Molecular Biology and Micro/Nano-Scale Engineering

(MCEN4228-006/5228-006 and MCDB4100-003/MCDB6440-002)

Y. C. Lee, Mechanical Engineering,
ECME 122, 303-492-3393, leeyc@colorado.edu

Michael H. B. Stowell, MCD Biology,
Porter B231, 303-735-2983, Michael.Stowell@colorado.edu

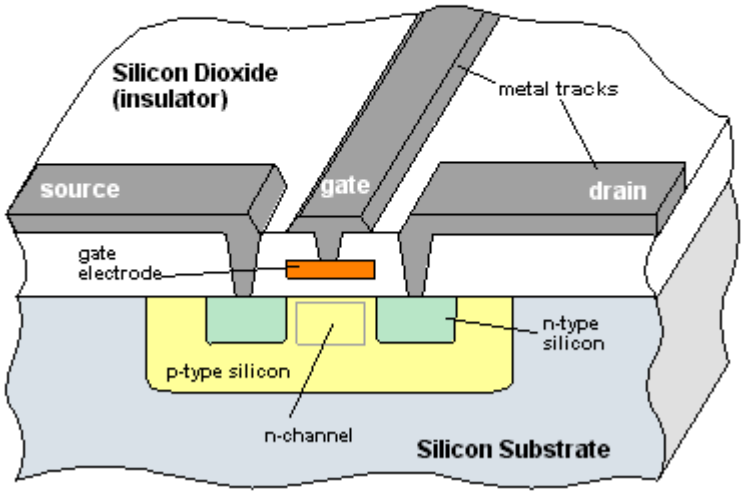
University of Colorado, Boulder, CO 80309

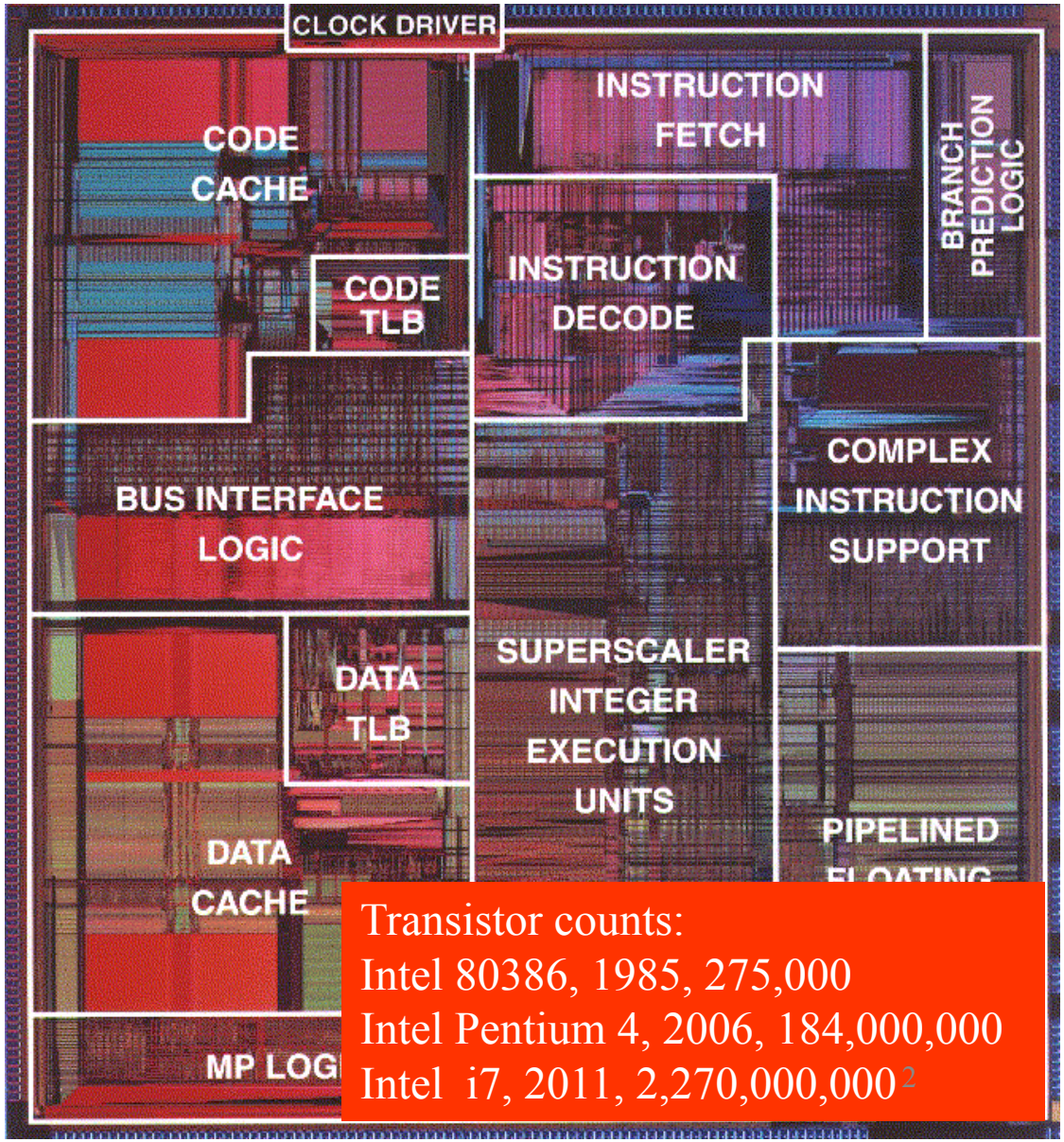
January 14, 2014

Integrated Circuits – Information Era

From Computer Desktop Encyclopedia
© 2004 The Computer Language Co. Inc.

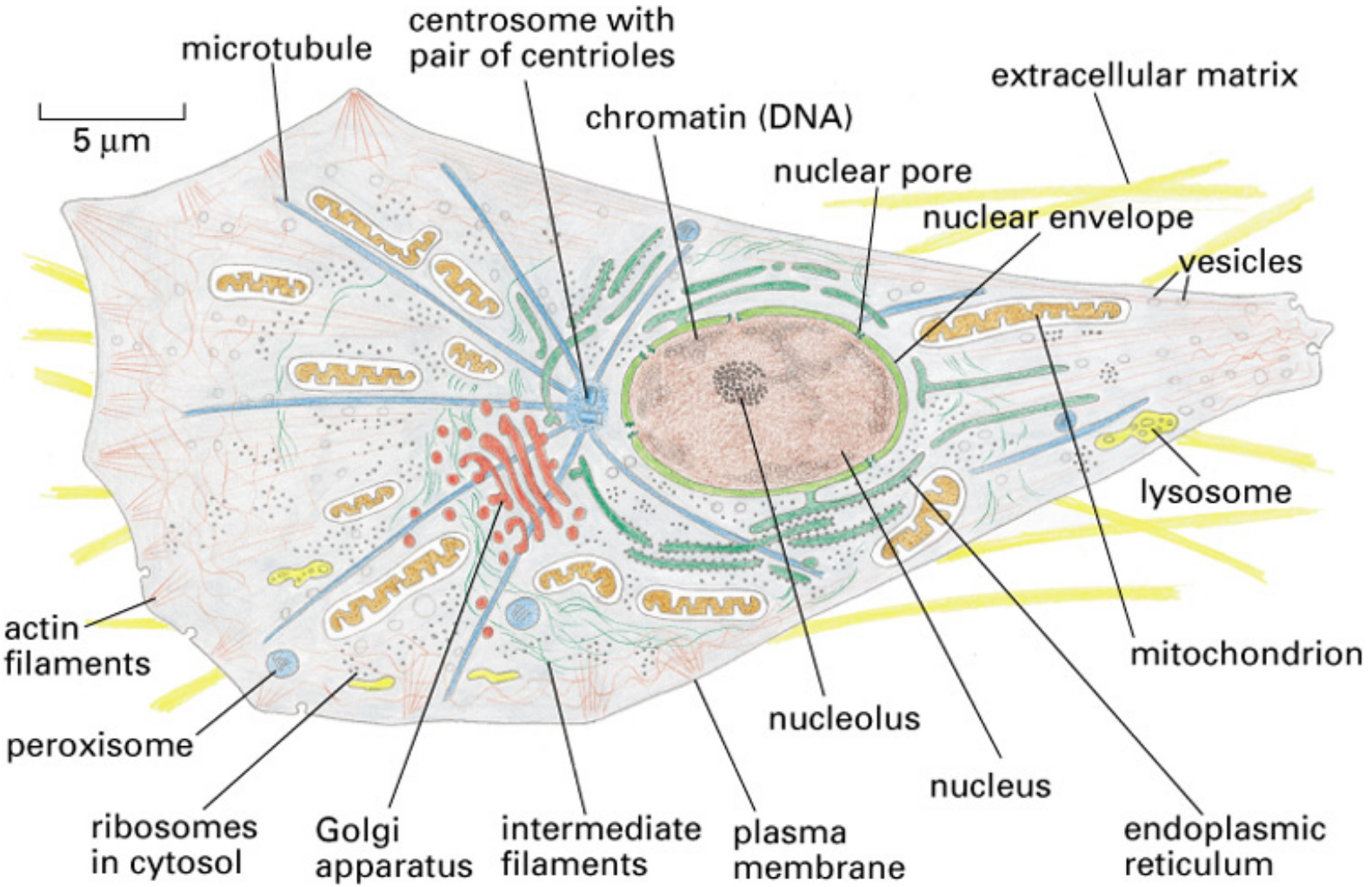
NMOS Transistor
(n-channel MOSFET)





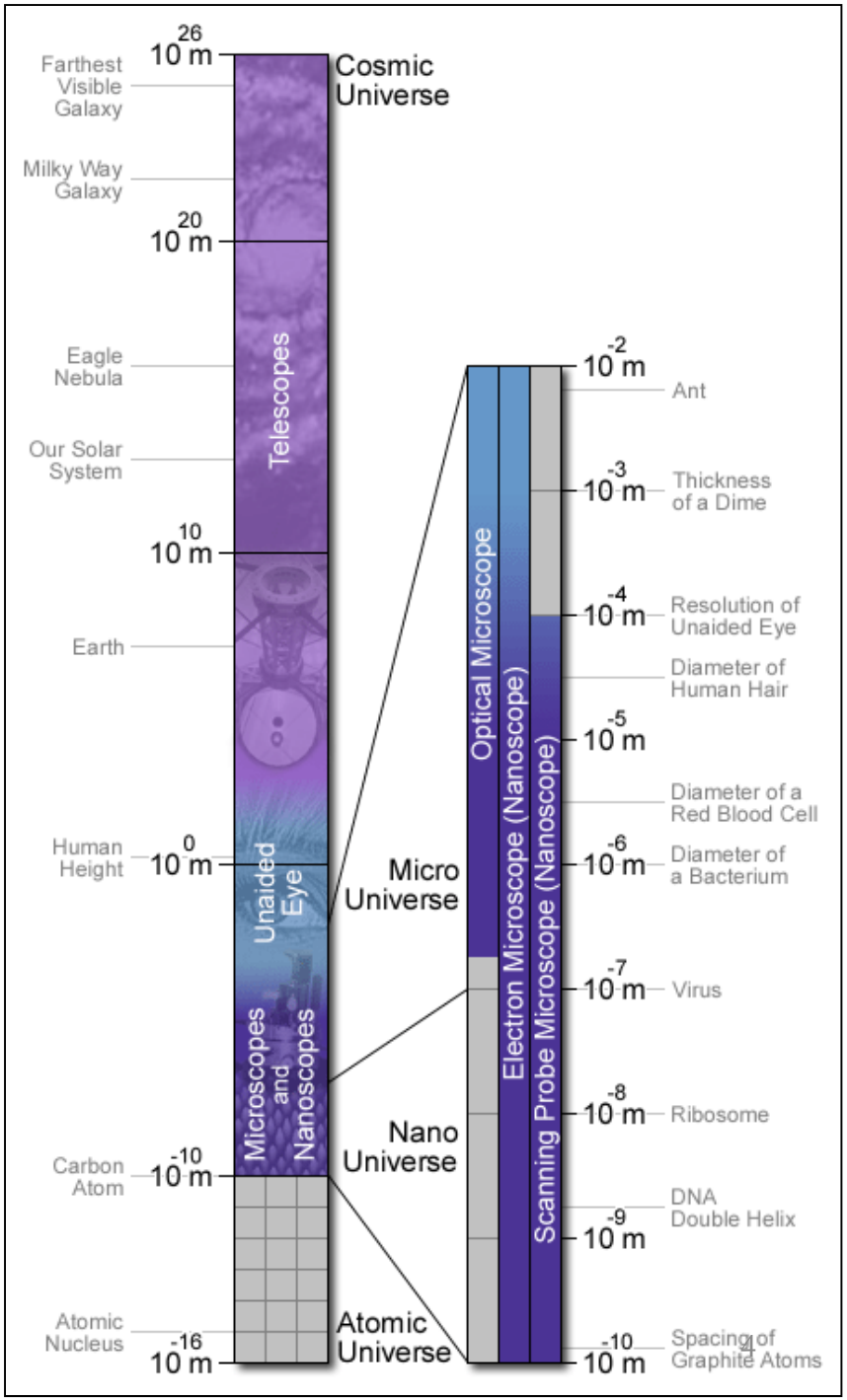
Transistor counts:
Intel 80386, 1985, 275,000
Intel Pentium 4, 2006, 184,000,000
Intel i7, 2011, 2,270,000,000[2]

Biological Cell



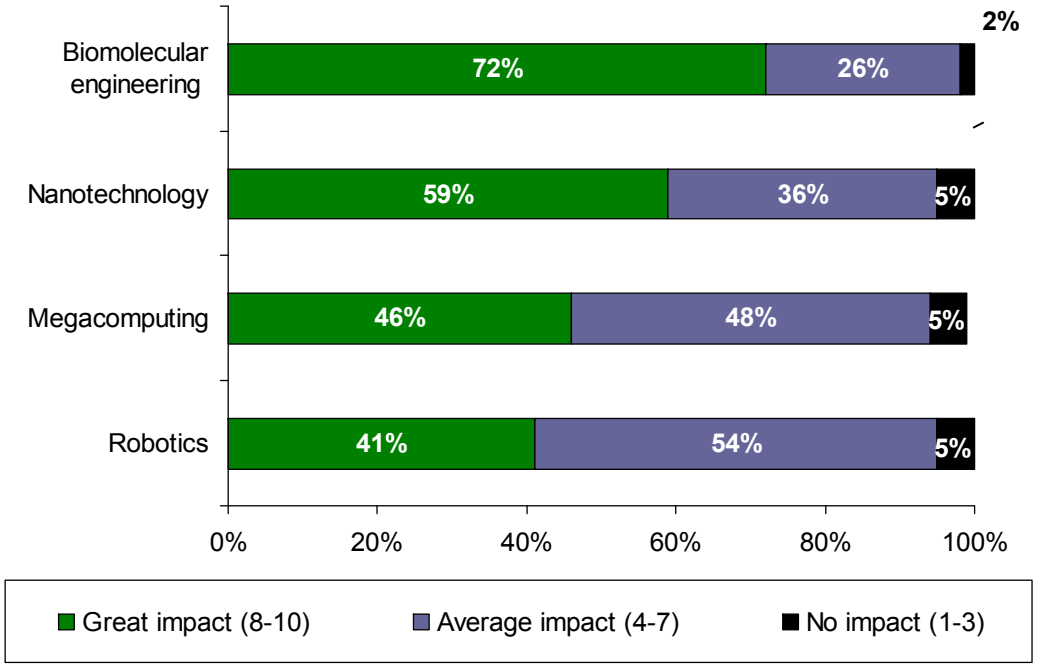
Bacteria (e.coli): ~1µm diameter, 2µm length, ~1µm^3 in volume; 10^9cells/ml in an overnight culture; 10^7 x 10^9 = 10^{16} proteins/ml.

Engineering Technology and Molecular Biology: Same Scales!



Survey in 2008: IEEE Fellows

- Question: Please indicate how much societal impact each of the following fields will have on the world over the next ten years. 10= great impact on the world; 1= no impact on the world.



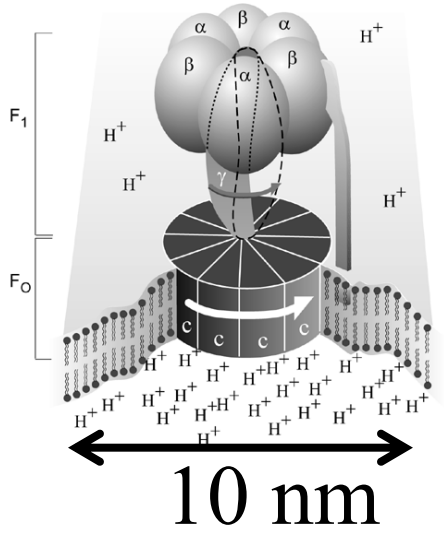
Q1: Base = "total" (901)

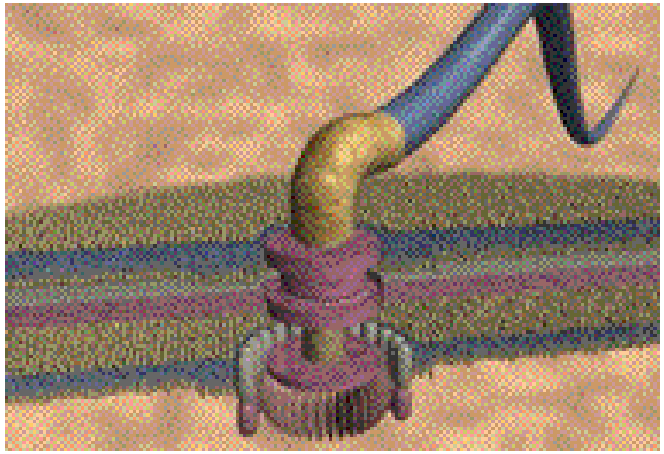
Contents

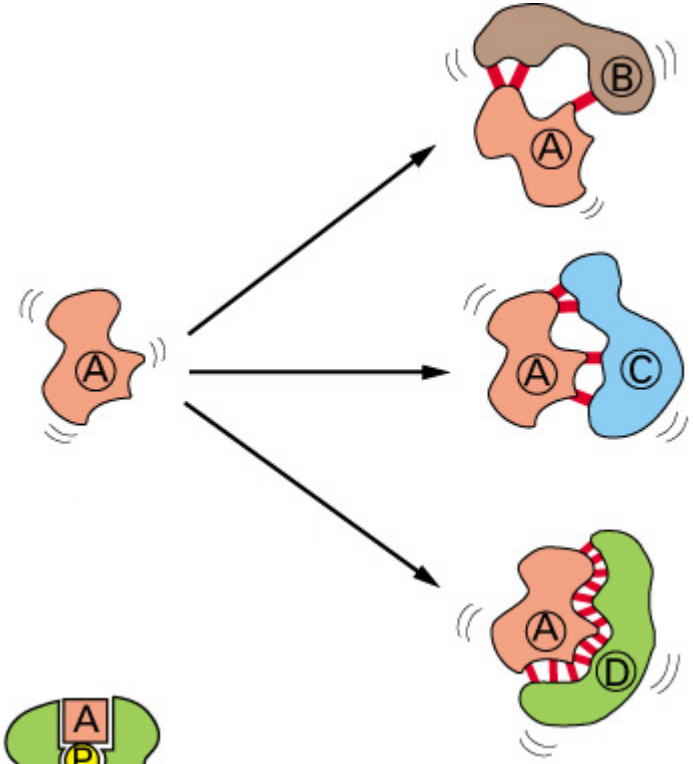
- Molecular Biology
- Micro/Nano-Scale Engineering
- Case: Electronics for Biomedical Applications
- Case: Lab on a chip
- Case: Bio-fuels
- Syllabus

Synergistic integration of molecular biology and micro/nano-scale engineering

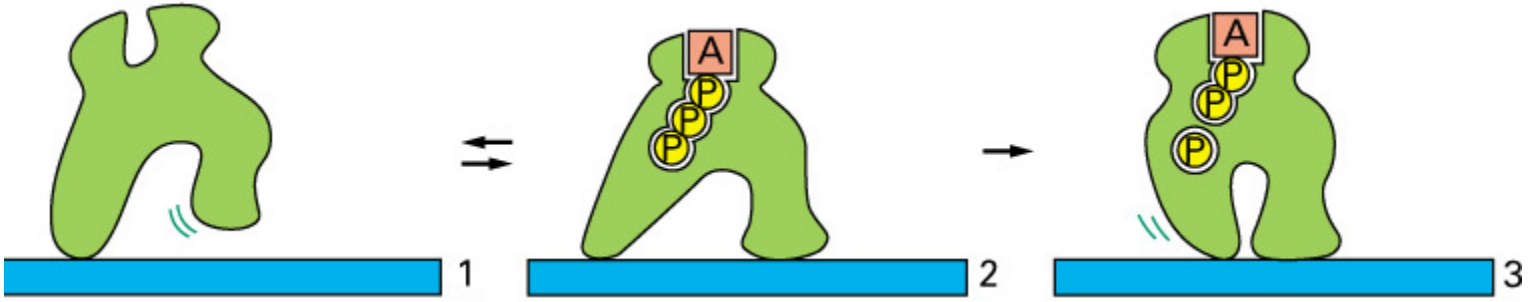
Protein: a Nano-Electro-Chemical-Mechanical Device







Activation



Millions or Billions of Proteins Working Together in a Cell

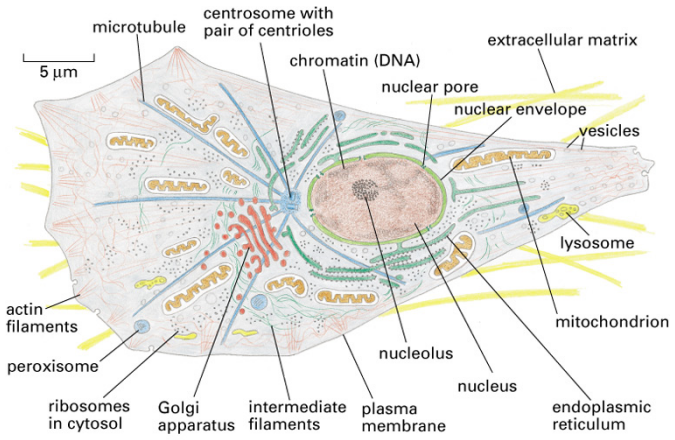


Figure 1–31. Molecular Biology of the Cell, 4th Edition.

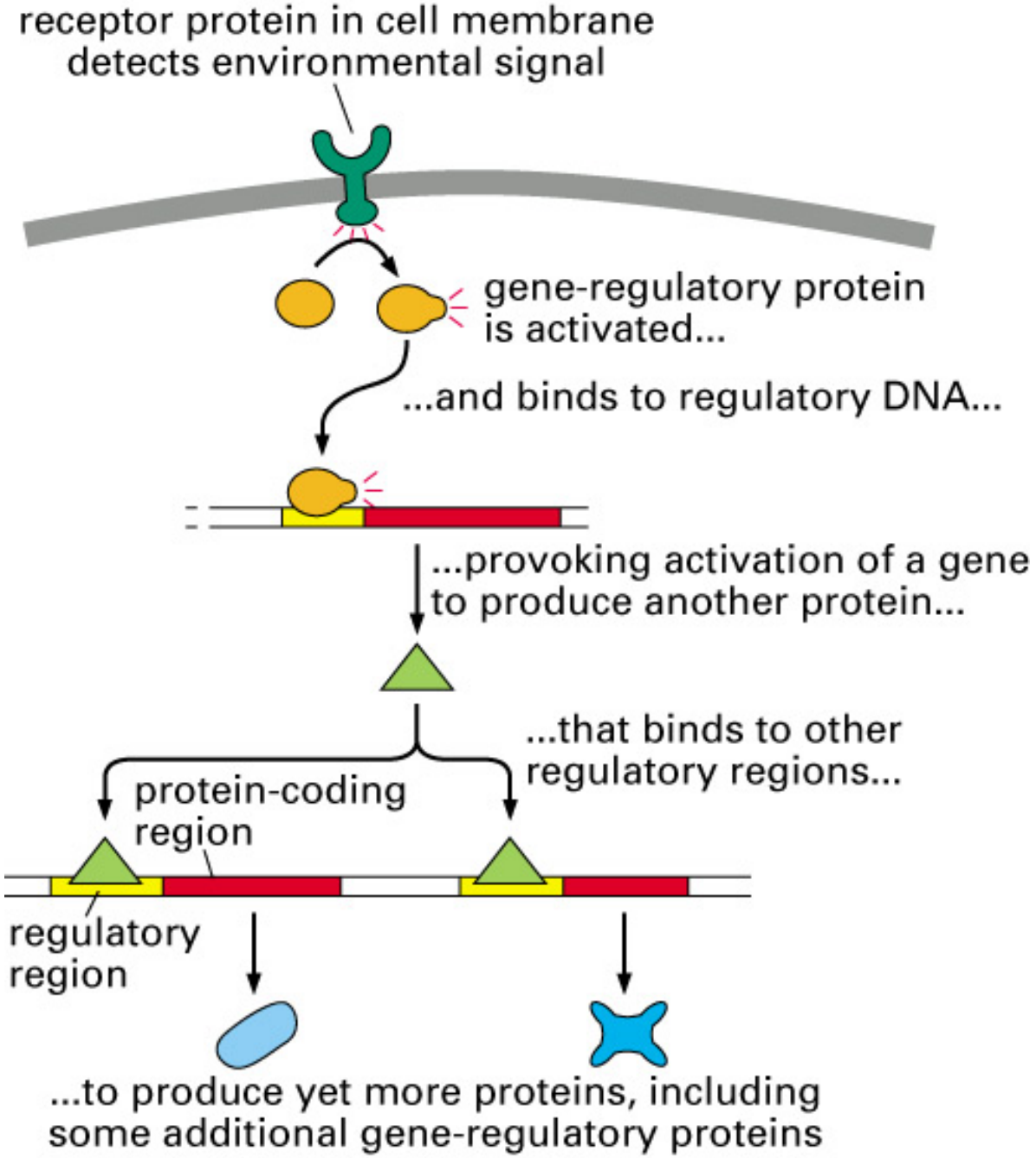
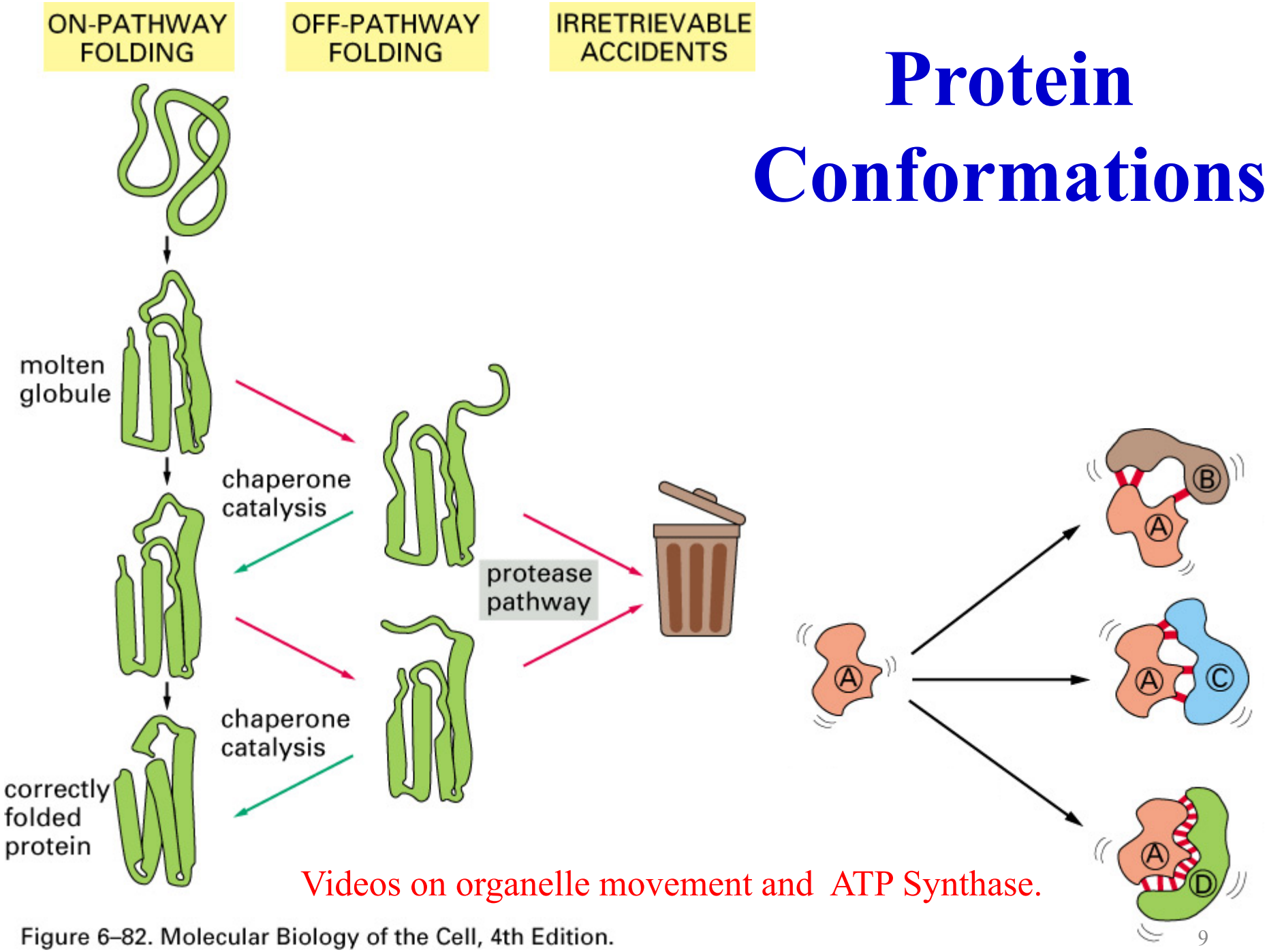


Figure 1–40. Molecular Biology of the Cell, 4th Edition.

Protein Conformations



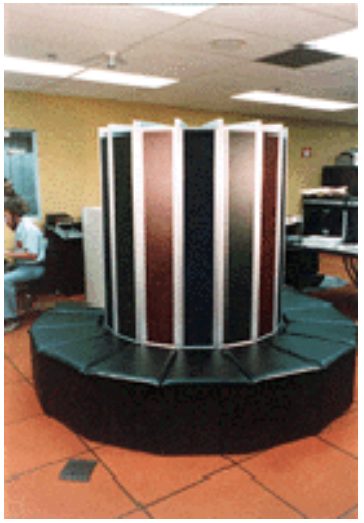
Videos on organelle movement and ATP Synthase.

Figure 6–82. Molecular Biology of the Cell, 4th Edition.

Contents

- Molecular Biology
- Micro/Nano-Scale Engineering
- Case: Electronics for Biomedical Applications
- Case: Lab on a chip
- Case: Bio-fuels
- Syllabus

Technology Drivers for Microsystems (Hardware)

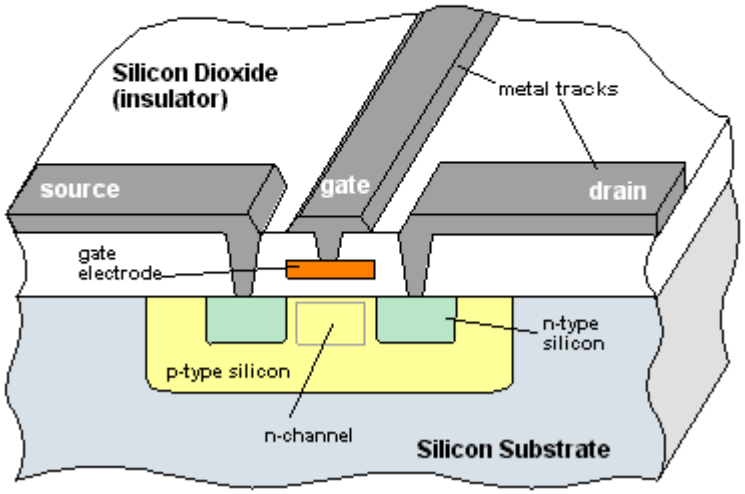


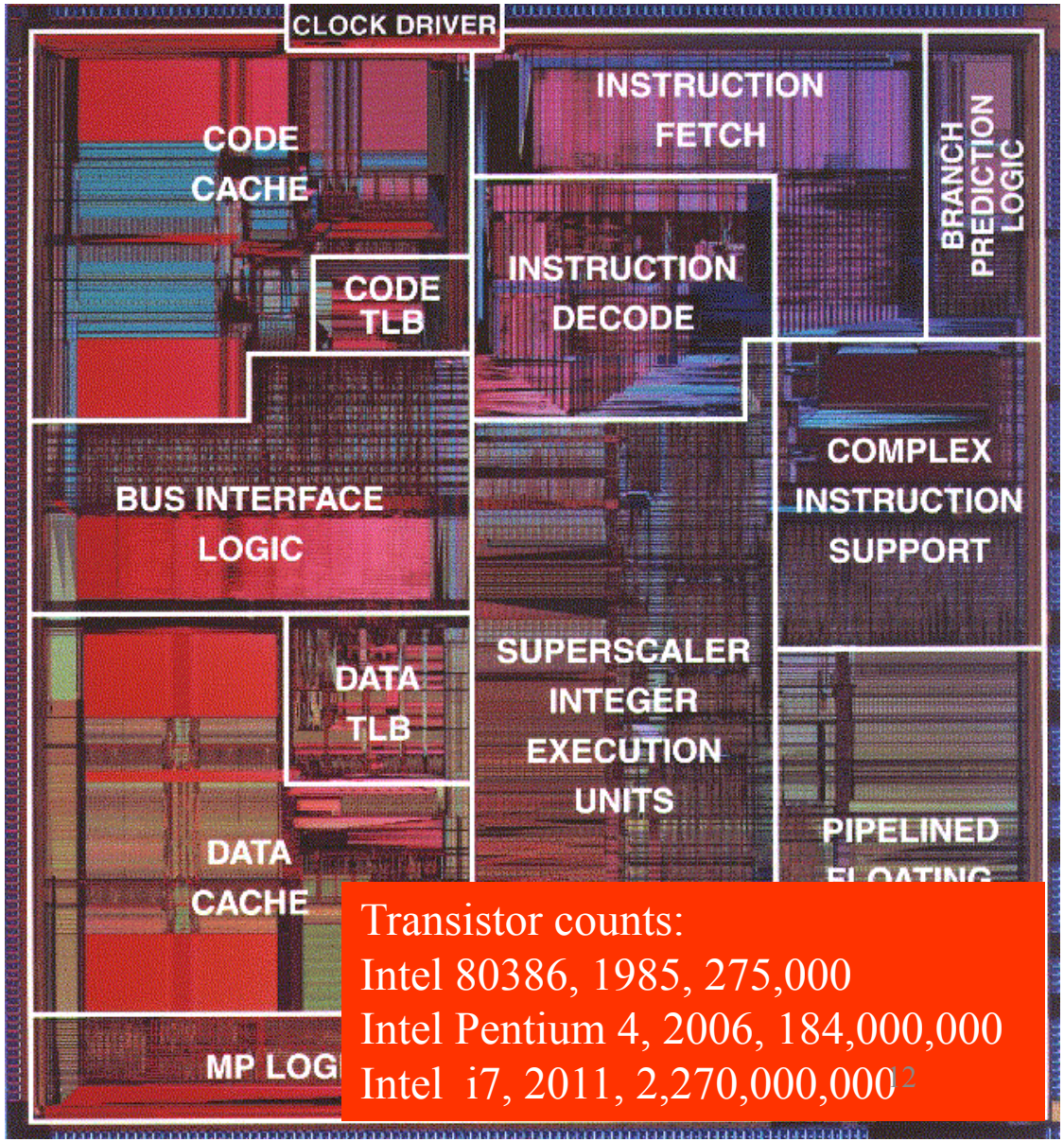
- Mainframe computers and supercomputers
- Desktop workstations/personal computers
- Laptop computers
- Smart phones or mobile computers (data centers)
- ?

Integrated Circuits – Information Era

From Computer Desktop Encyclopedia
© 2004 The Computer Language Co. Inc.

NMOS Transistor
(n-channel MOSFET)



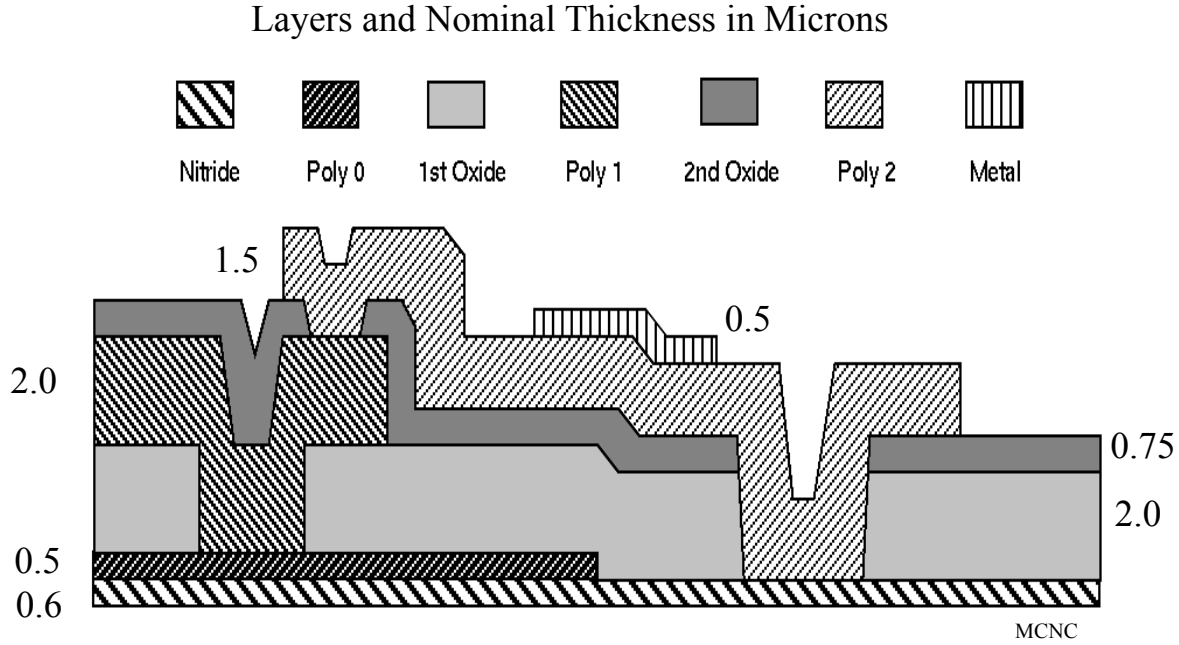


Transistor counts:
Intel 80386, 1985, 275,000
Intel Pentium 4, 2006, 184,000,000
Intel i7, 2011, 2,270,000,000

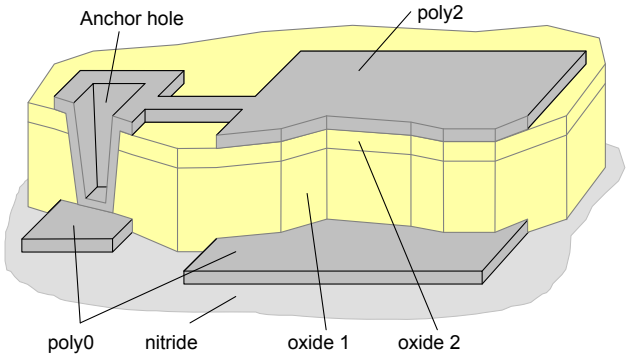
What's new?
accelerometers,
gyroscopes,
proximity,
pressure,
temperature,
humidity.

Microelectromechanical Systems (MEMS) for Sensors and Actuators

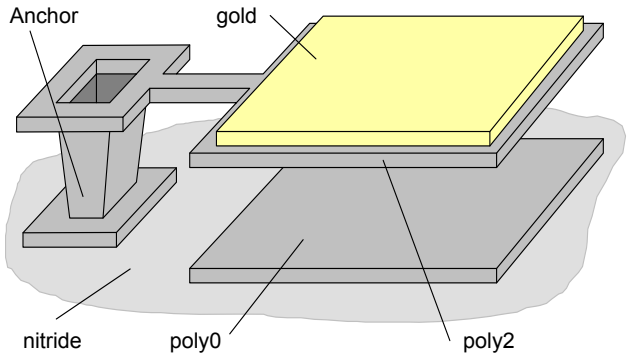
Multi-User MEMS Processes (MUMPS)



Example Design

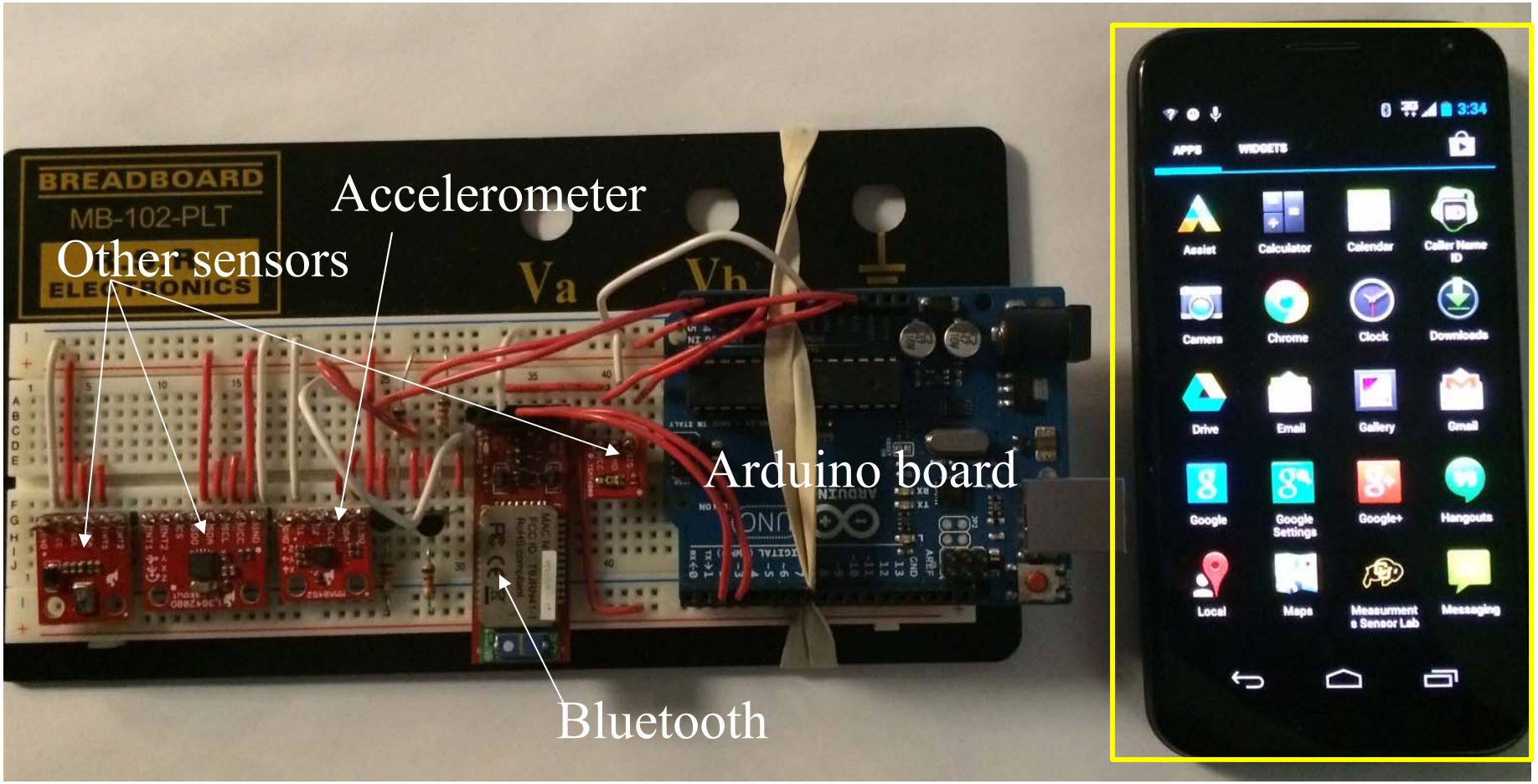


(a) After Poly2 Deposition



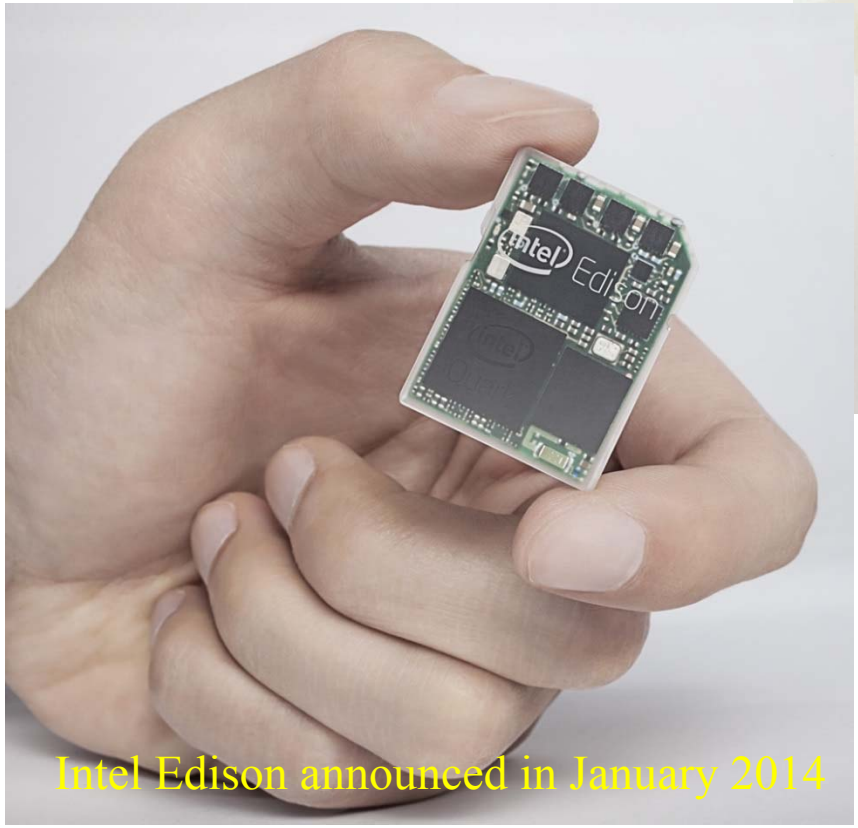
(b) Released Device

Smartphone-Controlled Sensors and Actuators



Wearable Electronics for Biomedical Applications (workshop)

The Intel Edison board features a low-power 22nm 400MHz Intel® Quark processor with two cores, integrated Wi-Fi and Bluetooth*.



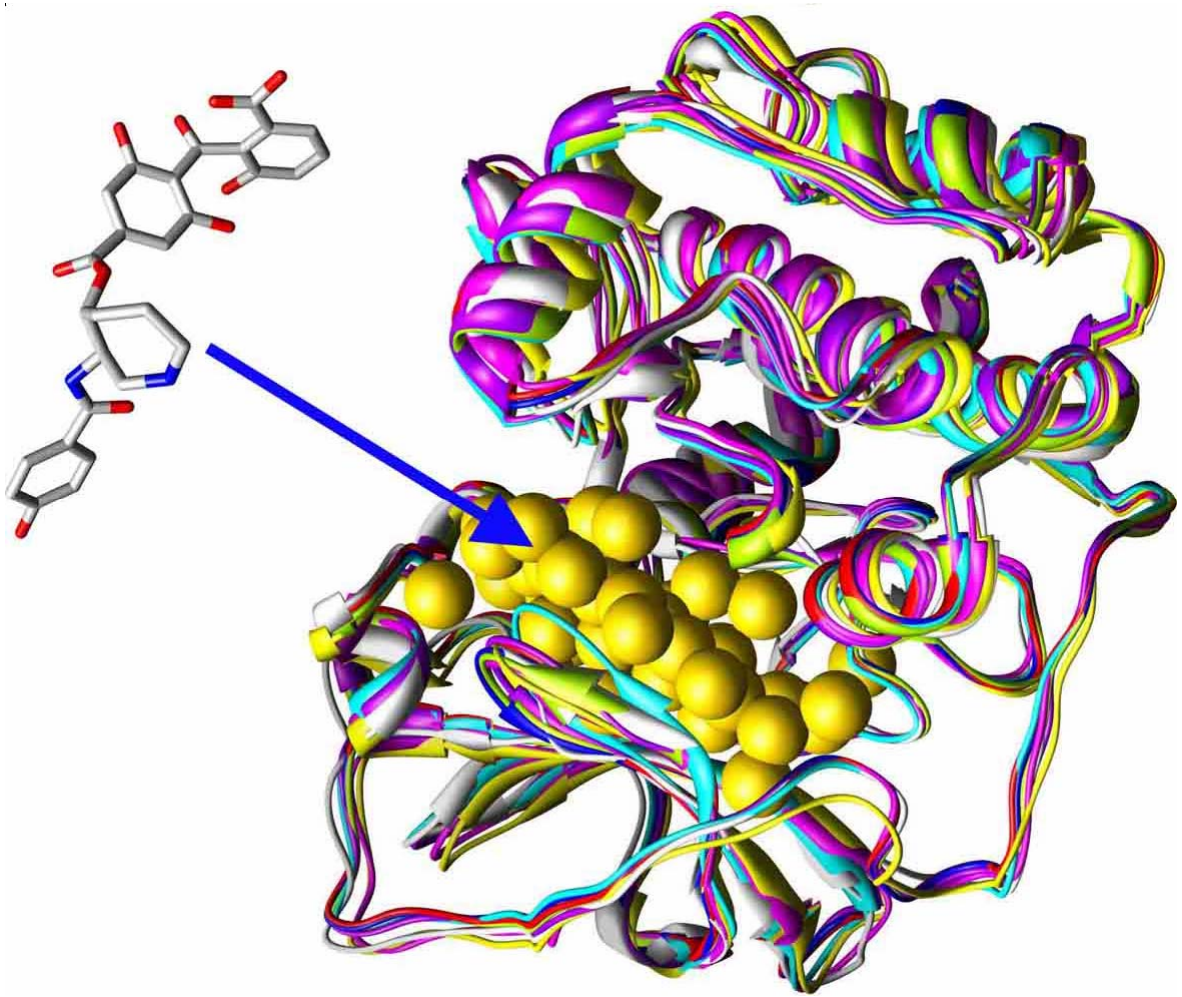
Intel Edison announced in January 2014

Upload a Windows or Android application to Intel Edison and control sensors and actuators through wireless connections.

Contents

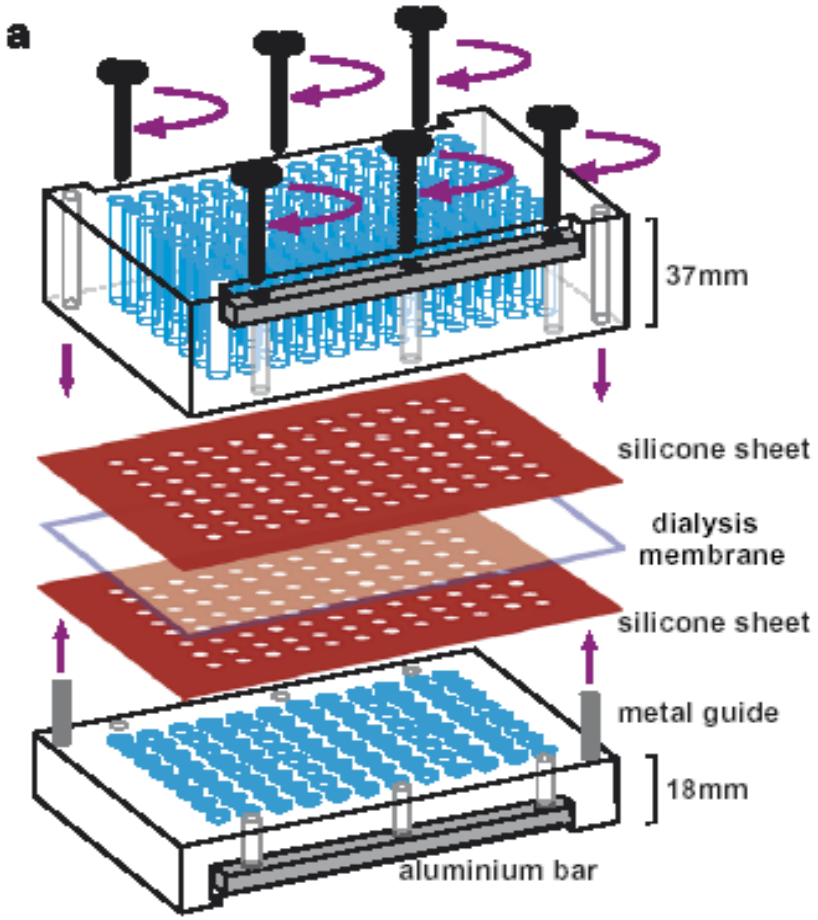
- Molecular Biology
- Micro/Nano-Scale Engineering
- Case: Electronics for Biomedical Applications
- Case: Lab on a chip
- Case: Bio-fuels
- Syllabus

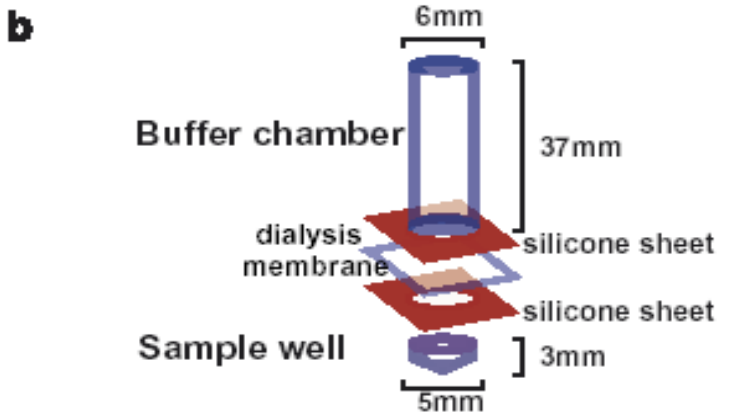
Structure Based Drug Design

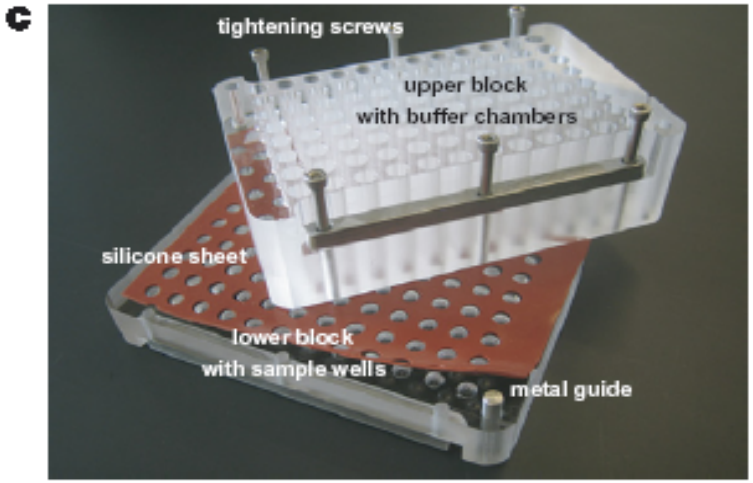


Membrane Protein
Polyhedral
Nanoparticles
→ Protein structure

Dialysis Chamber → Membrane Protein Polyhedral Nanoparticles

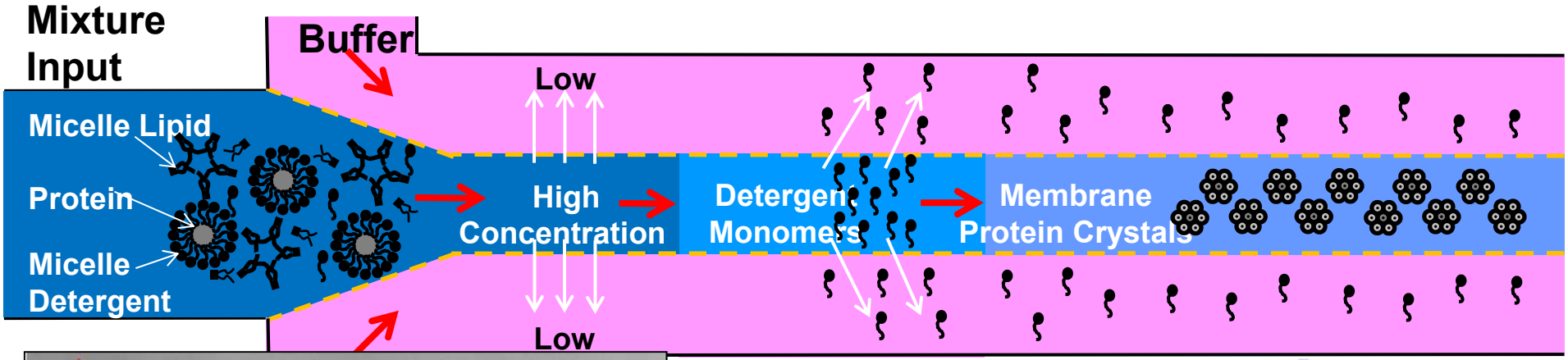


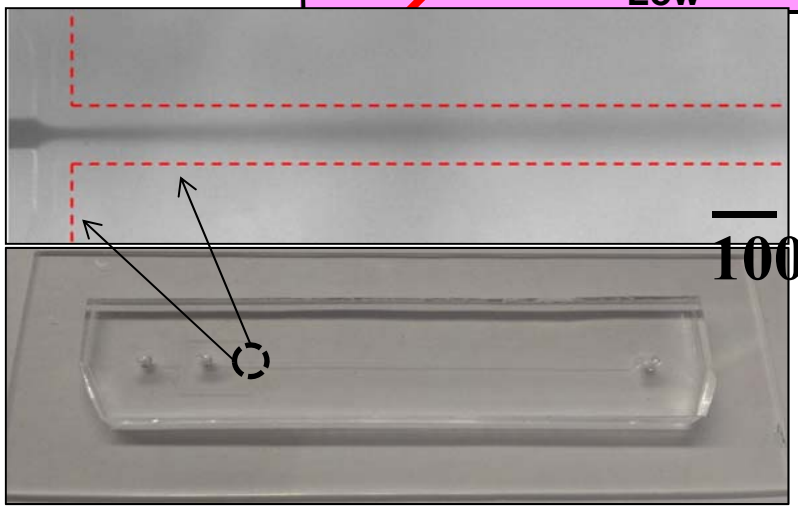


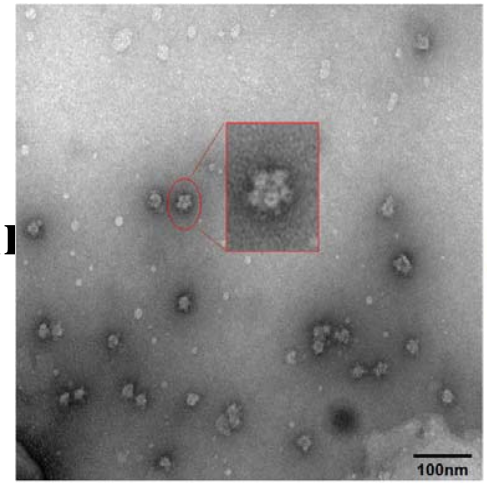


Lab-on-a-Chip for Membrane Protein Crystals

(CU-ME: Michael H.B. Stowell (& MCDB) and Y. C. Lee and Caltech)







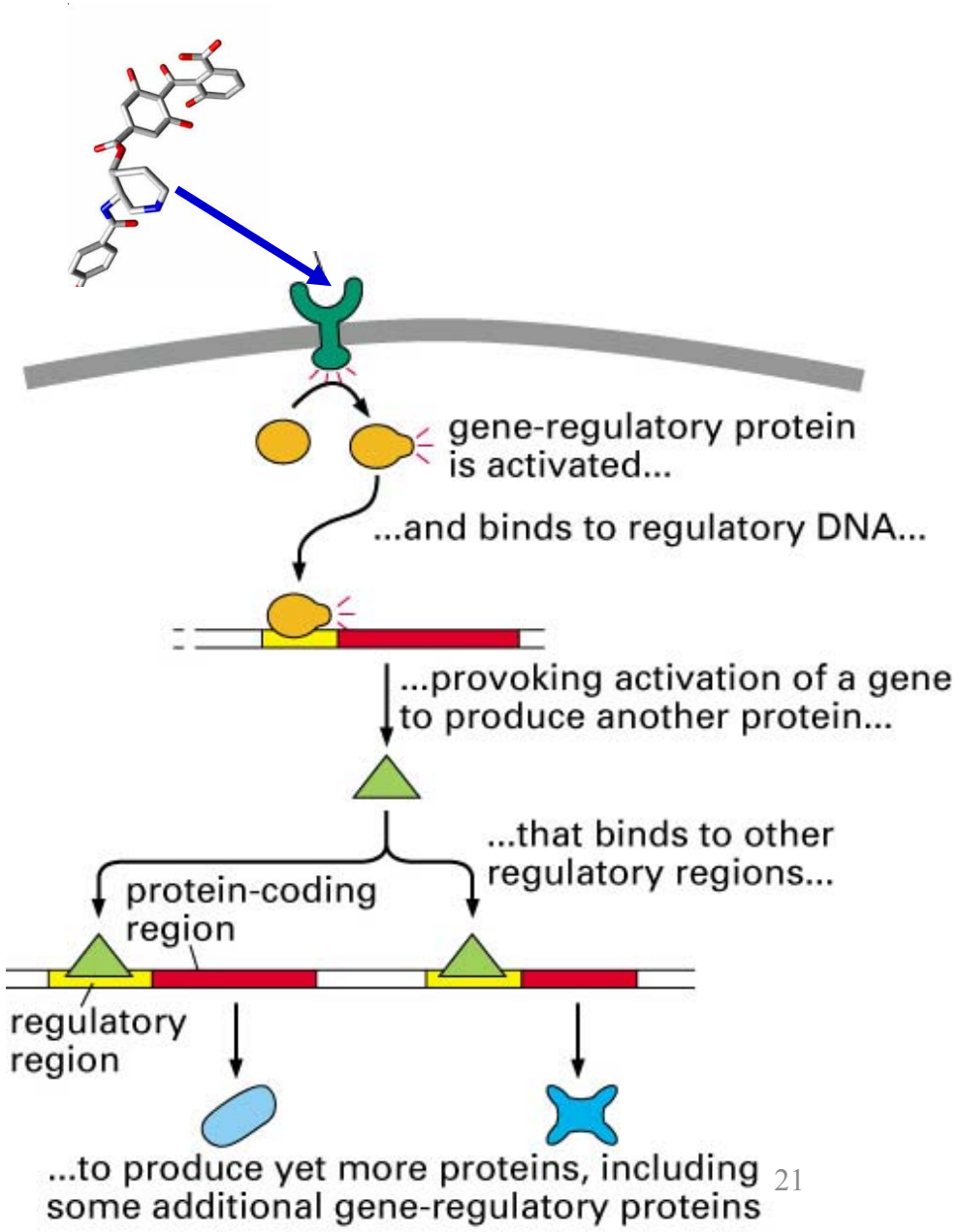
- Evaluation time reduced from weeks to seconds.
- Critical to increase the number of known structures from 1% to much higher.
- Basic technology to produce other biological nanoparticles and molecules.

DARPA: Rapid Threat Assessment

MAY 8, 2013

DARPA is soliciting innovative research proposals to develop new high-throughput methods and tools that will elucidate in thirty days the molecular mechanism by which threat agents, drugs, biologics or chemicals affect the function of biological cells.

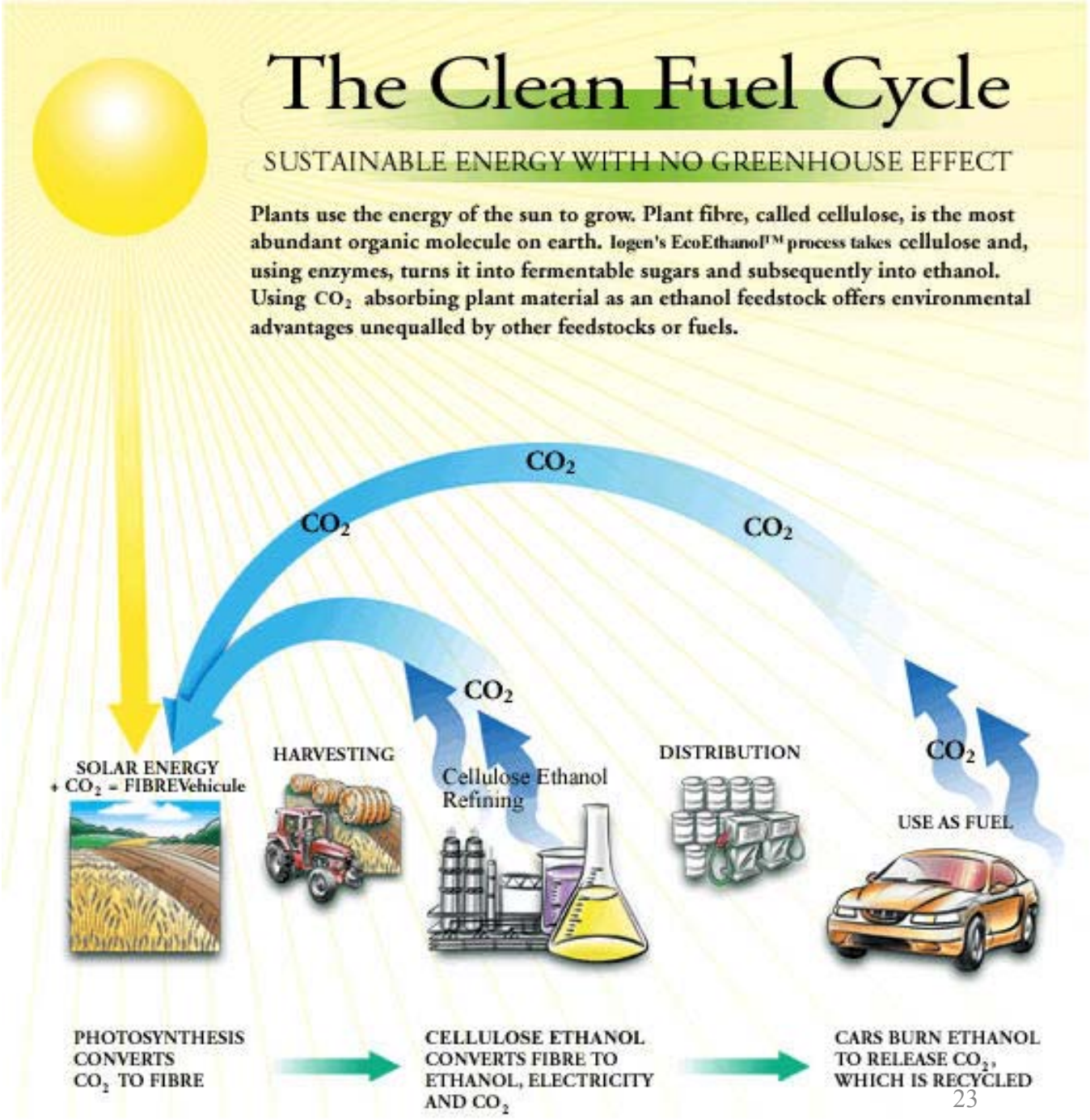
Years or decades → 30 days!
Important to drug discovery!



Contents

- Molecular Biology
- Micro/Nano-Scale Engineering
- Case: Electronics for Biomedical Applications
- Case: Lab on a chip
- Case: Bio-fuels
- Syllabus

Bio-Fuel


The Clean Fuel Cycle
SUSTAINABLE ENERGY WITH NO GREENHOUSE EFFECT
Plants use the energy of the sun to grow. Plant fibre, called cellulose, is the most abundant organic molecule on earth. Iogen's EcoEthanol™ process takes cellulose and, using enzymes, turns it into fermentable sugars and subsequently into ethanol. Using CO_2 absorbing plant material as an ethanol feedstock offers environmental advantages unequalled by other feedstocks or fuels.
CO_2
CO_2
CO_2
CO_2
CO_2
SOLAR ENERGY + CO_2 = FIBREVehicule
HARVESTING
Cellulose Ethanol Refining
DISTRIBUTION
USE AS FUEL
PHOTOSYNTHESIS CONVERTS CO_2 TO FIBRE
CELLULOSE ETHANOL CONVERTS FIBRE TO ETHANOL, ELECTRICITY AND CO_2
CARS BURN ETHANOL TO RELEASE CO_2, WHICH IS RECYCLED

CU: A leader in Biofuels

FOR IMMEDIATE RELEASE

Contact: Steven Silvers
303-596-9960
media@sundropfuels.com

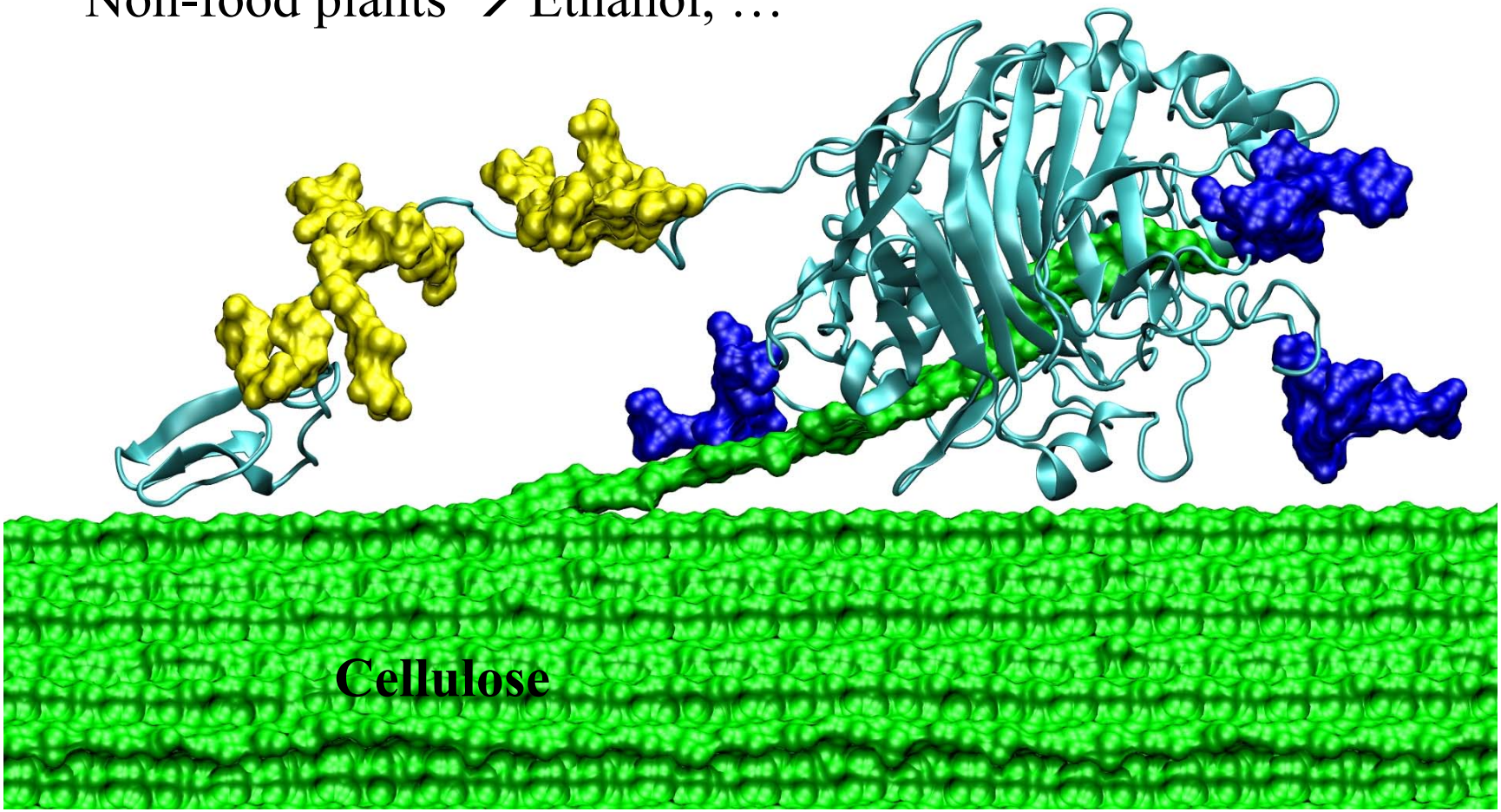
Chesapeake Energy Corporation acquires fifty percent stake in Sundrop Fuels

LOUISVILLE, COLORADO [July 11, 2011] – Sundrop Fuels, Inc., a gasification-based drop-in biofuels company, and Chesapeake NG Ventures Corp. (CNGV), a wholly owned subsidiary of Chesapeake Energy Corporation (NYSE:CHK), today announced that they have closed a transaction in which CNGV will invest $155 million, enabling Sundrop Fuels to expand operations and begin construction of a commercial demonstration facility to produce biobased "green gasoline" made from cellulosic material. Additionally, Sundrop Fuels announced that Oak Investment Partners, a current investor, has committed to invest $20 million pro rata with CNGV. The deals closed on July 11, 2011.

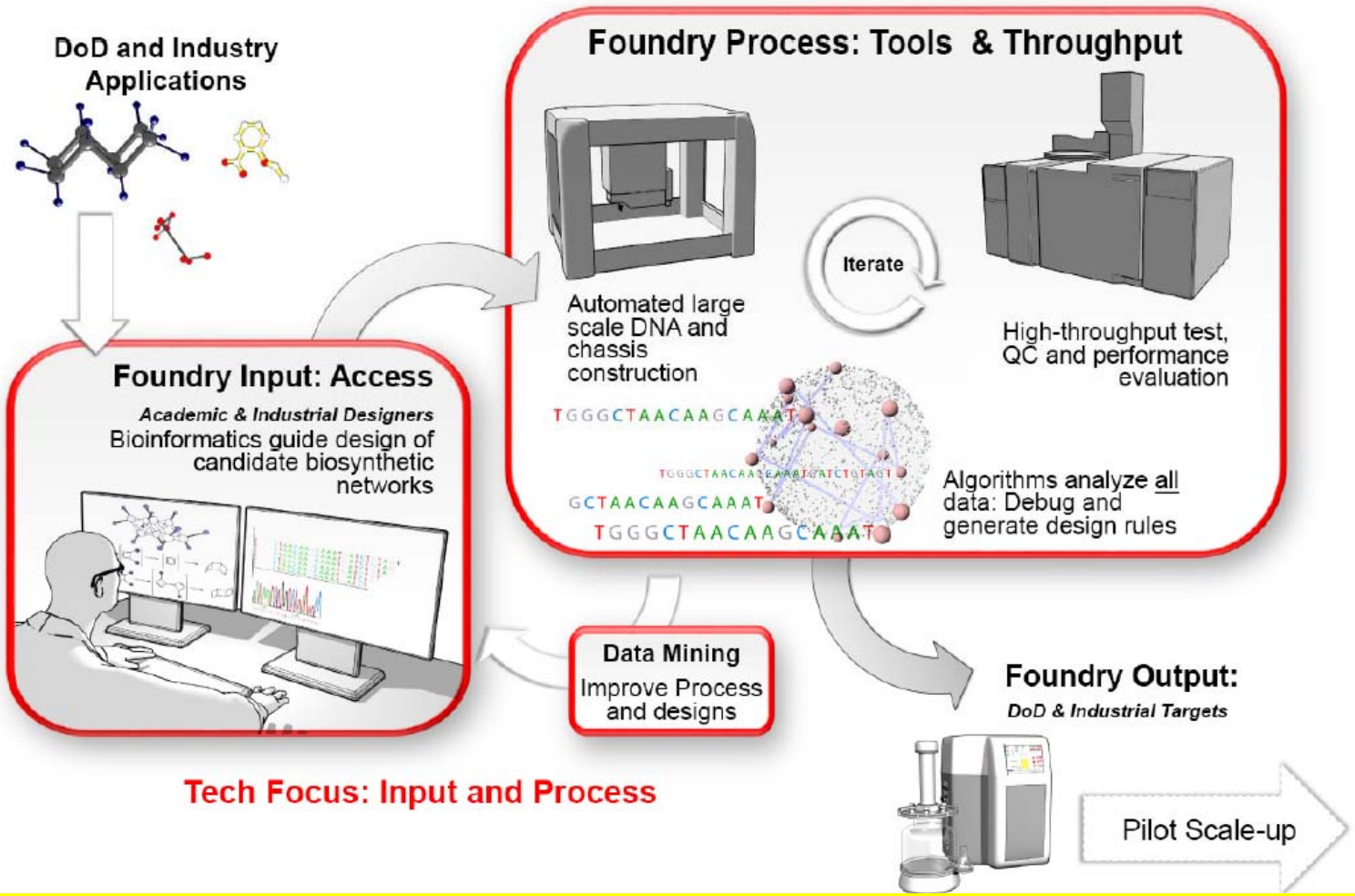
Biofuel: Cellulose-Digesting Enzyme

(National Renewable Energy Laboratory)

Non-food plants → Ethanol, …



DARPA:L Living Foundries: 1000 Molecules



July 12, 2013 Build a scalable, integrated, rapid design and prototyping infrastructure for the facile engineering of biology. This infrastructure will enable transformative and currently inaccessible projects to develop advanced chemicals, materials, sensing capabilities, and therapeutics.

Contents

- Molecular Biology
- Micro/Nano-Scale Engineering
- Case: Electronics for Biomedical Applications
- Case: Lab on a chip
- Case: Bio-fuels
- Syllabus