




SNNI
 SAFER NANOMATERIALS AND NANOMANUFACTURING INITIATIVE


ONAMI
 OREGON NANOTECHNOLOGY AND NANOMANUFACTURING INITIATIVE


Nanotechnology and Toxicology

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 Chemical, Biological and Environmental Engineering
 Oregon State University

Learning Objectives


- Gain an appreciation of nanotechnology applications and implications
- Understand the complexity of investigating nanomaterial-biological interactions
- Understand the fundamentals of green nanoscience
- Learn about how nanotechnology is/will impacting agriculture


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What is Nanotechnology?

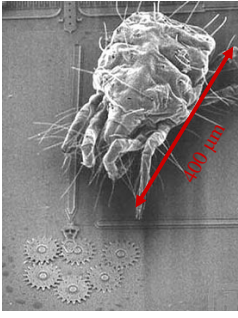
Definition:


“Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications.”


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A matter of scale

Gears are about 50 μ m diameter
Usually called “microtechnologies”



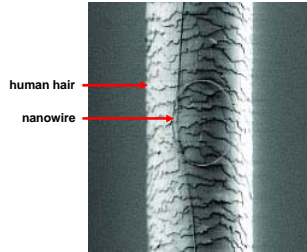

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What is new about nanotechnology?

1. Ability to visualize matter at the atomic/molecular level
2. Ability to manipulate matter at the atomic/molecular level
3. Novel properties and behaviors

carbon nanotubes
100 X stronger than steel
but 1/6 the weight

unusual heat and
conductivity properties



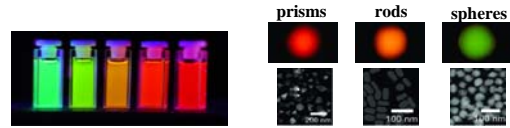
McCauley and McCauley: Naval Occupational Health and Preventive Medicine Conference presentation



What is new about nanotechnology?

1. Ability to visualize matter at the atomic/molecular level
2. Ability to manipulate matter at the atomic/molecular level
3. Novel properties and behaviors
4. Quantum phenomenology

At the nano-scale, quantum effects can strongly modify properties of matter: color, reactivity, magnetic or dipolar moment



small change in SIZE
makes a big difference

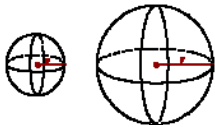
small change in SHAPE
makes a big difference

What is new about nanotechnology?

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At the nano-scale, quantum effects can strongly modify properties of matter: color, reactivity, magnetic or dipolar moment

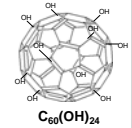
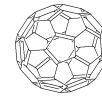
Increased relative surface area increases reactivity



2D: Surface area = $4\pi r^2$
3D: Volume = $\frac{4}{3}\pi r^3$

'Types' of Nanomaterials

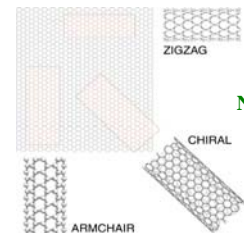
- Carbon-based



- Metal-based

- Polymeric

- Composites



Nanotubes



'Types' of Nanomaterials

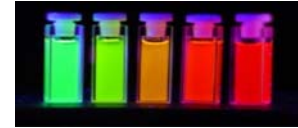
- Carbon-based

Bonding and size affect carbon's properties

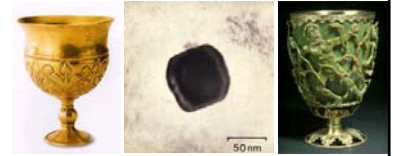
- Metal-based
- Polymeric
- Composites

'Types' of Nanomaterials

- Carbon-based
- Metal-based
- Polymeric
- Composites



quantum dots

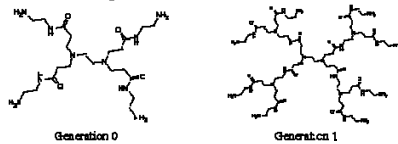


nanogold

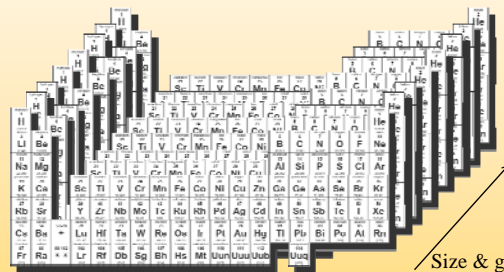
'Types' of Nanomaterials

Dendrimers

- Carbon-based
- Metal-based
- Polymeric
- Composites



3rd dimension of periodic table



National Nanotechnology Initiative

2001 - Federal R&D program established under the Clinton administration

Collaborative program involving 26 federal agencies



Nanotechnology Applications

Medicine and health

diagnostic probes
site-selective therapeutics
multi-functional drug delivery
prosthetics
regenerative medicine
imaging

Agriculture

food packaging
alternative sterilizers
nanoherbicides
nanopesticides

Engineering

enhanced strength
bottom-up assembly
soft lithography
self-assembly of devices

Electronics and technologies

molecular electronics
circuits only a few atoms wide
memory and data storage
display devices
military technologies/defense

Environmental

remediation
filtration
sensors
green energy
efficient manufacturing

Cosmetics

anti-oxidants
invisible UV blockage



Nanotechnology Applications

Consumer Products Inventory

Woodrow Wilson Center – *Project on Emerging Nanotechnologies*

- 803 products
- produced by 420 companies
- located in 21 countries

Annual sales of \$2.6 trillion by 2014

Lux Research: *The Nanotech Report, 5th edition, 2007*



The Agricultural Sector - Nanofood?

“Nanofood” - when nanoparticles, nanotechnology techniques or tools are used during cultivation, production, processing, or packaging of the food.

It does not mean atomically modified food or food produced by nanomachines. ([Nanotechnology in Agriculture and Food](#))



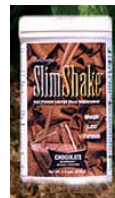
Agriculture

- Nanocapsules for controlled delivery of pesticides, vaccines, fertilizers, growth hormones and other agrichemicals
- Nanosensors: monitoring soil conditions and crop growth, detection of animal and plant pathogens
- Nanochips for identity preservation and tracking
- Targeted genetic engineering



Food Processing

- Nanocapsules to improve bioavailability of nutraceuticals
- Nanoencapsulated flavor enhancers
- Nanotubes and nanoparticles to increase viscosity
- Nanoparticles to selectively bind and remove chemicals or pathogens from food
- Nanoemulsions and nanoparticles for better dispersion of nutrients



Supplements

- Nanosize powders to increase absorption of nutrients
- Cellulose nanocrystal composites as drug carriers
- Nanoencapsulation for better absorption, better stability or targeted delivery
- Coiled nanoparticles to deliver nutrients more efficiently to cells without affecting color or taste of food
- Vitamin sprays dispersing active molecules into nanodroplets for better absorption



Food Packaging

- Antibodies attached to fluorescent nanoparticles to detect chemicals or food born pathogens
- Biodegradable nanosensors for temperature, moisture and time monitoring, detection of ethylene
- Nanoclays and nanofilms as barrier materials to prevent spoilage and prevent oxygen absorption
- Lighter, stronger and more heat-resistant films
- Modified permeation behavior of foils
- Antimicrobial and antifungal surface coatings with nanoparticles (silver, magnesium, zinc)



Nanotechnology Implications

Growing concerns about environmental and human health effects and safety

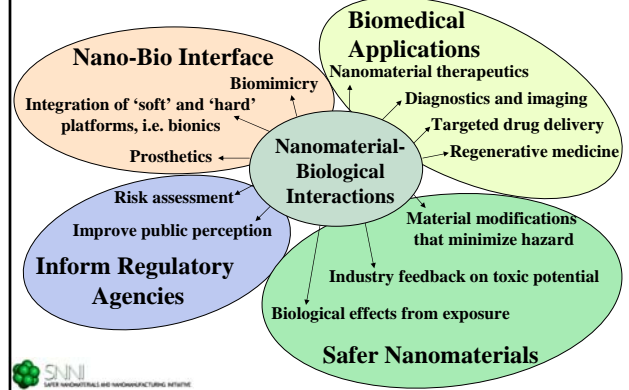
Exhibit unique physical and chemical properties
Nanoparticle-biological interactions largely unstudied
Impossible to assess potential risk without data

Importance of public acceptance

Perceptual risks may hinder progress for nanotech
Activists already making the case that untested nanomaterials are being forced on the public



Common need to understand how nanomaterials interact with biological systems



Investigations to Define Nanomaterial-Biological Interactions

Information void

Unique physicochemical properties – unique interactions with biological systems
No relative baseline for studies
Testing protocols may need to be adapted

Nanomaterials

Relative importance of nanomaterial characteristics?

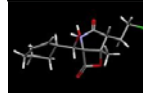


Physicochemical Properties

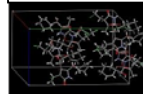
Chemicals

Structure
pKa
Solubility
log P

3-D Molecular Structure

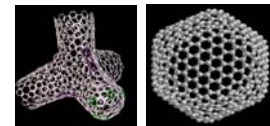


3-D Crystal Structure



Nanomaterials

Chemical Structure
Core Particle Composition
Size
Shape
Charge
Surface Chemistry
Surface Area
Agglomeration State
Zeta Potential



Illustrations reproduced with permission from Herr's Carbon Fullerene Gallery
<http://www.vinzenherr.com/cfnanomain.html>



Investigations to Define Nanomaterial-Biological Interactions

Information void

- Unique physicochemical properties – unique interactions with biological systems
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- Testing protocols may need to be adapted

Nanomaterials

- Relative importance of nanomaterial characteristics?
- Appropriate dose metrics?

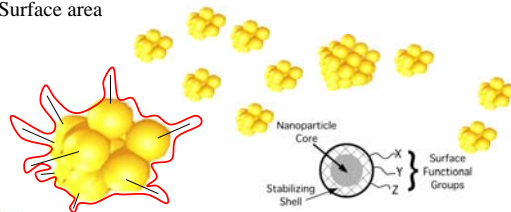


Appropriate Dose Metrics?

- Mass of core
- Total mass (core + ligands)
- # Atoms
- # Nanoparticles
- # Ligands
- Surface area

Periodic Table of Elements

H	He																	Ne																																											
Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Cu	Zn	Ga	Ge	As	Se	Br	Kr	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Pb	Bi	Po	At	Rn											
		K	Ca	Sc	Ti	V	Cr	Mn	Fe	Cu	Zn	Ga	Ge	As	Se	Br	Kr	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Pb	Bi	Po	At	Rn	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	Nv	Tl	Pb	Bi	Po	At	Rn			
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	Nv	Tl	Pb	Bi	Po	At	Rn														
		Rf	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	Nv	Tl	Pb	Bi	Po	At	Rn	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	Nv	Tl	Pb	Bi	Po	At	Rn



Investigations to Define Nanomaterial-Biological Interactions

Information void

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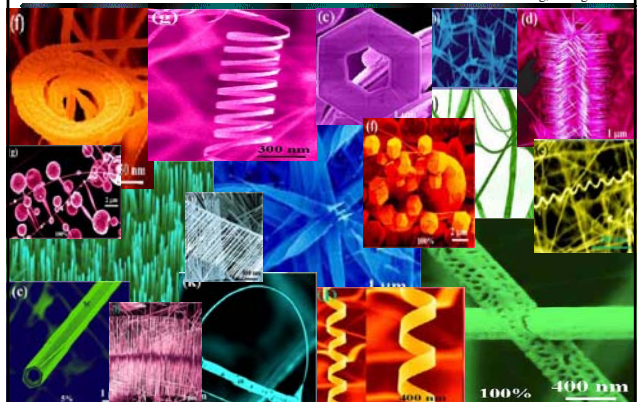
Nanomaterials

- Relative importance of nanomaterial characteristics?
- Appropriate dose metrics?
- Diversity of nanomaterials!



Diversity of Zinc Oxide Nanomaterials

Photos: Dr. Z. Wang, Georgia Tech



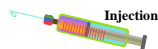
Exposure Scenario

Dose/Concentration
Timing
Duration
Route of Exposure

Dermal (skin) Exposure



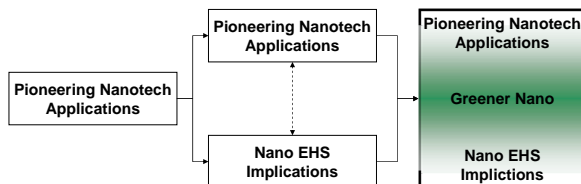
Oral Exposure



Inhalation (breathing) Exposure



Applications, Implications and Beyond



$$\text{Risk} = \text{Hazard} \times \text{Exposure}$$

A strong bridge between applications and implications will enable us to anticipate new problems and develop proactive solutions

Nanotechnology Opportunities

Guide development of safe nanomaterials

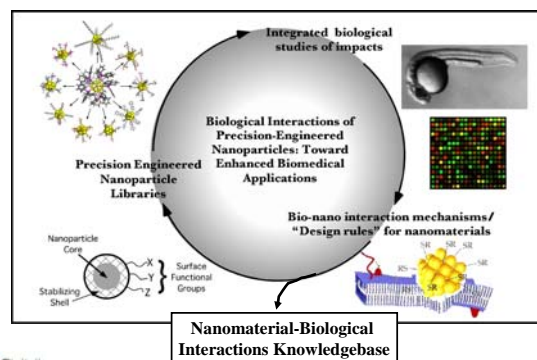
- Industry feedback on toxic potential (undesirable properties)
- Biomedical / industrial applications (desirable properties)
- Green nanoscience

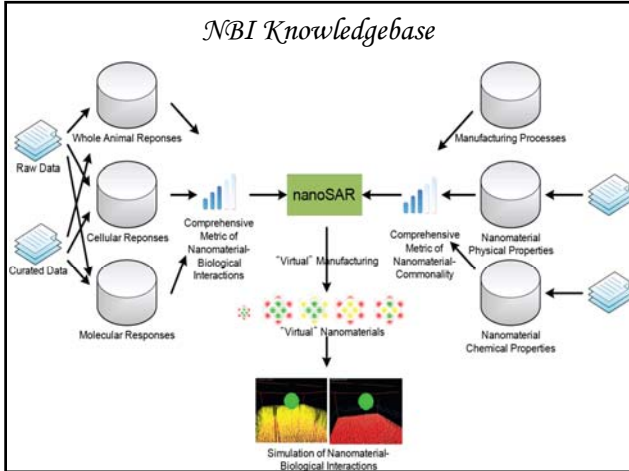


Higher performance
Cheaper
More convenient
Greener
Biocompatible

McKenzie and Hutchison "Green Nanoscience," *Chemistry Today*, 2004, 30.
Dahl, Maddux and Hutchison "Toward Greener Nanosynthesis," *Chem. Rev.* 2007, 107, 2228.

Iterative Process to Gain Knowledge





Thank you for your attention

“I'm on board for microbrews, but nanopizza is taking technology a step too far.”

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Balbus et al. (2005) Issues in Science and Technology