Introduction to Nanotechnology

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What is "nano"


100m


10m


1m

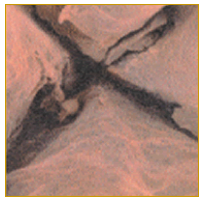

10^{-1}m


10^{-2}m

10^{-3}m

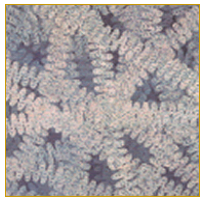
http://www.powersof10.com/

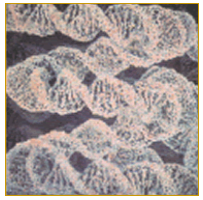
What is "nano"

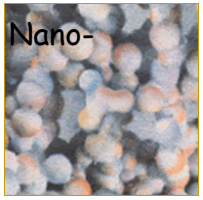

10^{-4}m

10^{-5}m

10^{-6}m


10^{-7}m

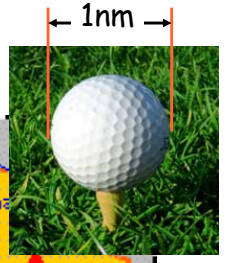

10^{-8}m



10^{-9}m

http://www.powersof10.com/

Perspective



Narrower than my pinky!

Nanotechnology, a definition

- American Heritage Dictionary
  "The science and technology of building electronic circuits and devices from single atoms and molecules."
- Wordnet
  "the branch of engineering that deals with things smaller than 100 nanometers (especially with the manipulation of individual molecules)"

Definitions continued

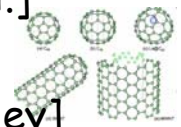
- M. Rocco, NSF
  "the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new properties and functions"
- NASA
  "the creation of functional materials, devices and systems through control of matter on the nanometer length scale (1-100 nanometers), and exploitation of novel phenomena and properties (physical, chemical, biological) at that length scale"

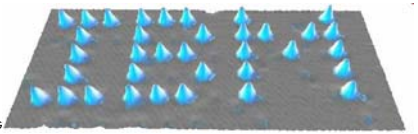
Ancient History of Nanotech?

- ~400BC, Atoms [Democritus of Abdera]
- ~500AD, glazes [artisan in Mesopotamia]
- 1661, elements [Boyle]
- 1803, atomic theory [Dalton]
- 1869, periodic table [Mendeleyev]
- 1915, Bohr Model [Bohr]
- 1920, carbon black

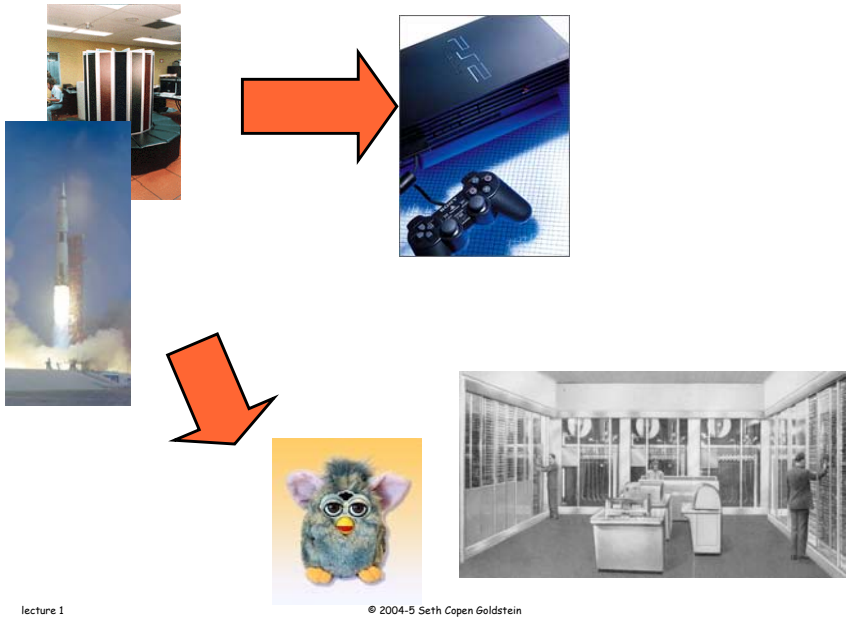
Modern history of nanotech

- 1959, Feynman's talk "There is plenty of room at the bottom"
- 1965, Moore's original paper
- 1974, "Nanotechnology" [Taniguchi.]
- 1984, invention of STM [Binning]
- 1985, discovery of fullerens [smalley]
- 1986, Drexler, Engines of Creation
- 1990, IBM written in Xenon

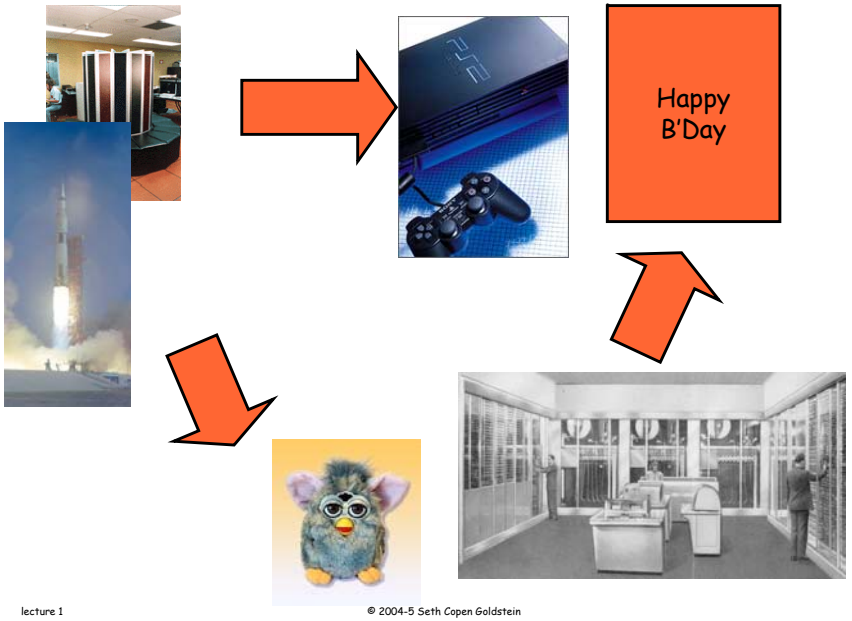




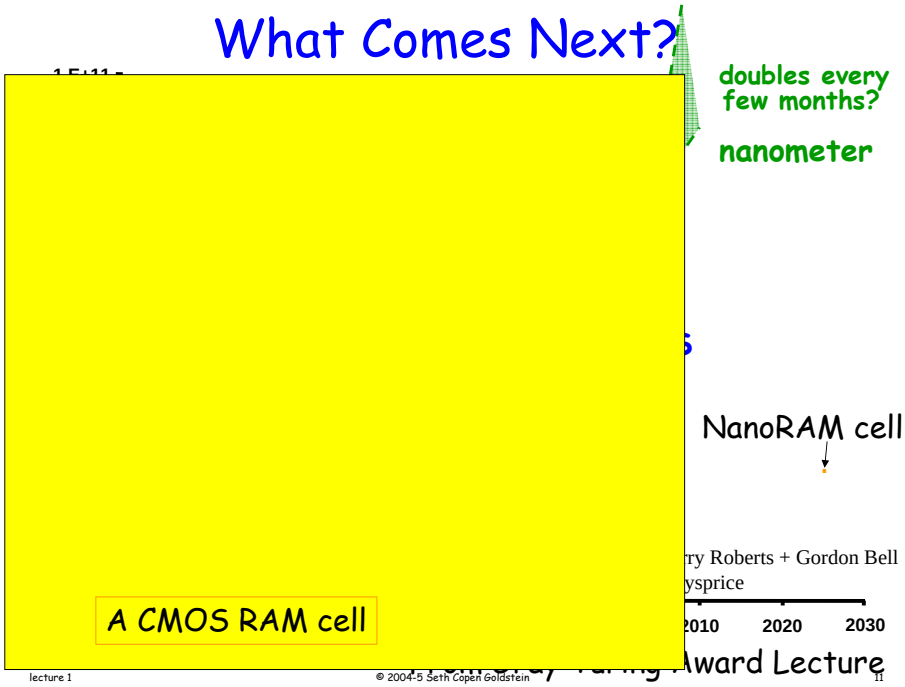
Moore's Law



Moore's Law



What Comes Next?

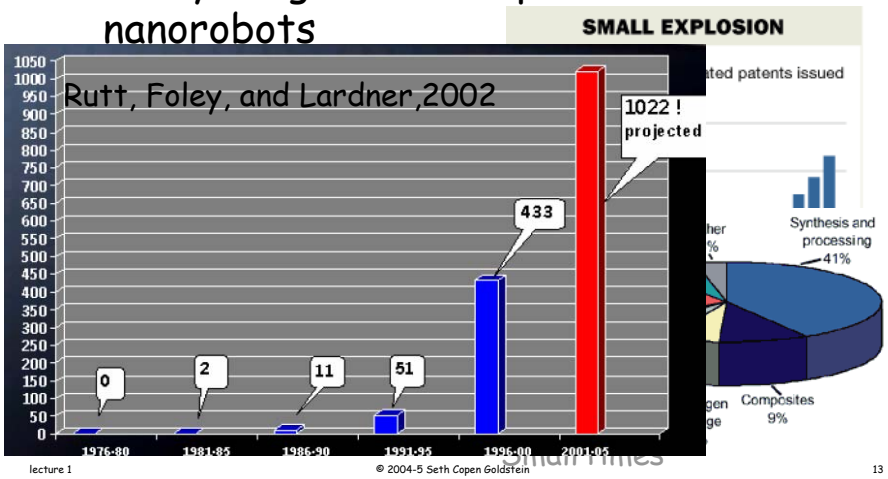


Technology Shifts

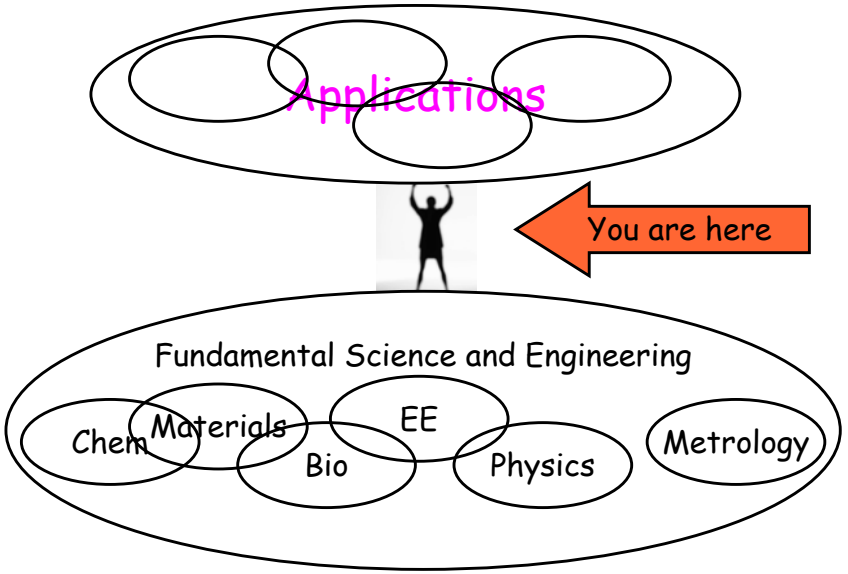
- Size of Devices
  - ⇒ Inches to Microns to Nanometers
- Type of Interconnect
  - ⇒ Rods to Lithowires to Nanowires
- Method of Fabrication
  - ⇒ Hammers to Light to Self-Assembly
- Largest Sustainable System
  - ⇒ 10^1 to 10^8 to 10^{12}
- Reliability
  - ⇒ Bad to Excellent to Unknown

Commercialization

- By 2015 predicted to be >10^{12} dollars
- Everything from nanoparticles to nanorobots



What Nanotechnology means to x

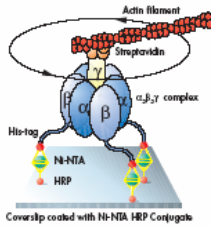


One Course Goal

- Understand what is important to you
  - Read literature in related fields
  - Understand relevance to your research
- Understand importance to others

Biology

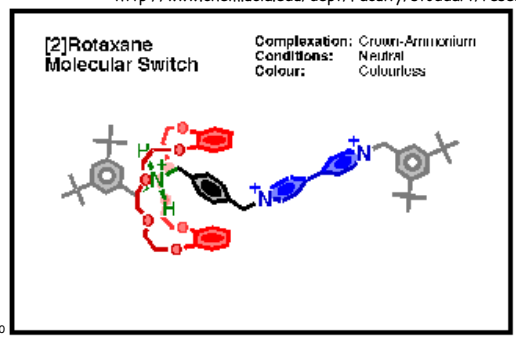
- DNA/RNA
  - 2-3nm per base pair
  - 10^9 base pairs for human genome
- Proteins
  - 100K different in human
  - "self-assembles"
- DNA-computing
- DNA-based self-assembly
- ATP motors



Chemistry

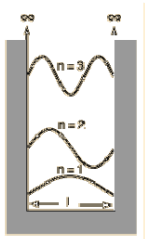
- Molecular diodes
- Molecular switches
- Block Polymers
- Fluidic self-assembly
- Molecular design

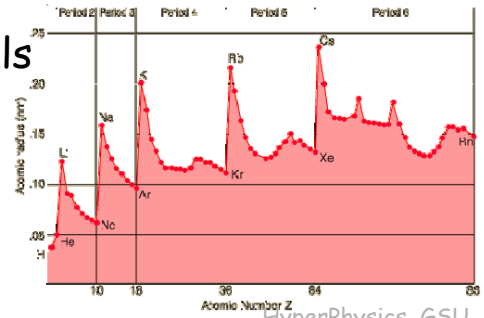
http://www.chem.ucla.edu/dept/Faculty/stoddart/rese



Physics

- Quantum mechanics
  - Confinement
  - De Brogli wavelength
  - tunneling
- Scattering
- Photonic Crystals
- Basic forces

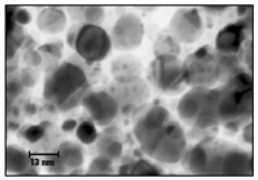




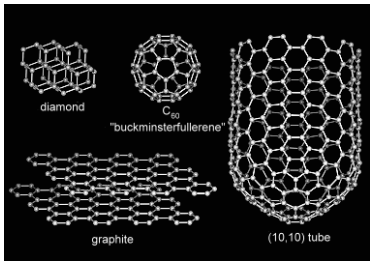
HyperPhysics, GSU

Materials

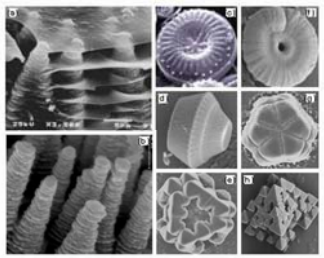
- Carbon Nanotubes
- Multifunctional materials
- Smart materials
- Nanostructured catalysts



QuantumSphere

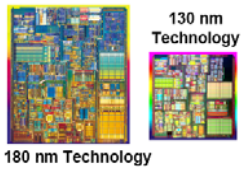


Azonano.com

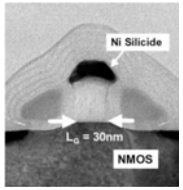


Electrical Engineering

- VLSI
- Lithography
  - Top-down assembly
  - Easily to 65nm, controlled gates to 15nm,
  - Thicknesses to sub-1nm!
- Transistor
- Electronic nanotechnology
- Nanocomputing



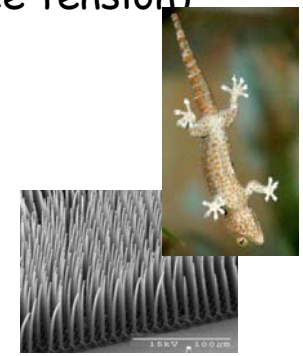
Intel Tech J., 2002



Rusu, 2001

Robotics

- Integration
- Actuation (e.g., surface tension)
- Power systems
- Sensing
- Emergent behavior



Sociology

- Disruptive technology
- Changes in social fabric
- Work habits
- Life expectancy
- Understanding fear

Policy

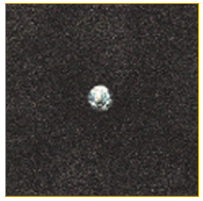
- Controlling & aiding research
- Risk of accidental or intentional harm
- Training and education
- Environmental impact
- What to fund

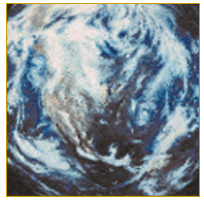
What is Nanotechnology?

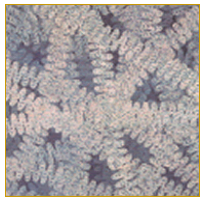
- Is the question important?
- Another goal of the course, understand what nanotech is
- Two perspectives
  - Size
  - Number

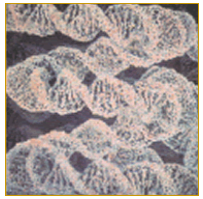
What is "nano"

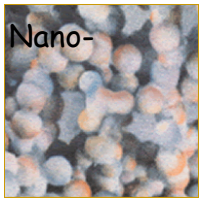

10^9m


10^8m


10^7m


10^{-7}m


10^{-8}m



10^{-9}m

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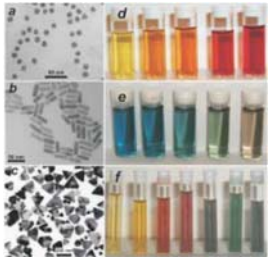
What is "nano"

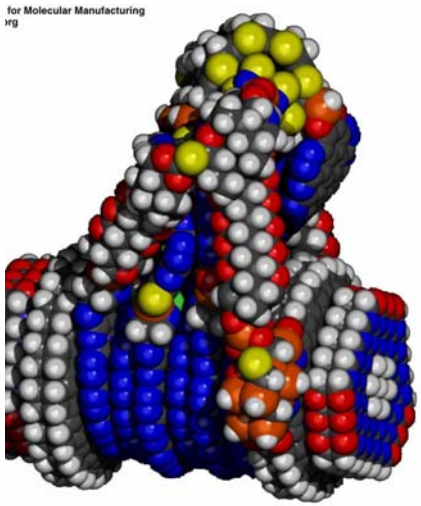
- Surface to volume ratio is different
- Individual atoms are important
- Forces/effects are new
  - Quantum
  - Van der Walls
  - Brownian
  - Electrostatic



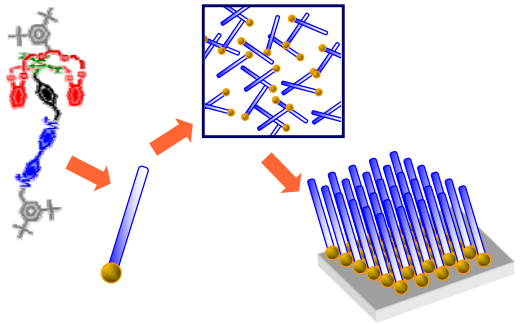
- E.g., how fast is the speed of sound

Is this nano?

- A motion controller for nanoassembly

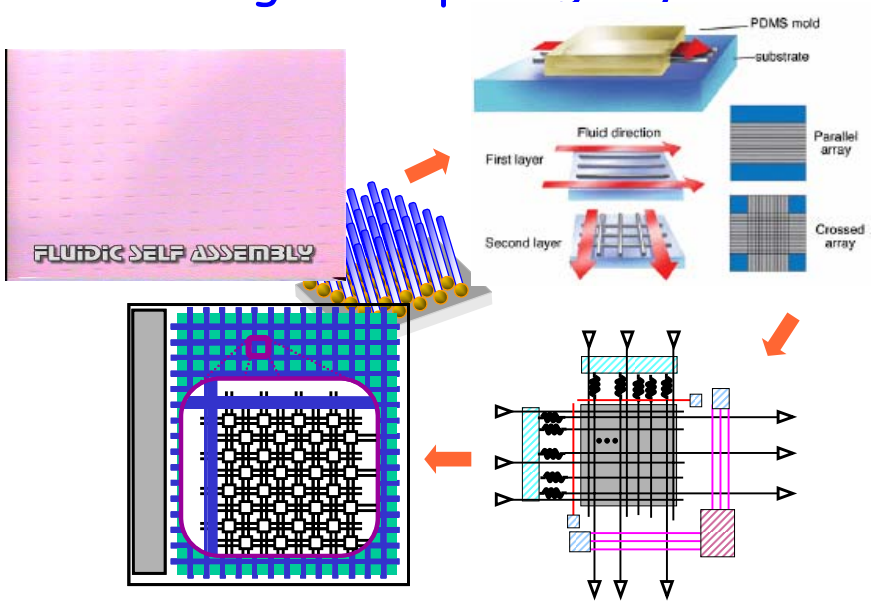


Building a Computing Crystal



Or, is this nano?

Building a Computing Crystal



The Nano design space

- Length scale
- Dimensions controlled
- Types of materials used
- Dynamic or static end-product
- Forces harnessed
- Assembly method
  - bottom-up
  - Top-down
  - Deterministic or self-assembly

Controlling Complexity

- What are the limits to self-assembly?
- How do we engineer 10^{23} of anything?
- What is the role of computer science?
- Understand the tradeoffs in manufacturing at the nanoscale
  - Precision
  - Randomness
  - programming

Course Structure

- Lectures
- Participation
- Readings
- Reviews
- homework
- Project

Topics Covered

- General nanotechnology
  - Materials
  - Science background as needed
- Tools
- Electronic nanotechnology
- Fabrication
  - Top-down
  - Bottom-up/self-assembly
- Nanorobotics
- Self-organization

For Next Time

- Read Feynman's lecture "There is plenty of room at the bottom" www.zyvex.com/nanotech/feynman.html
- Write ½ page about above
- Email pdf to seth@cs.cmu.edu before Wed Midnight

- Email me
  - brief background and
  - what you want to get out of this course