ChE 170  F11
Engineering Cell Biology
T Th  11-12:15

Prof. Patrick Daugherty

TA: Serra Elliot
109C topics that you should already know

- Carbohydrates & lipids
- Amino acids, peptides, and proteins
- Mechanisms of catalysis
- Nucleosides, nucleotides, and nucleic acids
Old view:
Chemistry and physics are the foundational sciences for Chemical Engineering.

New view:
Biology is a foundation for Chemical Engineering on equal footing with chemistry and physics.
Modern engineers often use molecular and cell biology

Biological Engineering & Biotechnology

• Alternative Energy; Biofuels production: ethanol, cellulosic conversions, sugar to alkanes
• Metabolic engineering; (e.g., artimisinin)
• Systems biology; drug delivery (e.g. insulin), fuels
• Synthetic biology; designer biological systems
• Drug development and production

Chemical Engineers are uniquely equipped to address these problems, using kinetics, thermodynamics and transport phenomena.
Novel Thermostable, Highly Active Cellulases by Non-Continuous SCHEMA Recombination

2011 Draper Prize Winners

Frances Arnold (Caltech ChE)
Willem Stemmer

“The Nobel prize of engineering.”

One of the active chimeric enzymes is half prokaryote (red) and half eukaryote (green).

Top: 2D parental sequence alignment showing pieces that come from each parent.

Bottom: The sequences from each parent are contiguous in 3D but not 2D.
Chemical Engineer Jay Keasling awarded a $42 million grant from the Bill & Melinda Gates Foundation, to produce artemisinic acid, a precursor to the anti-malarial drug artemisinin.
Modern engineers often use molecular and cell biology

- Tissue engineering
- Device engineering: Drug pumps, artificial organs
- Drug delivery

Chemical Engineers are uniquely equipped to address these problems, using kinetics, thermodynamics and transport.
Control algorithms enable automated delivery of insulin to Diabetics

Glucose concentration (mmol/L)

- glucose blood levels
- insulin blood levels
- starch-rich food (*[glucose]n)
- sucrose-rich food (*glucose-fructose)

Frank Doyle
UCSB ChE

The Glucose – Insulin Feedback Loop

Measure Glucose
Insulin Delivery
**Delivery of therapeutics** from blood vessels to tumors is influenced by...

*Transport*: convection, diffusion

*Kinetics*: binding, internalization, degradation

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Rakesh Jain  
ChE  
Harvard

Dane Wittrup  
ChE  
MIT
Chemical Engineers have a unique skill set to formulate and solve difficult problems.

Drug delivery to tumor

What is $[AB](t) = \text{??}$
Kinetics and transport are critical to drug metabolism.
Advanced Drug Delivery Systems

Polymers + Drugs

Robert Langer (MIT)  
Draper Prize 2002
Modern engineers often use molecular and cell biology

Biological Engineering

- Tissue engineering
- Device engineering: Drug pumps, artificial organs
- Drug delivery

Advanced Study

- Graduate School
- Law
- Medicine

Chemical Engineers are uniquely equipped to address these problems, using kinetics, thermodynamics and transport.
Biologically assembled materials
A battery built on viruses

Angela Belcher
MIT
Scientist of the Year TIME
McCarther Foundation Award
Biochemical Engineering

- Drugs & antibiotics
- Foods
- Food additives
- Beverages
- Special Chemicals
Fed Batch Mass Balances

Cell \[ \frac{dXV}{dt} = \mu XV \]

Substrate \[ \frac{dSV}{dt} = FS_f - \frac{1}{Y_{X/S}} \mu XV - \frac{1}{Y_{P/S}} q_p X V \]

Product \[ \frac{dPV}{dt} = q_p X V \]

Total Mass \[ \frac{dV}{dt} = F \quad \text{(assumes constant density)} \]

Use Monod Equation for Specific Growth Rate \[ \mu = \frac{\mu_{\text{max}} S}{K_S + S} \]
Le Tour de France
A blood sample is taken

Blood is put on monitor

Insulin is adjusted in the pump according to the monitor reading
Microbial life has been found living:

- in the cold of the Arctic and Antarctic – psychrophiles
- in volcanic vents on land - thermophiles
- on the ocean floor - thermophiles
- in very dry places - Dry and hot, dry and cold
- in hot volcanic vents of the deep ocean - thermophiles
- in rock, deep inside the Earth - rock dwellers
- in severe chemical environments harmful to most life-forms – acid, alkali and salt - acidophiles, alkaliphiles, halophiles
- in high-radiation environments, (e.g. on control rods at nuclear powerplants)
What organism from the hot springs of Yellowstone Park transformed biotechnology, and led to a Nobel prize?
Genomes big or small....

477 genes

mycoplasma

(A) 5 µm

(B) 0.2 µm

Figure 1–14. Molecular Biology of the Cell, 4th Edition.
Figure 1–21. Molecular Biology of the Cell, 4th Edition.
spherical cells e.g., Streptococcus
rod-shaped cells e.g., Escherichia coli, Vibrio cholerae
the smallest cells e.g., Mycoplasma, Spiroplasma
spiral cells e.g., Treponema pallidum
Figure 1–18 part 1 of 2. Molecular Biology of the Cell, 4th Edition.
Figure 1-30. Molecular Biology of the Cell, 4th Edition.
The membrane structure of Gram negative bacteria (e.g. *E. coli*)
Escherichia coli

- Used for production of *first* rDNA biopharmaceutical (Insulin) by Eli Lilly

- Production of bovine growth hormone bGH on ton scale by Monsanto in 1994 ($11.60 /g)

  (both Insulin and bGH require oxidative folding)
Viruses of Bacteria (Bacteriophage)
The applications of baker’s yeast range from ethanol production to the discovery of therapeutic human antibodies.
Yeast Cells Divide by 'Budding'
Fungi

Aspergillus niger

Aspergillus nidulans

Tricoderma harzianum
Figure 1–31. Molecular Biology of the Cell, 4th Edition.
Cell Membranes

Figure 1
The Cell Nucleus

- Nucleolus
- Nuclear Envelope
- Nuclear Pores
- Chromosomes
- Chromatin

Figure 1
Figure 1–23 part 1 of 2. Molecular Biology of the Cell, 4th Edition.
Genome size does not predict organism complexity
Mice remain a critically important model organism
To better understand human disease
Other widely used model organisms include...