Chemical and Biological Engineering at CU Boulder

Vision

The Department of Chemical and Biological Engineering at the University of Colorado will conduct impactful research and provide rigorous training resulting in faculty, students, and alumni widely recognized as leaders in the field.
The ChBE Department is recognized for:

- Outstanding students, alumni, and faculty
- Excellence in education with attention to individual students
- Innovative research at the forefront of interdisciplinary science and engineering

**History and Personnel**

- First B.S. degrees in 1908; first PhD degree in 1951
- 22 TT faculty, 3 Instructors, 2 Research Faculty
- 440 undergraduates, 115 grad students, 25 Post Docs

**ChBE Department Characteristics**

- **Vertical Integration**: Faculty work together with postdocs, PhD students, undergraduates, and alumni
- **Horizontal Integration**: Community outreach and interdisciplinary and industrial collaborations

**Some Characteristics**

- At 20 FTE faculty, the smallest department in the college by 25% relative to 2nd; 75% smaller than two largest departments
- 3rd Largest UG Enrollment and 2nd Largest PhD Enrollment
- Largest Expenditures (170%), PhD's graduated (55%), SCH (35%), UG students (tied, 55%) per FTE – percentages relative to college avg wo/ChE
- Ranked 8th by Appropriate NRC Rankings of Public ChE Dep’ts and 14th overall in NRC, 17th in US News
- Highly interdisciplinary – curriculum and faculty strongly connected to both sciences and engineering
- Heavily leveraged into and often leading campus initiatives
Examples of BS Graduates

Mark Fordney  Chevron
Samantha Jo Johnson  CalTech ChE Grad School
Sam and Brittany Michael  Entrepreneur and Grad to be
Katie Barrett  Micron
Tyler Silverman  Abengoa Solar, Spain
Sarah Hoyt  OpX Technologies
Kate Jankousky  Teach for Amer., West Gen. Academy
Amanda Parker  TDA Research
Heath Briggs  Greenbery Traurig, CU Instructor
Demetrios Syrpes  Practicing Dentist, CU Dental School
Greg Bunker  Dow Chemical
Mariah Mason  CU MD/PhD Graduate
Christopher Kloxin  Faculty, University of Delaware
Undergraduate Program and Student Highlights
– Chemical and Biological Engineering Degree, Est. 2006, Accredited 2010
  • Great Interest from Students – Already Equal to Traditional ChE Program
  • Core Degree and Curriculum Remain Focused on Molecular Processes
– Emerging Opportunities
  • Energy Option, Energy Classes
  • Cooperative Education Program with Industrial Training
  • Other options and electives in various areas
– Focus on Educational Excellence, Active and Discovery Learning
  • Numerous Faculty Teaching Awards
  • Active Learning Including “Clicker” Technology, Reading Quizzes, Screencasts
  • Faculty Commitment to Educational Excellence: > 10 with Teaching Awards
– Undergraduate Research and Senior Thesis
  – Individual mentoring and training is highly valued
  – > 100 undergrad students participated in research in 2011
– Teach Several Large Service Classes
  • Chemistry for Engineers, Creative Technology
– Individual Attention to Students
  • Programs for Student Development
    – Study Abroad, Earn-Learn, Discovery Learning, Cooperative Education Program
What are Chemical and Chemical and Biological Engineering Degrees all about?

*Chemical engineers (BS since 1906)* understand and manage the chemistry that converts raw materials into products of value. Chemical engineering as a profession is well established and remains a critical industrial need.

*(Chemical and)* Biological engineers *(BS since 2006)* are evolving as those individuals that understand and manage living systems to create beneficial change and generate important, useful products through *molecular transformations*. 
Educational Program Developments
The ChBE Department is helping implement improved teaching methods internationally in engineering education, including:

**Concept Tests with Peer Instruction** Engage students with difficult concepts during class time

**Screencasts (so one can use class for active learning)** Downloadable, narrated video example problems or explanations that students follow at their own pace

*Active learning*: Anything students do in class related to the material other than simply watching, listening, taking notes

http://learncheme.com
ConcepTest example

Water is in vapor-liquid equilibrium at 1.2 bar in a piston-cylinder that contains only water. When 1 cm³ of air is injected into the system at constant pressure and temperature,
_____ of the water ____________ .

A. all, vaporizes
B. all, vapor condenses
C. some, vaporizes
D. some, vapor condenses
575 screencasts on LearnChemE.com

Short narrated videos that capture Tablet PC screen for 8 CBEN courses (5 courses useful for MCEN students)

Increases College visibility
154,000 plays/downloads in 2011
March 2012: 80,000 plays/downloads from around the world

Screencasts are:
Very well received by students and faculty
Example problems
Concept explanations
Exam reviews
Software tutorials
Introductions to topics

Funding:
NSF, EEF, Shell, Chancellors award
College Teaching Workshop
August 2008-2011
Falconer, deGrazia, Medlin (CBEN)

- Overview of teaching
- Alternatives to lectures
- Using Clickers and ConcepTests
- Just-in-time teaching
- Cooperative Learning
- Desire to Learn Course Management Software
- How to increase productivity
- Course planning/organization/syllabus
- Tablet PCs and screencasts
- Used for New Faculty, TA, and Other Training
- Also transitioning to Faculty Training Program for grad students and post-docs
Examples of PhD Graduates

Chris Perkins   Sundrop Fuels
Daniel Webb   ExxonMobil
April Kloxin   Assistant Prof Univ. of Delaware
Ryan Soderquist   Amgen
Alexia Finotello   Dow Chemical
Kathryn Berchtold   Staff Scientist, Los Alamos Lab
Michael Lynch   OpX Technologies Founder
Jason Burdick   Associate Prof Univ. of Pennsylvania
Jason Bara   Assistant Prof, Univ of Alabama
Michelle Staben   Product Engineer, Glaxo Smith Kline
Changiun Xue   Bristol-Myers
Amber Fradkin   Formulation Scientist, Merck
Kristin Thunhorst   3M
Recent CU Products in Academia

Also Faculty in Korea, China, Australia, etc.

Six Faculty at Universities with top 16 (NRC) ChE Schools
Approach: To conduct fundamental, multi-disciplinary world-leading research towards application to impact key grand challenges.

Advanced Materials Initiative
Materials Simulation
Polymers
Self-assembly
Surface science
PV materials
Nanomaterials

Energy
- RASEI
- Biofuels
- Metabologic engineering
- Catalysis
- Fuel Cells
- Solar Thermal
- Solar OPV

Biology
Biofronteirs
- Biopharma, Biotechnology, Biomaterials
- Tissue Engineering

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Materials Simulation
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Chemical Biology and Engineering (ChBE)

Energy
- RASEI
- Biofuels
- Metabologic engineering
- Catalysis
- Fuel Cells
- Solar Thermal
- Solar OPV

Application
Measurement
Theory
Synthesis
Graduate Program and Student Highlights

– Dramatic Growth
  • Doubled Students in 15 Years while also becoming exclusively PhD
  • 2006: 171 graduate applications (30%), 3.70 avg GPA of Entering Class
  • 2012: 485 graduate applications (11%), 3.92 avg GPA of Admits
  • FY 2006 Research Grants: $5.9 M ($7.0 expenditures)
  • FY 2011 Research Grants: $15.9 M ($13.6M expenditures)
  • Patents, Publications, Citations, Start-Ups, Awards, and Grants Lead CU

– Numerous Interdisciplinary Interactions
  • Leadership in Renewable and Sustainable Energy Institute, Biofrontiers Institute, Materials Science and Engineering
  • Excellent Departments in the Sciences (Physics, Chemistry, Biology)
  • Strong Departments Across Engineering
  • Research Centers (C2B2, MAST, CFAP, CPB)
Faculty Highlights

– Exceptional Faculty

• NAE, IOM, NSF Waterman, Colburn, Professional Progress, Industrial Gases, ASEE, Dreyfus, Sloan, NSF CAREE, DOE, ONR, NIH, and MRS Young Investigator Awards, Inaugural MRS MidCareer, Numerous College and Campus Research and Teaching Awards

– Dramatic Changes

• 10 Faculty Hired in Last 10 Years and Four Openings (7 offers this spring!) – Young Faculty
• Diverse Backgrounds with Multiple Non-ChE Degrees

– Interdisciplinary Efforts

• Joint Positions in Chemistry, Medical School, Dental School, Pharmacy

– Research Vision and Performance Dramatically Upgraded

• Funding Base Includes Funds from NSF, NIH, DARPA, Dept. of Educ., Dept. of Energy, NASA, and Numerous Industrial and Private Sources
• Publications per Faculty up nearly 100% in Fifteen Years – Citations more dramatic
• Increasing Entrepreneurial Endeavors
• PhD, Funding, Publication Gradients All in Right Direction
• Gill Group: bioTechnologists (Synthetic Biology and Genomics)
  • Vision: To develop new technologies that broadly enable the more efficient engineering of life
  • Applications:
    • Sustainable production of fuels and chemicals
    • Engineering of new pharmaceuticals
Team Weimer: Solarthermal H$_2$O Splitting

1st Half Cycle

O$_2$  →  H$_2$  

(Reduction):  CoFe$_2$O$_4$ + 3 Al$_2$O$_3$  →  [CoAl$_2$O$_4$:2Fe$_2$AlO$_4$] + 1/2O$_2$

(Oxidation):  [CoAl$_2$O$_4$:2Fe$_2$AlO$_4$] + H$_2$O  →  CoFe$_2$O$_4$ + 3 Al$_2$O$_3$ + H$_2$

H$_2$O  →  H$_2$+1/2O$_2$
Development of Ultrastable Ricin Vaccine - Randolph Group

- Stockpiling of bioterrorism defenses requires ultrastable vaccine
- Current vaccine shelf life \(~1\text{ day}\) at room temperature
- Strategy: Co-immobilization of ricin toxin protein with nanoparticulate aluminum salts in glassy powders
- Result: New formulation stable at least 2 months at elevated temperature (40 C).
- Extrapolated room temperature stability: 5 years!!

- Ricin Toxicity (Estimated LD$_{50}$)
  - Inhalation (\(~1$-$10 \text{ µg/kg}\))
- Symptoms:
  - Respiratory distress
  - Severe vomiting
  - Gastroenteritis & Inflammation
  - Multiple organ failure
  - Death within \(~72\text{ hrs}\)
- Malaria and Botulinim Vaccines also Targeted
Single-molecule Tracking on Surfaces for Biotechnology and Energy Applications: Dan Schwartz

Representative projects, applications, and support:
- Using molecular probes to map surface chemistry (separations & catalysis - DOE)
- DNA binding and folding on surfaces (biosensing & nanotechnology – NIH and industry)
- Protein damage at the oil/water interface (pharmaceuticals – NSF and industry)
- Surface fouling (membrane separations & biomaterials – NSF, NIH, and industry)

Direct dynamic observations of millions of individual molecules on surfaces provides unique mechanistic information about a variety of complex and heterogeneous systems.

Nature Communications, 2, 515 (2011)
Anseth Group: Design of Advanced Hydrogel Materials

i. Cytocompatible
ii. Controlled presentation of biochemical cues (orthogonal, on demand)
iii. Control of physical microenvironment through photodegradation
iv. Mimicking of cell-ECM and cell-cell interactions

DeForest and Anseth (2011) Nature Chemistry
Directing Differentiation and Connectivity of Motor Neurons

Introduction and removal of physical and chemical cues are used to understand how to direct and manipulate axon extension.

Research Team:
- Dr. Mirza Pjelto (neuroscientist)
- Dan McKinnon (PhD engineering student)
- Laura Tremblay (undergraduate student)

Hosted three Boulder High School Students
Jennie Smoly Caruthers Biotechnology Building

- Bringing together Chemical and Biological Engineering, Biochemistry and the Biofrontiers Institute into a single, collaborative space
- Preeminent research and education space for chemical/biological engineering and biotech in Rocky Mountain region
- Opportunity for opening the next stage for the Chemical and Biological Engineering Department
Jennie Smoly Caruthers Biotechnology Building

Technological Impact – Changing the Future!

- Microbial genetics and genomics
- Bioengineering (tissues, cells, etc.)
- Human disease genetics
- Imaging (cells, molecules, whole organism)
- Bioscience technology development
- Vaccine Development
- Small molecule screening
- Biomaterials
- Biopharmaceuticals
- Catalysis, Surface Science, and Reaction Engineering
- Complex Fluids and Microfluidic Devices
- Computational Materials Science and Biology
- Energy and Environmental Applications
- Computational Materials Science and Biology
- Energy and Environmental Applications
- Membranes and Separations
- Protein Engineering, Metabolic Engineering and Synthetic Biology
- Nanostructured Films and Devices
- Polymer Engineering
- Tissue Engineering

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