ChE 170
Molecular and Cell Biology for Engineers

TuTh 11-12:15

Prof. M. Scott Shell

TA: Sunyia Hussein

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

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the number of civilizations in our galaxy with which communication might be possible

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

rate of star formation / year (in our galaxy) $\rightarrow$ ~ 7

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

fraction of stars with planets $\rightarrow$ ~ 50%

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

average number of life-supporting planets per star with planets $\rightarrow$ ~ 2

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

fraction that actually proceed to develop life $\rightarrow$ ~ 33%

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

fraction that proceed to develop *intelligent* life $\rightarrow$ ~ 1%

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

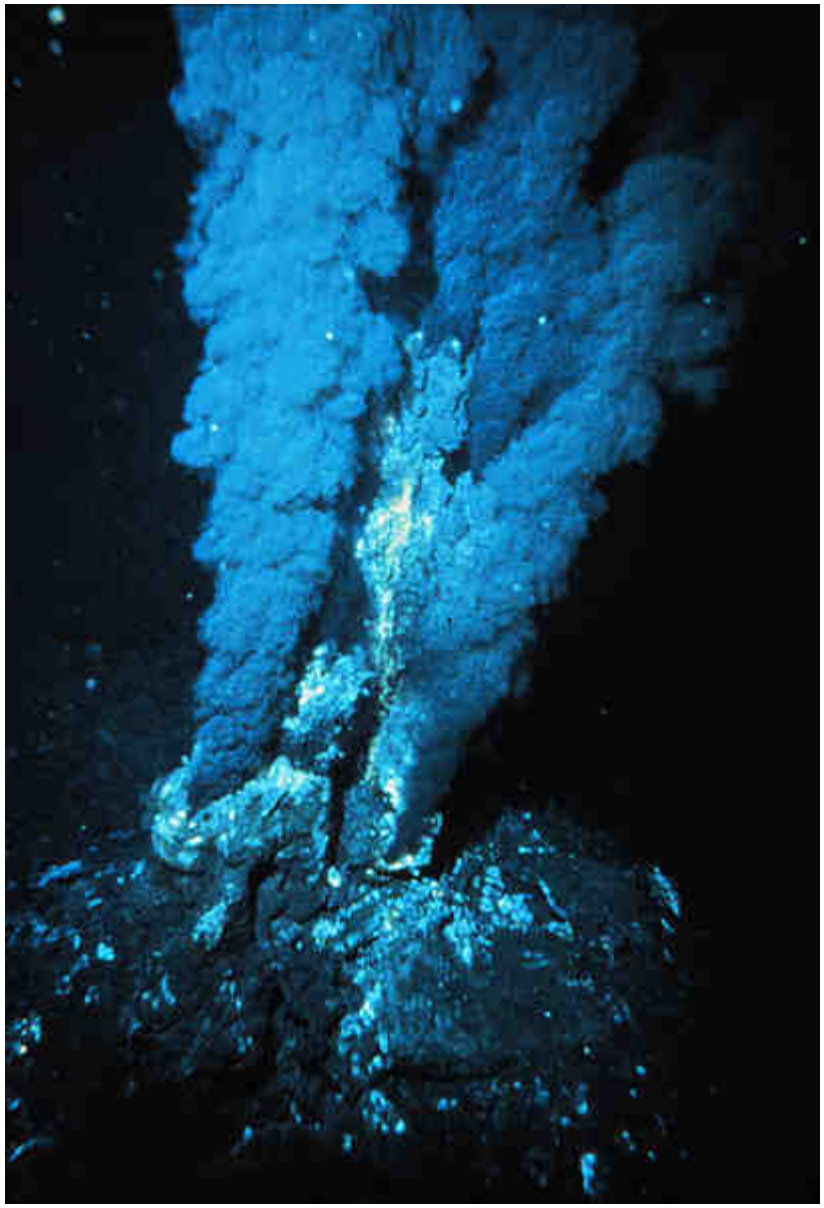
fraction of civilizations that develop technology to make them detectible from space $\rightarrow$ ~ 1%

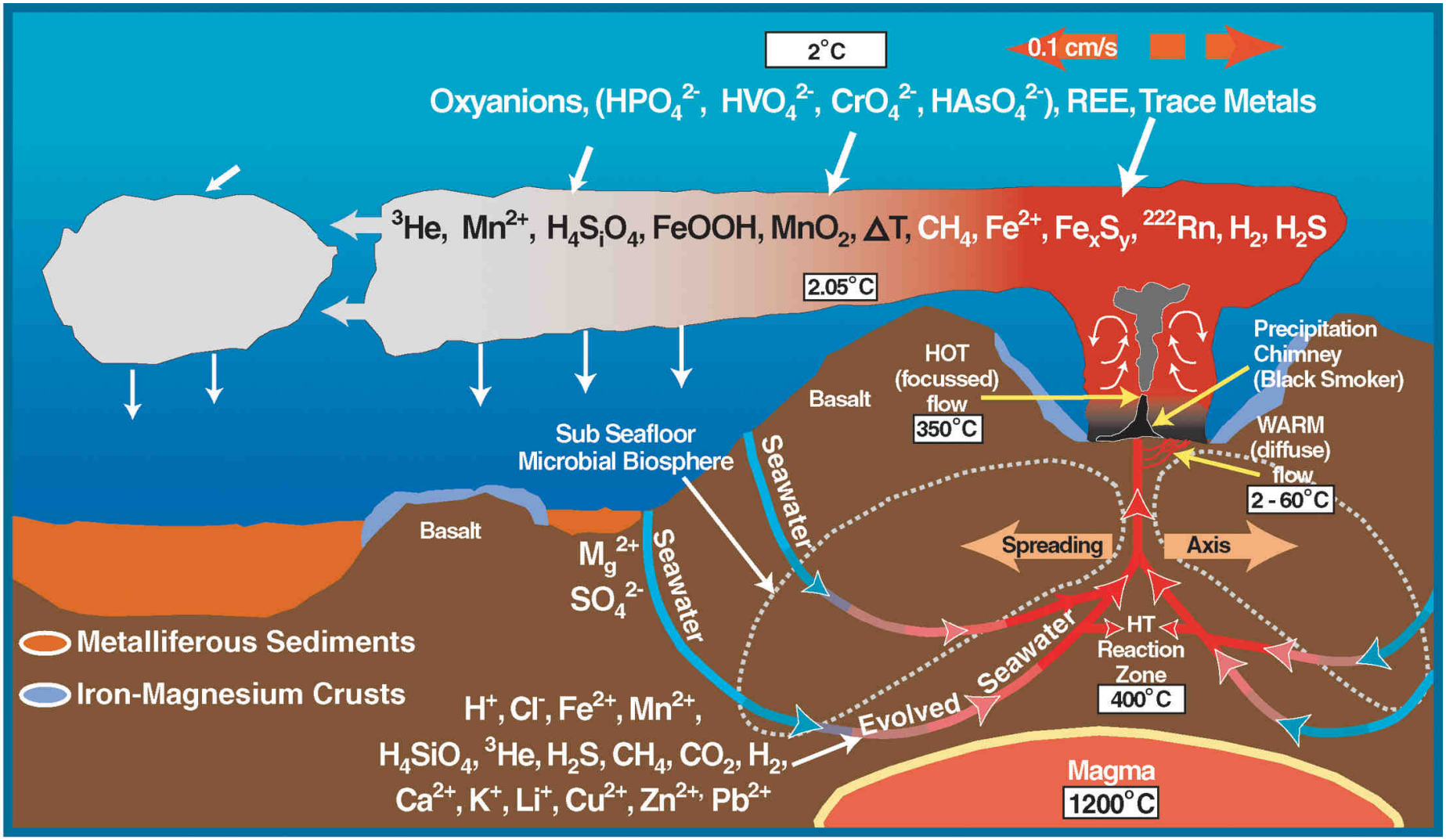
$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

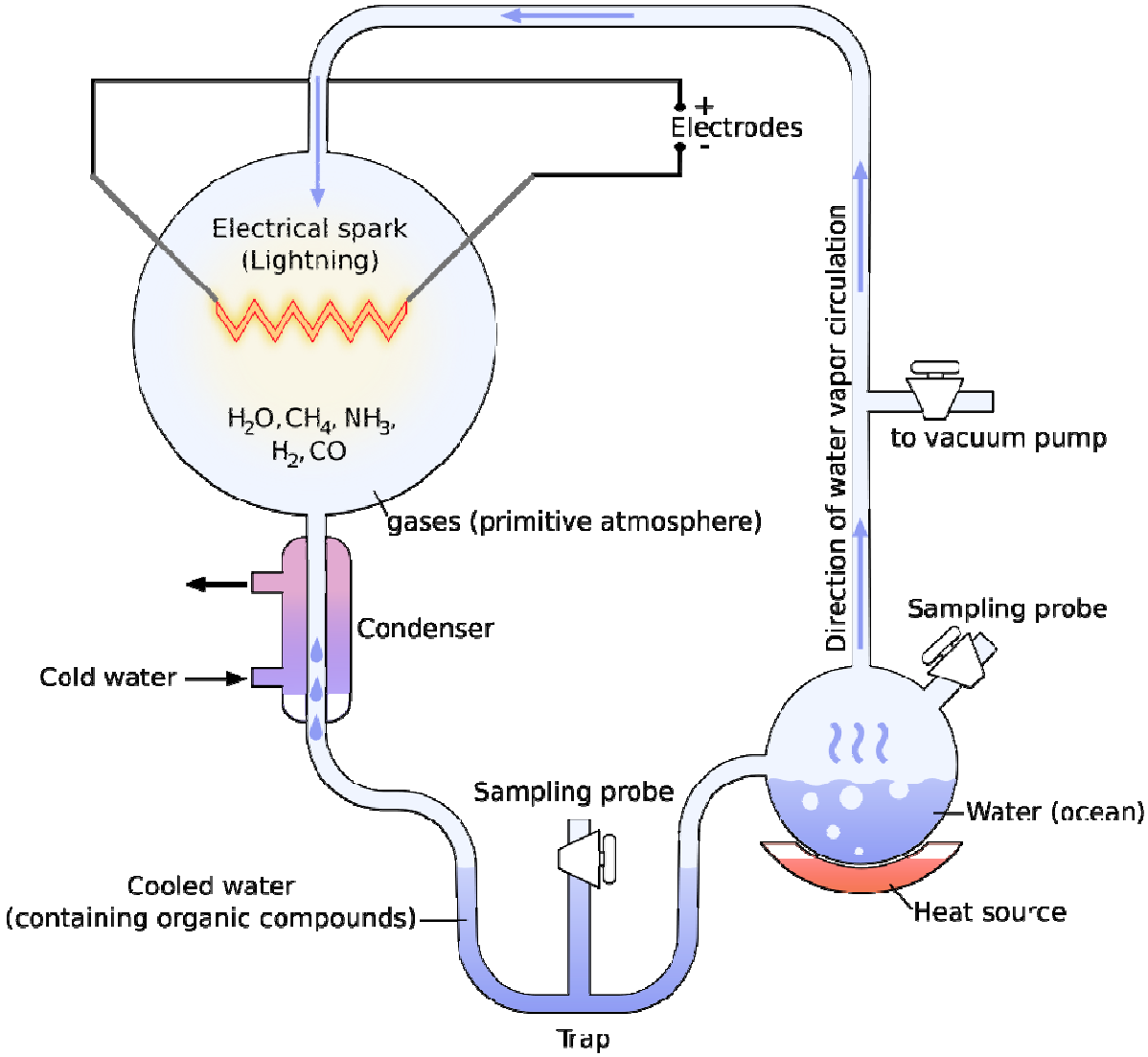
length of time that these civilizations release detectable signals $\rightarrow$ ~ 10000 years

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

$$\approx 2.31$$




2°C
0.1 cm/s
Oxyanions, (HPO_4^{2-}, HVO_4^{2-}, CrO_4^{2-}, $HAsO_4^{2-}$), REE, Trace Metals
^3He, Mn^{2+}, H_4SiO_4, FeOOH, MnO_2, ΔT, CH_4, Fe^{2+}, Fe_xS_y, ^{222}Rn, H_2, H_2S
2.05°C
Precipitation Chimney (Black Smoker)
HOT (focussed) flow
350°C
Basalt
WARM (diffuse) flow
2 - 60°C
Sub Seafloor Microbial Biosphere
Seawater
Basalt
Mg^{2+}
SO_4^{2-}
Seawater
Spreading
Axis
Metalliferous Sediments
Iron-Magnesium Crusts
HT Reaction Zone
400°C
Seawater
Evolved
H^+, Cl^-, Fe^{2+}, Mn^{2+},
H_4SiO_4, ^3He, H_2S, CH_4, CO_2, H_2,
Ca^{2+}, K^+, Li^+, Cu^{2+}, Zn^{2+}, Pb^{2+}
Magma
1200°C



Miller – Urey Experiment (1952)

Old view:

Biology entails highly specialized chemistry and physics to accomplish complex tasks.

New view:

Biology uses very general chemical and physical principles, and illustrates how they may be used to accomplish complex tasks.

Old view:

Chemistry and physics are foundational sciences for Chemical Engineering.

New view:

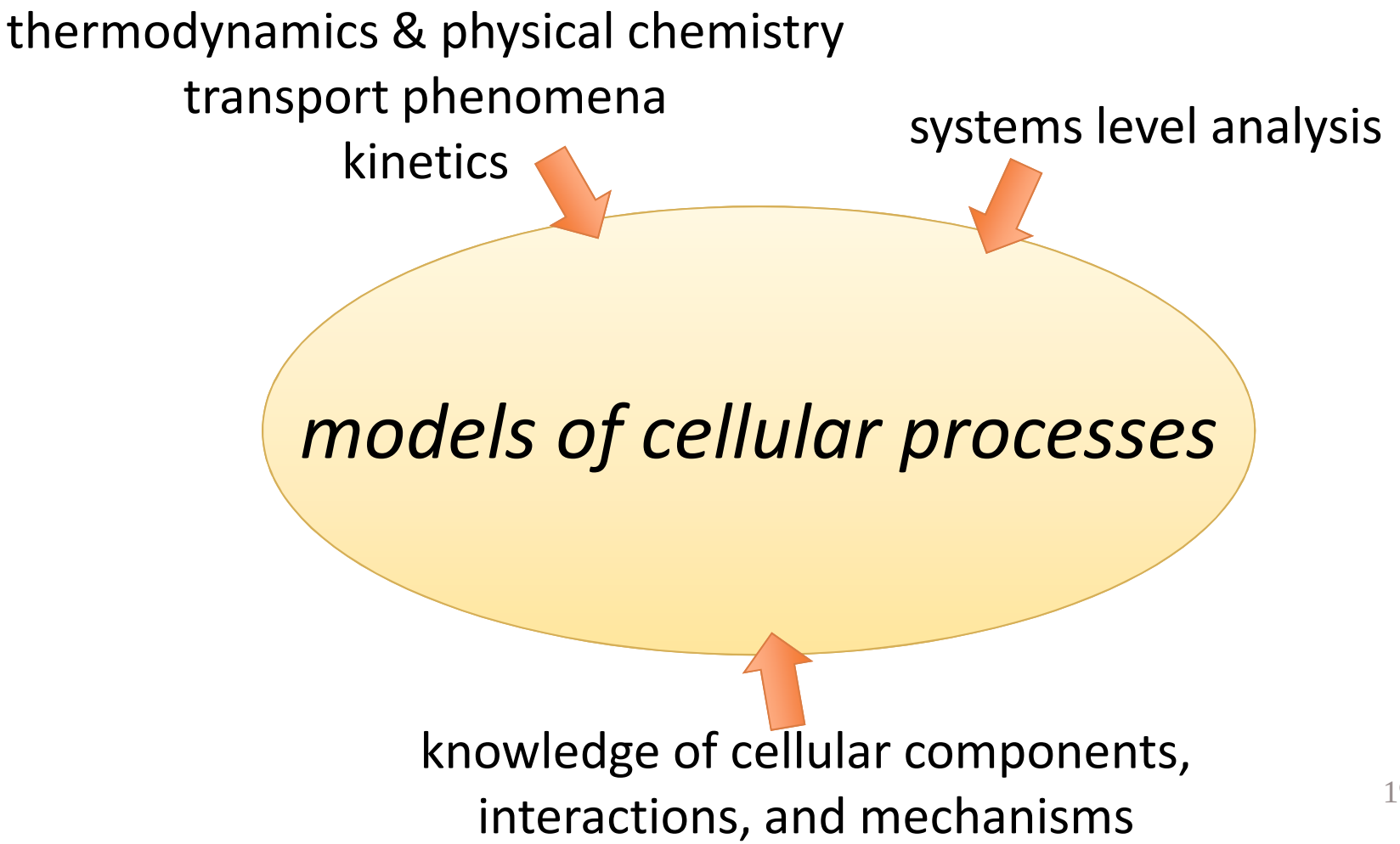
Biology is a foundation for Chemical Engineering on equal footing with chemistry and physics.

Table 1. In what industries are new chemical engineering BS graduates employed?	
Petroleum Production and Refining	15%
Engineering / Design / Construction	10%
Specialty Chemicals	9%
Other / Nonchemical Business	9%
Pharmaceuticals	7%
Commodity Chemicals	5%
Forest Products / Pulp and Paper	5%
Natural Gas	5%
Research and Development	5%
Oilfield Service and Exploration	4%
Alternative Energy Sources	3%
Biotechnology / Life Science	3%
Environmental Engineering	3%
Nuclear Energy and Allied	3%
Plastics and Rubber	3%
Agricultural Chemicals	2%
Food and Beverages	2%
Materials and Composites	2%
Petrochemicals and Petroleum Products	2%
Catalyst	1%
Electronics / Computers	1%

Employment of chemical engineering class of 2009

source: CEP Magazine, 9/09

Why should engineers know molecular and cell biology?



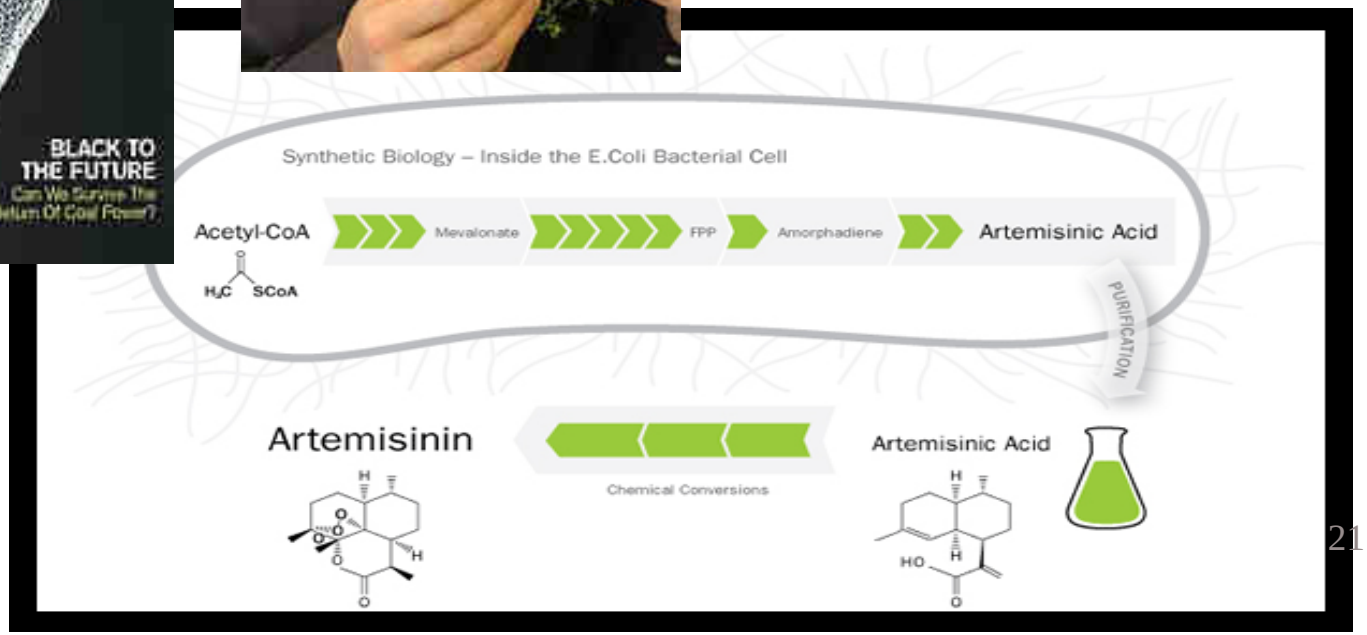
Why should engineers know molecular and cell biology?

Biochemical Engineering & Biotechnology

- Alternative energy
  Biofuels production: ethanol, cellulosic conversions, sugar to alkanes
- Metabolic engineering
  cellular engineering, genetic engineering
- Systems biology
  drug delivery (e.g. insulin), fuels
- Synthetic biology
  designer biological systems
- Drug development and production

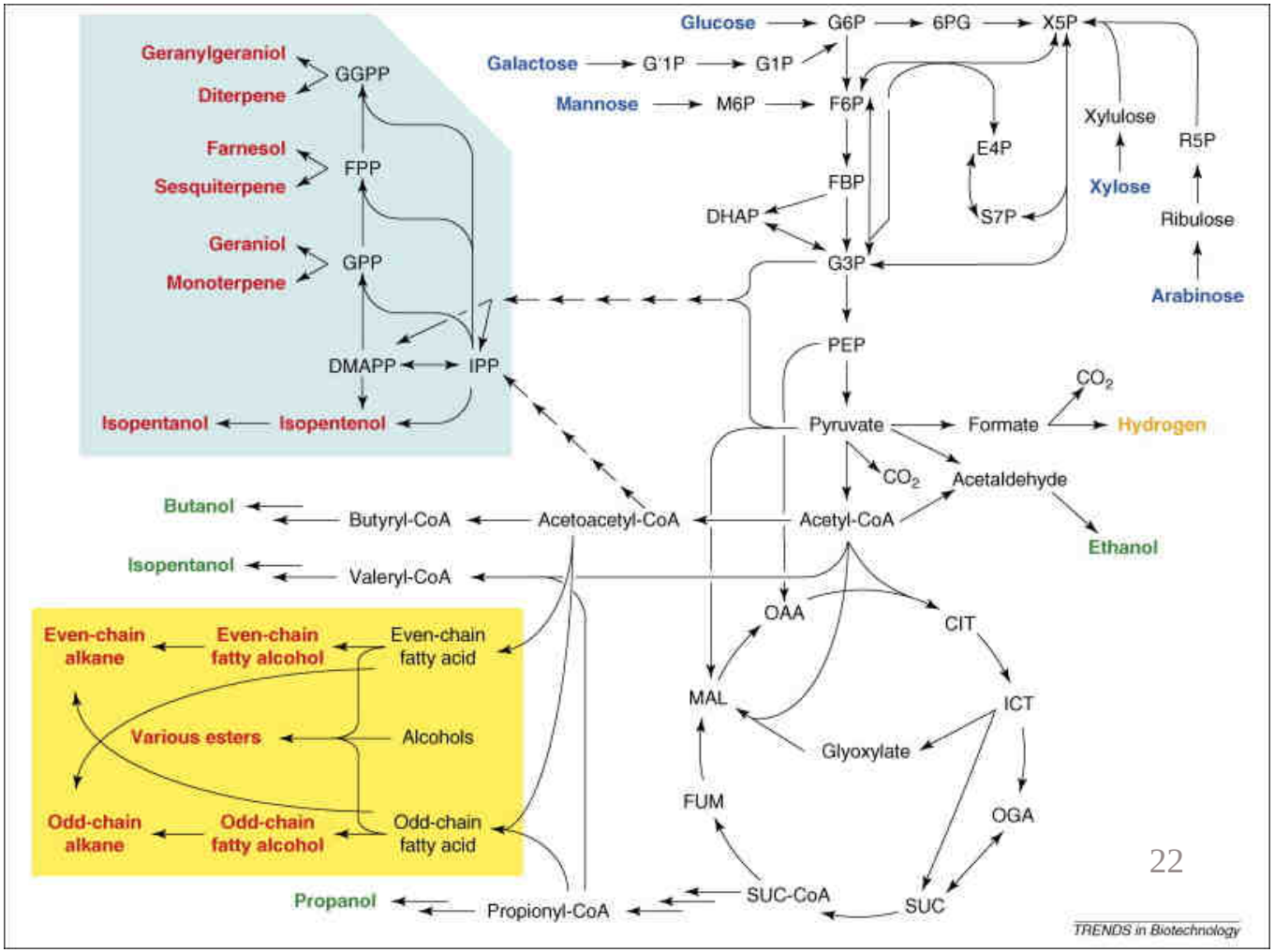
Chemical Engineers are uniquely equipped to address these problems, using kinetics, thermodynamics and transport phenomena.

Chemical Engineering (UCB) awarded a $42 million grant from the Bill & Melinda Gates Foundation, to produce artemisinic acid, a prescursor to the anti-malarial drug artemisinin.



Rethinking Mother Nature's Choices

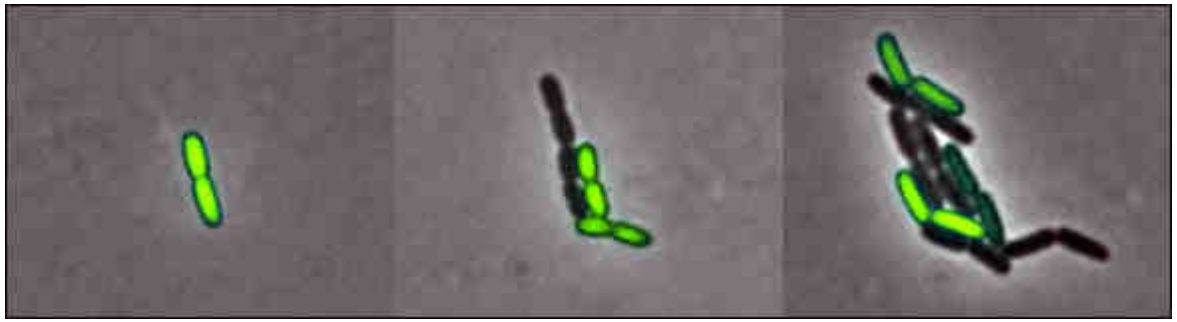
"Jay Keasling believes ethanol is a poor biofuel. So he's going to get microbes to make something better." Robert F. Service



The New York Times

"Custom-Made Microbes, at Your Service"

Frances Arnold (Caltech)

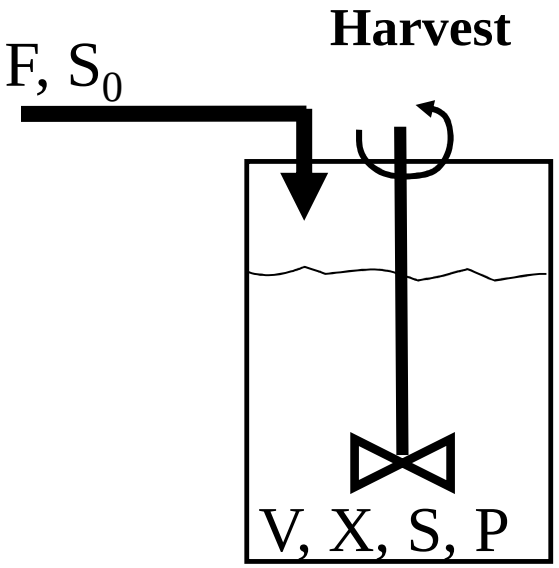


ChE Professor Frances Arnold is using synthetic biology and protein engineering to design better enzymes for making biofuels from cellulose.

$$
\begin{aligned}
\langle m \rangle_{T,M} &= Te \sum_{m=0}^{\infty} m f_m \mathbf{W_m P_M} \\
&= Te^{-\mu} \sum_{m=1}^{\infty} m \frac{\mu^m}{m!} \mathbf{e W^m p_o} \\
&= Te^{-\mu \langle \nu \rangle_o} \sum_{m=1}^{\infty} m \frac{\mu^m}{m!} \langle \nu \rangle_\infty^{m-1} \\
&= \mu T e^{-\mu \langle \nu \rangle_o} \sum_{m=0}^{\infty} \frac{(\mu \langle \nu \rangle_\infty)^m}{m!} \\
&= \mu T \langle \nu \rangle_o e^{\mu \left(\langle \nu \rangle_\infty - 1 \right)}.
\end{aligned}
$$

Biochemical Engineering for Bioproducts Production

- Drugs (e.g., antibiotics)
- Foods
- Food additives
- Beverages
- Special Chemicals



Fed Batch Mass Balances

Cell $\frac{dXV}{dt} = \mu XV$

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

Product $\frac{dPV}{dt} = q_p XV$

Total Mass $\frac{dV}{dt} = F$ (assumes constant density)

Monod equation for specific growth rate $\mu = \frac{\mu_{\max} S}{K_S + S}$

Why should engineers know molecular and cell biology?

Biomedical Engineering

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

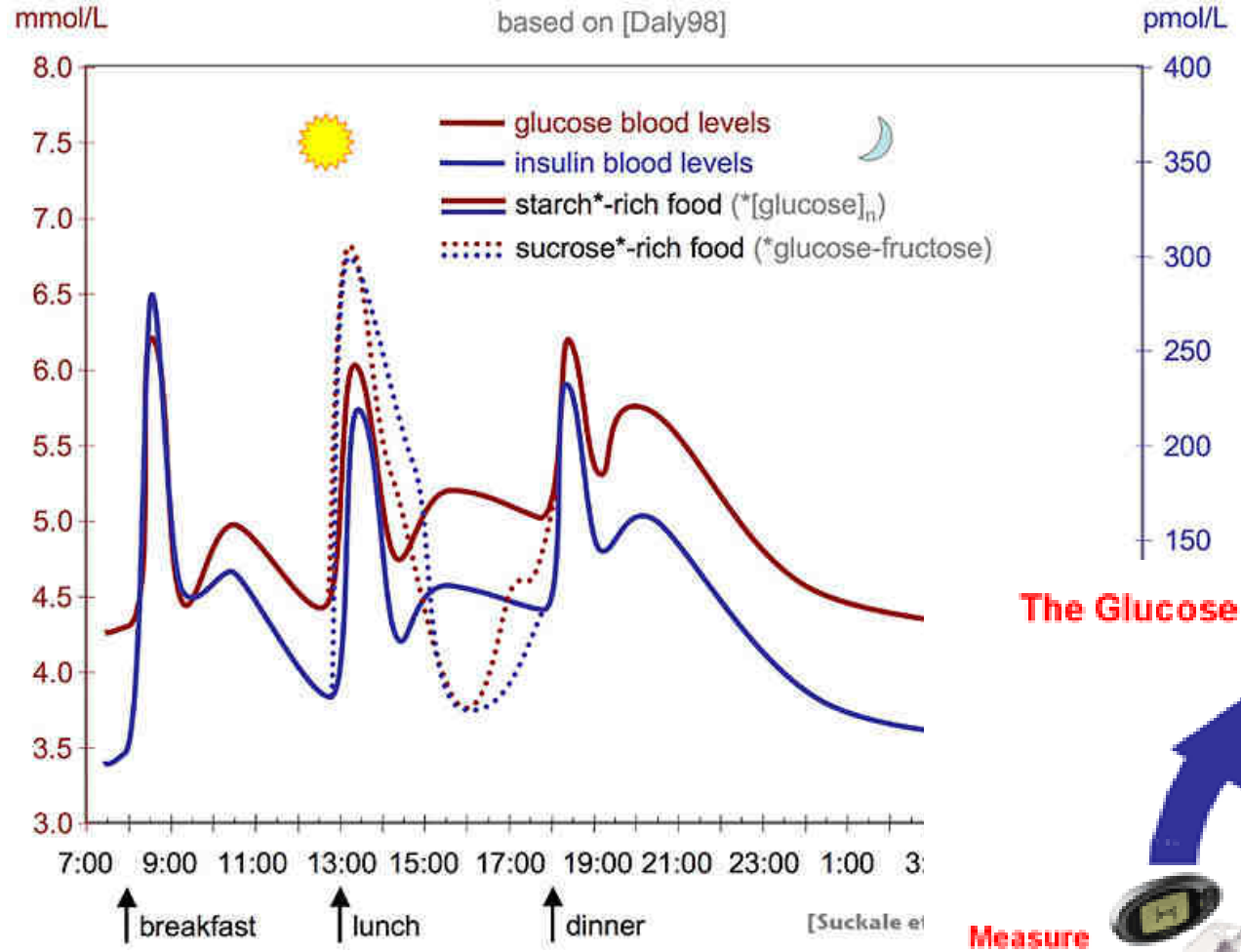
Advanced Study

- Graduate School
- Law
- Medicine

Chemical Engineers are uniquely equipped to address these problems, using kinetics, thermodynamics and transport.

Control algorithms enable automated delivery of insulin to Diabetics

Glucose concentration



Systems Biology: Mathematical Descriptions of Cellular and Physiological Phenomena

UCSB and Pfizer Enter into Research Consortium to Expand Understanding of Diabetes and Obesity Pathobiology

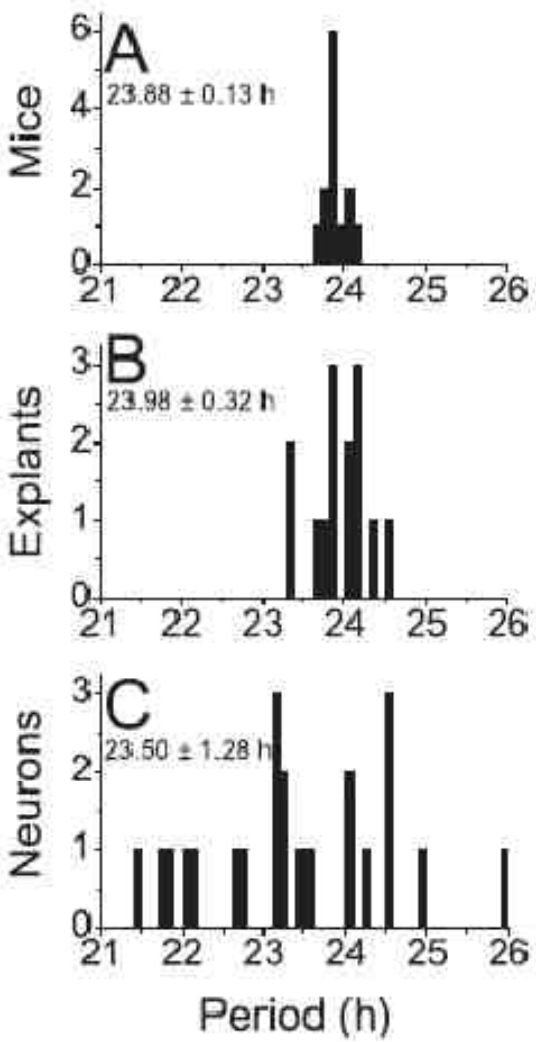
UC Santa Barbara's Institute for Collaborative Biotechnologies has joined into a research consortium with Pfizer, three other major research universities—Caltech, Massachusetts Institute of Technology, and the University of Massachusetts—and Entelos, a physiological modeling company, to seek out new targets for drugs to treat diabetes. Pfizer is funding the three-year, $14 million Insulin Resistance Pathway (IRP) Project to look at insulin signaling in adipose (fat) cells to increase understanding of diabetes and obesity, inextricably linked conditions which affect 7 percent of the US population.

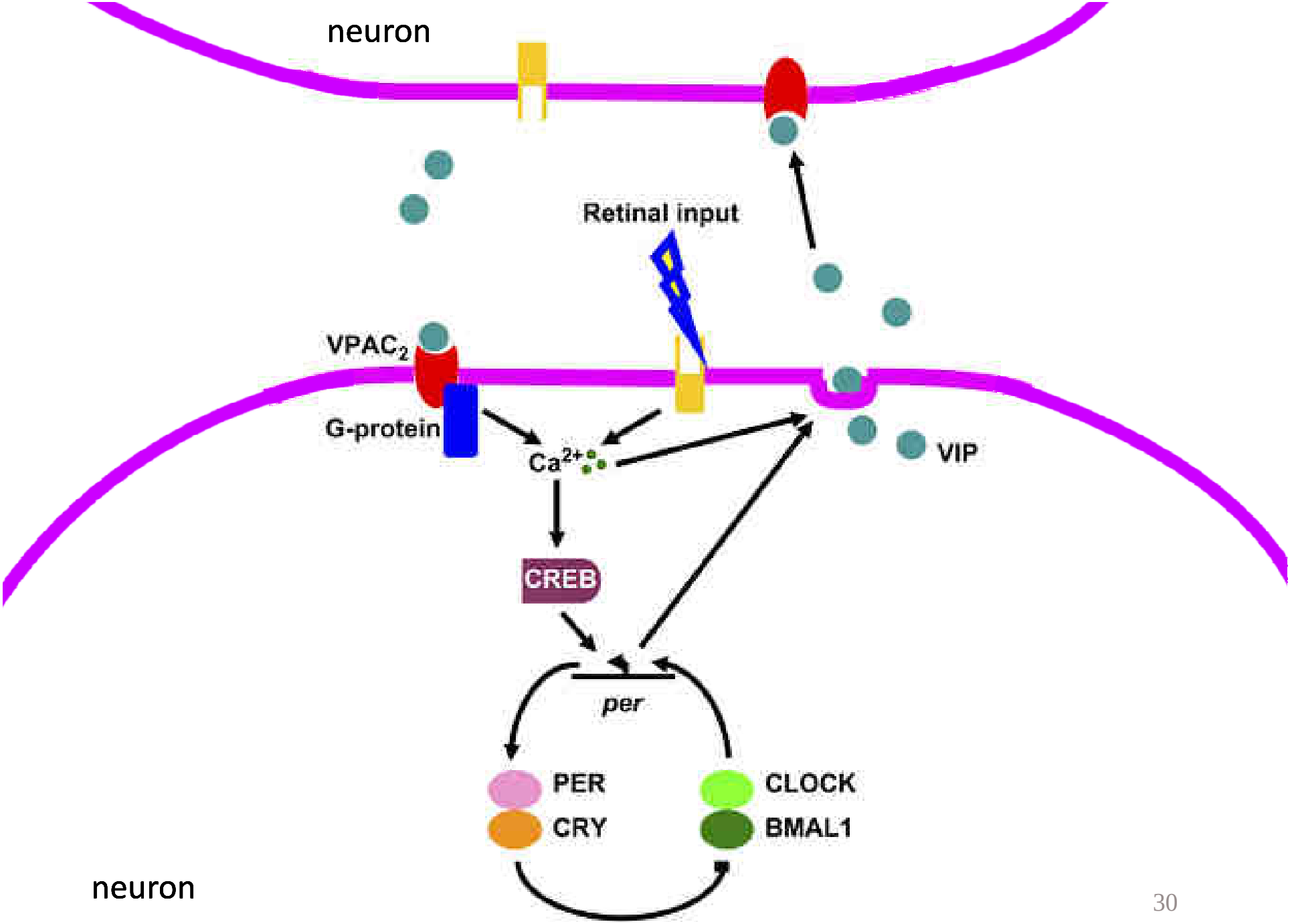
experiments

neurons in the brain

in tissue cultures

alone



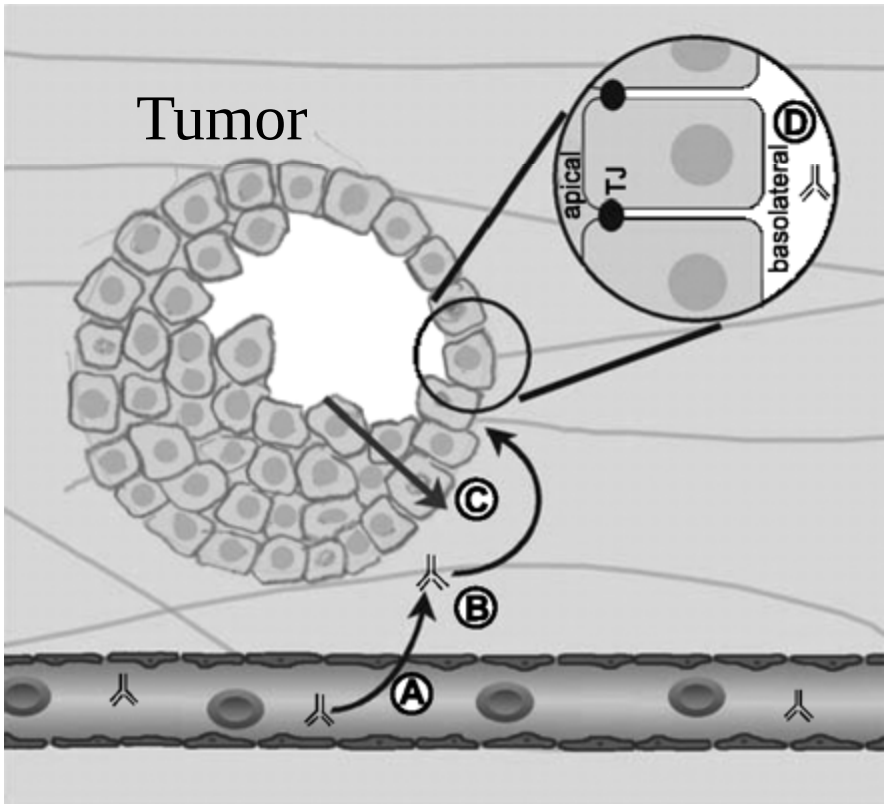

neuron
Retinal input
VPAC2
G-protein
Ca2+
VIP
CREB
per
PER
CRY
CLOCK
BMAL1
neuron

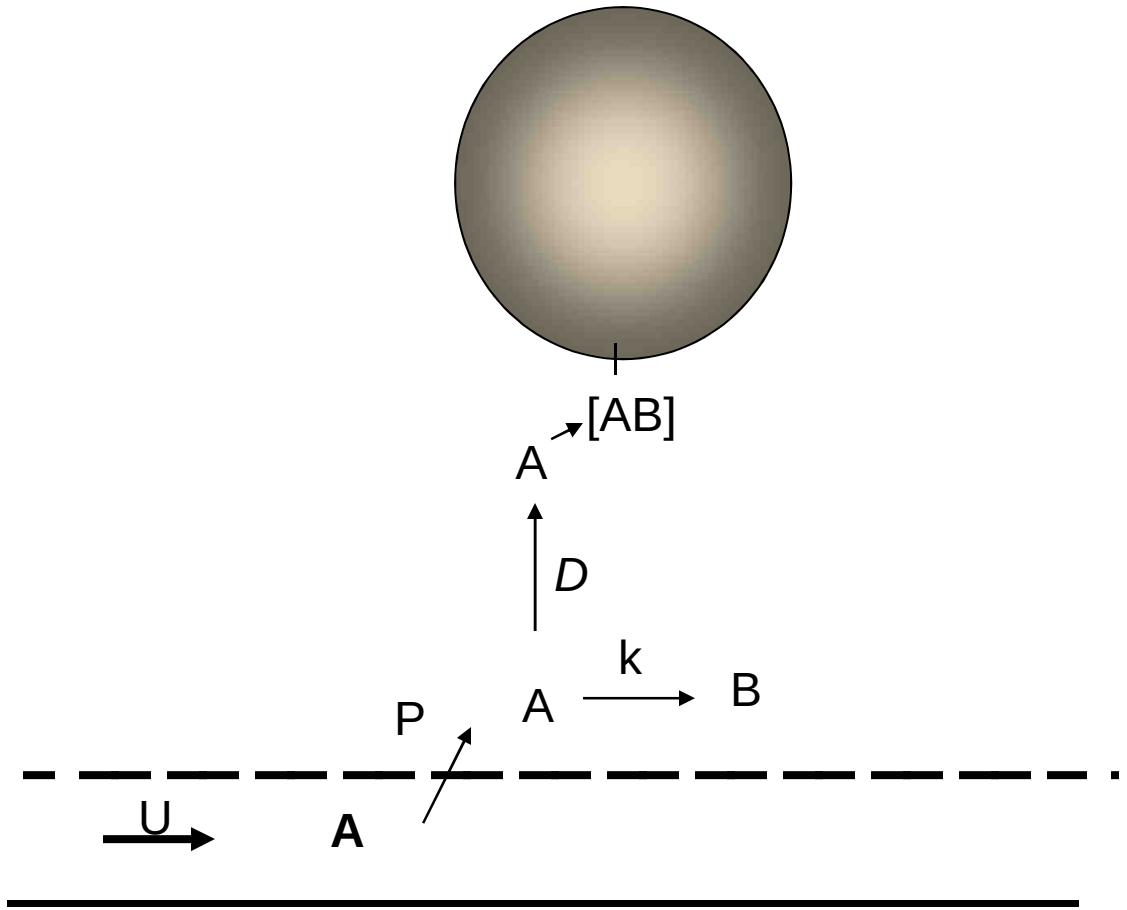
Delivery of therapeutics from
blood vessels to tumors is influenced by…

transport

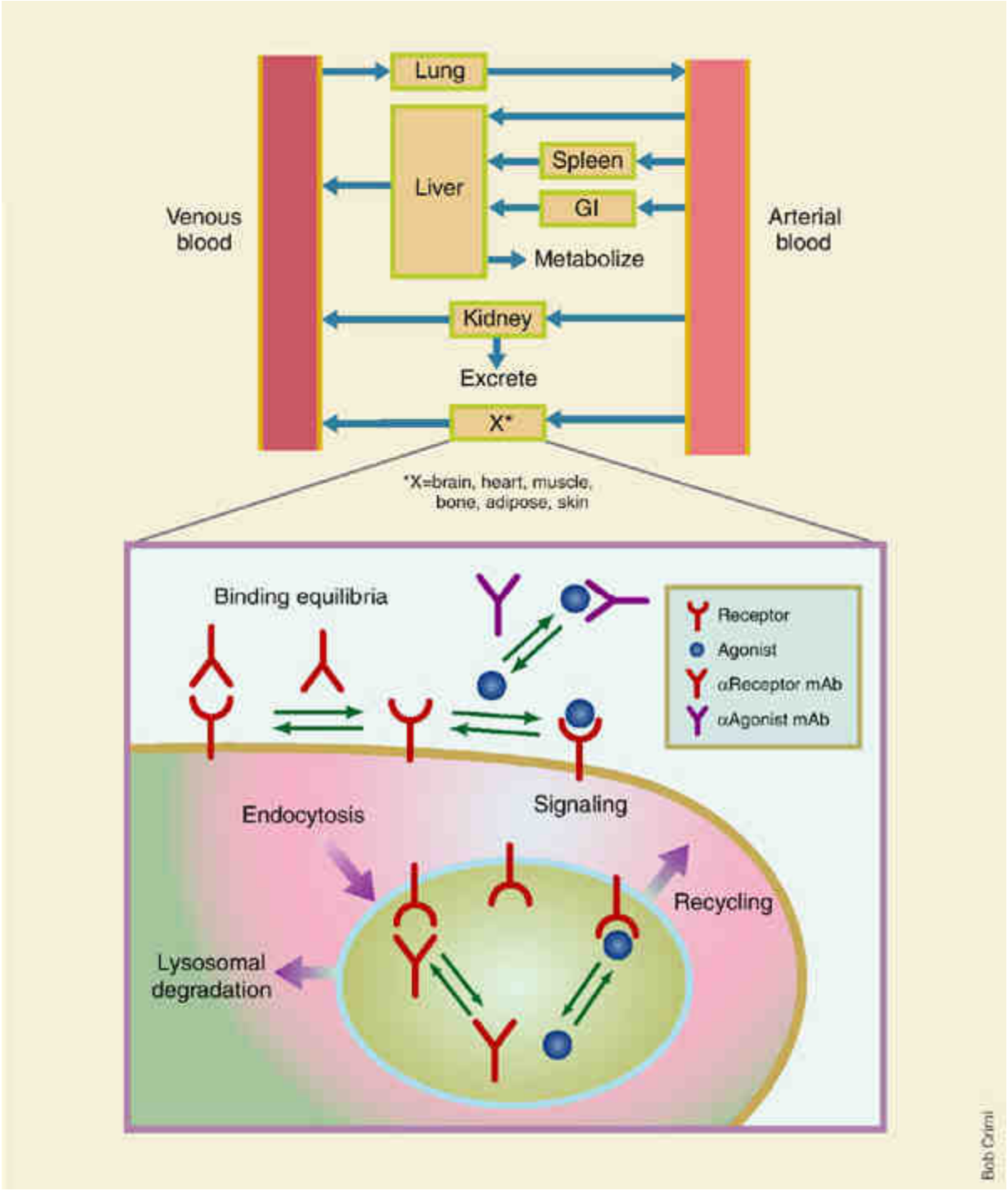
convection, diffusion kinetics

binding, internalization, degradation





What is [AB](t) =??

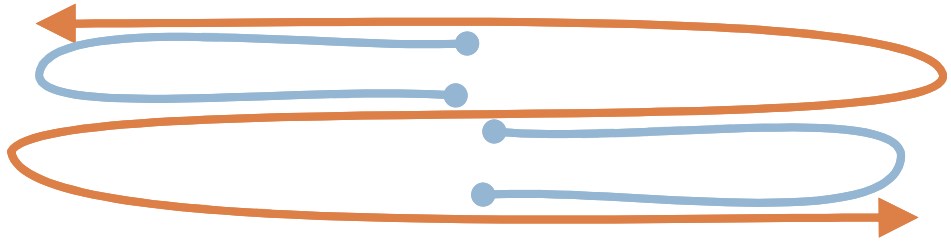

Lung
Liver
Spleen
GI
Metabolize
Venous blood
Arterial blood
Kidney
Excrete
X*
*X=brain, heart, muscle, bone, adipose, skin
Binding equilibria
Receptor
Agonist
αReceptor mAb
αAgonist mAb
Endocytosis
Signaling
Recycling
Lysosomal degradation
Bob Crimi

Why should engineers know molecular and cell biology?

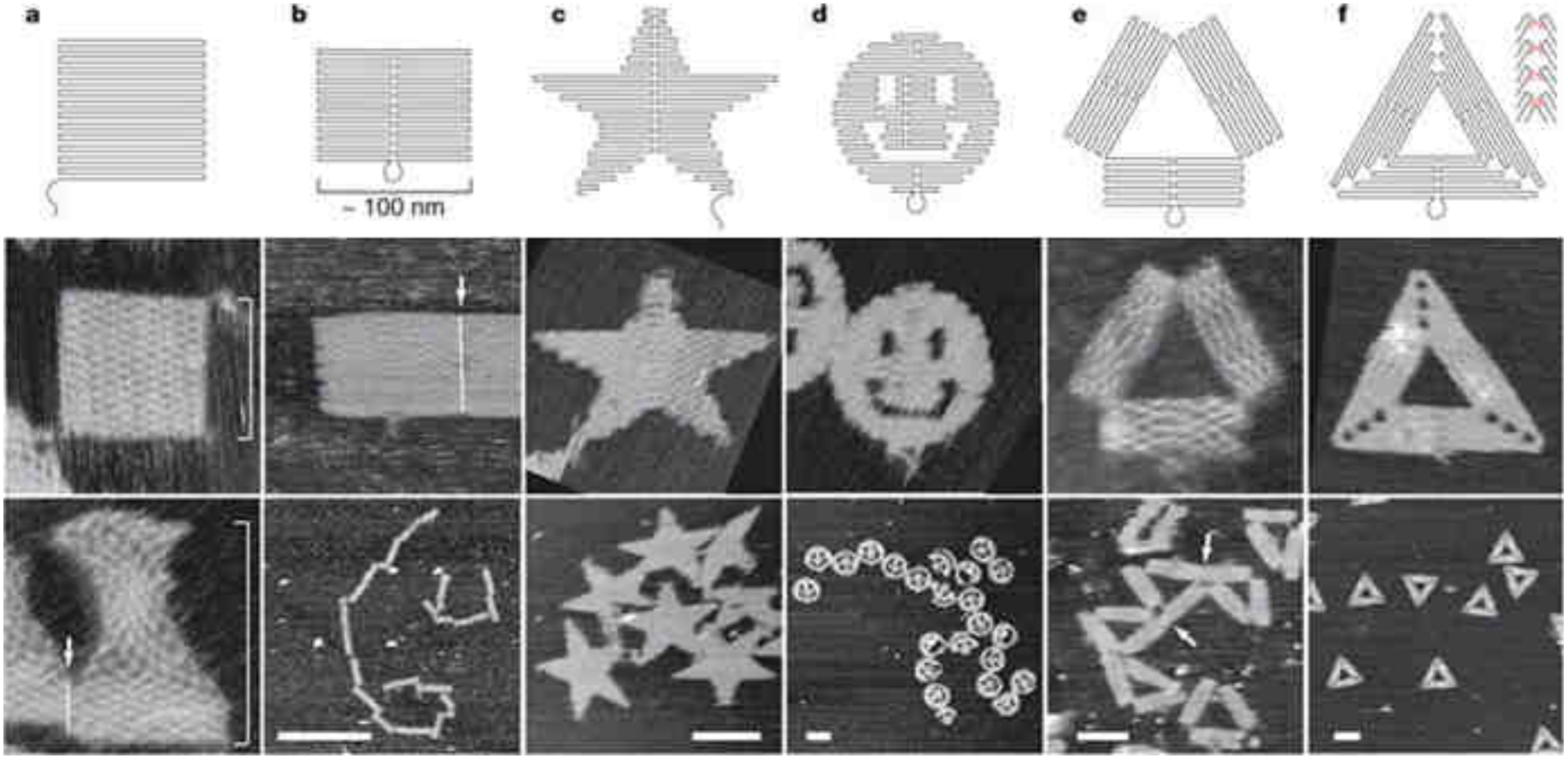
Biology suggests new ways of nanoscale engineering

- Nanomaterials
- Nanodevices
- Nanomachines

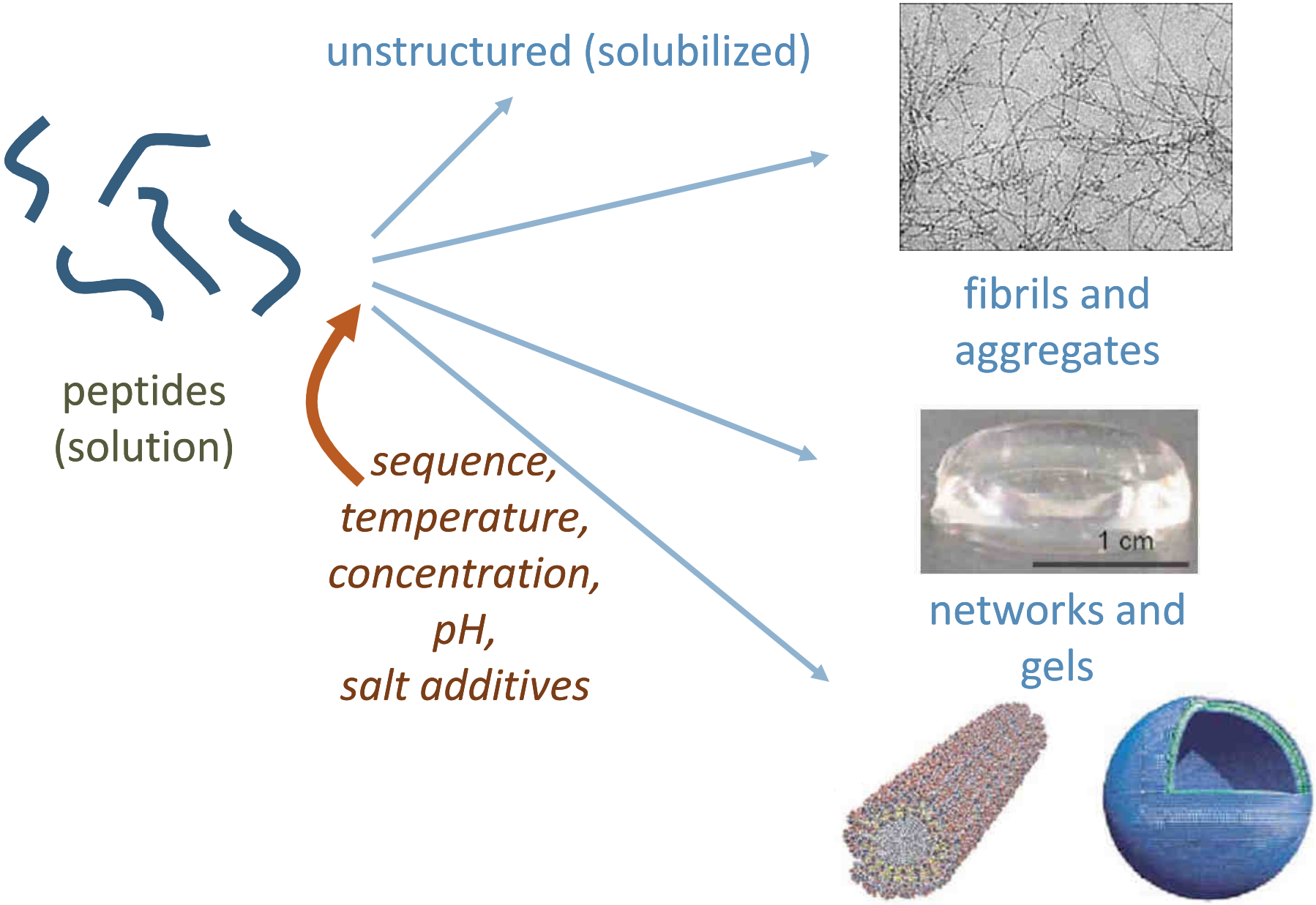
Chemical Engineers are uniquely equipped to address these problems, using kinetics, thermodynamics and transport.

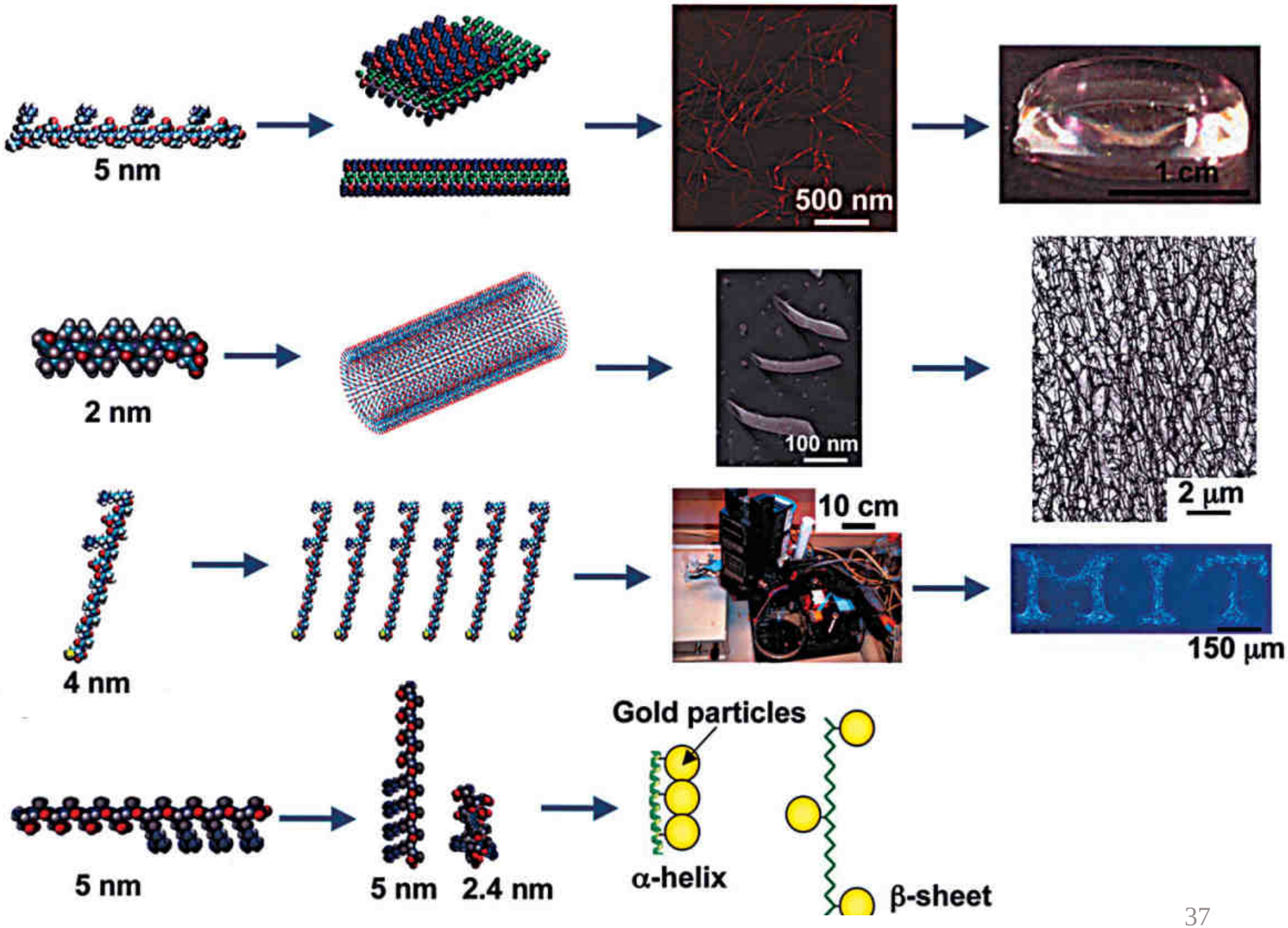


DNA “staples”



Rothemund, Science, 2006.


unstructured (solubilized)
peptides
(solution)
sequence,
temperature,
concentration,
pH,
salt additives
fibrils and
aggregates
1 cm
networks and
gels
micelles,
nanotubes,



Zhang, Nature, 2003.

109C Topics Essential to an understanding of molecular and cell biology

- Carbohydrates & lipids
- Amino acids, peptides, and proteins
- Mechanisms of catalysis
- Nucleosides, nucleotides, and nucleic acids