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UNIVERSITY | NEW BRUNSWICK

# Introduction to Chemical and Biochemical Engineering (CBE)

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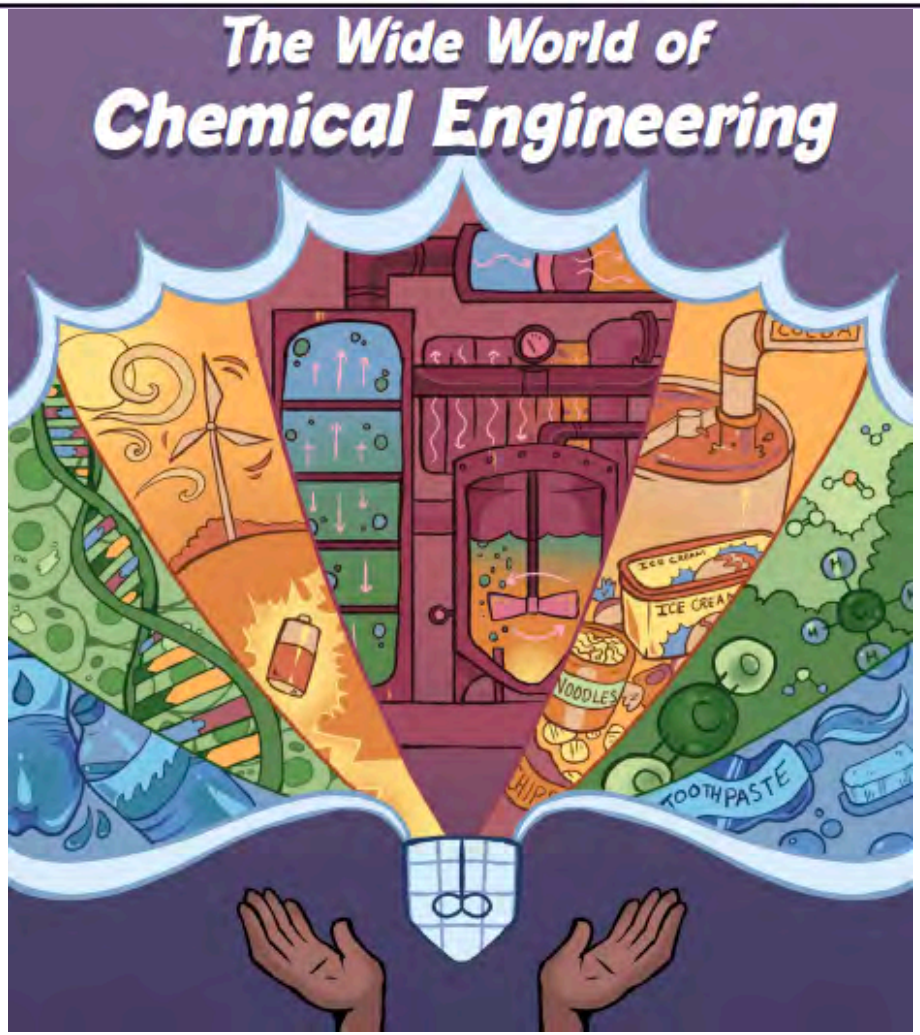
# THE WIDE WORLD OF CHEMICAL ENGINEERING

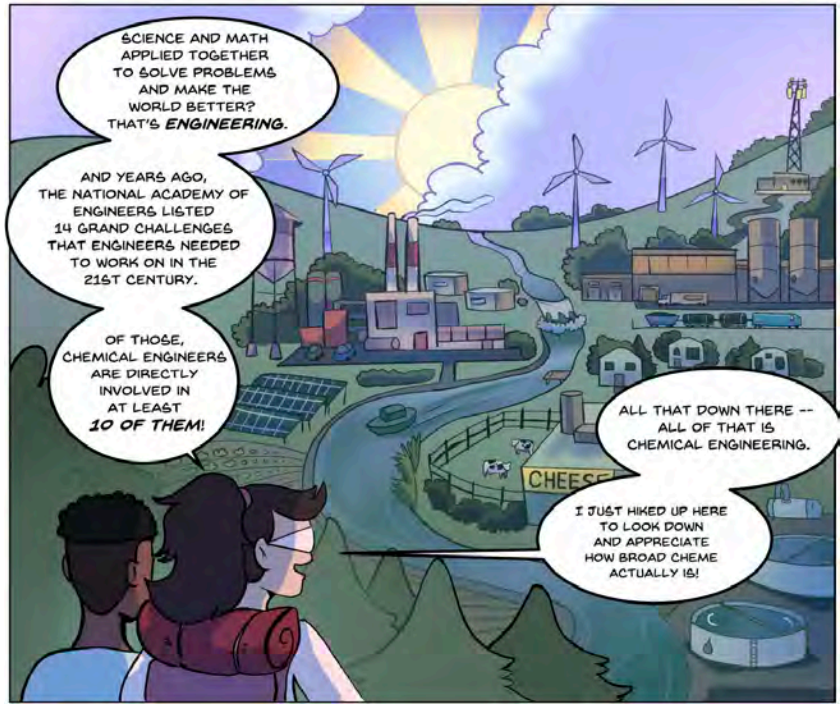
WRITTEN BY: IRA HYSI AND LUKE LANDHERR

DRAWN BY: MONICA KESZLER

AIChE The Global Home of Chemical Engineers | DOING A WORLD OF GOOD | AIChE K-12








NATIONAL ACADEMY OF ENGINEERING NAE GRAND CHALLENGES FOR ENGINEERING

https://www.northeastern.edu/landherr/stem-comics/cheme-comic/; https://www.northeastern.edu/landherr/stem-videos/crash-course-engineering/

Make solar energy economical

Provide energy from fusion

Develop carbon sequestration methods

Manage the nitrogen cycle

Provide access to clean water

Restore and improve urban infrastructure

Advance health informatics

Engineer better medicines

Reverse-engineer the brain

Prevent nuclear terror

Secure cyberspace

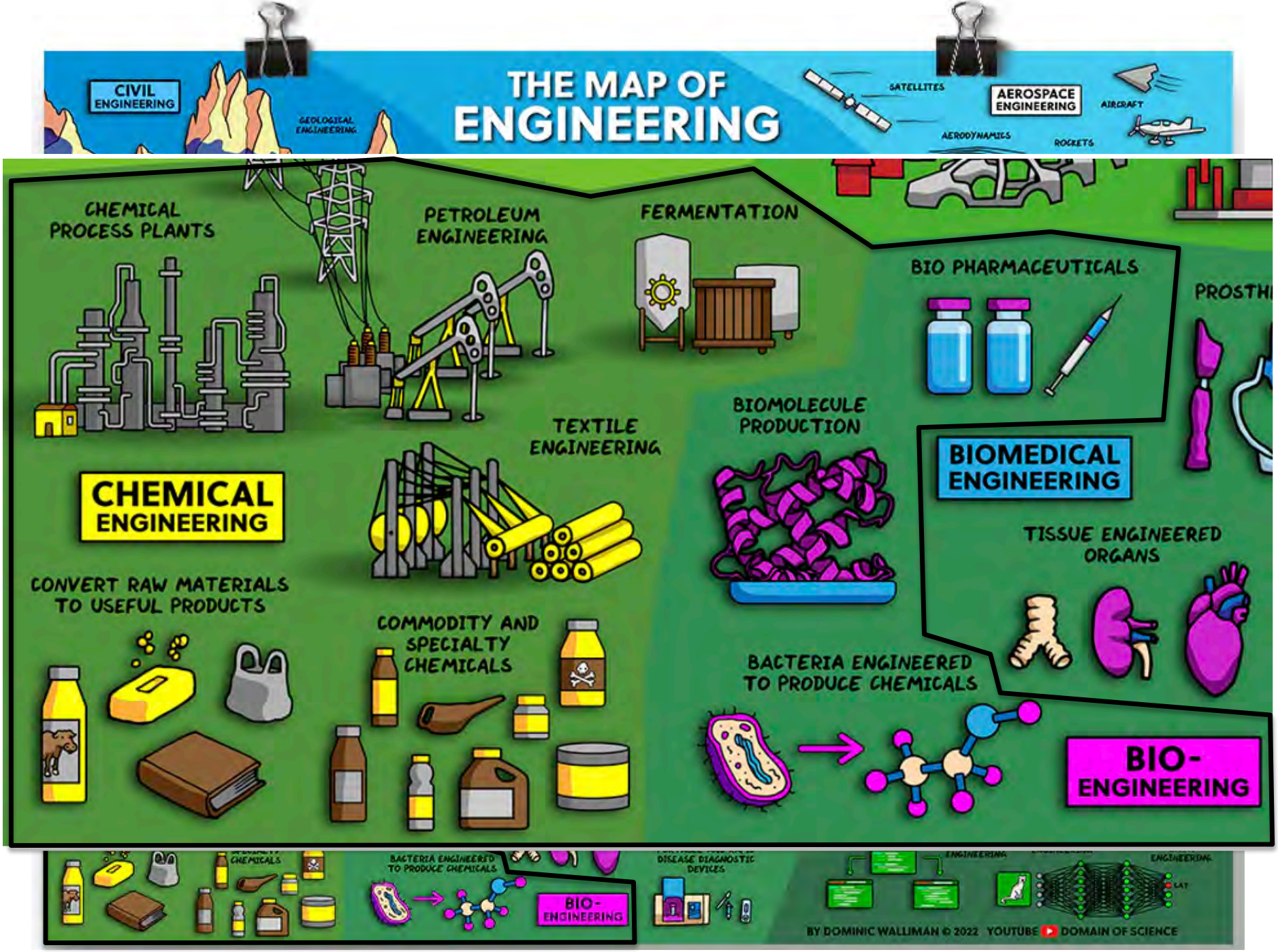
Enhance virtual reality

Advance personalized learning

Engineer the tools of scientific discovery

GRAND CHALLENGES FOR ENGINEERING

https://www.engineeringchallenges.org

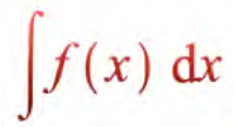


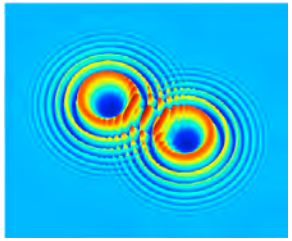

Domain of Science: The Map of Engineering (https://www.youtube.com/watch?v=pQgxiQAMTTo)

# What is Chem-Bio Engineering?

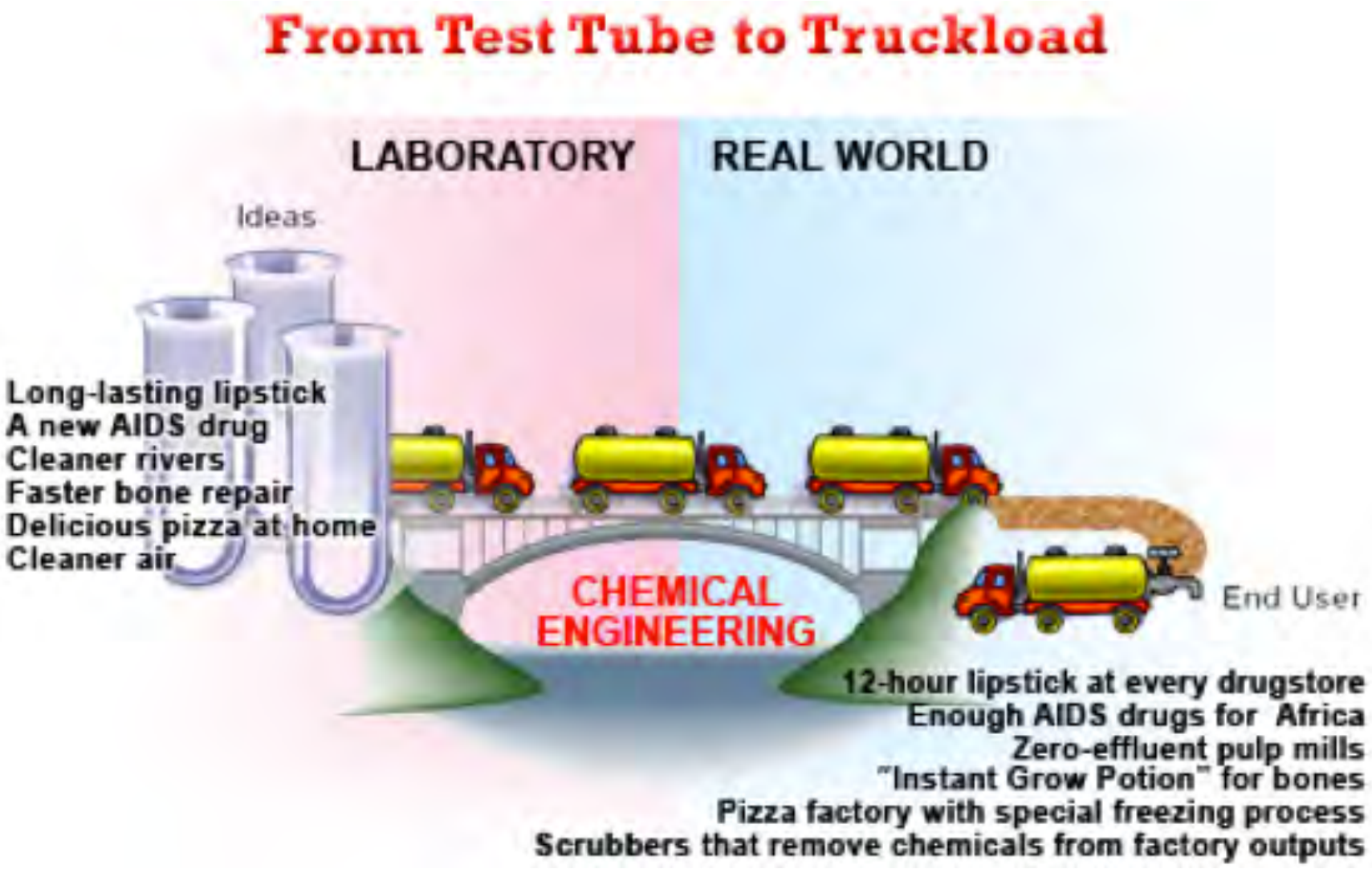
- No universal definition…

- CBE's apply basic sciences – math, chemistry, physics & biology – and engineering principles to understand, develop, design, operate & maintain processes that: **convert raw materials to desired products, and improve quality of life in a sustainable manner!**

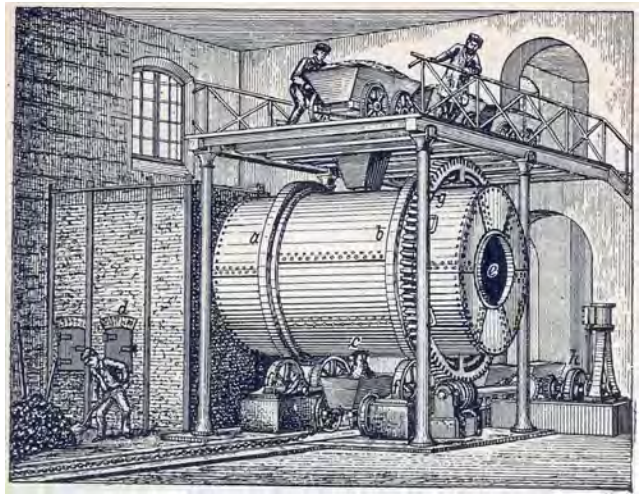


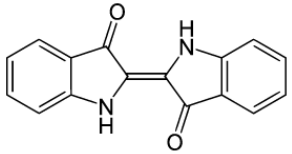

# CBE: Bridge Between The Laboratory & Real World



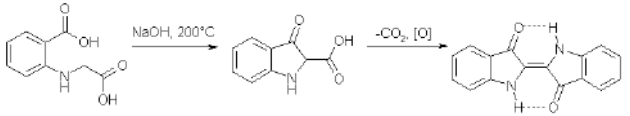
# Historical Origins of Chemical Engineering



- **Scale-up** of chemical processes during industrial revolution



- Principles of operation of simple chemical reactions as batch processes (or **unit operations** like distillation)



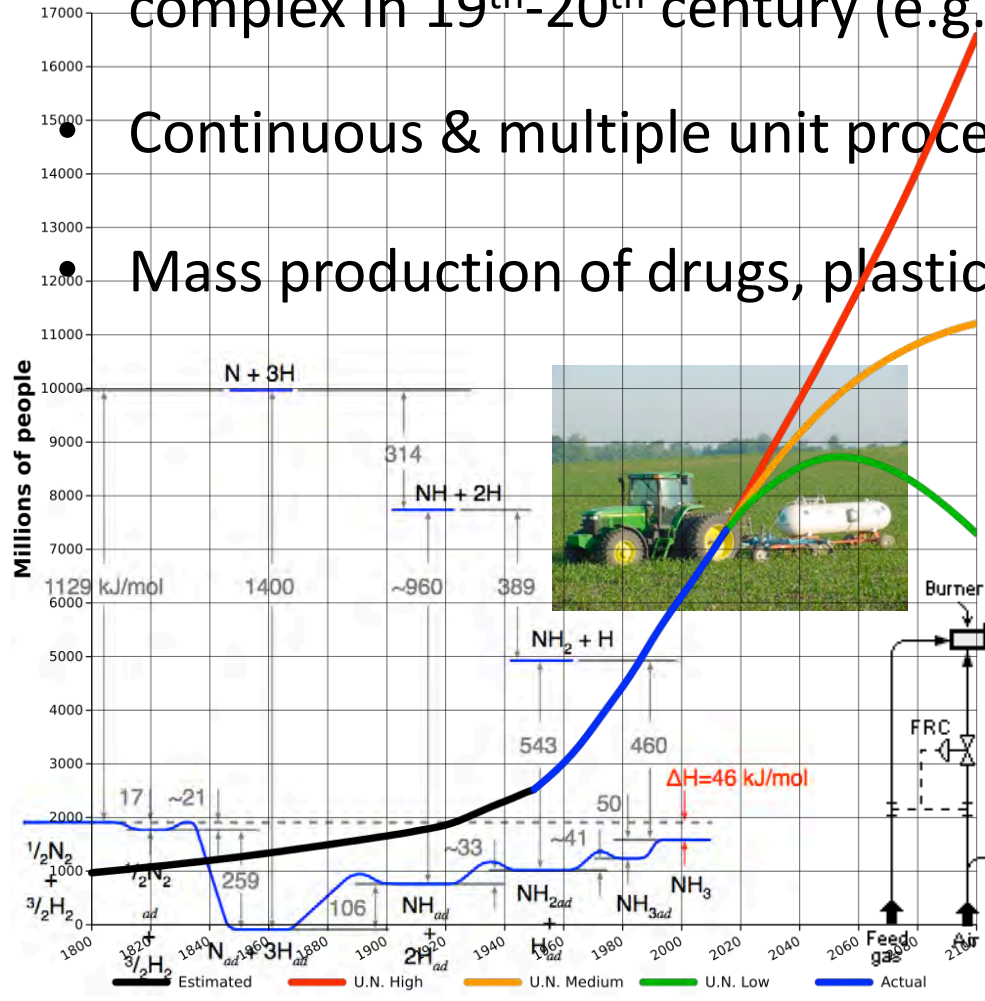

- Initially, chemists & mechanical engineers worked together (18th century)

*BASF Indigo Plant*

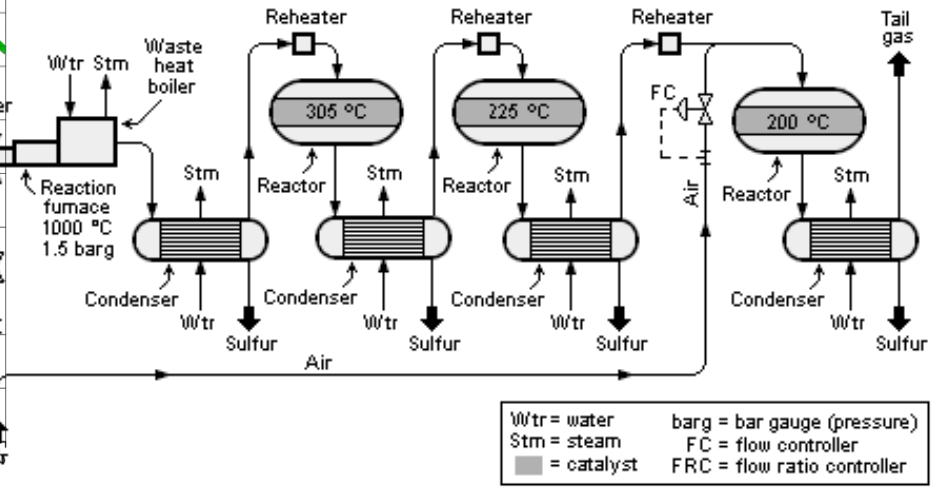
- Complicated chemistry demanded new concepts and innovations by 19th century

# Petro-Agrochemical Revolution Made Possible by ChemE

- Chemical engineering developed as processes became more complex in 19th-20th century (e.g., Haber-Bosch Process)
- Continuous & multiple unit processes, control and safety designs
- Mass production of drugs, plastics, chemicals…& electronics/chips!

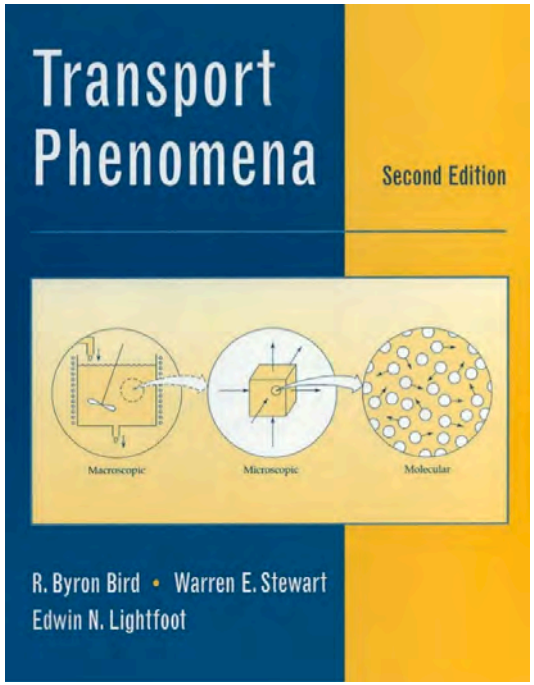


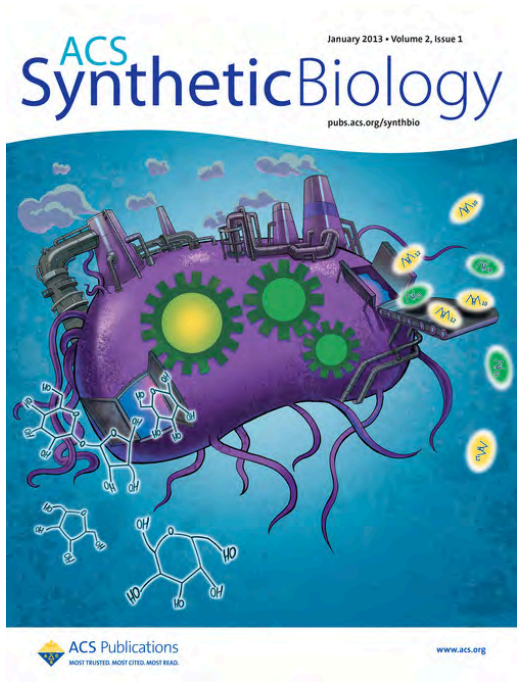


# Evolution over last 60 yrs...

- 1960s – advanced mathematical methods
- 1970s – biochemical & biomedical applications
- 1980s – advanced computational methods
- Present day – highly interdisciplinary (e.g., nanotechnology, biotechnology, genetic engineering, materials engineering)



# So, who is a chemical engineer?

One who applies principles of chemistry, math, physics, and biology to problems relevant to chemical, biological, biomedical, energy, environmental, food, and pharmaceutical systems

ChE courses are ~ Mech Eng + Chemistry/Bio

**Materials Sci & Eng**

**Product**

**Hard Materials**

**Microscopic**

**What's the Difference?**

**Chemical Engineering**

**Process**

**Soft Materials**

**Micro and Macro**

**Large systems**

~ Industrial-Process Eng + Chemistry (+ Biology)

# CBE Student Societies & Clubs

# American Institute of Chemical Engineers (AIChE)

AIChE is a student organization that helps foster a sense of community within the department through professional development and social events

*Resume Critiquing*

*Alumni Panels*

*Industry Panels*

*Holiday Party*

*Coffee with Professors*

*VBA Workshops*

AIChE The Global Home of Chemical Engineers

# Omega Chi Epsilon (ΩXE): The Chemical Engineering Honor Society

Events focus on Professionalism, Academics, and Chapter Development:

# Chem-E Car Club

Club members participate at AIChE competitions where teams design and construct a car that must:

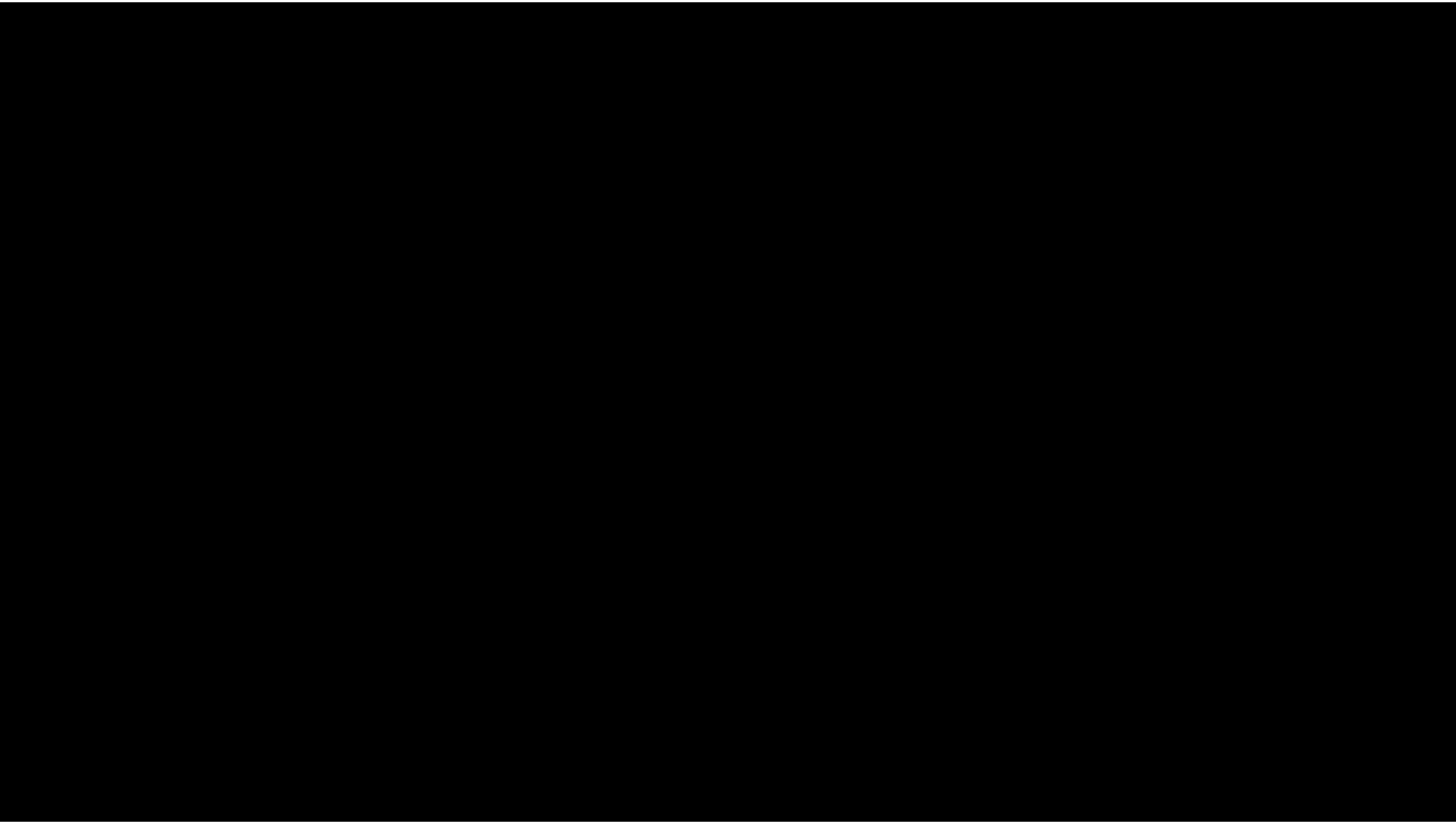
- **Be powered by chemical energy sources**
- **Carry a specified load**
- **Be able to stop after a certain distance**

In 2018 and 2019 Rutgers placed in the **Top Five** in the regional competition.

In October of 2018, Rutgers placed **Second** in the national competition.


https://www.youtube.com/watch?v=rOuycSo-NQk (Rutgers Knight Wagon Video from 2018 AIChE National Competition)

# Introducing Knight Wagon!



https://www.youtube.com/watch?v=rOuycSo-NQk (Rutgers Knight Wagon Video from 2018 AIChE National Competition)

# Professional Opportunities


Business & Finance

Other Industry

Environmental Engineering

Research & Testing

Design & Construction

Pulp & Paper

Pharmaceutical & Biotechnology

Fuels

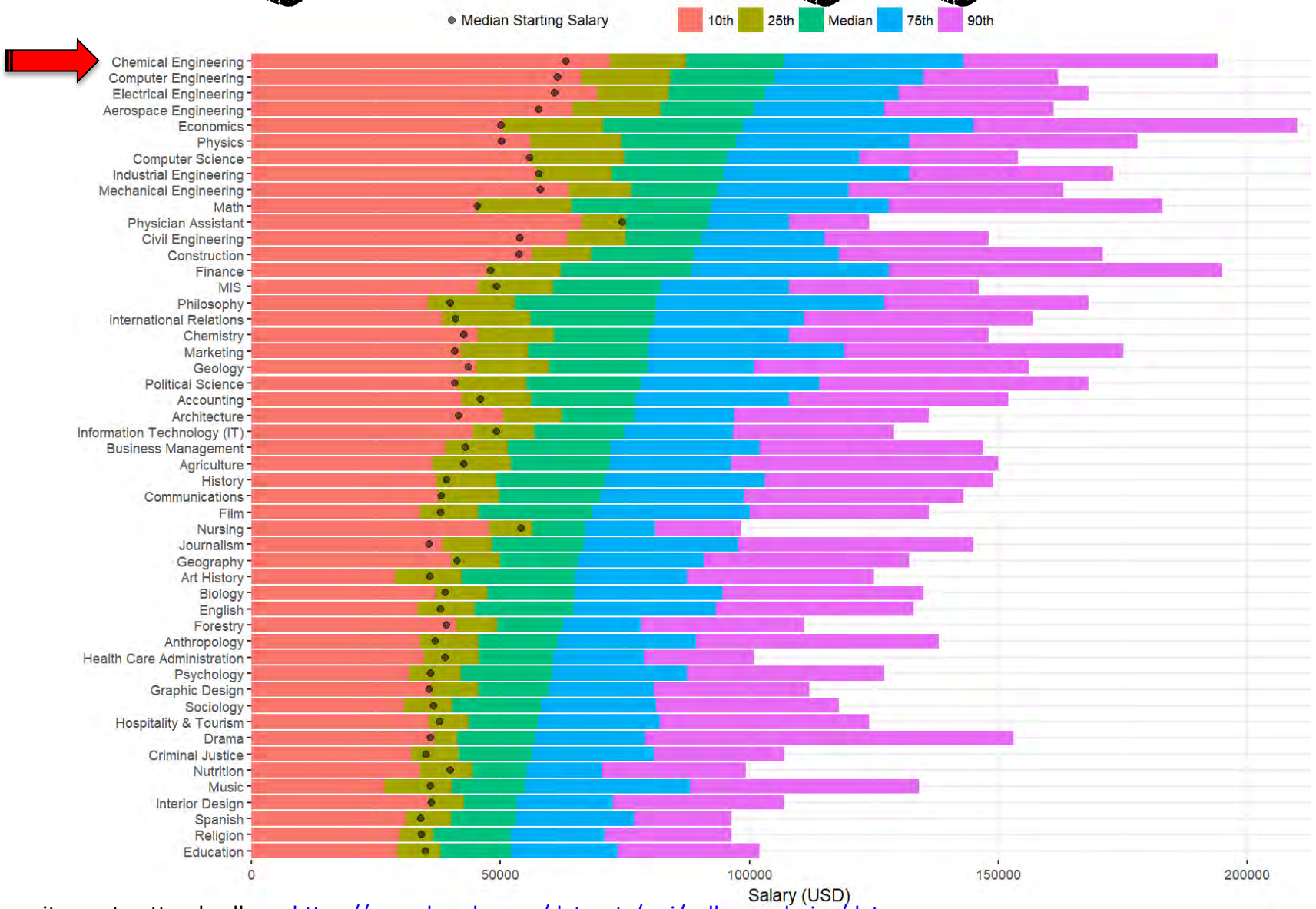
Materials

Food/Consumer Products

Electronics

- Rubber
- Plastics
- Textiles
- Metals
- Minerals
- Agricultural
- Cosmetics
- . . .

# ChemE's earn highest salaries amongst all college graduates

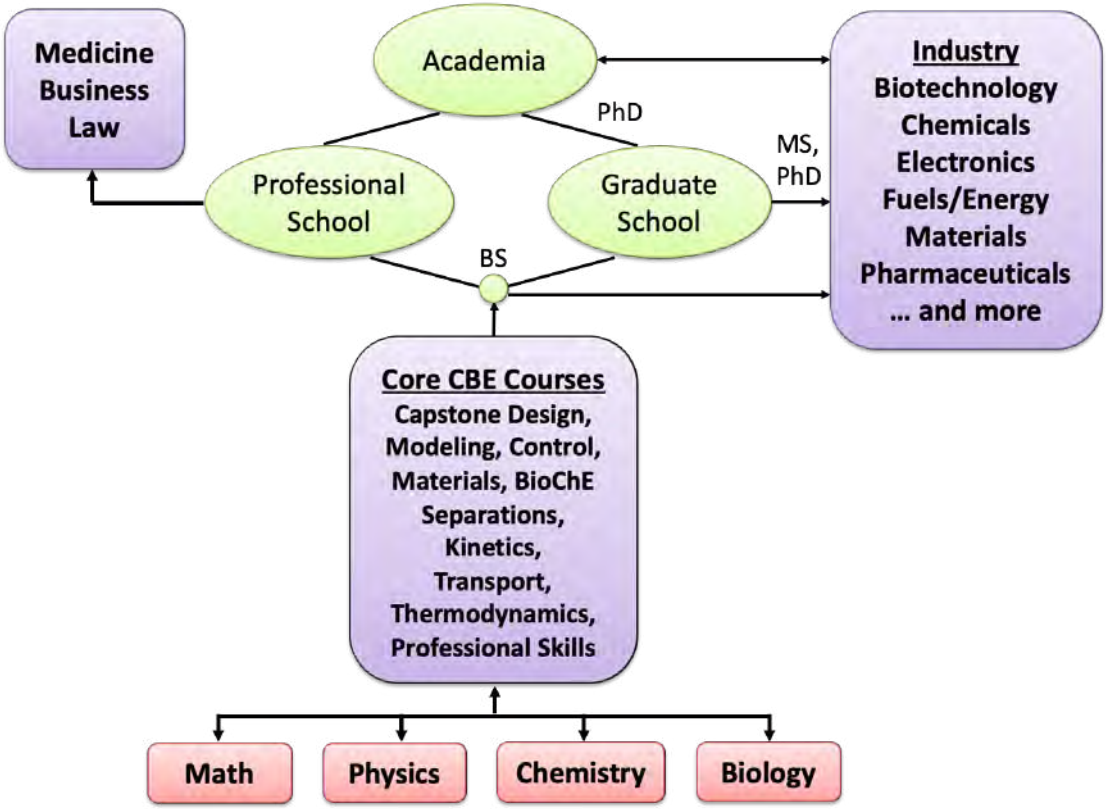



Where it pays to attend college: https://www.kaggle.com/datasets/wsj/college-salaries/data

# CBE Prepares Students for Post-Grad Options

**Data on the 2023 Senior Class**

- **76%** of students in the senior year have completed **internships**
- **62%** of students in the senior year have **research** experience
- **93%** have had either **one or both** of those experiences



# RU CBE students work at...









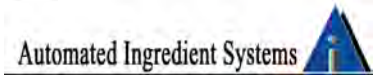


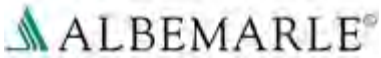





…and many more companies in the US around the world

# RU CBE Industry Partners

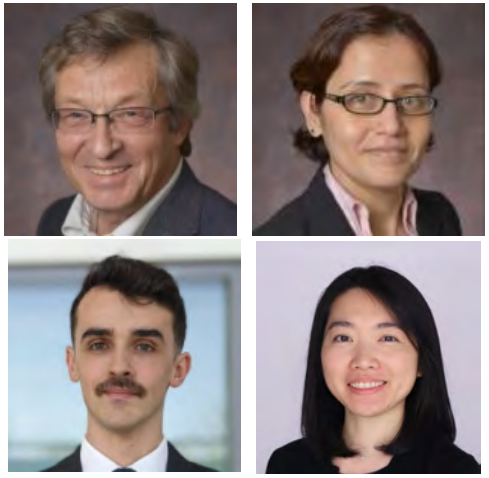





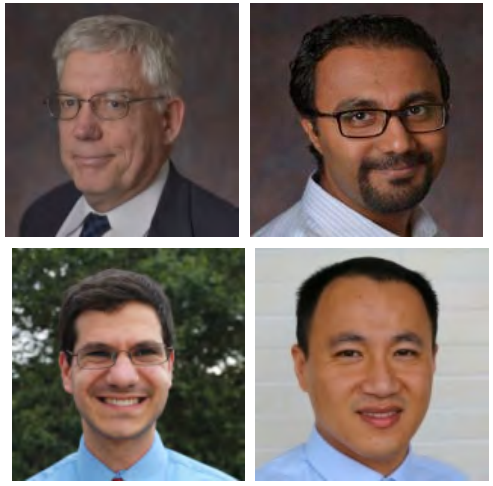
## Nanomedicine, Drug Delivery, & Systems Biology

## Pharmaceutical Engineering

## Molecular Simulations, Computing, & Data Sciences



## Bioengineering, Bioimaging, & Industrial Biotechnology



## Sustainability, Catalysis, & Process Systems Engineering

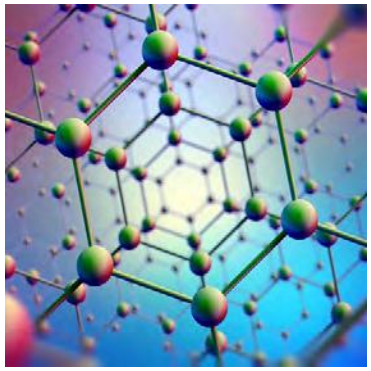
- Translational Nanomedicine
- Biotech for Waste Upcycling
- Advanced Bio/Manufacturing
- Pharmaceuticals Engineering
- Process Systems Engineering
- Industrial Catalysts
- Soft Matter Simulations
- Single-Molecule Biophysics

# Chemical & Biochemical Engineering Faculty

CBE Highlights

- *24 Faculty (TT and Non-TT)*
- *6 Women Faculty (#1 in SOE)*
- *4 joint with Biomedical Engineering*
- *1 joint with Chemistry-Chemical Biology*
- *NJ Edison & Inventor of Year Award*
- *Biotech Training Program*
- *NSF Engineering Research Center*
- *NSF Early Career Awards*

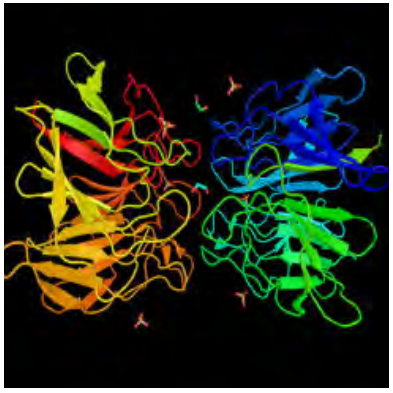
# RU CBE Faculty Expertise



**Biomolecular Engineering**
Androulakis, Chundawat, Dignon, Dutt, Guo, Moghe, Roth, Schuster, Zhang

**Pharmaceutical Engineering**
Chundawat, Dignon, Glasser, Muzzio, Ramachandran, Razavi, Roth, Schuster, Scicolone, Singh, Tomassone, Tsilomelekis, Zhang

**Clean Energy and Sustainability**
Asefa, Celik, Chundawat, Dignon, Guo, Hildebrandt, Neimark, Shapley, Tsilomelekis, Zhang



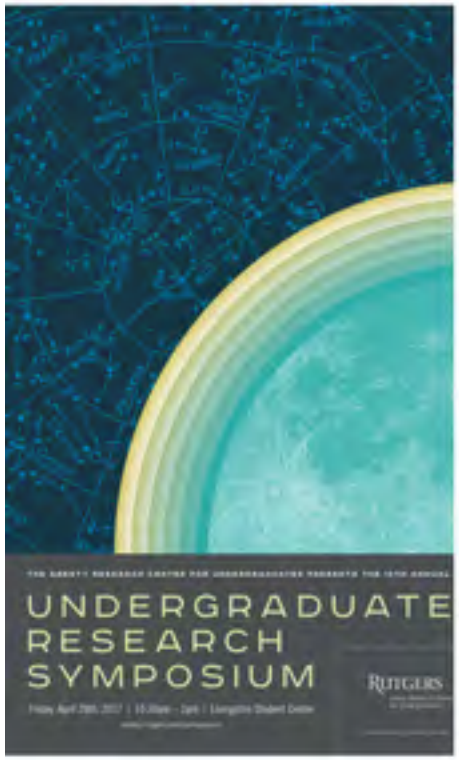
**Soft Matter and Advanced Materials**
Asefa, Celik, Chundawat, Dignon, Dutt, Guo, Neimark, Schuster, Shapley, Tomassone, Tsilomelekis

**Computing and Data Sciences**
Androulakis, Celik, Dignon, Dutt, Glasser, Guo, Hildebrandt, Neimark, Ramachandran, Tomassone

# Aresty Research & Honors Program Opportunities

CBE Honors Academy & Aresty Research Options for Undergrads:

- 1 year as Aresty Research Assistant (e.g., end of freshman year)
  + 2 years of research
  + Professional and scientific skills development

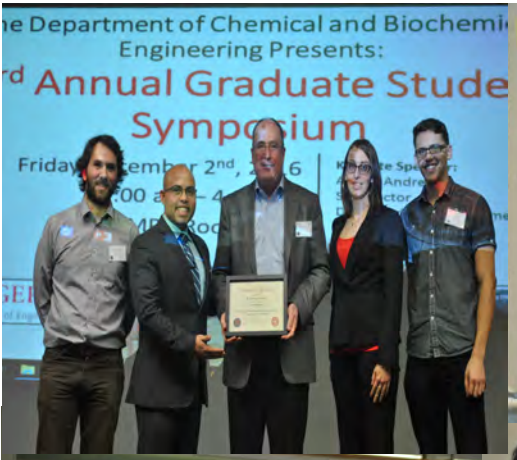


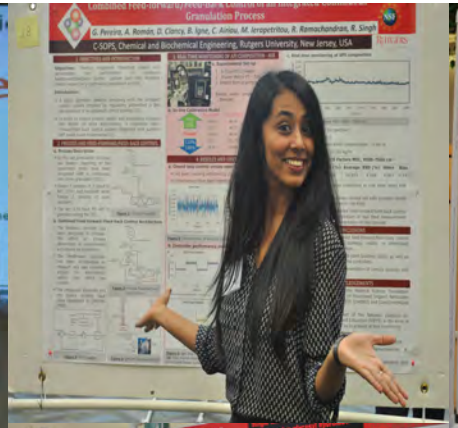

# RU CBE graduate's study at...

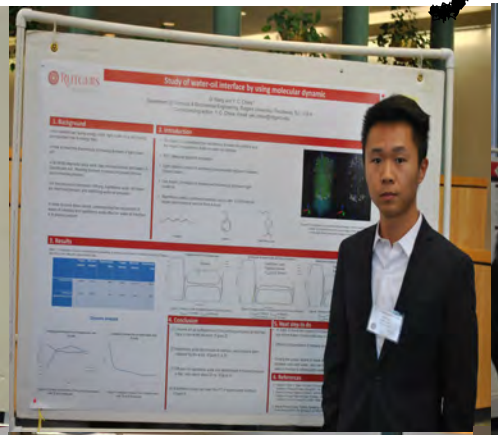


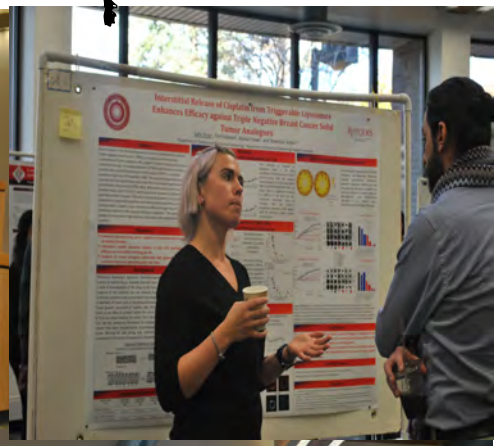
…and many more MS/PhD granting graduate programs including Rutgers

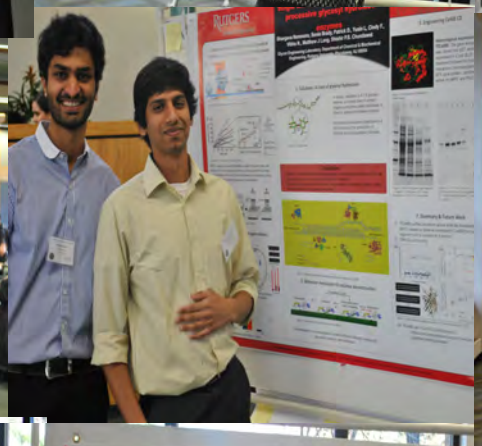
# CBE Students Research Symposium

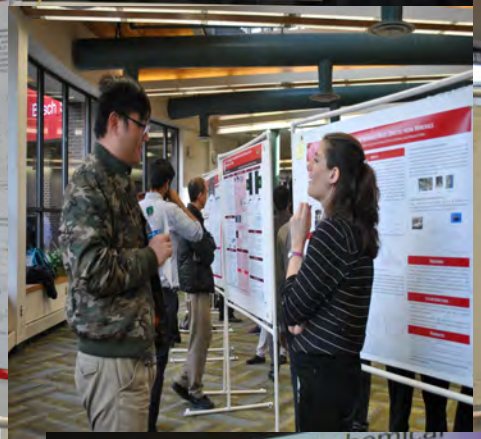


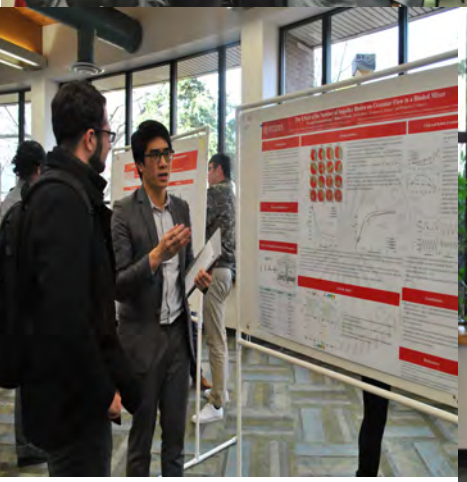



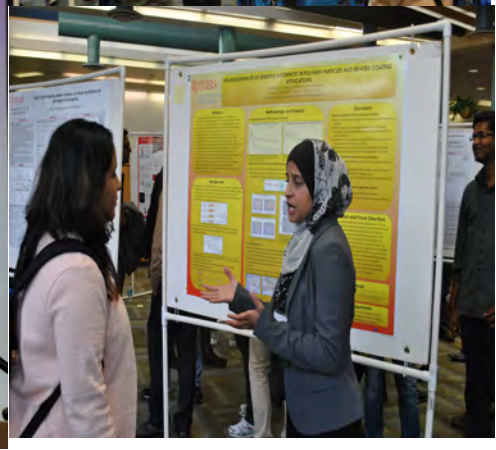




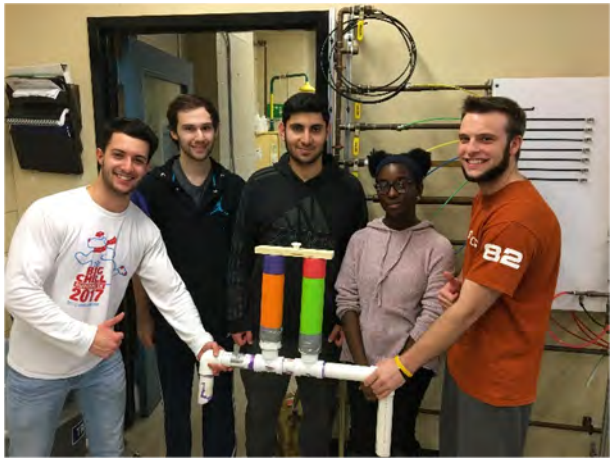


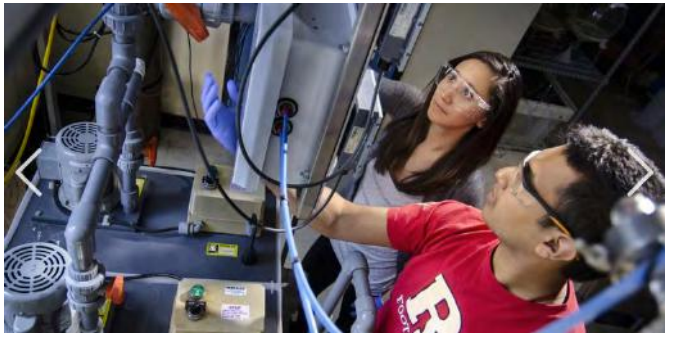


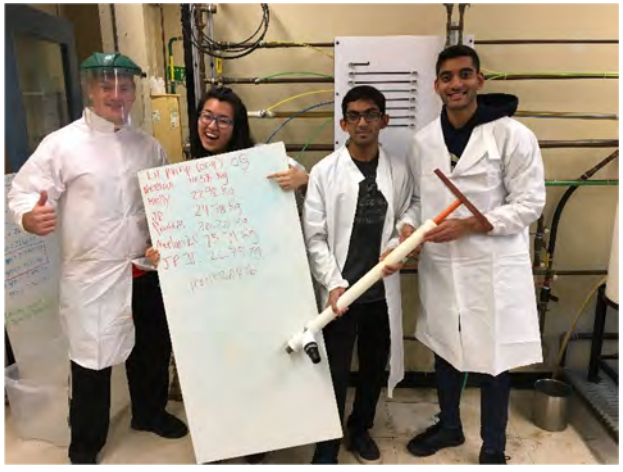


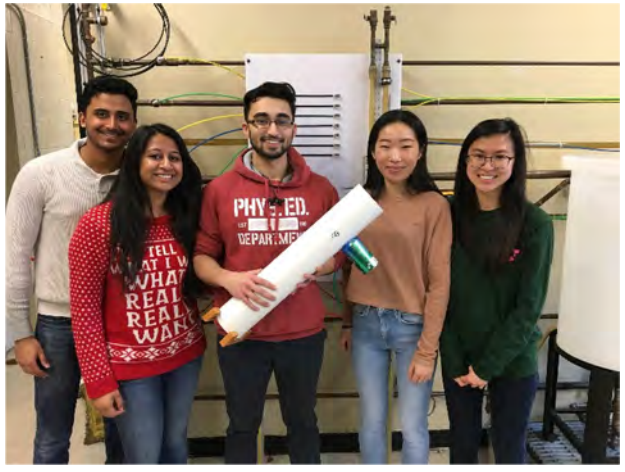



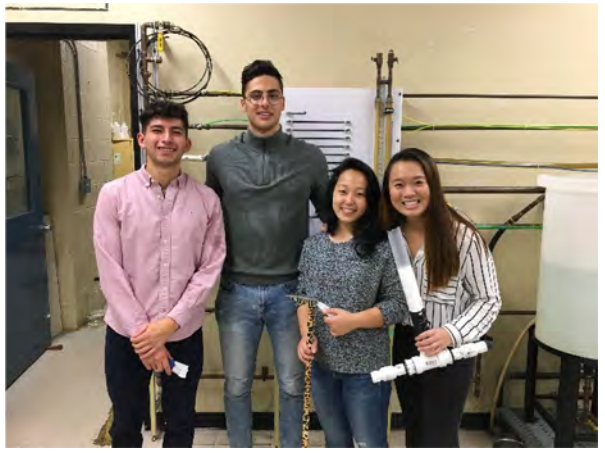
# CBE Undergrads At Work









# How to 'swim' in a sandbox?

https://www.youtube.com/watch?v=My4RA5I0FKs

# Rutgers has top-ranked program in Pharmaceutical Engineering

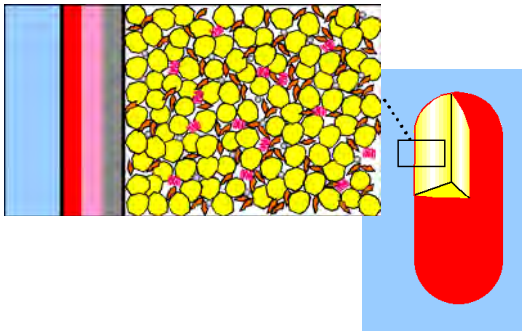
Rutgers Develops Continuous Drug Tablets and Advanced Biologics Manufacturing Processes to Enable Pharma Industry!

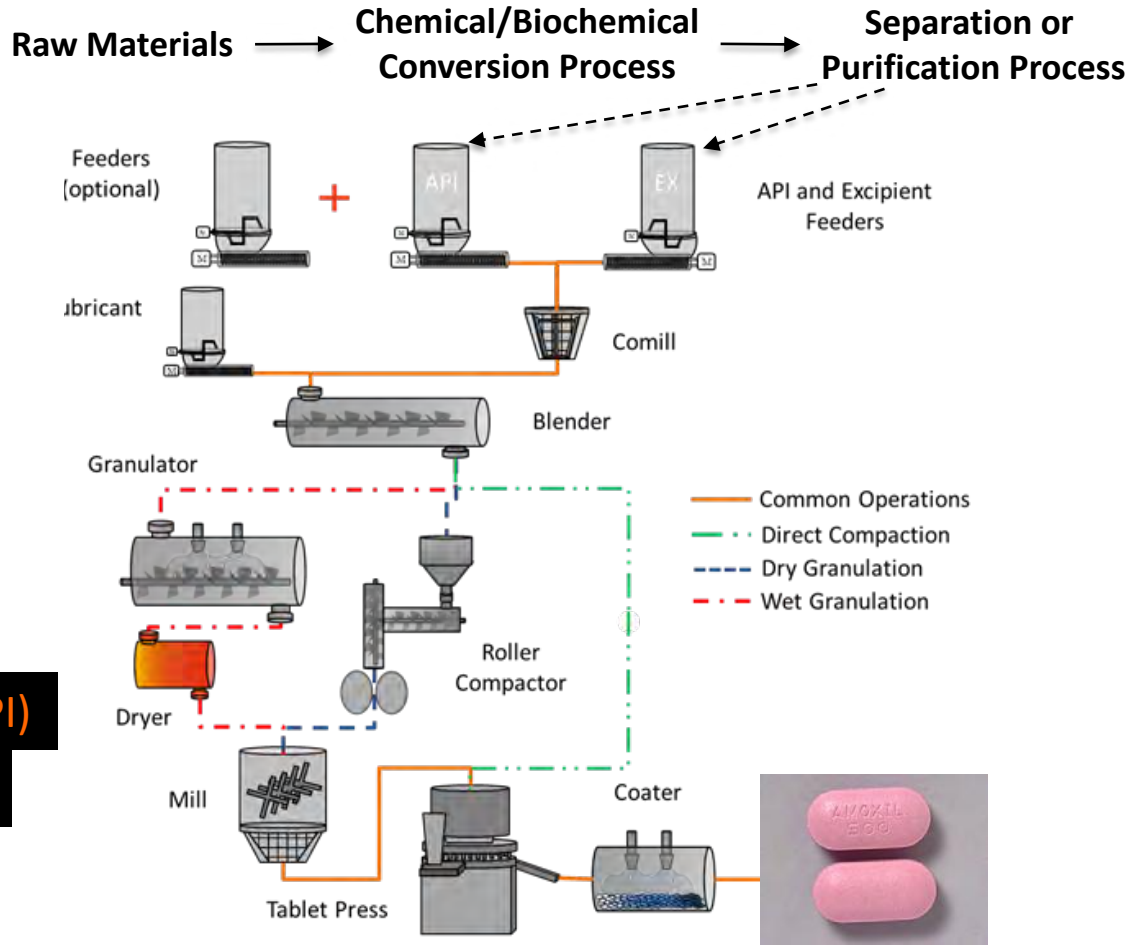


http://www.biopharminternational.com/fda-awards-five-grants-advanced-biomanufacturing-research-0

# Powder Technology in Medicine

- A medicinal product consists of active therapeutic substances (API) and inactive ingredients (Excipients) combined in a delivery system.
- The tablet is the most common delivery system. Other e.g., Injectables, Patches
- The active and inactive ingredients are combined in the form of powders consisting of many fine particles.






Active Pharmaceutical Ingredient (API)

Excipients, Inert Fillers, & Lubricants

Coating

Slide Courtesy: N. Shapley and F. Muzzio (CBE)

# Mixing of fine powder particles is critical to tablet manufacture

Powders are made up of small, solid particles…

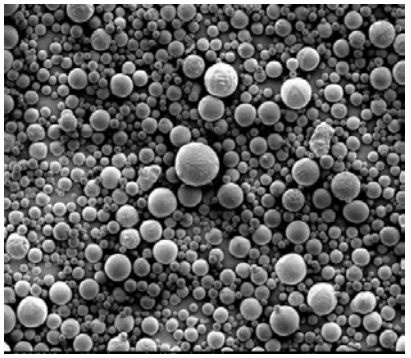


Figure 4-2. Large gravel piles at rock and stone facility near Marblehead, Ohio.

Sometimes powders act like a solid.

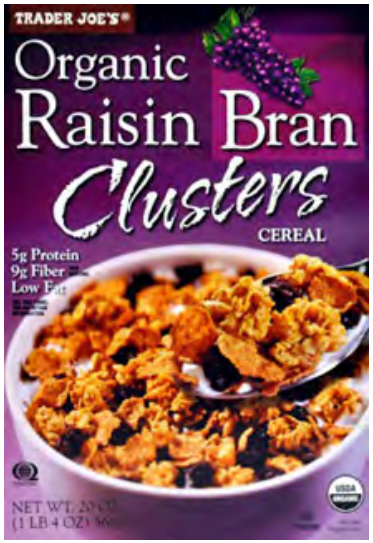
Sometimes powders flow like a fluid.
We call such flows granular flows.

Figure 4-3. Baldy Mountain, Philmont Boy Scout Ranch, New Mexico. The top of the mountain is largely loose rock and stone that prevent plants from taking root.

Y.-J. Jiang & I. Towhata, Rock Mech. & Rock Eng., 46, 713-729 (2013).

# Why is mixing of solids or powders so difficult?

It is often observed that in a can of mixed nuts, the largest nuts (Brazil nuts) are usually at the top.





We often observe this 'Brazil Nut Effect' when opening a cereal box or package of granola: the largest pieces are at the top, especially if you shake it up first.

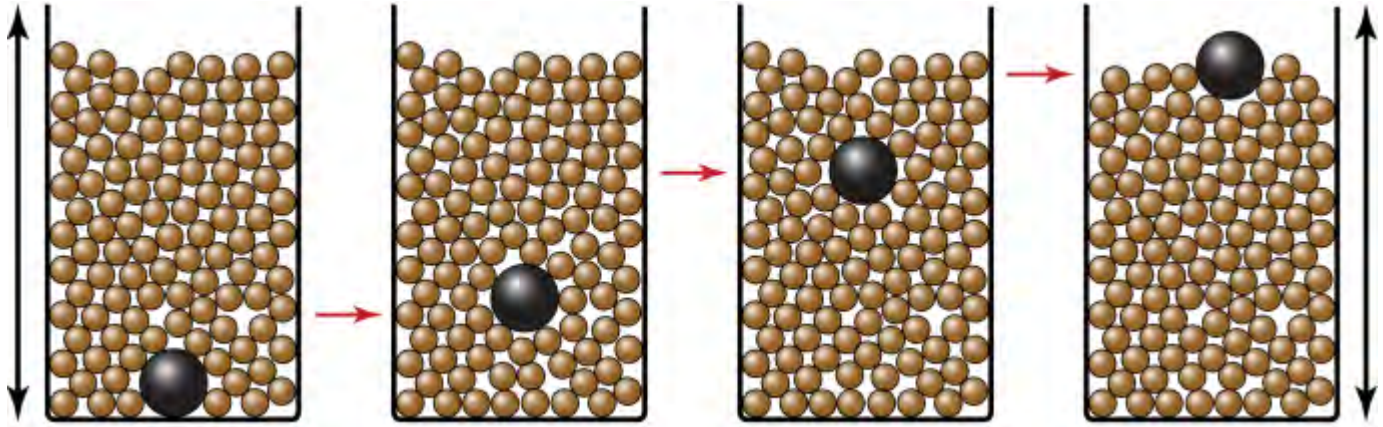
Why does this happen?

Now you will have a chance to experiment with some granular flows in class today!

Particle size separation is a big problem for pharmaceutical manufacturing, where a uniform powder mixture is required

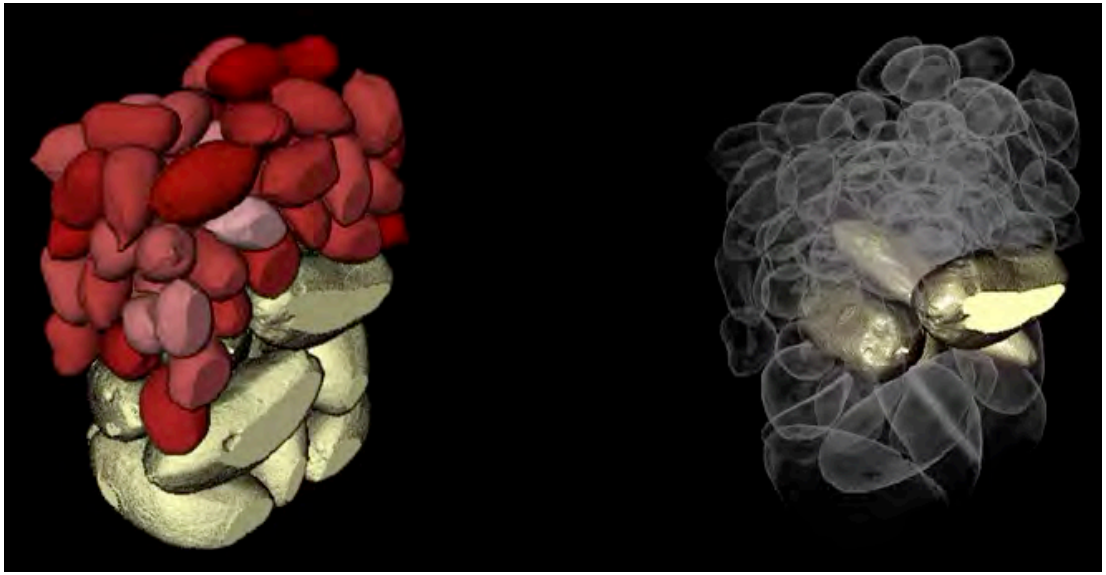
Slide Courtesy: N. Shapley (CBE)

# Why is mixing of solid powder particles so difficult?



Why do the large particles or objects move to the top?

As the large particle moves upward when you shake it up, small particles fall through the gaps that form. Then, the large particle is stuck at a higher position. Eventually, it reaches the top...



https://www.nature.com/articles/s41598-021-87280-1

# Pharmaceutical Powder Blender Designs

## V-blender

## Conical Bin Blender

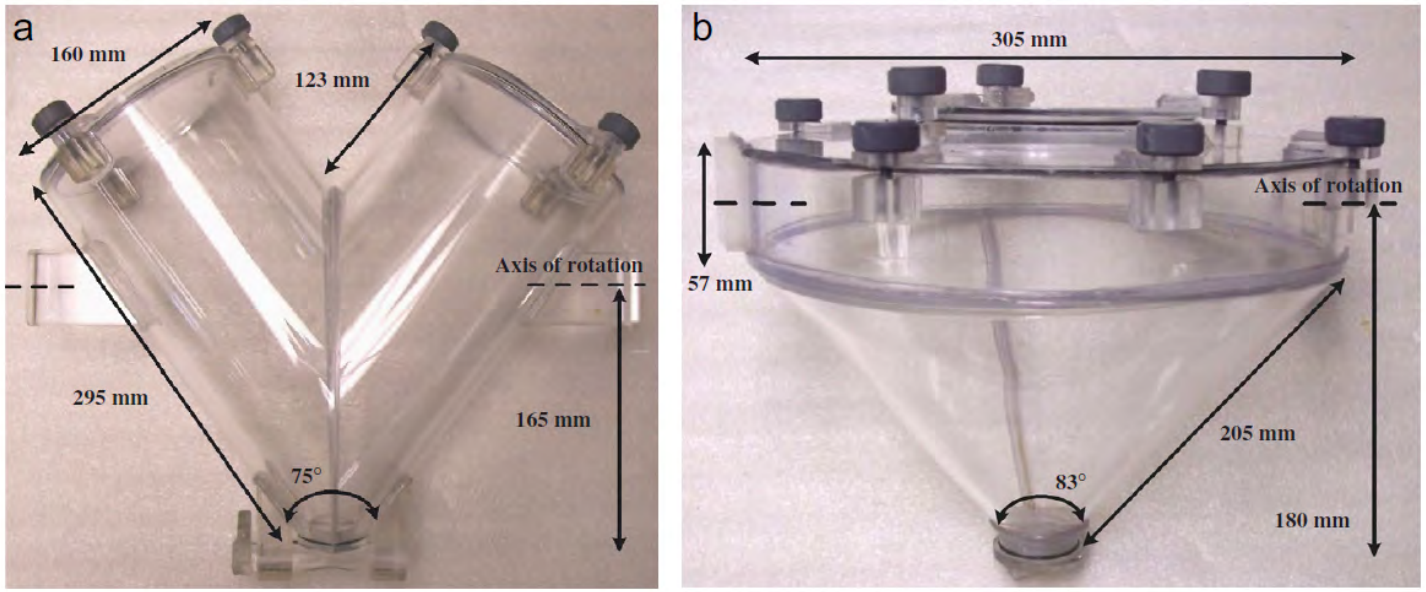


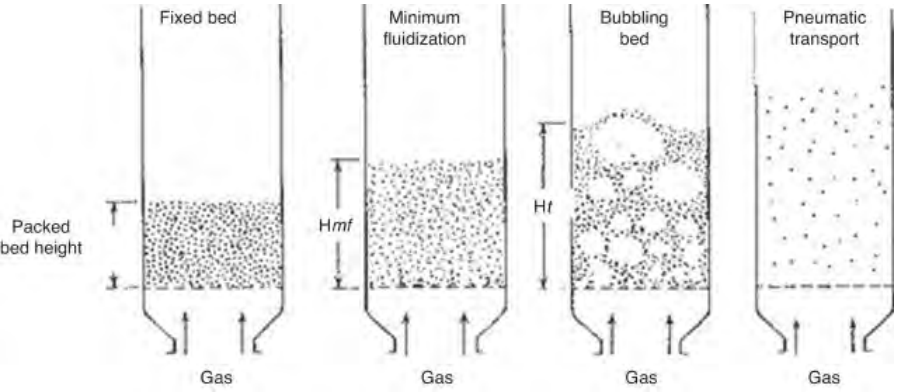

Fig. 1. Blenders used for this work: (a) 7.5-L V-blender and; (b) 7.5-L conical bin-blender.

M. Lemieux et al., Chemical Engineering Science 62 (2007) 1783-1802.

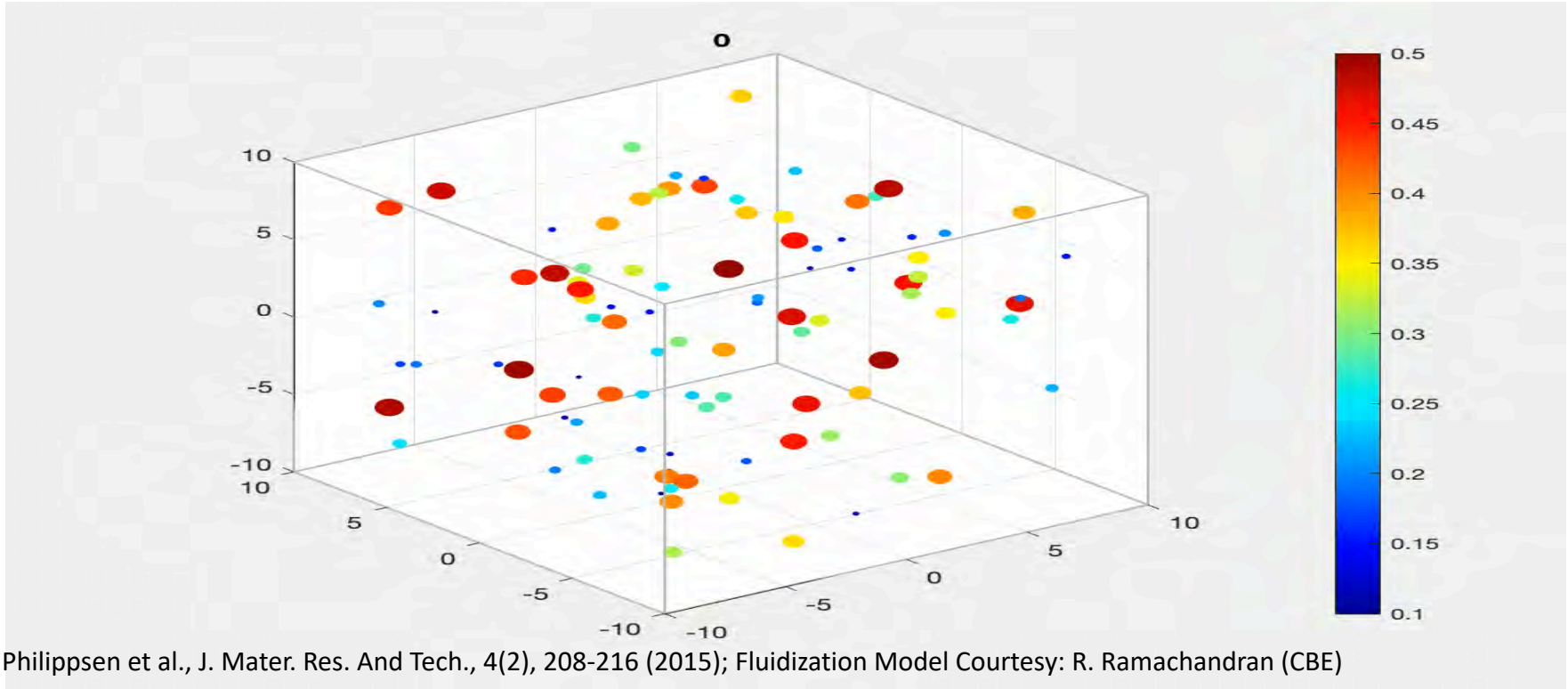
- Powder blending is a key step in tablet manufacturing.
- Need specialized equipment designs to minimize separation of powder particle types during blending.

http://bectochemloedige.com/index.php/machines/blenders/v-blender

# Fluidization of particles in granulation processes

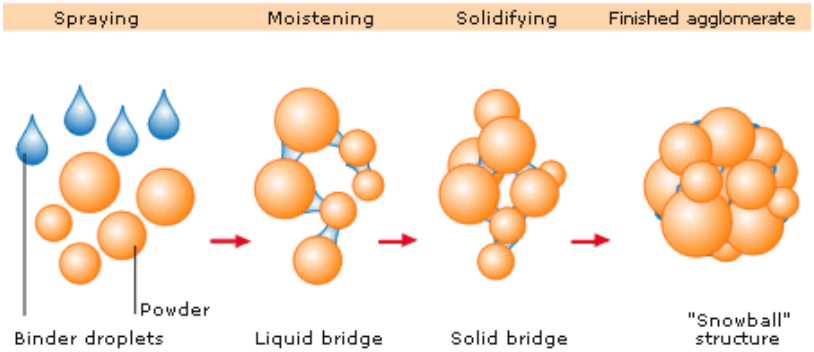



- A fluidized bed is a system where the weight of powder particles is supported by flow of a gas or liquid and the particles are suspended in the flow
- Drag force of fluid flow equals force of gravity on each particle
- Applications: Catalysis, Pharma Manufacturing

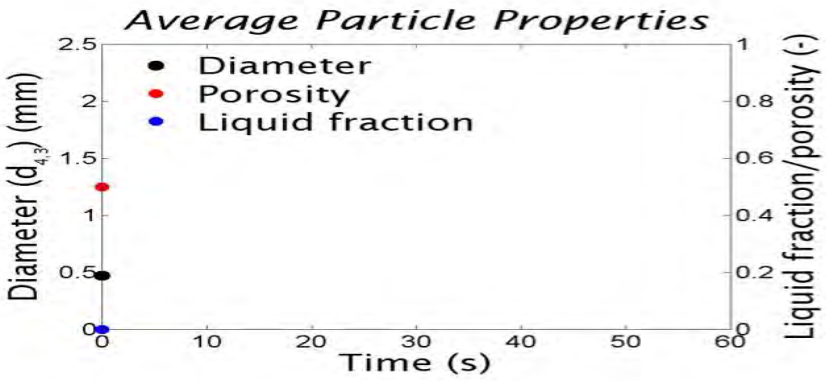


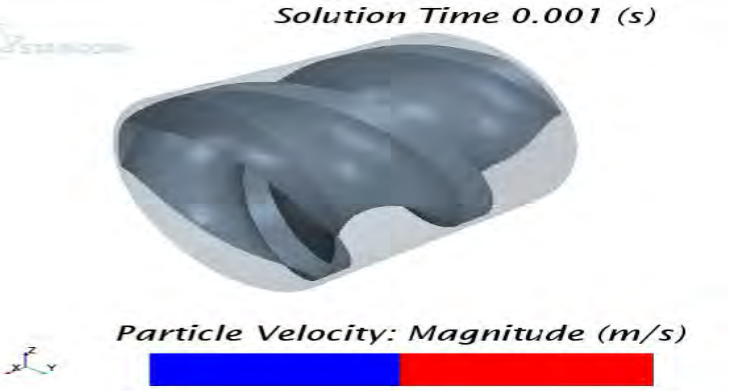

C.G. Philippsen et al., J. Mater. Res. And Tech., 4(2), 208-216 (2015); Fluidization Model Courtesy: R. Ramachandran (CBE)

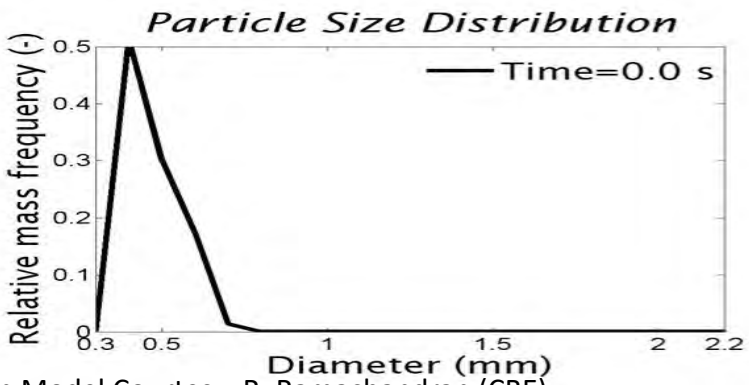
# Granulation models can predict process attributes from particle-scale behavior

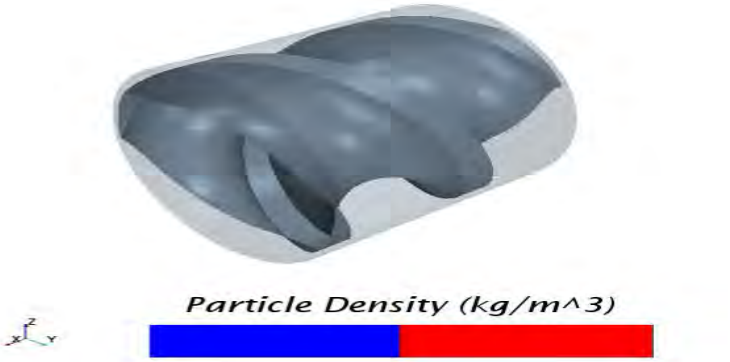



- Sticky or hard to mix fine powder is clustered together with liquid to form freely flowing granules in wet granulation process, unlike dry granulation processes



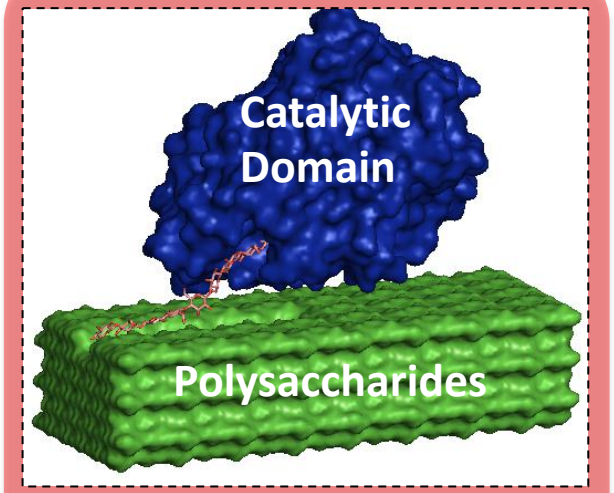



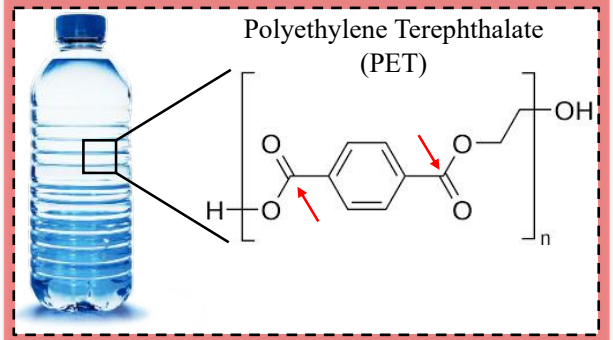




Granulation Model Courtesy: R. Ramachandran (CBE)

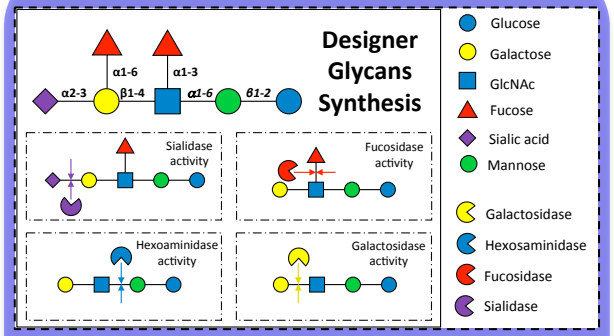
# Chundawat Lab Research Themes at Rutgers CBE:
# Waste Upcycling, Accessible Healthcare, Biophysics of Life



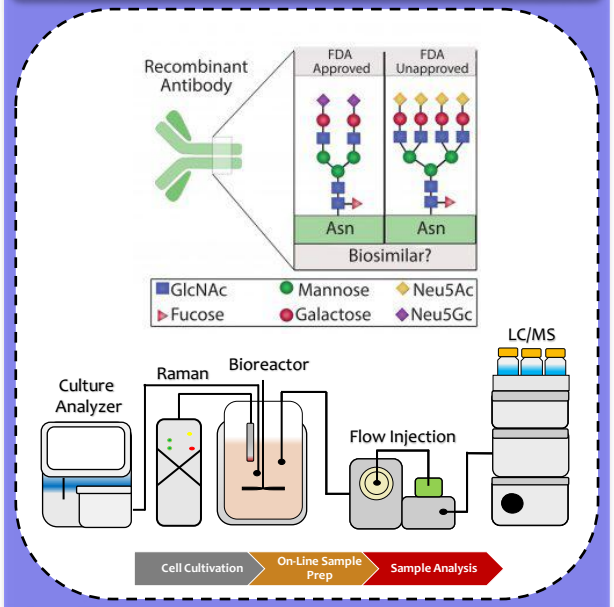

Carbohydrate-Active enZymes for waste biopolymers hydrolysis



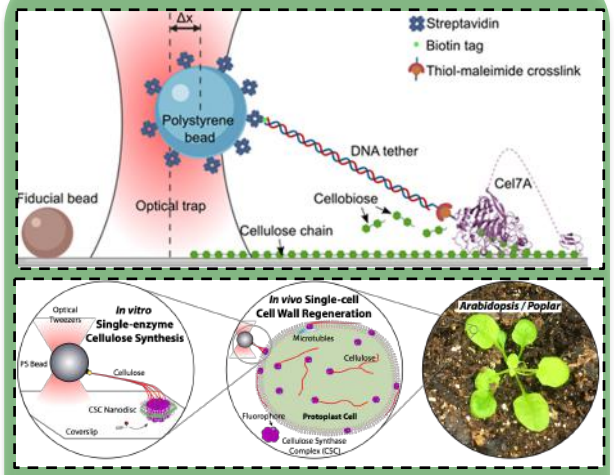

Protein engineering for waste plastic polymers upcycling



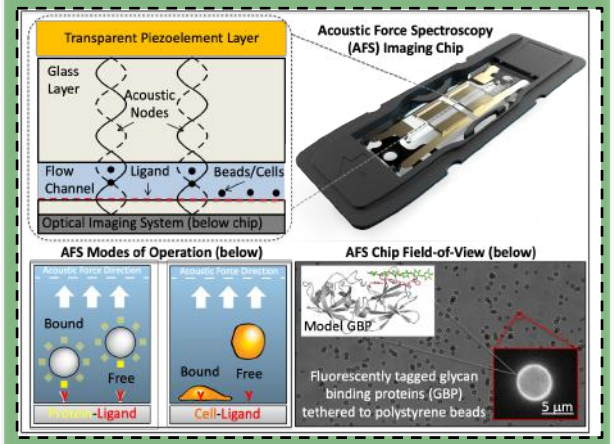

Glycoengineering toolkit for designer prebiotics & antibiotics




Continuous manufacturing & process analytics for biologics

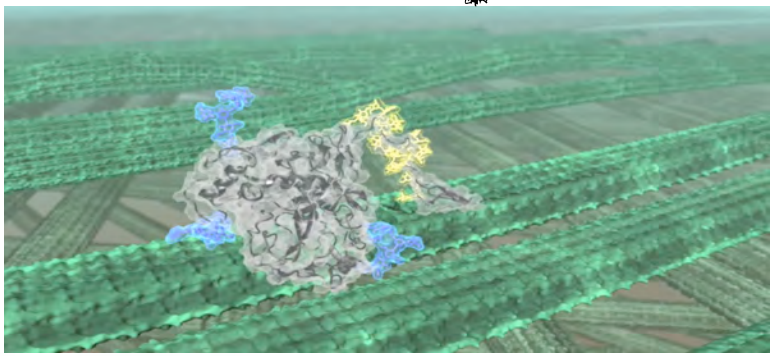


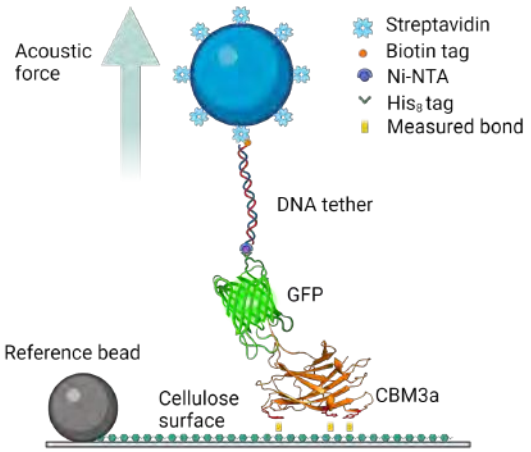

Visualizing cell wall polymers biosynthesis & hydrolysis

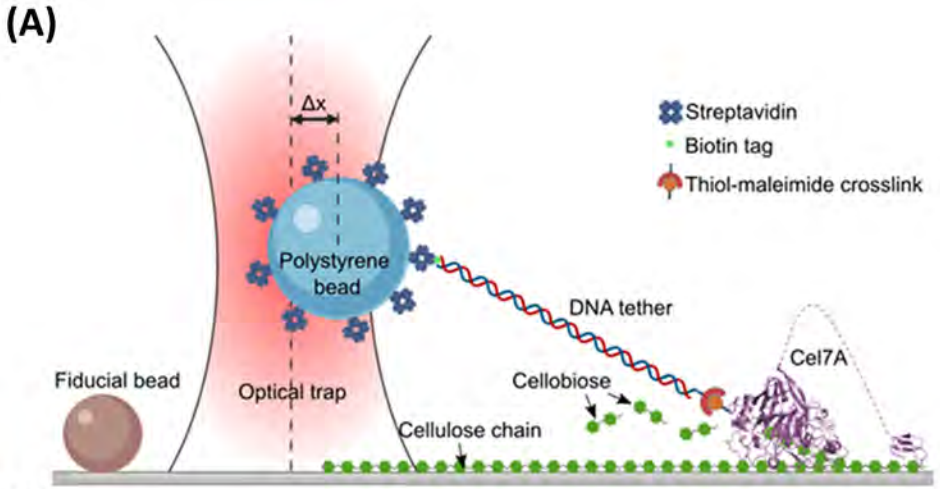


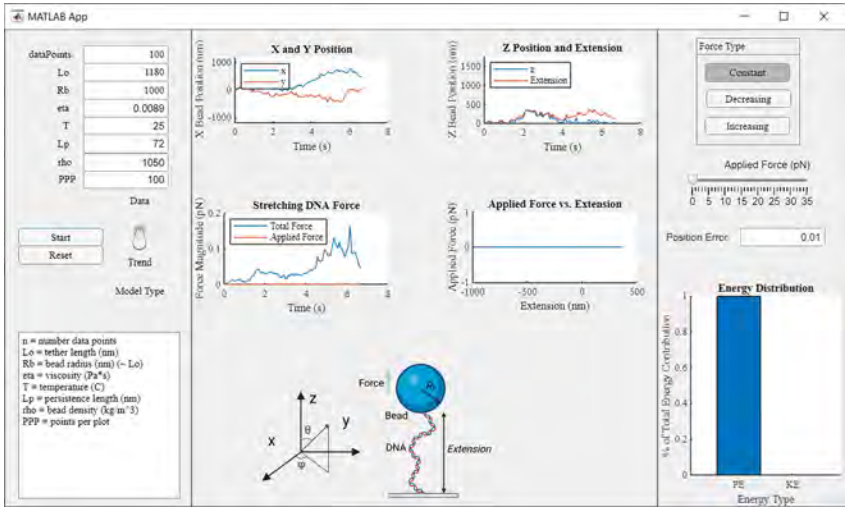

Force spectroscopy enabled enzyme & cellular engineering

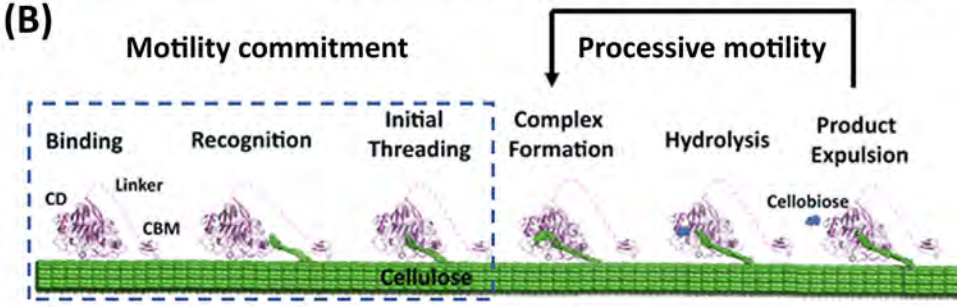
# Single-molecule bioengineering enabled by single-particle tracking




**Download MATLAB App to simulate & visualize tethered single-particle motion under applied forces!**

https://github.com/ChundawatLab/TPM-GUI

https://www.biorxiv.org/content/10.1101/2022.08.31.506066v1

Chundawat et al 2021 JBC, Markus et al. 2022 PNAS, Animations Courtesy NREL & LUMICKS

# Thank you for your attention!

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