

Introduction to Nanotechnology

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What is "nano"



100m



10m



1m



10^{-1}m



10^{-2}m



Milli-

10^{-3}m

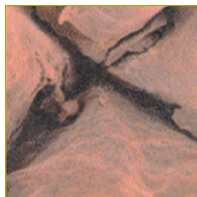
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What is "nano"



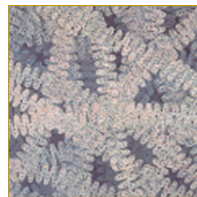
10^{-4}m



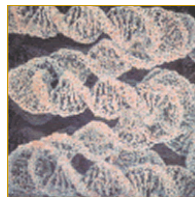
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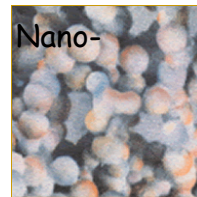
10^{-6}m



10^{-7}m



10^{-8}m



10^{-9}m

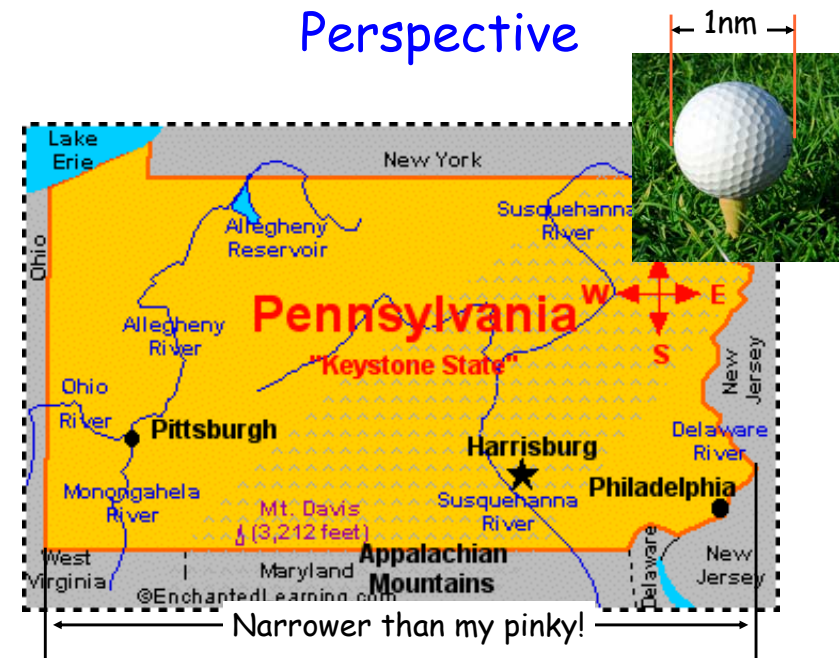
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Perspective



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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

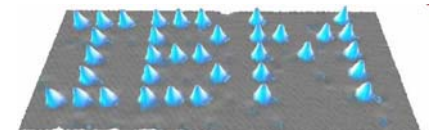
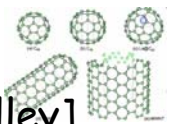
- M. Rocco, NSF
"the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new properties and functions"
- NASA
"the creation of functional materials, devices and systems through control of matter on the nanometer length scale (1-100 nanometers), and exploitation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

Ancient History of Nanotech?

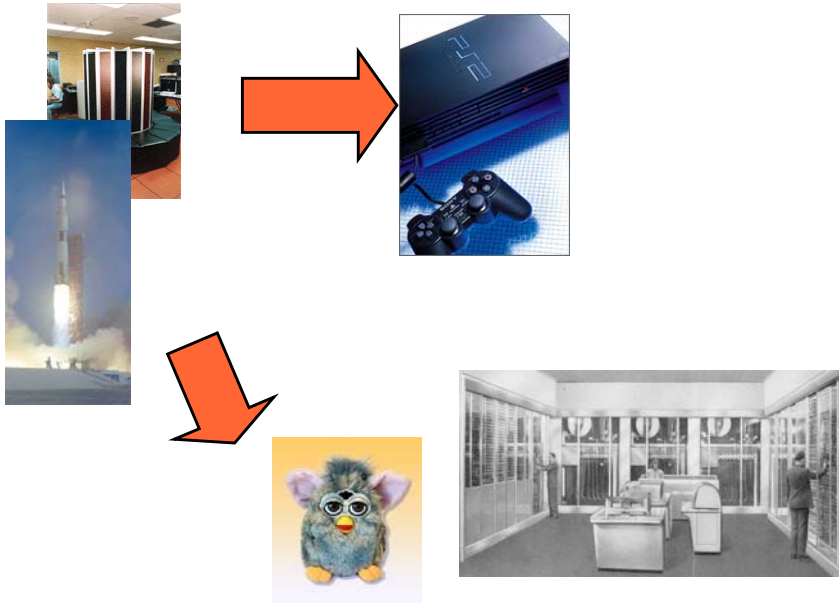
- ~400BC, Atoms [Democritus of Abdera]
- ~500AD, glazes [artisan in Mesopotamia]
- 1661, elements [Boyle]
- 1803, atomic theory [Dalton]
- 1869, periodic table [Mendeleyev]
- 1915, Bohr Model [Bohr]
- 1920, carbon black

Modern history of nanotech

- 1959, Feynman's talk "There is plenty of room at the bottom"
- 1965, Moore's original paper
- 1981, Drexler began popularizing
- 1984, invention of STM [Binnig]
- 1985, discovery of fullerenes [Smalley]
- 1990, IBM written in Xenon



Moore's Law

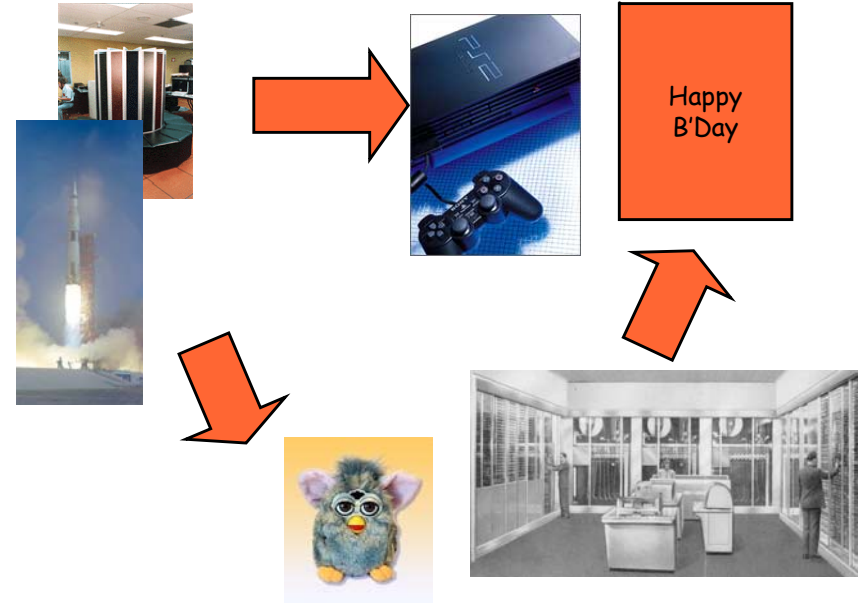


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Moore's Law

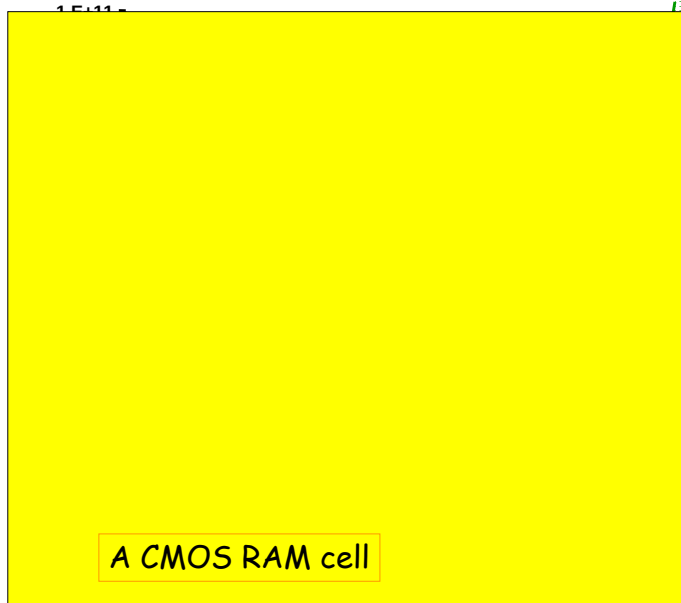


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What Comes Next?



doubles every
few months?
nanometer

NanoRAM cell

Robertson + Gordon Bell
prize

2010 2020 2030

Robertson + Gordon Bell
prize

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Robertson + Gordon Bell
prize

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**

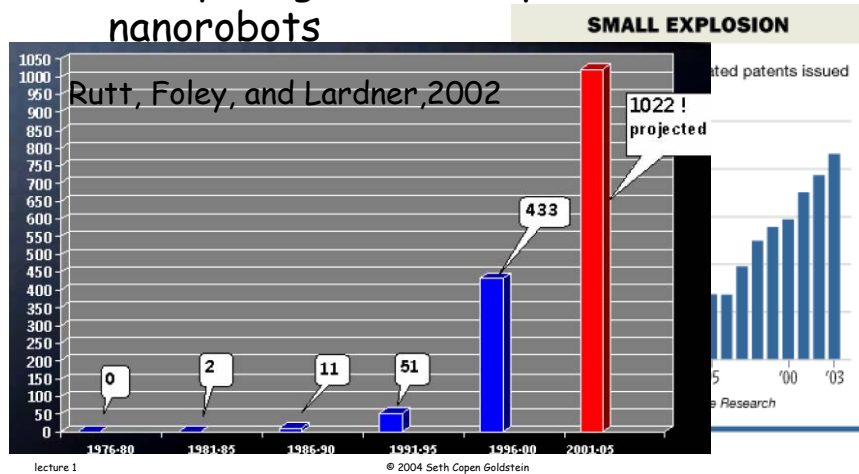
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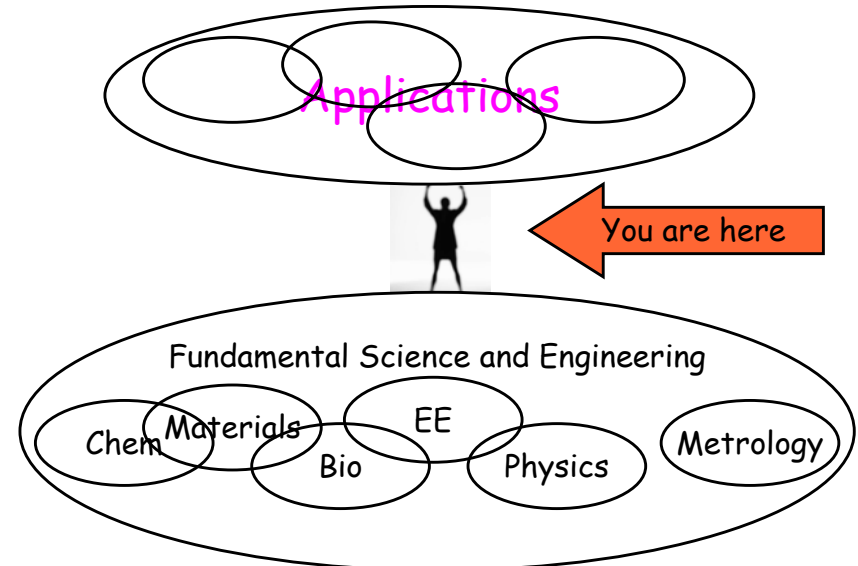
Commercialization

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



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What Nanotechnology means to x



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One Course Goal

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

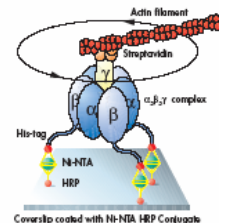
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Biology

- 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



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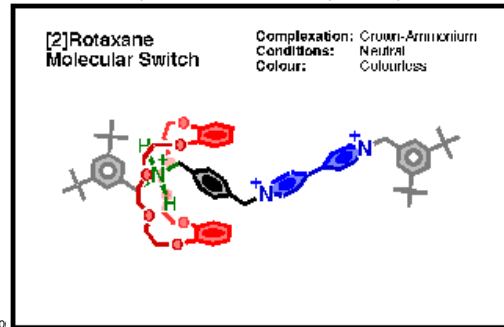
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Chemistry

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

<http://www.chem.ucla.edu/dept/Faculty/stoddart/research/>



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Physics

- Quantum mechanics
- Scattering

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Materials

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

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Electrical Engineering

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

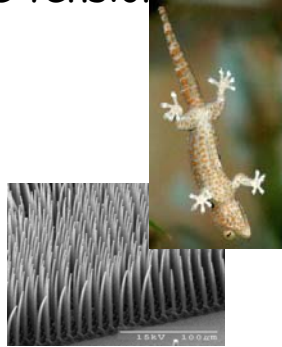
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Robotics

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



Sociology

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

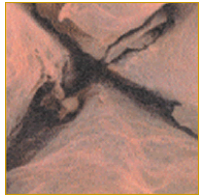
Policy

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

What is Nanotechnology?

- Does anyone really know?
- Another goal of the course, determine precisely what nanotech is

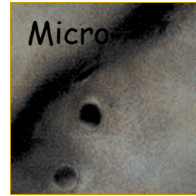
What is "nano"



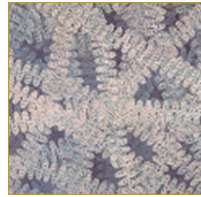
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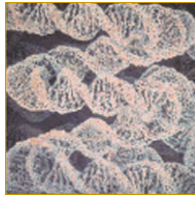
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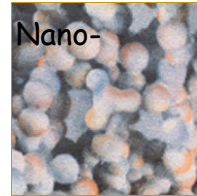
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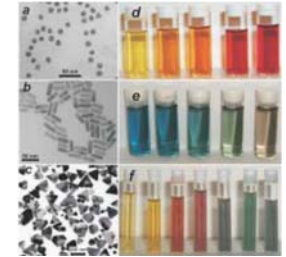
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What is "nano"

- Surface to volume ration is different
- Individual atoms are important
- Forces/effects are new
 - Quantum
 - Van der Waals
 - Brownian
 - Electrostatic
- E.g., how fast is the speed of sound



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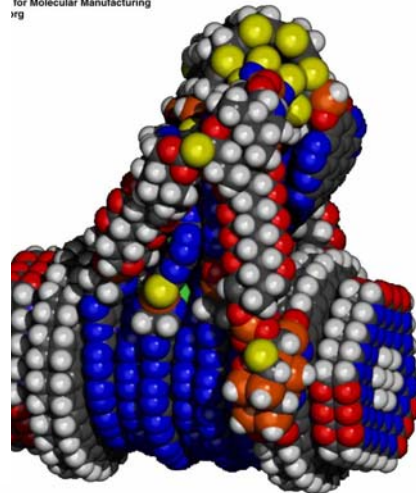
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Is this nano?

- A motion controller for nanoassembly

for Molecular Manufacturing
vrg

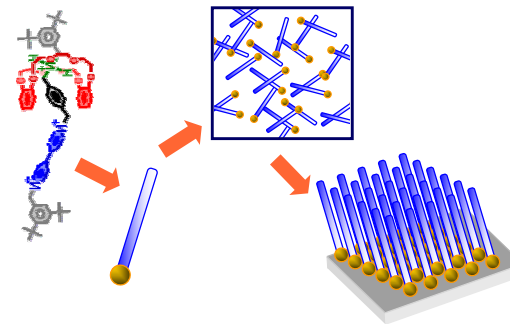


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Building a Computing Crystal



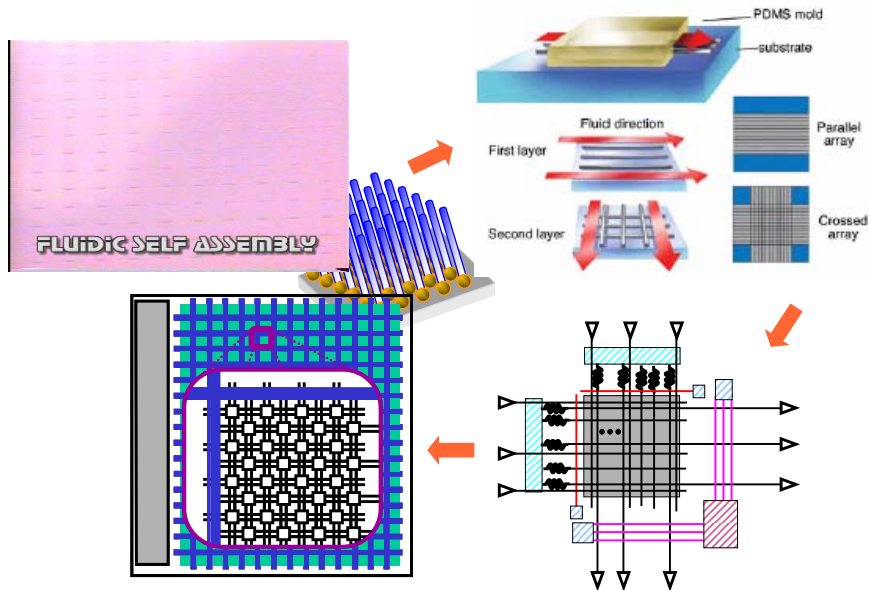
Or, is this nano?

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Building a Computing Crystal



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Defining Nanotechnology

- Why?
 - Asilomar conference of 1975 for biotech
 - Funding priorities
- How?
 - First, describe design space
 - Then, linearize

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The Nano design space

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

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Course Structure

- Lectures
- Participation
- Readings
- Reviews
- Projects

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Topics Covered

- General nanotechnology
- Electronic nanotechnology
- Bottom-up/self-assembly
- Tools
- Nanorobotics
- Self-organization
- Policy

For Next Time

- Read Feynman's lecture "There is plenty of room at the bottom"
www.zyvex.com/nanotech/feynman.html
- Write $\frac{1}{2}$ 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