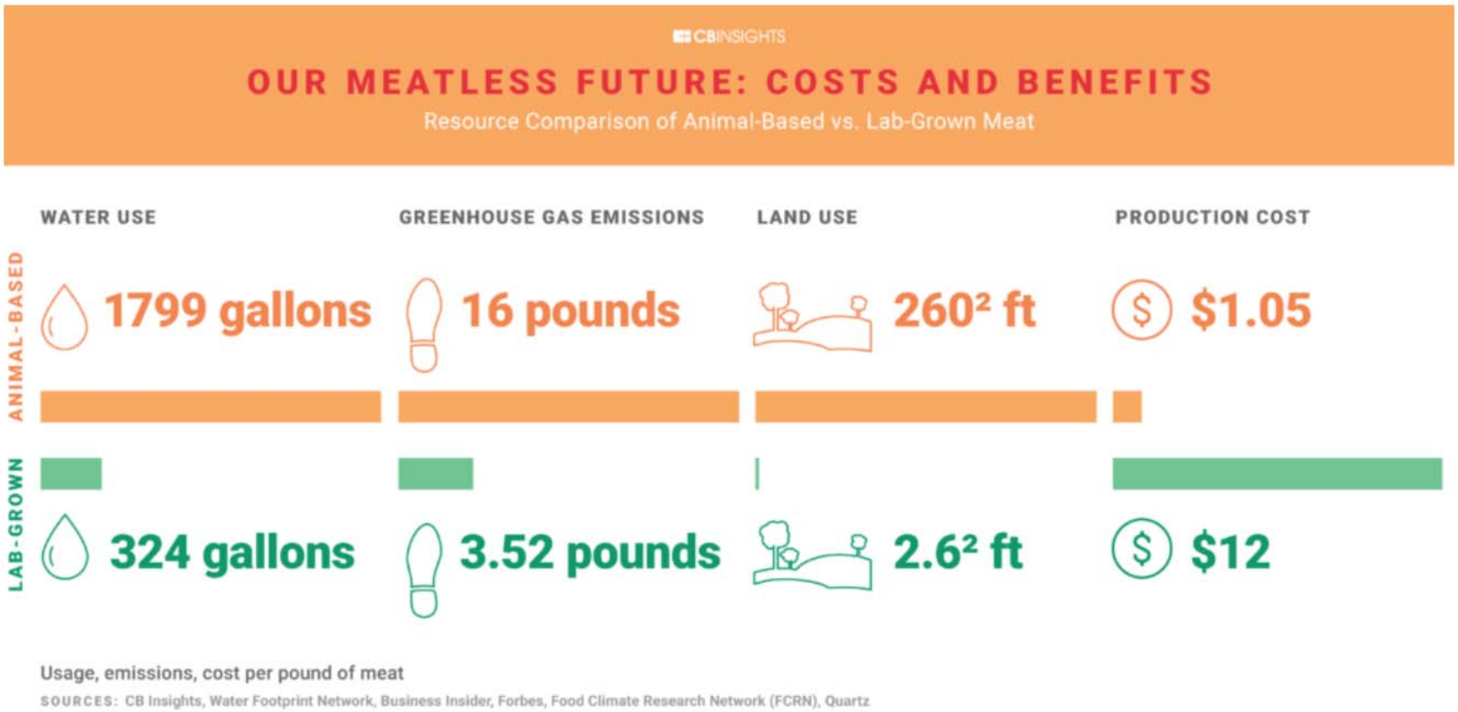


Raised $360M to date including $203 series D from Dubai Sovereign Fund

Microbial seed coatings for corn, soy, wheat, and cotton
Help crops to withstand environmental stressors such as drought, high temperatures, salty soils or low nitrogen and bolster resistance to disease and pests

Products also produce higher quality crops, such as increasing the protein content of wheat.

Evolving Science Priorities - Meatless Future



Evolving Funding Model – Leading Investors

MOST ACTIVE AGTECH INVESTORS

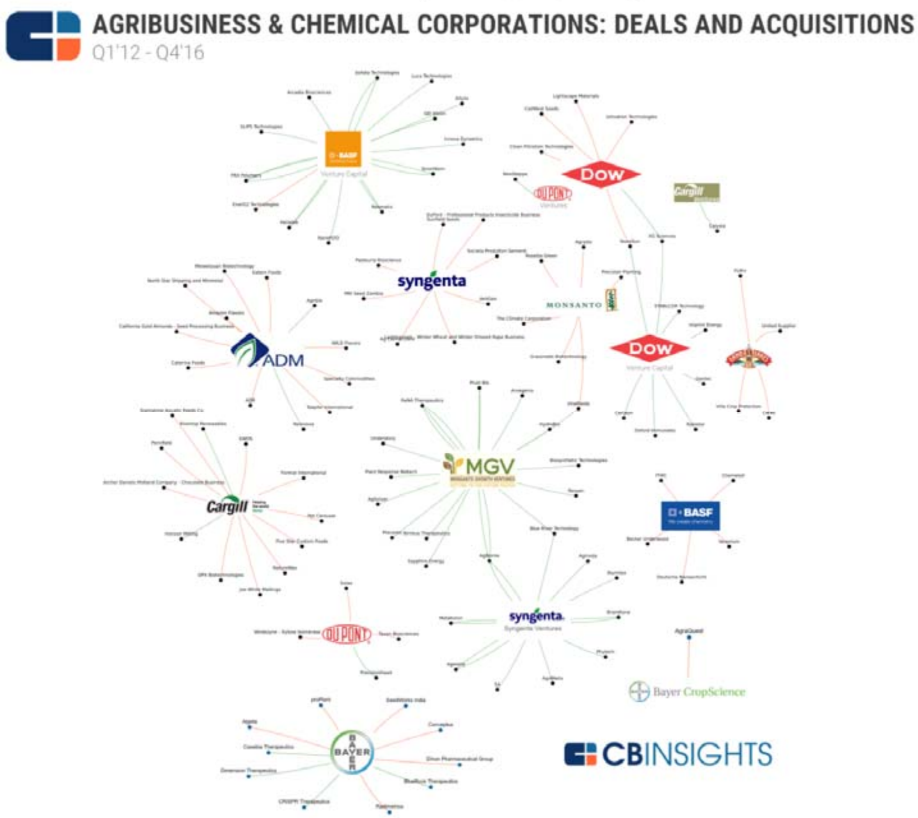
FIRMS RANKED BY UNIQUE AGTECH INVESTMENTS, 2012 - 2016

Investor	Rank	Companies					
Y Combinator	1	TL Biolabs	PickTrace	Raptor Maps	Edyn	TerrAvion	Farmlogs
Monsanto Growth Ventures	2	AgSolver	HydroBio	Resson	VitalFields	Blue River Technology	
Middleland Capital	2	Benson Hill Biosystems	Conservis	AAD	Mercaris	AeroFarms	
Syngenta Ventures	4	Phytech	Agworld	S4	Blue River Technology		
Khosla Ventures	4	Granular	Blue River Technology	Climate Corporation	Solum		
Andreessen Horowitz	4	Granular	Solum	AgLocal	Farmlogs		
Omnivore Venture Partners	7	Stellapps	Eruvaka Technologies	FrontalRain Technologies			
Google Ventures	7	FBN	Granular	Climate Corporation			
Felicis Ventures	7	Grove Labs	Granular	Climate Corporation			
Techstars	7	Platfarm	Freight Farms	Avemus			

www.cbinsights.com

https://www.cbinsights.com/research/agriculture-tech-top-investors/

Evolving Market Dynamics - Acquisition Landscape



Farm Tech Exits (2010 to date, $50m+)

Year	Target	Acquirer	Category	Amount ($m)	Notable Investors
2011	**Divergence**	Monsanto	Ag Biotech	71	Cultivian Ventures, Prolog Ventures
2011	**Beeologics**	Monsanto	Ag Biotech	114 ★	
2012	**AgraQuest**	Bayer	Ag Biotech	425 ★	TPG Growth, Otter Capital, Generation Capital
2012	**Precision Planting**	Monsanto	Robotics, Machinery & Other Farm Equip	250	
2012	**Pasteuria Bioscience**	Syngenta	Ag Biotech	113 ★	Advantage Capital Partners
2012	**Becker Underwood**	BASF	Ag Biotech	1020 ★	Norwest Equity Partners
2013	**The Climate Corporation**	Monsanto	Farm Management Software, Sensing & IoT	930	Khosla Ventures, GV, Founders Fund, First Round Capital
2013	**Devgen**	Syngenta	Ag Biotech	523 ★	Capricorn Venture Partners, ING Group, Flanders Biotech Fund
2013	**Marrone Bio**	IPO	Ag Biotech	57	Syngenta Ventures, Mitsui Global Investment, Saffron Hill Ventures
2014	**Wolf Trax**	Compass Minerals	Ag Biotech	85	Avrio Ventures
2014	**Virdia**	Stora Enso	Biomaterials & Biochemicals	62	Khosla Ventures
2014	**Allylix**	Evolva	Miscellaneous	59	Middleland Capital, Cultivian Ventures, BASF Venture Capital, Tate & Lyle Ventures
2014	**640 Labs**	The Climate Corporation	Farm Management Software, Sensing & IoT	not disclosed	Serra Ventures
2015	**Zoner**	Bayer	Farm Management Software, Sensing & IoT	not disclosed	
2015	**Arcadia Biosciences**	IPO	Ag Biotech	$65.6m	Mandala Capital, BASF Venture Capital, Saints Capital, CMEA Capital
2015	**Taxon Biosciences**	DuPont	Ag Biotech	not disclosed	BP Ventures
2015	**Oxitec**	Intrexon	Ag Biotech	160	Oxford Capital Partners
2015	**AgConnections**	Syngenta	Farm Management Software, Sensing & IoT	not disclosed	
2015	**AGRI-TREND**	Trimble	Misc	not disclosed	
2016	**proPlant**	Bayer	Farm Management Software, Sensing & IoT	not disclosed	
2016	**EnviroFlight**	Intrexon	Ag Biotech	not disclosed	
2017	**Granular**	DuPont	Farm Management Software, Sensing & IoT	300	Andreessen Horowitz, GV, Khosla Ventures
2017	**Blue River Tech**	John Deere	Robotics & Equipment	305	Khosla Ventures, Monsanto Growth Ventures, Syngenta Ventures, Data Collective
2017	**Agronomic Tech Corp**	Yara International	Farm Management Software, Sensing & IoT	No disclosed	

AGFUNDER

Implications for Cornell Ag-Biotech Engineering

University Level

- Cornell has a unique opportunity to position itself as an institution that can foster innovation in the field due to its unique set of capabilities across schools (Engineering, Ag School, Bio&Chem from Arts and Science school
- Explore creating a 'Cornell Center of Excellence for Ag-Biotech for a Sustainable Future' – CCEABSF - a new vehicle through which we can drive and execute on the mission of establishing Cornell as a leader in ag-biotech
    - Establish tiger team – made up of inter school faculty
    - Identify key faculty to spearhead the effort
    - Establish board made up of key players in industry and investment community
- Through this vehicle gain access to **research monies from institutions**
- **Startups -** The CEABSF can provide a platform to enable Cornell faculty, researchers and graduates to start companies
    - Startups will have immediate access and visibility with potential acquirers (industry members of the CEABSF)
    - Easier access to funding due to participation from leading investor members of the CEABSF)
    - Provide opportunities for and leverage undergraduates to participate in research geared towards startups and commercialization of technology
- Beyond Ag-Biotech? Should we go broader than Ag-Biotech – and look at creating a platform for Ag-Tech?

Field Level

- Understand the overall strategy of the big 6 by studying their acquisitions, and the startups that are receiving funding, to zero in on some key areas of future investments, and use the information to help build the multi-year roadmap – Microbes, CRISPR, man made meat ,etc

Faculty / Program Level

- Identify existing faculty working in the areas of interest across schools (eg. Microbes, genetics) and form a tiger team to help build a multi-year roadmap for the school
- Explore recruiting top researchers in the areas of interest

Bioenvironmental Engineering Trends

Bioenvironmental Competitive Landscape – Universities

Many Universities have interdisciplinary environmental/sustainability programs:
- Few Universities have initiatives dedicated to environmental engineering

Federal funding contributes heavily to smaller Universities' sustainability programs:
- Most Fortune 500 corporate partnerships are with larger Universities

Some Universities focus on sustainability specific to their geographic area:
- These are typically public universities located in unique climates
  - E.g. UCLA focuses heavily on its local environmental issues (LA smog from traffic)

Leading University Environmental Engineering Programs

University	Program Name	Notes
Georgia Institute of Technology	Brook Byers Institute for Sustainable Systems	Creates knowledge and technologies that improve environmental, social, and economic systems. Particularly focused on engineered systems for environmental infrastructure (e.g. storm water systems).
The University of Texas at Austin	Center for Energy and Environmental Resources	Founded in 1974 and occupies over 43,000 square feet. Works with 25 departments in 10 colleges at UT with a heavy focus on engineering. Research projects are from a variety of state, federal, and private sources.
Carnegie Mellon University	Center for Engineering and Resilience for Climate Adaptation	Develops methods to incorporate climate change impacts into engineering infrastructure designs and decision-making
Harvard University	Wyss Institute for Biologically Inspired Engineering	Uses design principles for engineering innovations to create a more sustainable world.
Illinois University of Illinois at Urbana-Champaign	Institute for Sustainability, Energy, and Environment	Offers funding for student research, Fellows training, education, and corporate partnerships.
UCLA	Institute of the Environment and Sustainability	Focuses on public projects, research publications, field experiments, and research collaboration in environmental sustainability.

ECC Task Force Recommendations

ECC Bioengineering Task Force Recommendations (1)

Initiate a strategic dialog at School / University level to determine critical areas of focus and discuss if we have a need for a Cornell wide bioengineering vision

- What technology areas do we want to focus on as the core of our leadership in the field(s)?

- Are there broader themes which can unify our mission and efforts?
  - Human wellness
  - Cost effective technology delivery

ECC Bioengineering Task Force Recommendations (2)

Launch an initiative to consider how to support and target programmatic efforts without overly interfering with academic freedom

- How can we better integrate cross disciplinary science (internal to Cornell or outside) into our programs?
- How do we make sure our thinking and direction tracks the critical trends impacting the field?
- How do we routinely and effectively review and where needed, redirect our research and investments?

ECC Bioengineering Task Force Recommendations (3)

Pilot enhanced program support model in two or three key areas to build tools and test concepts

- Develop an external trend map impacting the program and consider how to integrate it into research strategy
- Map and build relationships to promote technical exchange, funding and commercialization partnerships for the program
- Define review criteria and frequency to enable effective review and course correction

ECC Bioengineering Task Force Recommendations (4)

Develop a set of metrics and tools to continuously map activities and assess progress against goals across Cornell's bioengineering efforts

- A standard way of looking at bioengineering across the various departments involved
- A tool to guide investment and recruitment decisions based on the needs of the mission and goals
- A common package to describe to the world our leadership in bioengineering

Advancing to Phase 2

Our phase 1 analysis indicates a substantial opportunity for Cornell to enhance its position in Bioengineering

Capturing the value will require inside out thinking, a willingness to broaden our definitions of success in an academic enterprise, and an investment in our faculty and supporting infrastructure

The ECC Bioengineering Task force stands ready to help, and suggests a smaller discussion with a College / University leadership team to refine a plan for phase 2