Nanotechnology, Medicine, & the Body

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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

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<th>Unit</th>
<th>Abbr</th>
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<tr>
<td>Millimeter</td>
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<td>Nanometer</td>
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<td>Angstrom</td>
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A nanometer is *one billionth* of a meter.
Size and Scale: Factors of 1000

- **meters**: $10^0$
- **millimeters**: $10^{-3}$
- **micrometers**: $10^{-6}$
- **nanometers**: $10^{-9}$

**Hair**: ~40 microns

1 nm = 10 Hydrogen atoms

**DNA**: 1-2 nm diameter

**Virus**: 3-50 nm

**Bacteria**: 3-5 microns

**Red blood cell**: 3 microns

**MEMS**

**Red blood cell**: 3 microns

**DNA**: 1-2 nm diameter

**Virus**: 3-50 nm
**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.

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**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

Mighty Small Dots

...nanoscience and nanotechnology will change the nature of almost every human-made object in the next century.

—The Interagency Working Group on Nanotechnology, January 1999

Quantum

Chemical

Biological

Howard Lee and his colleagues have synthesized silicon and germanium quantum dots ranging in size from 1 to 6 nanometers. The larger dots emit in the red end of the spectrum, the smallest dots emit blue or ultraviolet.
New properties at nanoscale

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.”
New properties at nanoscale

Quantum

Chemical

Biological

Completely different physical behavior than bulk.

More surface area per volume. More reactive.

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

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

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

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*Sources: Norman Poire, Merrill Lynch*
Example: Carbon in the macro

Allotropes of Carbon: different crystal structures with different properties.

Diamond

Graphite

Graphite sheets
Example: Carbon in the nano

A new form of Carbon: buckminsterfullerenes

buckyballs

- (a) $C_{60}$
- (b) $C_{70}$
- (c) La@$C_{82}$

nanotubes

- (d) SWNT
- (e) MWNT

Amazing properties:
- 100 times stronger and 6 times lighter than steel
- Good conductors OR good semiconductors
Nanotubes are useful

Move over, Spider-Man

“Nanotube fibers outdo spider silk”

**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.

**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. 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
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)
Testing/Detection

- Microfluidics (MEMS/NEMS)
  - “Lab on a chip”

- DNA sequence detection:
  - Gold nanoparticles with the complimentary half of a DNA sequence
  - If the sequence is present, the nanoparticles will clump and the solution will change color
• 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

Vasculocyte

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)