NANO-THERMODYNAMICS

Ryan Ginder
Hsaio-Yu Ko
Tejas Shastry

NORTHWESTERN
UNIVERSITY

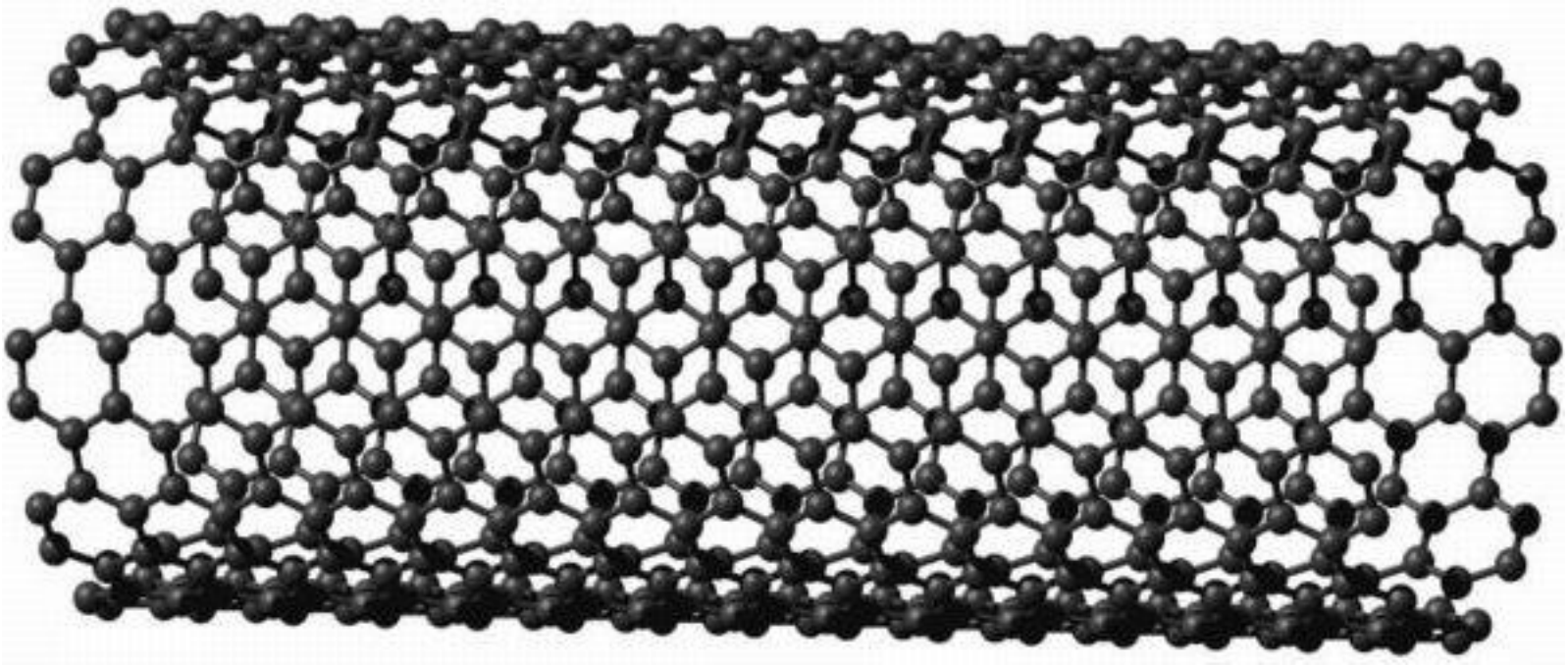
Presentation Goals

- Explain why nanotechnology is important
- Define and explain nanoscale, surface area to volume ratio, and melting point depression
- Demonstrate learning module's ability to simulate and elaborate the nanoscale concepts

Why is nanotechnology important?

- Properties and behavior change
- Applications
  - Carbon nanotubes
  - Nanoparticles for drug delivery
  - Nanomaterials
- New Industries and oppertunities

Carbon NanoTube



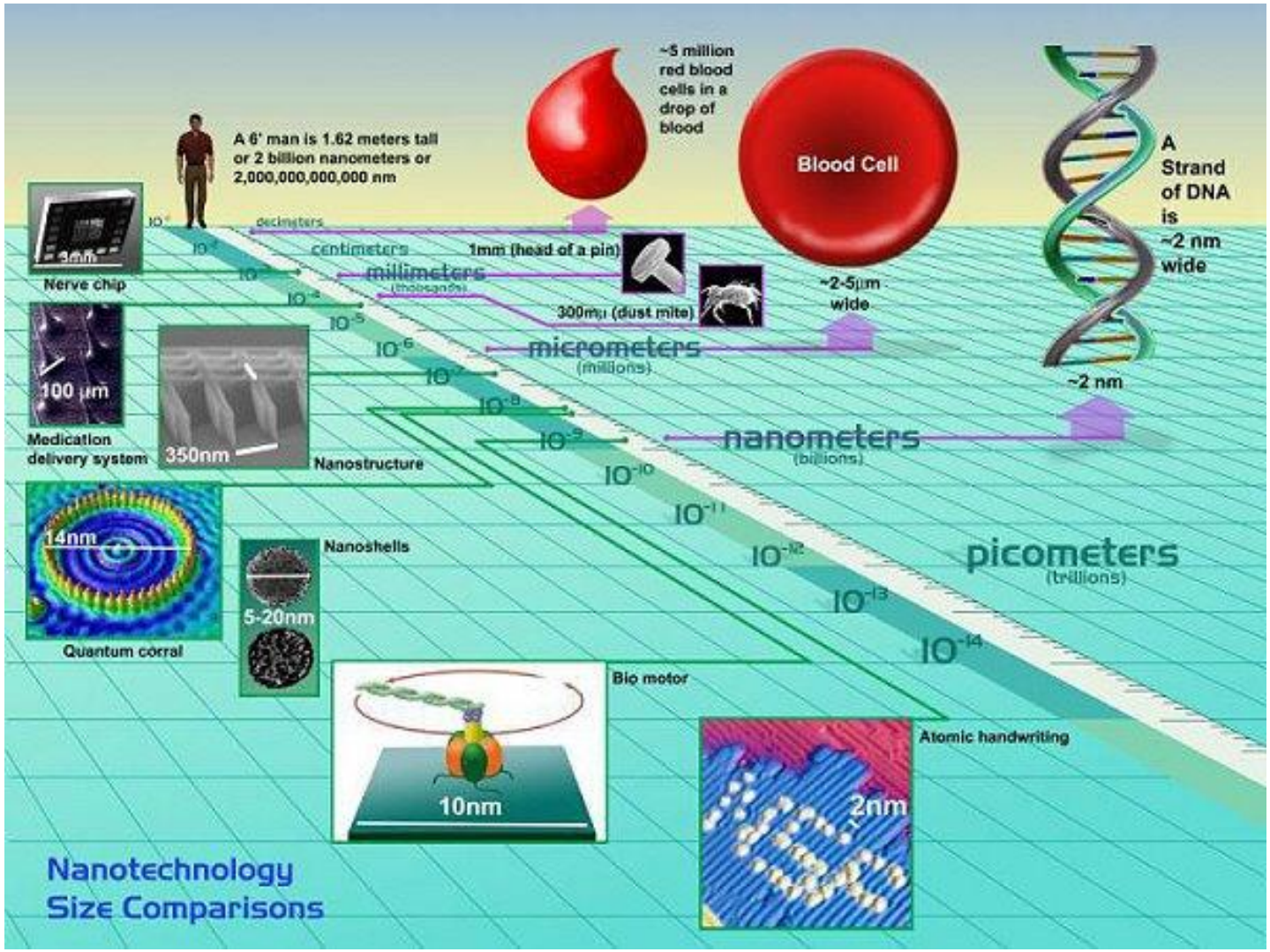
What is “nano”?

- Exact scale example
- Relative scale example
- Dimension limit for nanoscience
  - Upper bound - 100nm for effects to be seen
  - Lower bound – 1nm to avoid atomic effects

Scale of Metric System

Prefix	Symbol for Prefix		Scientific Notation
exa	E	1 000 000 000 000 000 000	10^{18}
peta	P	1 000 000 000 000 000	10^{15}
tera	T	1 000 000 000 000	10^{12}
giga	G	1 000 000 000	10^{9}
mega	M	1 000 000	10^{6}
kilo	k	1 000	10^{3}
hecto	h	100	10^{2}
deka	da	10	10^{1}
----	--	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000 001	10^{-6}
nano	n	0.000 000 001	10^{-9}
pico	p	0.000 000 000 001	10^{-12}
femto	f	0.000 000 000 000 001	10^{-15}
atto	a	0.000 000 000 000 000 001	10^{-18}

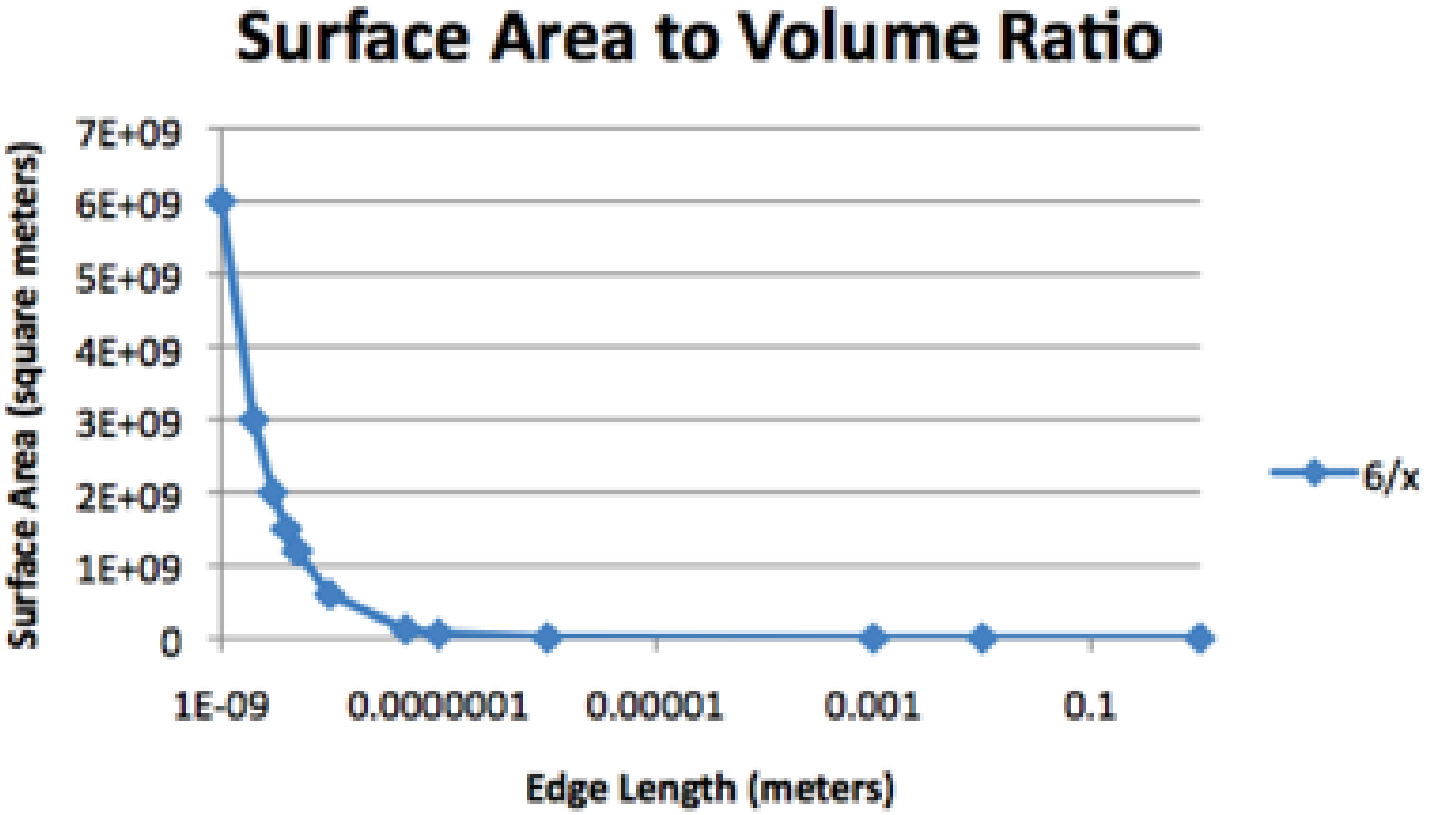
Size/Scale


A 6' man is 1.62 meters tall or 2 billion nanometers or 2,000,000,000,000 nm
~5 million red blood cells in a drop of blood
Blood Cell
~2-5µm wide
A Strand of DNA is ~2 nm wide
~2 nm
Nerve chip
decimeters
centimeters
millimeters
1mm (head of a pin)
300mµ (dust mite)
micrometers
(millions)
100 µm
Medication delivery system
350nm
Nanostructure
nanometers
(billions)
14nm
Quantum corral
Nanoshells
5-20nm
picometers
(trillions)
Bio motor
10nm
Atomic handwriting
2nm
Nanotechnology
Size Comparisons

Surface Area/Volume Ratio

- The SA/V ratio is the surface area of a shape divided by its volume.
- Explain the behavior of the SA/V ratio as the size of an object changes.
- Explain how the SA/V ratio is used to define the nanoscale region as 1-100nm.

SA/V Ratio Vs. Edge Length



Effects of SA/V ratio

- More surface for interaction
- More surface energy than bulk material
- Melting point depression

Melting Point Depression

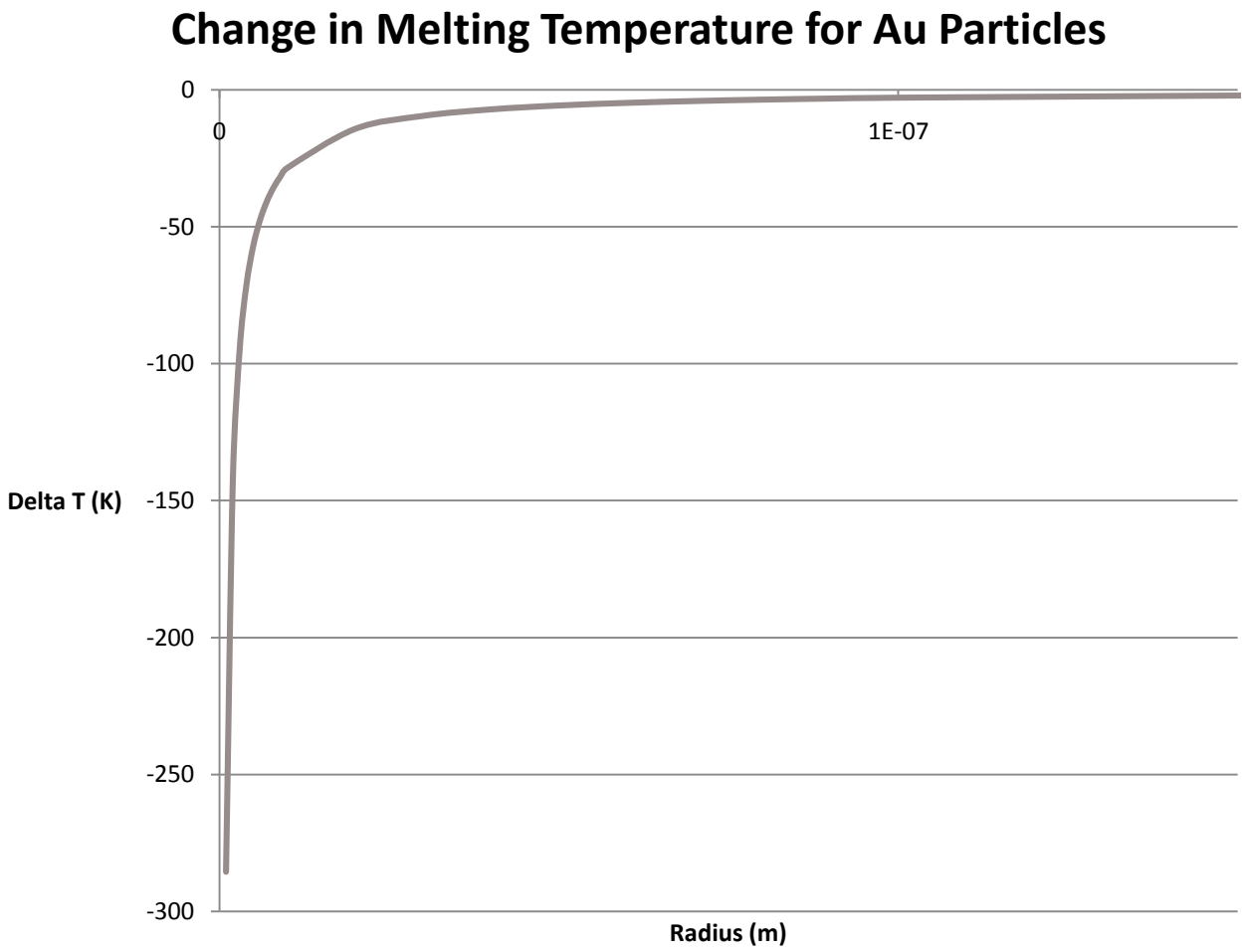
- When heating a solid to a certain point, there will be enough energy to break the bonds holding the material together
- Since the atoms on the surface are bonded to fewer atoms, they are easier to pull apart
- At the nanoscale, SA/V increases, and thus melting requires less energy
- Just as SA/V, 100nm is the critical point

Melting Point Depression Formula

$$\Delta T_m = -\frac{2\gamma V_s T_{m\infty}}{\Delta H_m}\left(\frac{1}{r}\right)$$

- ΔT-change in melting temperature
- γ-surface energy
- Vs-molar volume
- Tm-melting temperature in normal scale (r=∞)
- ΔHm-enthalpy of melting
- r-the radius of the pieces that a material is sliced into

Melting Point Depression of Gold



$\gamma = 0.132\ T/m^2$

$\Delta Hm = 12{,}600\ J/mole$

$Tm = 1336K\ (at\ r = \infty)$

$Vs = 10.2E\text{-}6\ m^3/mol$

Learning Module Goals

- Introduce the importance of nanotechnology
- Describe the changes that occur at the nanoscale level
- Explain size and scale from 1 meter to 1 nanometer
- Demonstrate the mechanism behind the increase of surface area to volume ratio with decreasing particle size
- Demonstrate the mechanism behind melting point depression with decreasing particle size

How Software Works

- What is a nanometer?: This section features a step-by-step animation going from the macroscopic to nanoscale world.
- Surface Area to Volume Ratio: Users derive the surface area/volume relationship by observing the change in surface area as they decrease particle size
- Melting Point Depression: Users observe how the melting point of gold changes as they decrease the particle size.

Advantages of Software

- Sections are very visual when presenting the concepts
- Use of the software is self-explanatory
- Helpful and concise explanations are provided for each of the concepts
- Software is flash-based, so it can be easily accessed from any web browser

References

- Case Western Reserve University. Nanopedia: The Nanoscale. 15 March 2009 <http://nanopedia.case.edu/NWPage.php?page=nanoscale>.
- ChemED Collaborative. The International System of Units (SI). 5 December 2008. 15 March 2009 <http://wiki.chemeddl.org/index.php/1.3_The_International_System_of_Units_(SI)>.
- Dorling Kindersley. Matter: Gold Atom. 2009. 15 March 2009 <http://www.dorlingkindersley-uk.co.uk/nf/ClipArt/Image/0,,239037_1584219_,00.html>.
- Feng Shui Supply. 3" Gold Bar. 2009. 15 March 2009 <http://www.fengshui-supply.com/store/product.php?productid=16644>.
- Northwestern University. Size Matters! 2005. 15 March 2009 <http://www.discovernano.northwestern.edu/whatis/index_html/sizematters_html/?searchterm=gold>.
- Owen, James. Nanotubes and Fullerenes for Quantum Computing. 15 March 2009 <http://homepage.mac.com/jhgowen/research/nanotube_page/nanotubes.html>.
- Ströck, Michael. Wikimedia Commons: Types of Carbon Nanotubes. 24 January 2009. 15 March 2009 <http://commons.wikimedia.org/wiki/index.html?curid=847494>.
- University of Wisconsin at Madison. Making and Conjugating Colloidal Metals. 15 March 2009 <http://www.ansci.wisc.edu/facstaff/Faculty/pages/albrecht/albrecht_web/Programs/microscopy/colloid.html>.