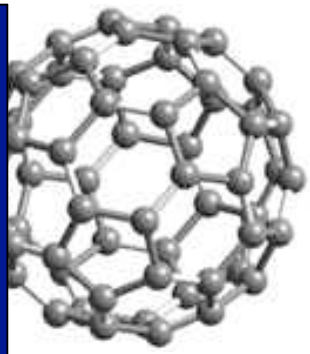
Nanotechnology, Medicine, & the Body

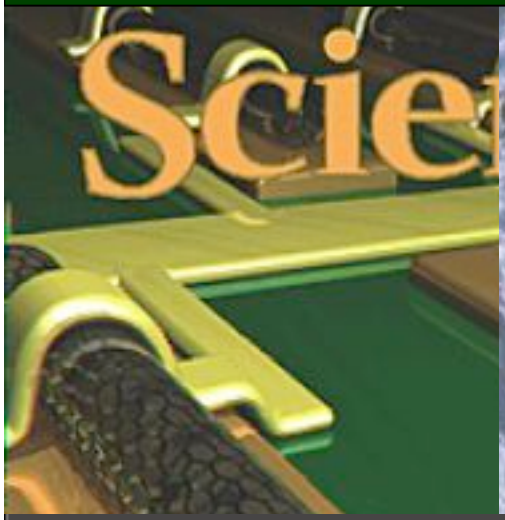


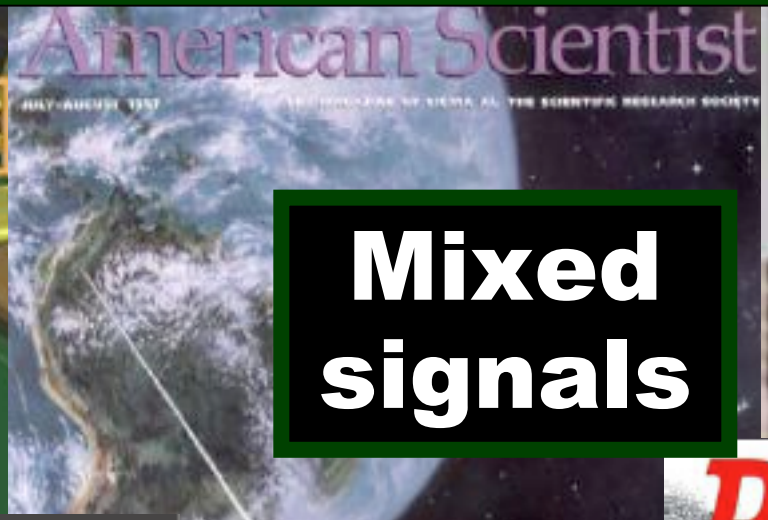
Charles Tahan and Ricky Leung
December 2, 2004
Medical History and Bioethics 559
University of Wisconsin, Madison

Outline for Today

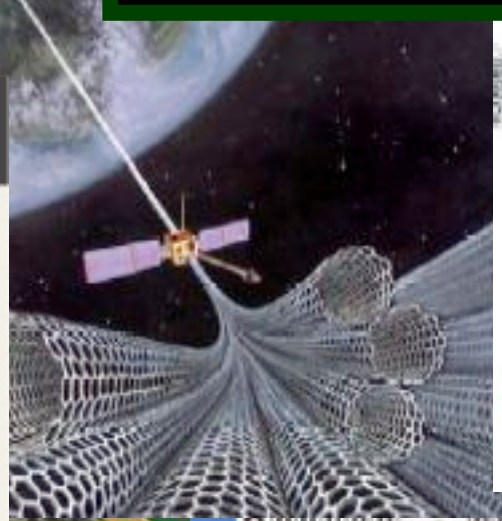
- **Introduction to Nano** [Charlie Tahan]
- **Medical Applications Today**
- **Nanomedicine's future** [Ricky Leung]
- **Implications Discussion**

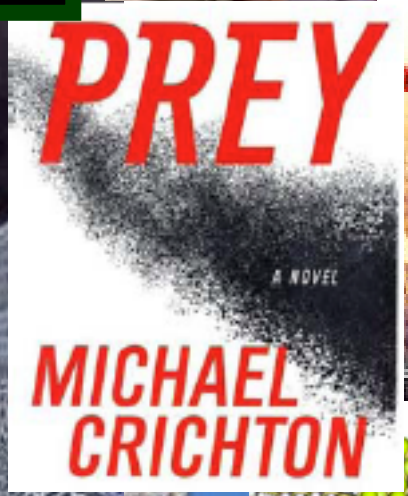
Nanotechnology

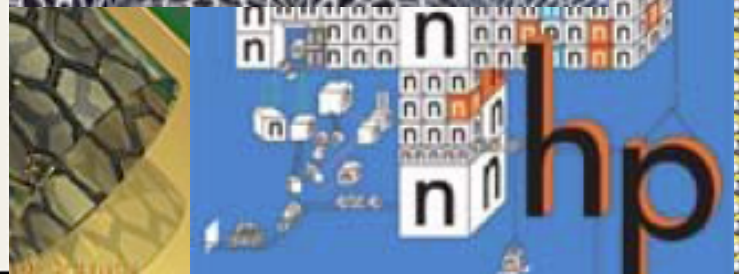


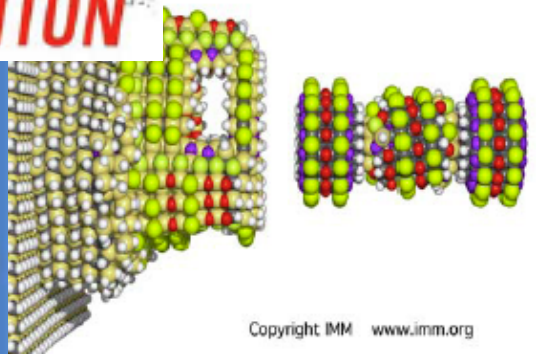


Mixed signals







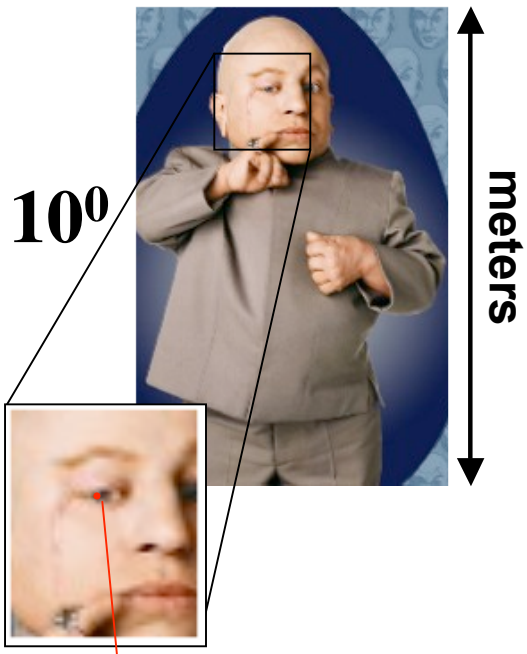


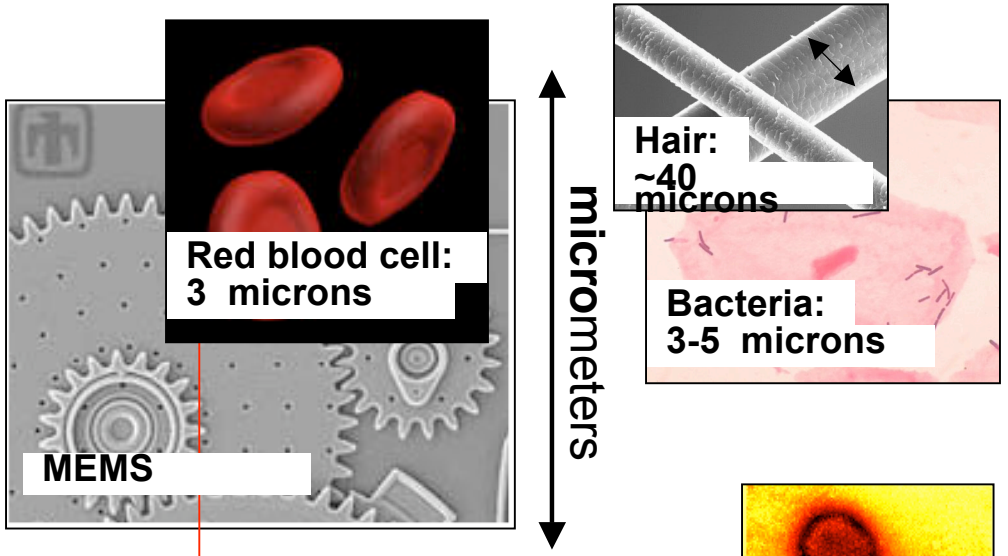
Nanotechnology

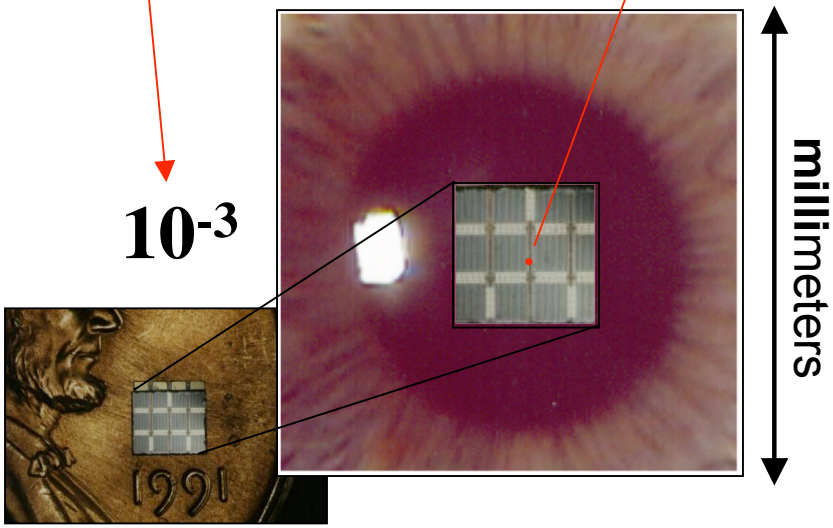
kilometer	km	1000	$1X10^{3}$
meter	m	1	$1X10^{0}$
millimeter	mm	1/1000	$1X10^{-3}$
micrometer	μm	1/1000000	$1X10^{-6}$
nanometer	nm	1/1000000000	**$1X10^{-9}$**
angstrom	Å	1/10000000000	$1X10^{-10}$

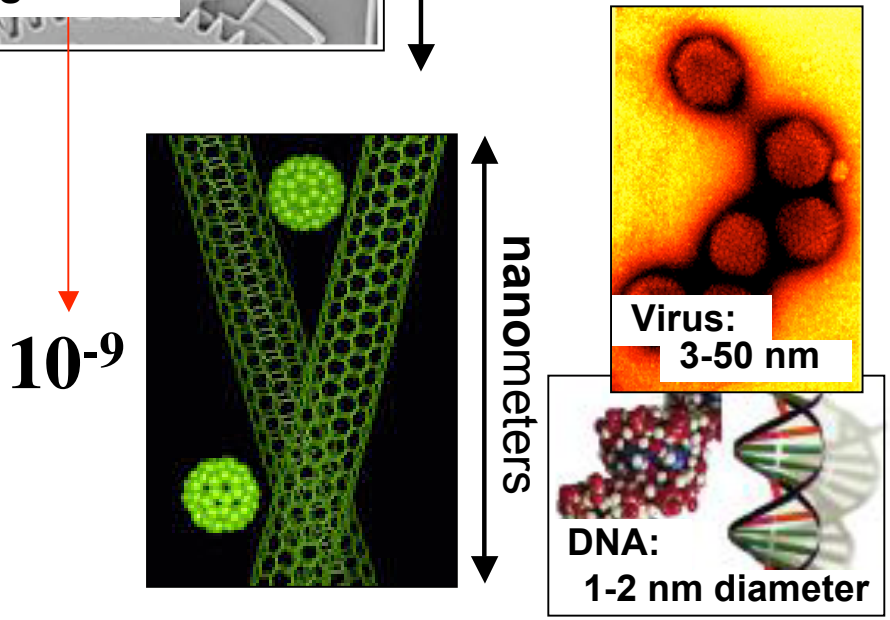
A nanometer is one billionth of a meter

Size and Scale: Factors of 1000







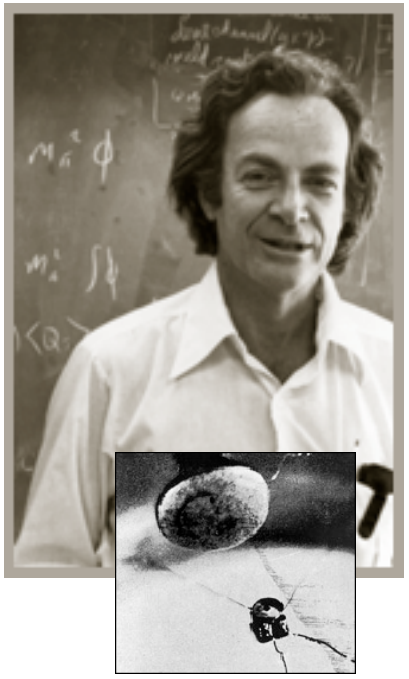


1 nm = 10 Hydrogen atoms:

Defining Nanotechnology

Federal Gov.'s def:

Nanotechnology is the creation of functional materials, devices, and systems through control of matter on the nanometer length scale, exploiting novel phenomena and properties (physical, chemical, biological) present only at that length scale.



History

c. 1960

Feynman:

- **miniaturization**
- **info. storage**
- **precision chemistry**
- **tiny machines making tinier machines**

c. 1980s

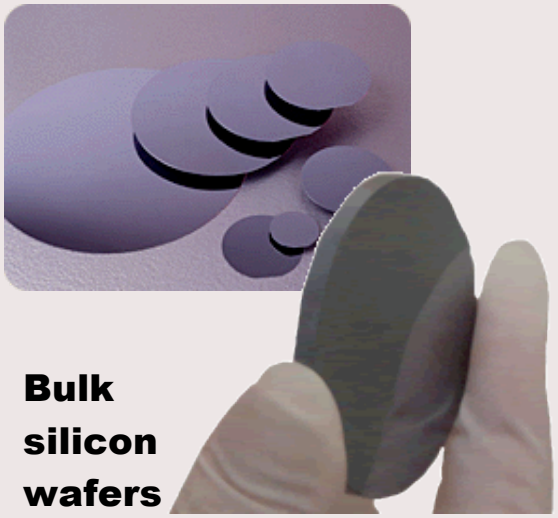
- **"nanotech" popularized**
- **idea of molecular self-assemblars**

c. 1990

- **science and technology started to catch up**

New properties at nanoscale

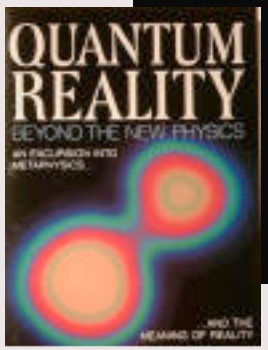
The amazing shrinking silicon crystal...



Bulk silicon wafers for computer chips

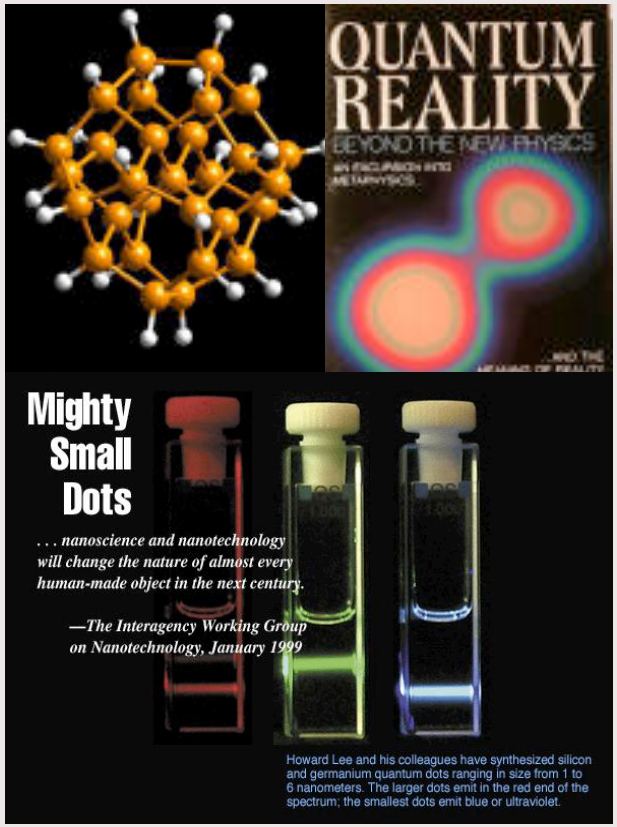
Silicon nanocrystal

< 100 nm



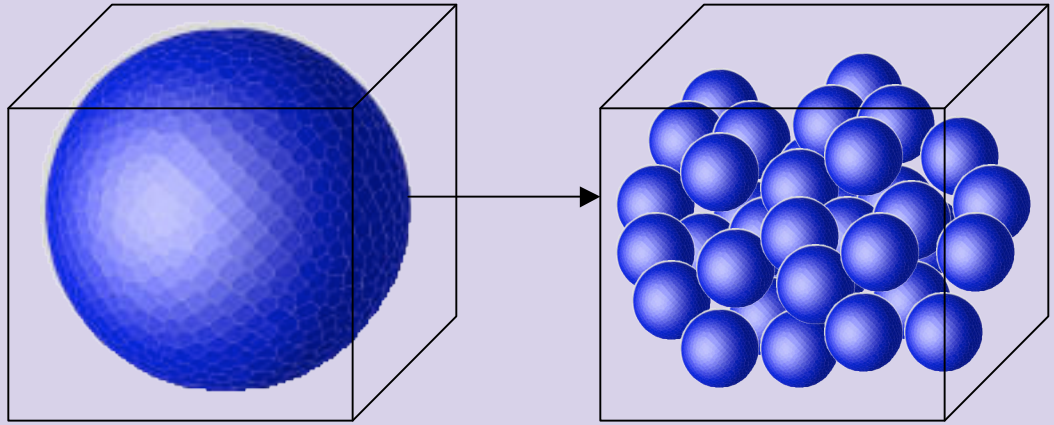
Quantum	Chemical	Biological

New properties at nanoscale



Completely different physical behavior than bulk.

Reactivity may depend on surface area.

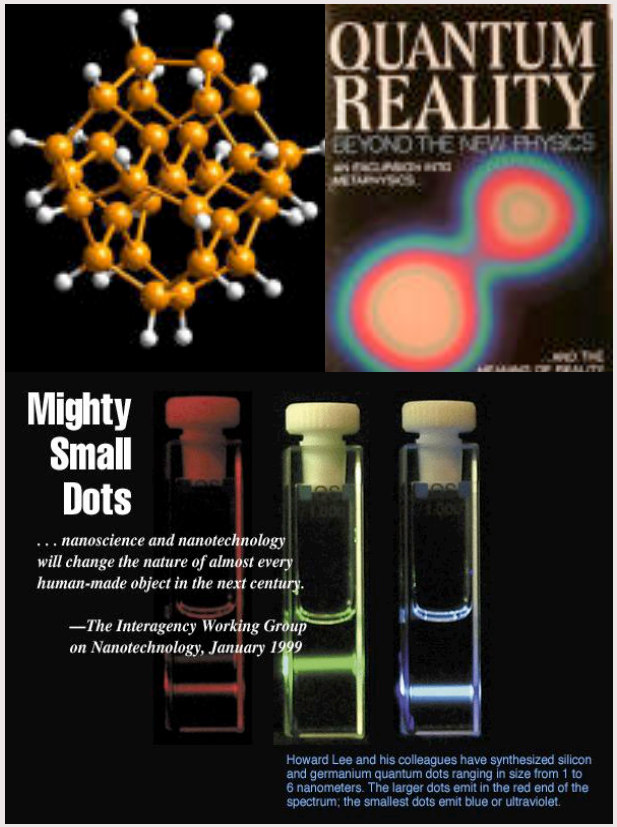


More, smaller particles = more surface area

"A catalyst of 10 nm nanoparticles is 100 times more reactive than the same amount of material in 1 micron particles."

Quantum | **Chemical** | **Biological**

New properties at nanoscale



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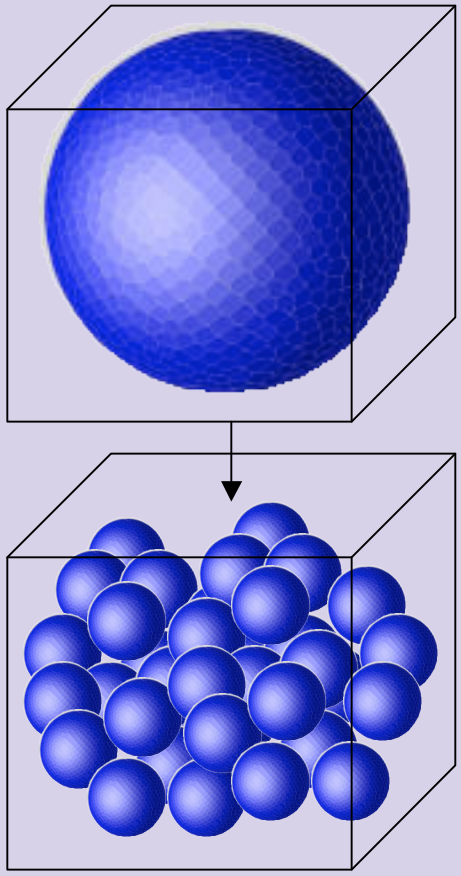
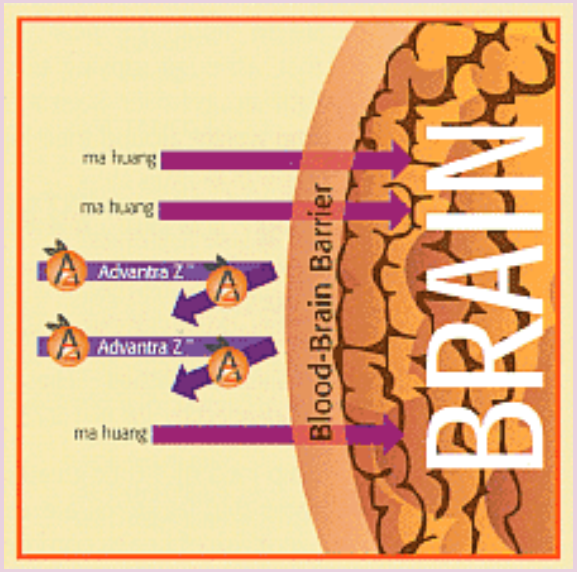
Quantum



More surface area per volume. More reactive.

Chemical



Nanoparticles can cross the blood brain barrier; Microparticles can't.

Cells tend to not recognize nanoparticles as a threat and ignore them.

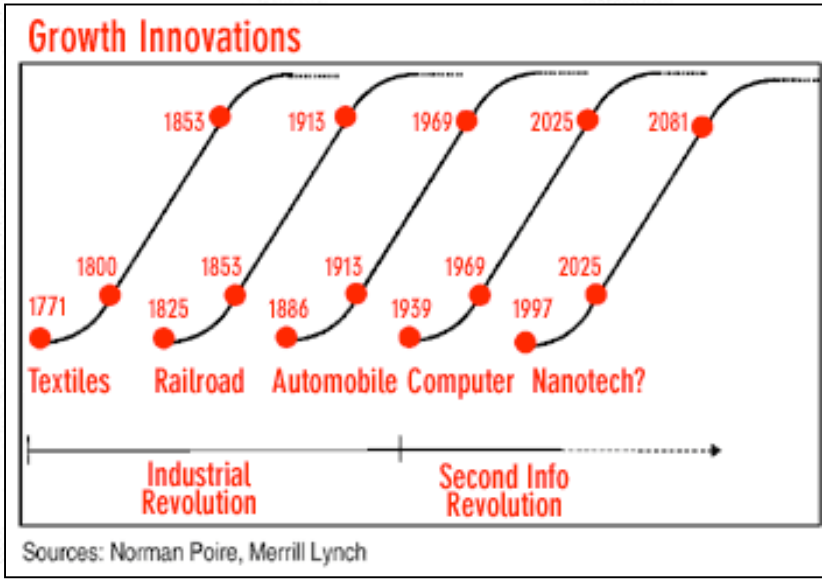
Biological

Nanotech -is- Interdisciplinary

Physics, Chemistry, Materials Science, Biology, Engineering, Informatics, … and even Humanities!

National Nanotechnology Initiative
(Budget authority, dollars in millions)

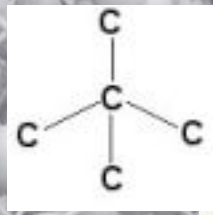
	2001 Actual	2005 Request	Dollar Change 2001 to 2005	% Change 2001 to 2005
National Science Foundation	150	305	155	103
Defense	125	276		
Energy	88	211		
National Institutes of Health	40	89		
Commerce (NIST)	33	53		
NASA	22	35		
Agriculture	0	5		
EPA	5	5		
Justice	1	2		
Homeland Security	0	1		
TOTAL	**464**	**982**		

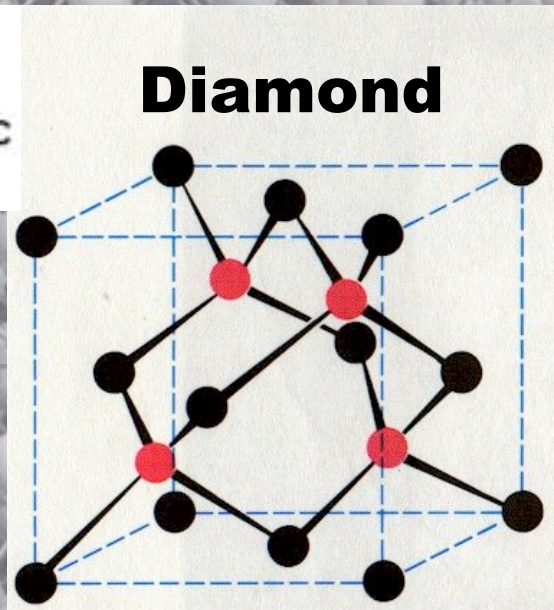


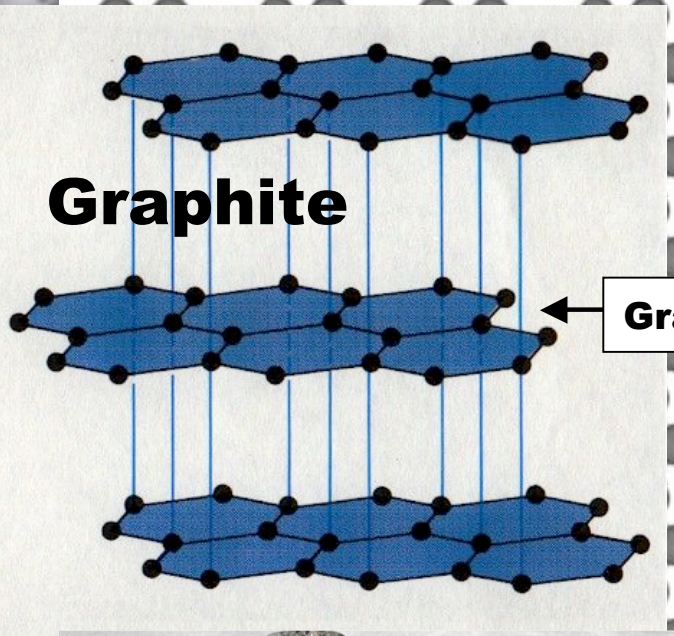
Sources: Norman Poire, Merrill Lynch

Example: Carbon in the macro

Allotropes of Carbon: different crystal structures with different properties.



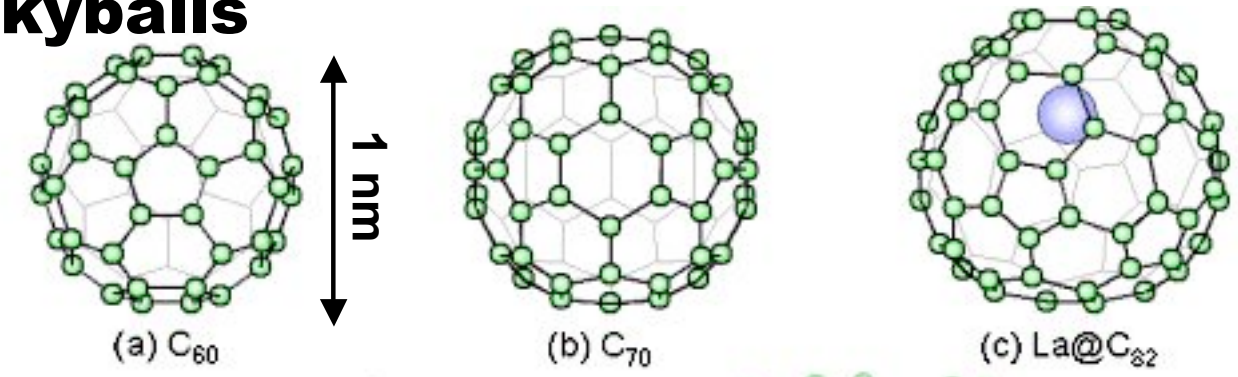




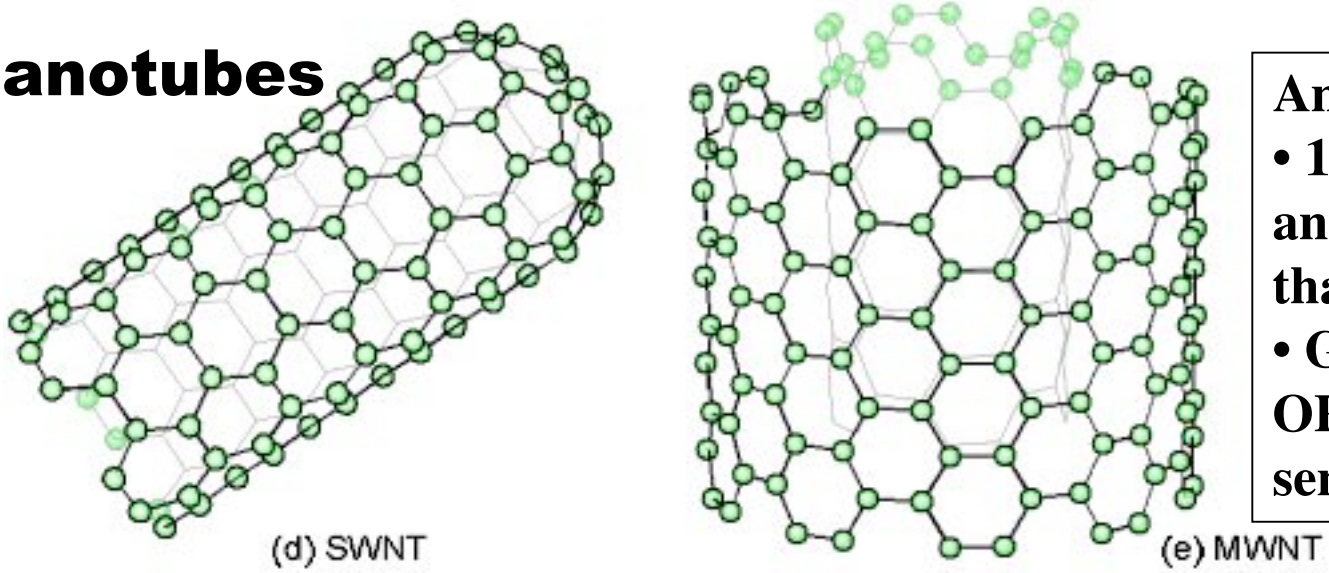
Example: Carbon in the nano

A new form of Carbon: buckminsterfullerenes

buckyballs



nanotubes



Amazing properties:

- **100 times stronger and 6 times lighter than steel**
- **Good conductores OR good semiconductors**

Nanotubes are useful

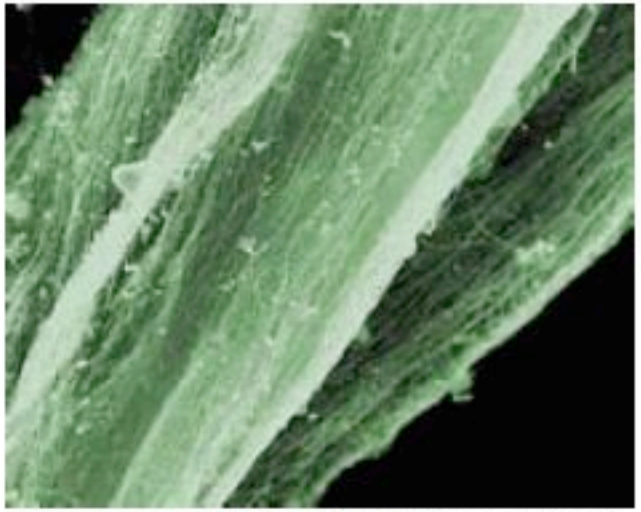
Move over, Spider-Man

CARBON WORLDS

Scientists Make Long Nanotubes

Troy - May 07, 2002

For the first time, researchers have created a simplified method for making long, continuous, hair-like strands of carbon nanotubes that are as much as eight inches in length.



brief communications

isselaer

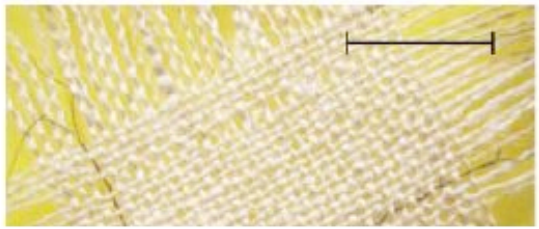
Super-tough carbon-nanotube fibres

These extraordinary composite fibres can be woven into electronic textiles.

The energy needed to rupture a fibre (its toughness) is five times higher for spider silk than for the same mass of steel wire, which has inspired efforts to produce spider silk commercially[1–3]. Here we spin 100-metre-long carbon-nanotube composite fibres that are tougher than any natural

process. This stage involves unwinding the fibres onto a series of godets that carry them through an acetone-washing bath and then through a drying path so that they can be wrapped onto a mandrel.

The resulting composite fibres are about 50 μm in diameter and contain around



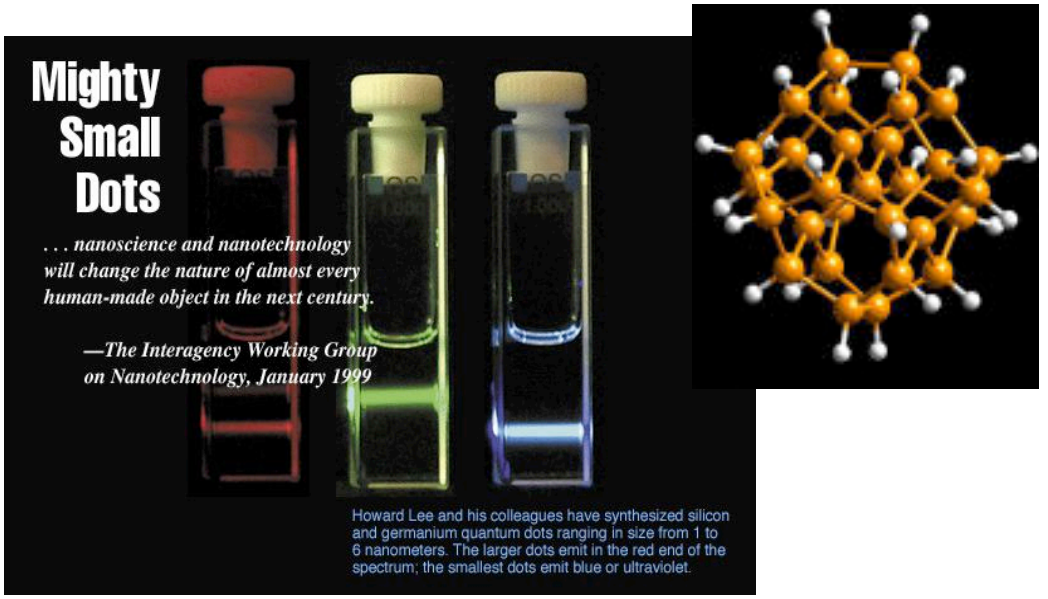
that (CVD), grow ld of r-

Applications to medicine

- Labeling/Contrast Imaging
- Cancer treatment or drug delivery
- Testing/detection
- Visualizing the nanoscale: the AFM
- Nanotoxicology & Environmental Impact

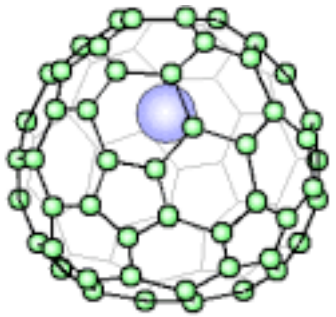
Labeling/Contrast Imaging

- Quantum dots = Nanoparticles = Artificial Atoms
- Different colors depending on size of dot
- Magnetic nanoparticles (ala NMR)



Cancer treatment/Drug delivery

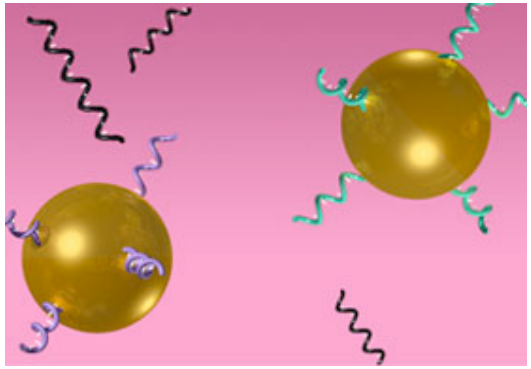
- Make nanoparticles which will be accepted by tumor cells
  - For drug delivery
  - For frying (coated iron-oxide nanodots from MagForce)
- General drug delivery to cells, etc. (no immune response)



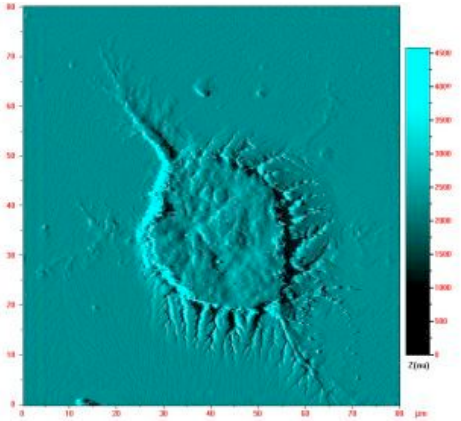
(c) La@C_{82}

Testing/Detection

- Microfluidics (MEMS/NEMS)
  - "Lab on a chip"
- DNA sequence detection:
  - Gold nanoparticles with the complimentary half of a DNA sequence
  - It the sequence is present, the nanoparticles will clump and the solution will change color

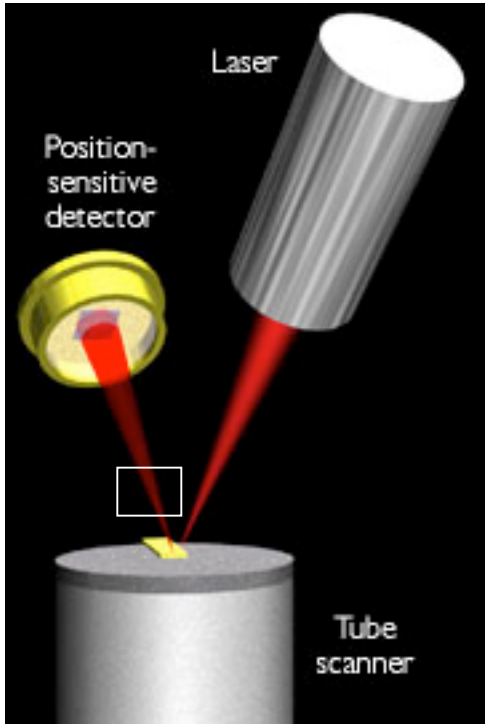


Atomic Force Microscope

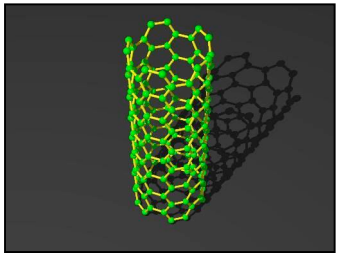


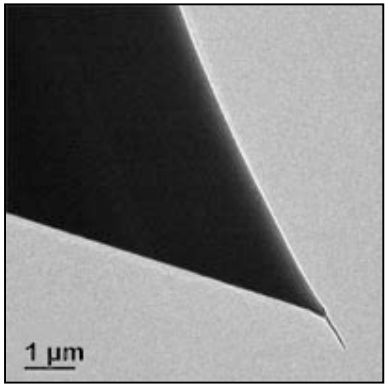
- **Seeing is believing.**

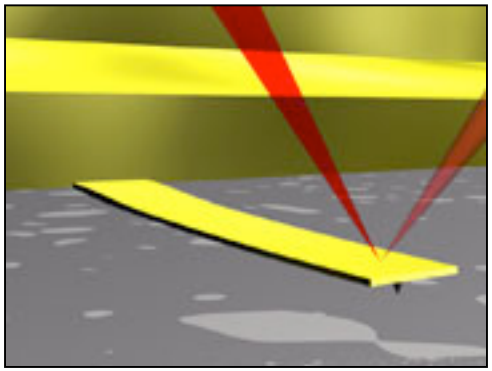
"Unfortunately, AFM cannot image all samples at atomic resolution. The end radii of available tips confines atomic resolution to flat, periodic samples such as graphite. In addition, because biological structures are soft, the tip-sample interaction tends to distort or destroy them. " - Baselt, 1993



Solution: Nanotube tip







Nanotoxicology

- Nanoparticles can be extremely reactive = Good for cleanup of environmental disasters?
- BUT
  - What if they get in our lungs? Or our brains?
  - Two things: extremely small and reactive
  - Nanotubes? String-like fibers, scary?

Biomedical applications of nanotechnology

- Body monitoring
- Intervention
- Replacement
- They are still POSSIBILITIES!

Body Monitoring

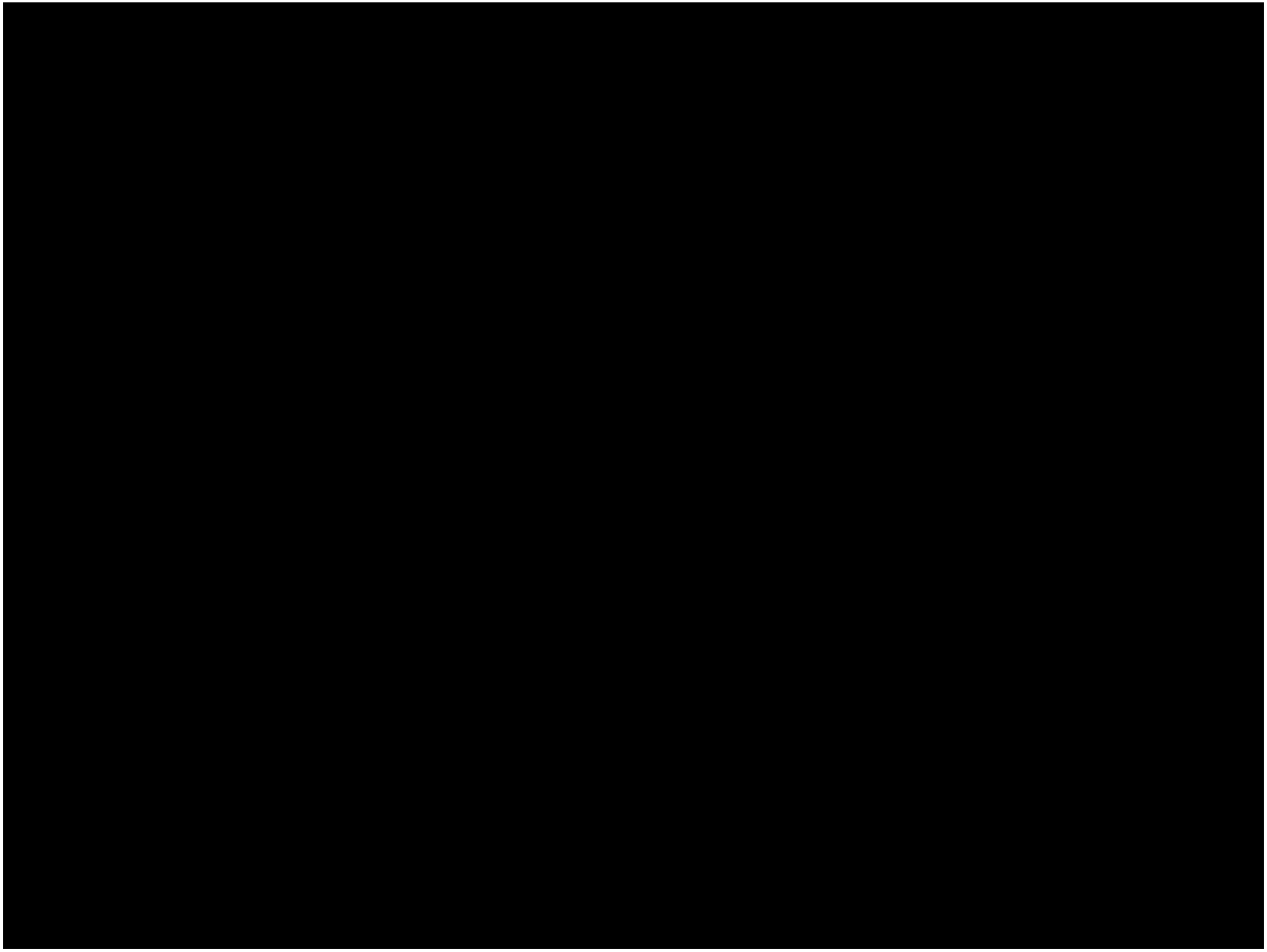
- Miniaturization of chemical sensors
- Continuous monitoring of bodily changes
  - E.g. Concentration of proteins in living cells, blood pressure and so on
- Requires many sensors

Intervention

- Drug delivery and surgery
- Apply drugs precisely
- Minimize adverse impact

Replacement

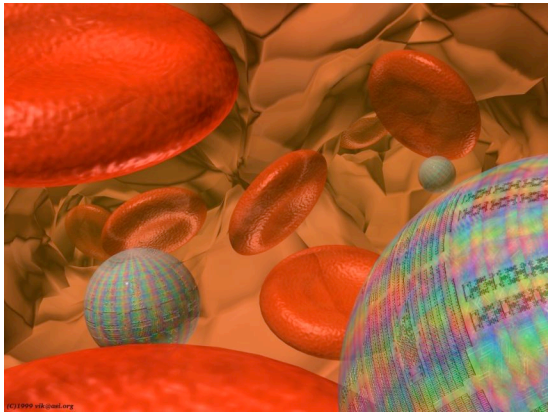
- Organ rejections
- Artificial organs
- Blood? Two flavors …

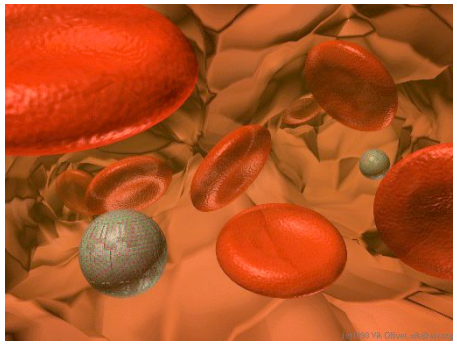


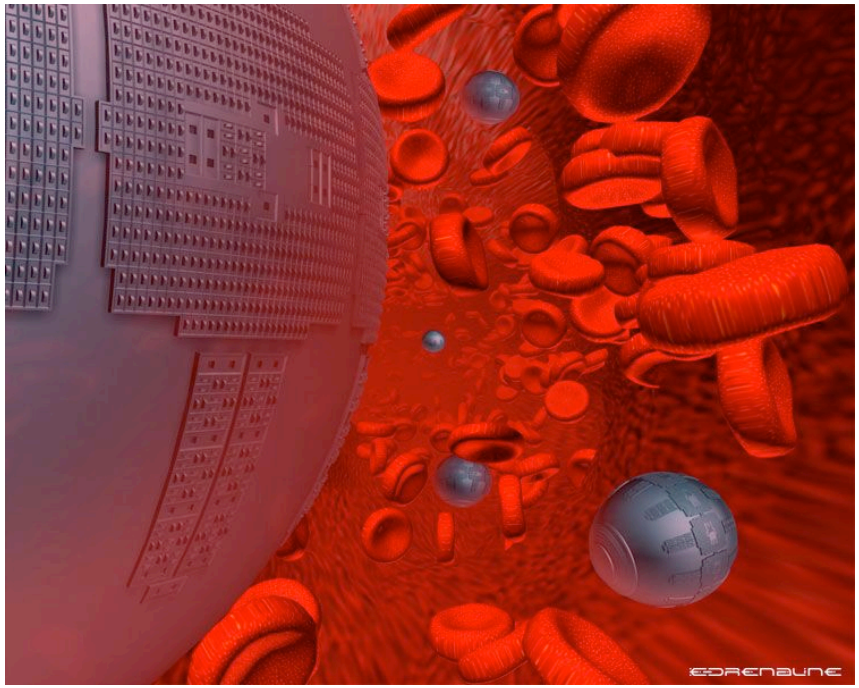
Nanobots.

Source: Popular Science Magazine (July 2000)

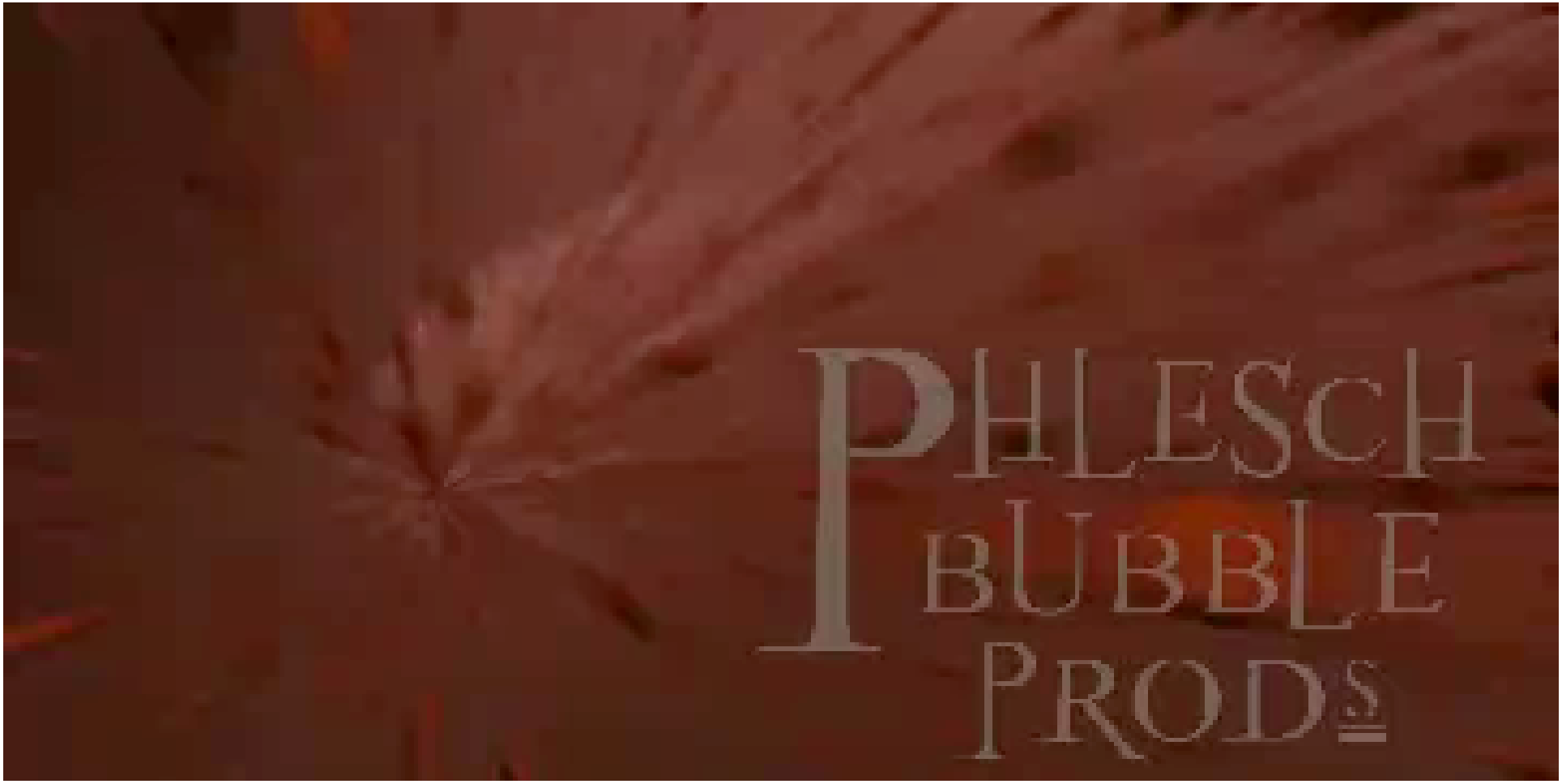
Respirocyte







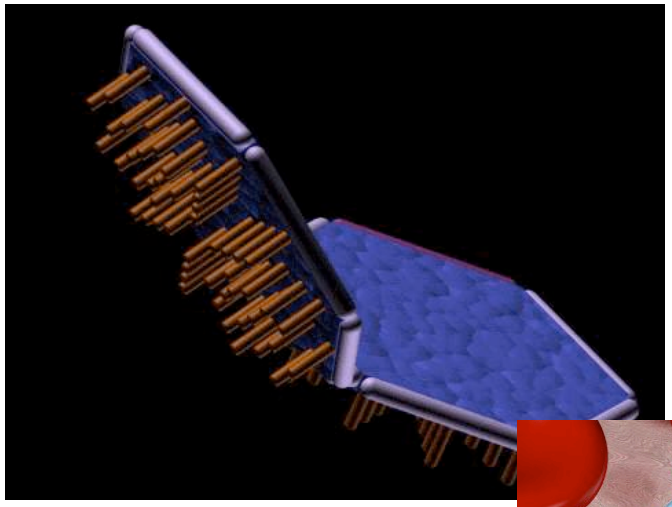
http://www.foresight.org/Nanomedicine/Gallery/Species/Respirocytes.html

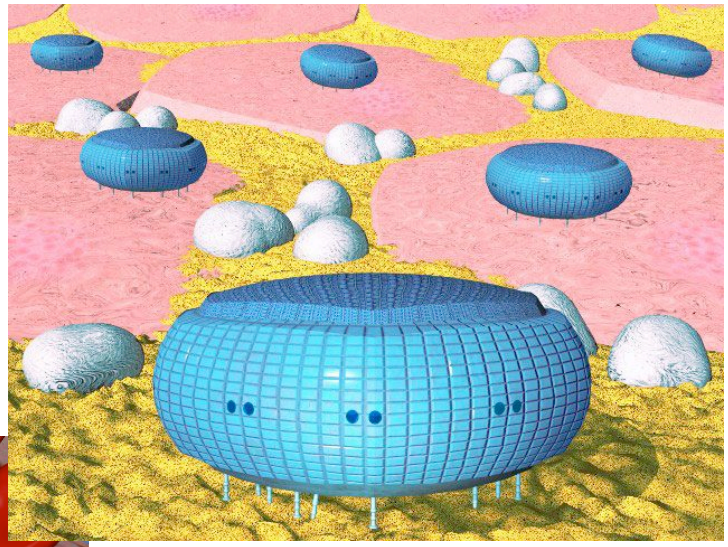


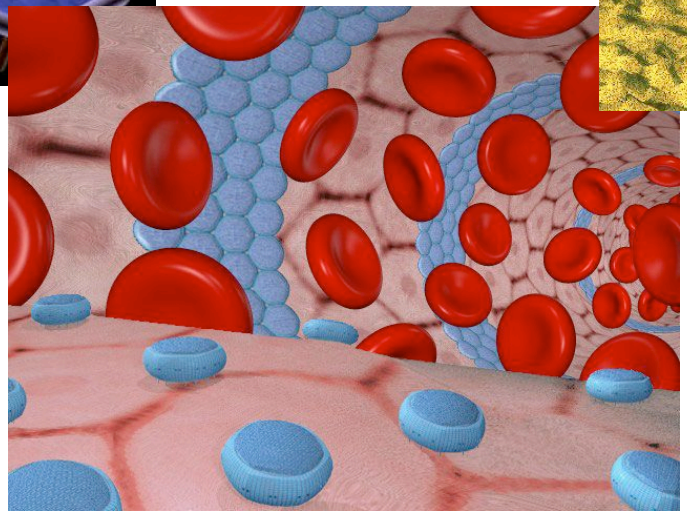
Source: http://www.phleschbubble.com/album/movies/index.html

Robert A. Freitas Jr., "Exploratory Design in Medical Nanotechnology:
A Mechanical Artificial Red Cell," *Artificial Cells, Blood Substitutes, and Immobil. Biotech.* **26** (1998):411-430.

Vasculocyte







Source: Robert A. Freitas 2002. Vasculocyte Images.
www.foresight.org/Nanomedicine/Gallery/Species/Vaculocytes.html

Just a vision?

- Chris Pheonix: “Vasculoid is extremely complicated and would require much research to build and use successfully. This particular device may never be used, but it can provide a hint of the possibilities inherent in advanced nanomedicine.” (Pheonix 2001; 2003 - Nanotechnology and Life Extension)