



# Nanotechnologies and Biology

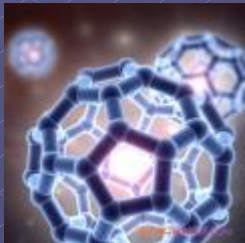
Jennifer Sass, Ph.D.

NRDC, Washington, DC

<http://www.nrdc.org/health/science/nano.asp>

# How small is one billionth of a meter?

- A dollar bill is 100,000 nm wide
- A red blood cell is 5,000 nm
- A virus is 50 nm
- There are as many nanometers in an inch as there are inches in 400 miles – 25,344,000



# No regulatory oversight

- Must trigger a mass/vol threshold to trigger regulation (TSCA, 10k kg/yr; OSHA, nuisance dust std 5 mg/cu.m)
- Burden on govt to prove harm; No data means no risk
- Reg's target chemical, not final use/product
- No detection equipment means no enforcement ability

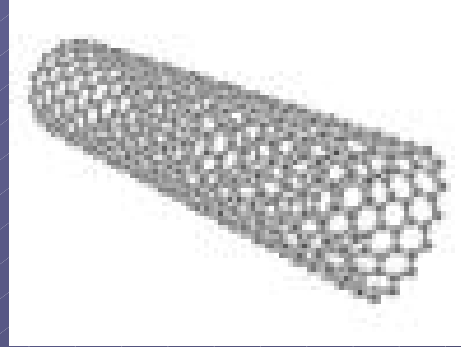
# Large corporations are embracing nanotechnology to drive product innovation



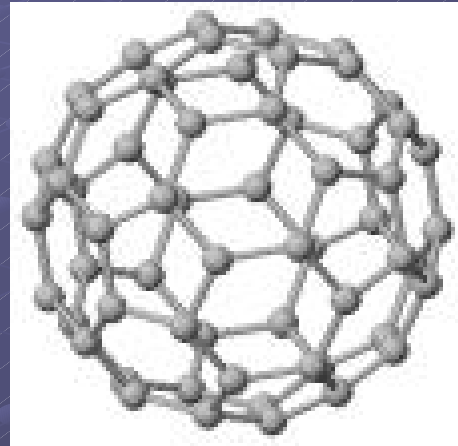
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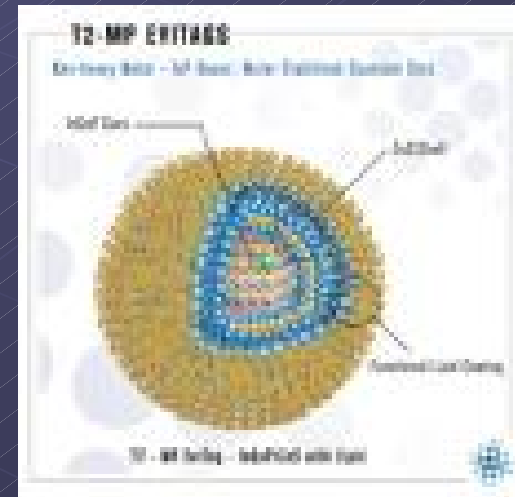
Nanotubes (single or double walled; carbon)



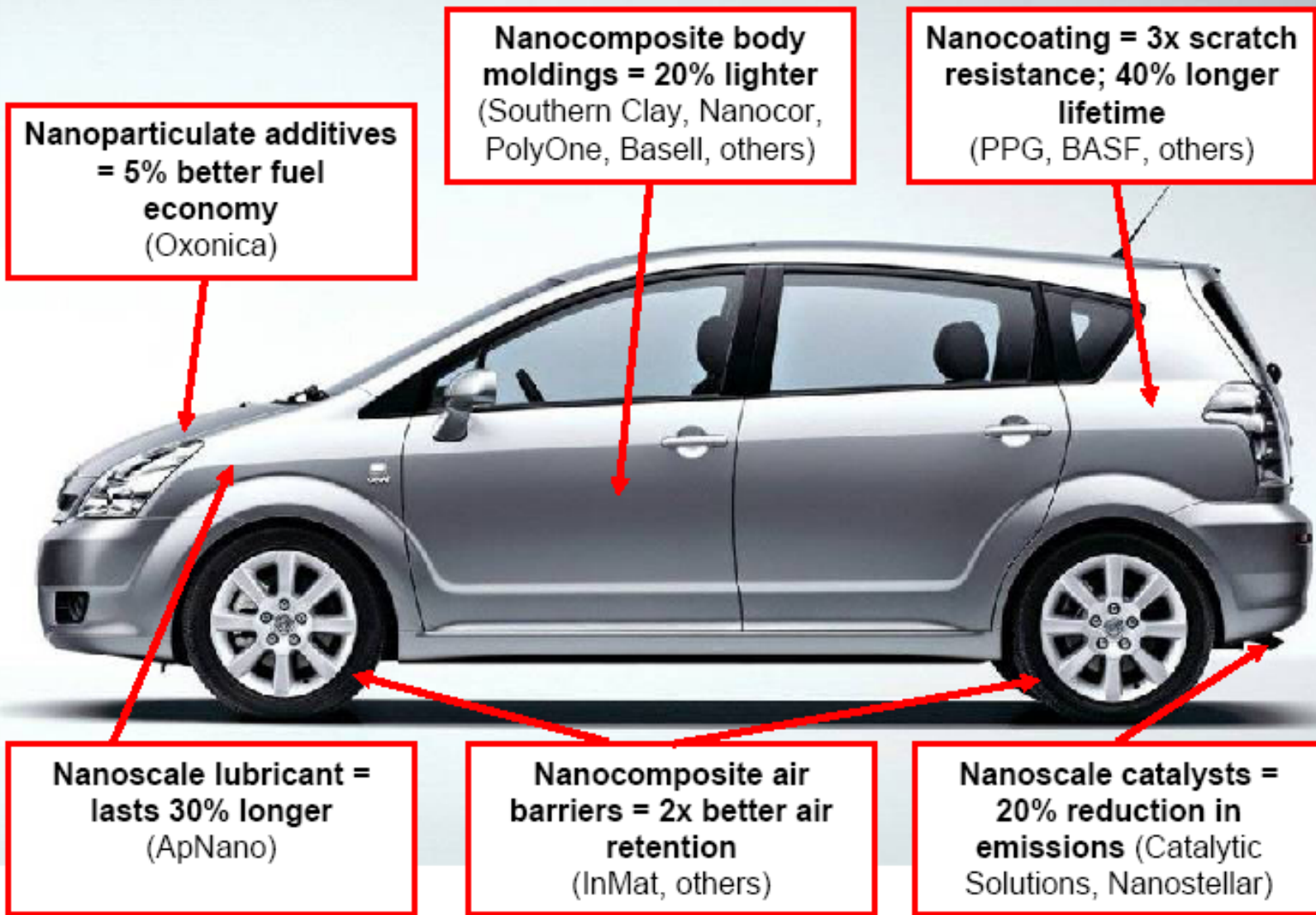
Nanospheres (fullerenes, AKA buckyballs; carbon)



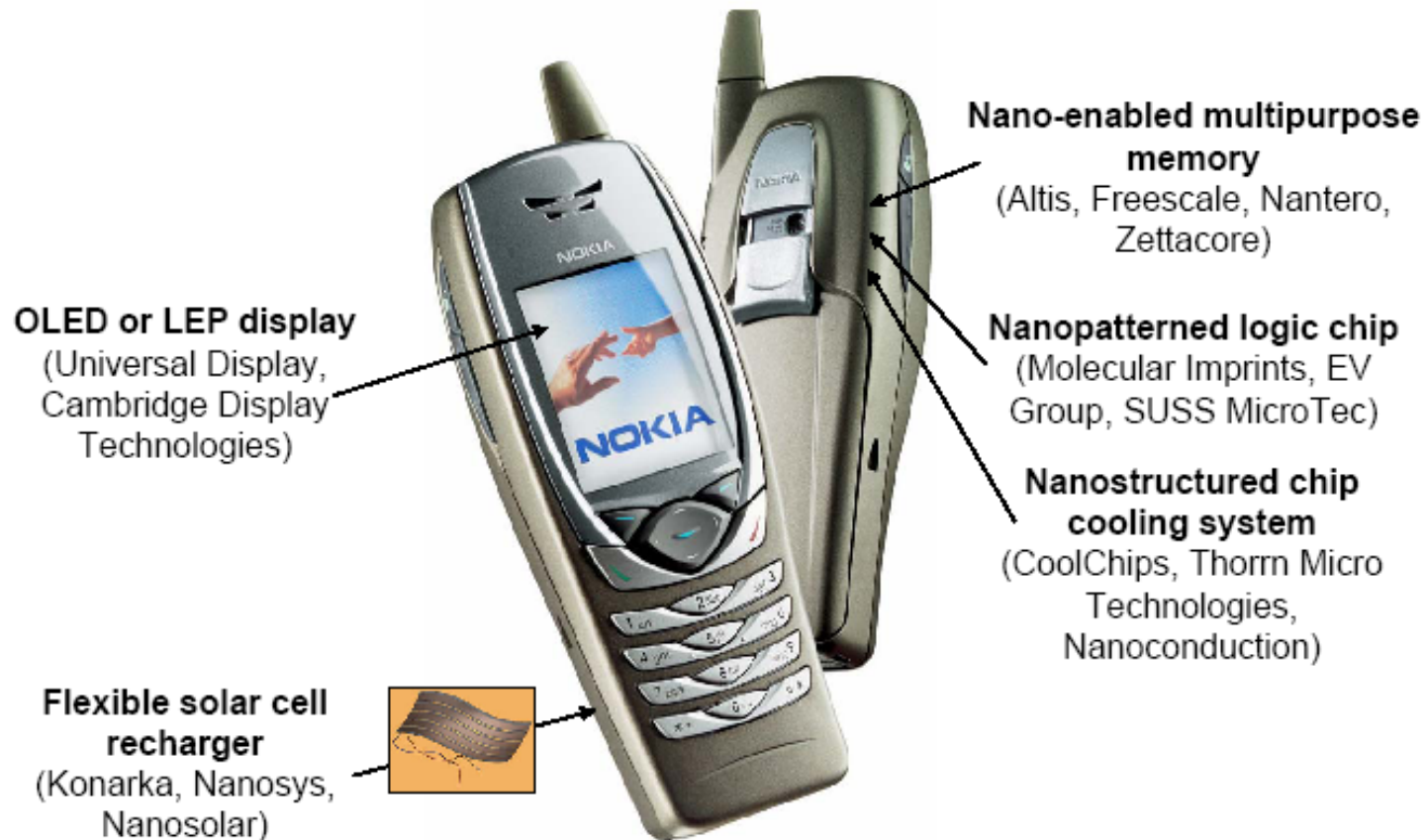
Nanodots (quantum dots, often metal-based; cadmium, lead)



## Case study: Near-term nanotech innovations in a car



## Case study: near-term nanotech innovations in a phone



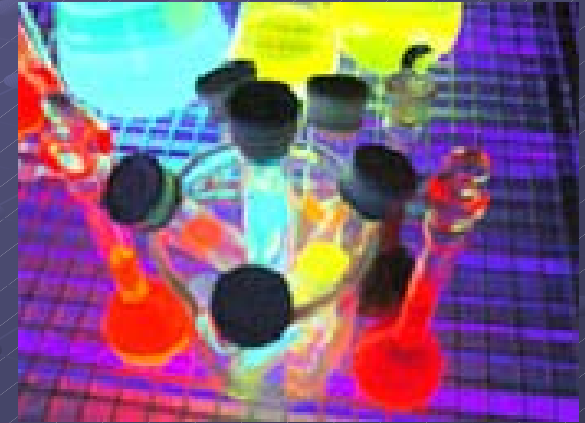
Source: March 2005 Lux Research report "How Nanotechnology Adds Value to Products"



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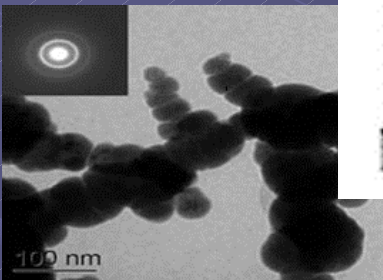
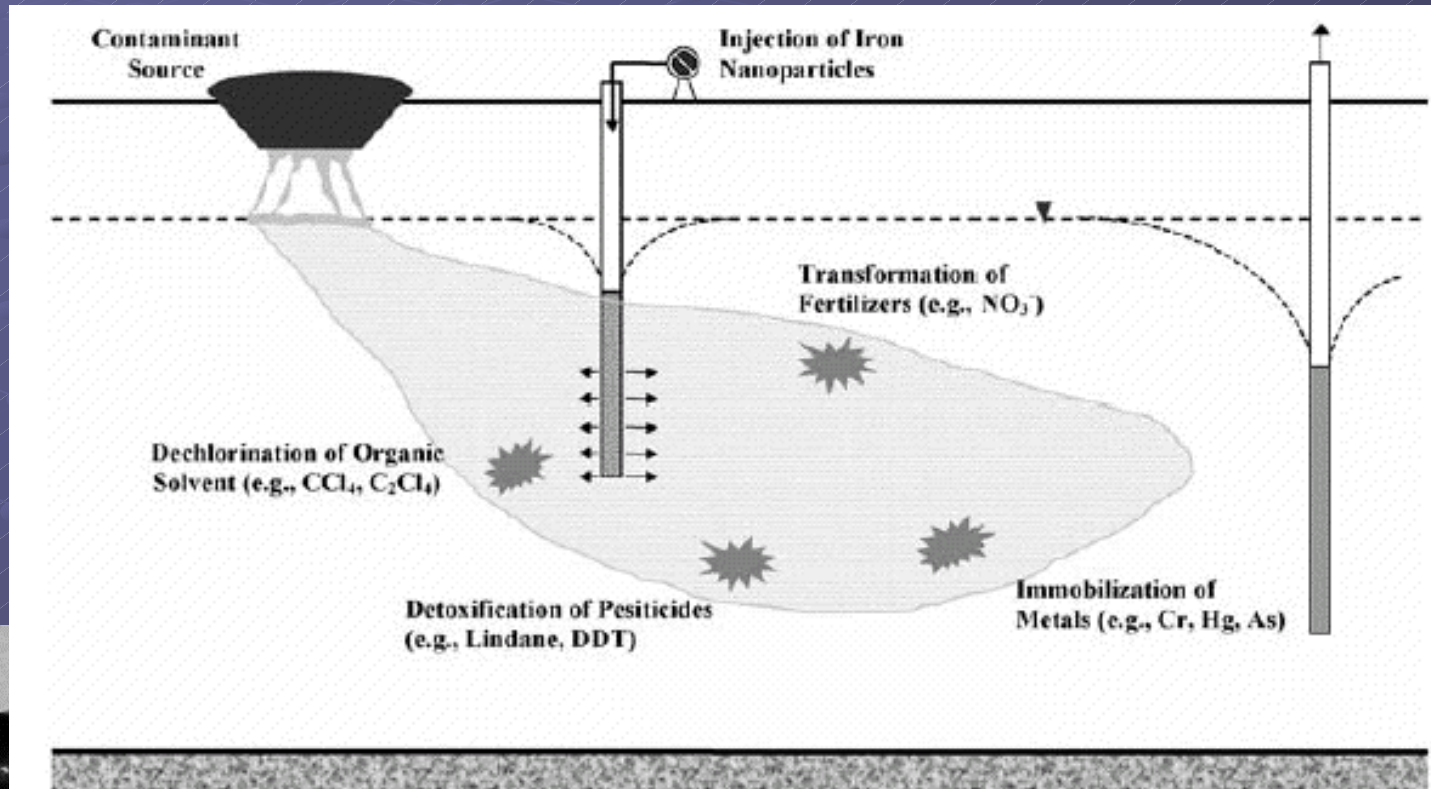
Nanogold particles of different sizes are used as surface coatings, imaging systems, and electromagnetic shielding



The red in ancient stained glass is nanogold particles of different sizes

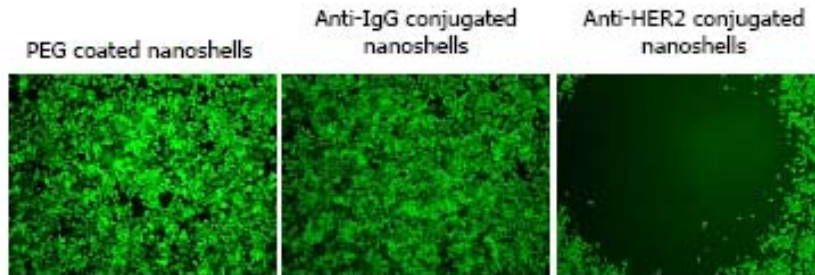


# Nano zero-valent iron used to “clean up” TCE contaminated water at Superfund sites. The byproduct may be benzene

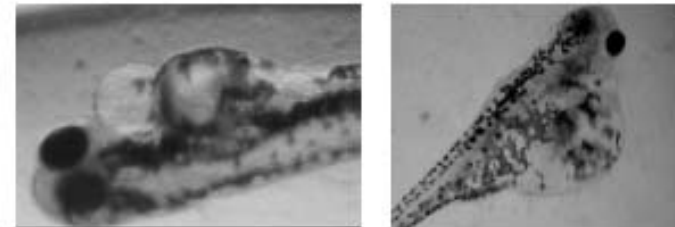


Use of iron and iron oxide nanoparticles for in situ remediation: reaction and adsorption. W.-X. Zhan, Nanoparticle Res., 2003

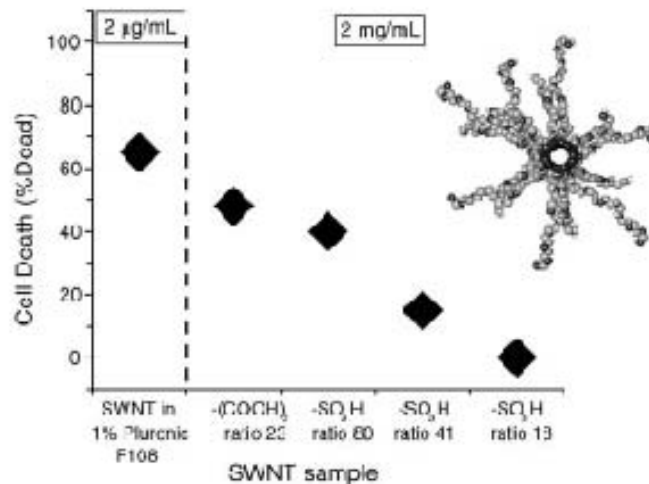
# CBEN Research Highlights



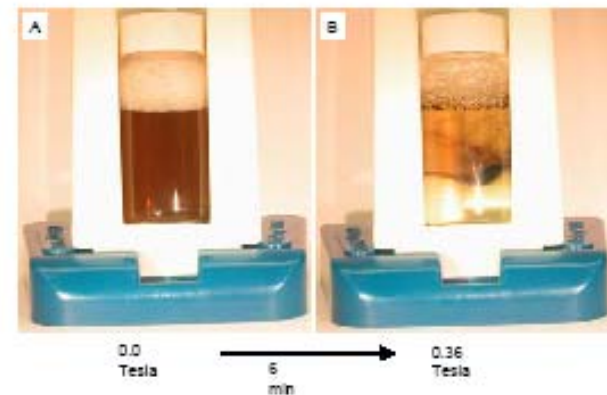
Targeted Ablation of Breast Tumor Cells (West, Drezek)



Buckyball aggregates cause pericardial edema in zebrafish (Alvarez, Tomson, Colvin)



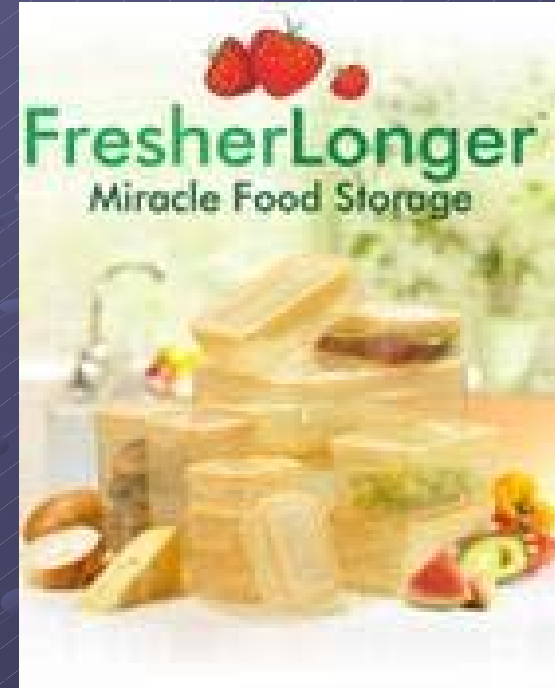
Surface modifications reduce nanotube toxicity (Colvin, West)



Nano magnets soak up poisonous arsenic (Tomson, Colvin)



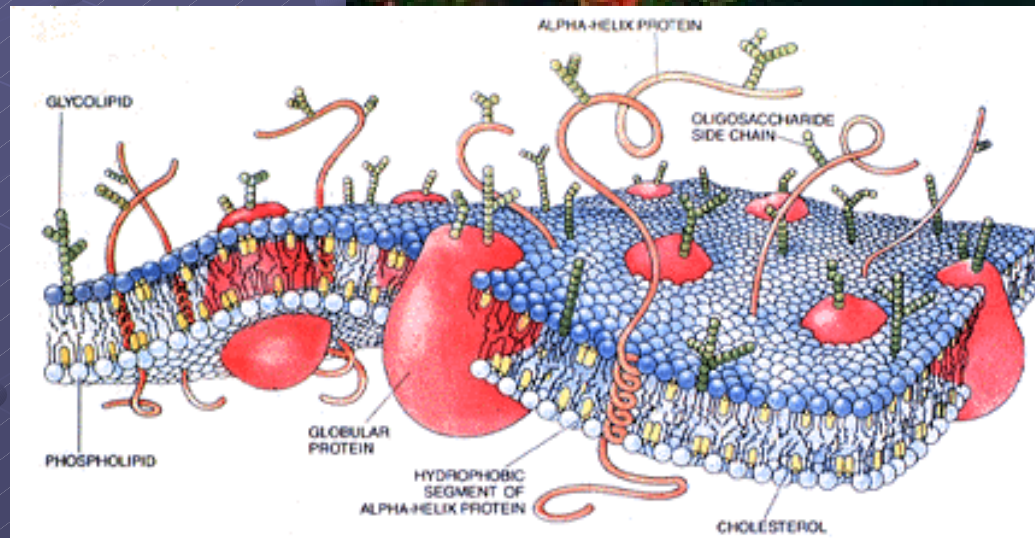
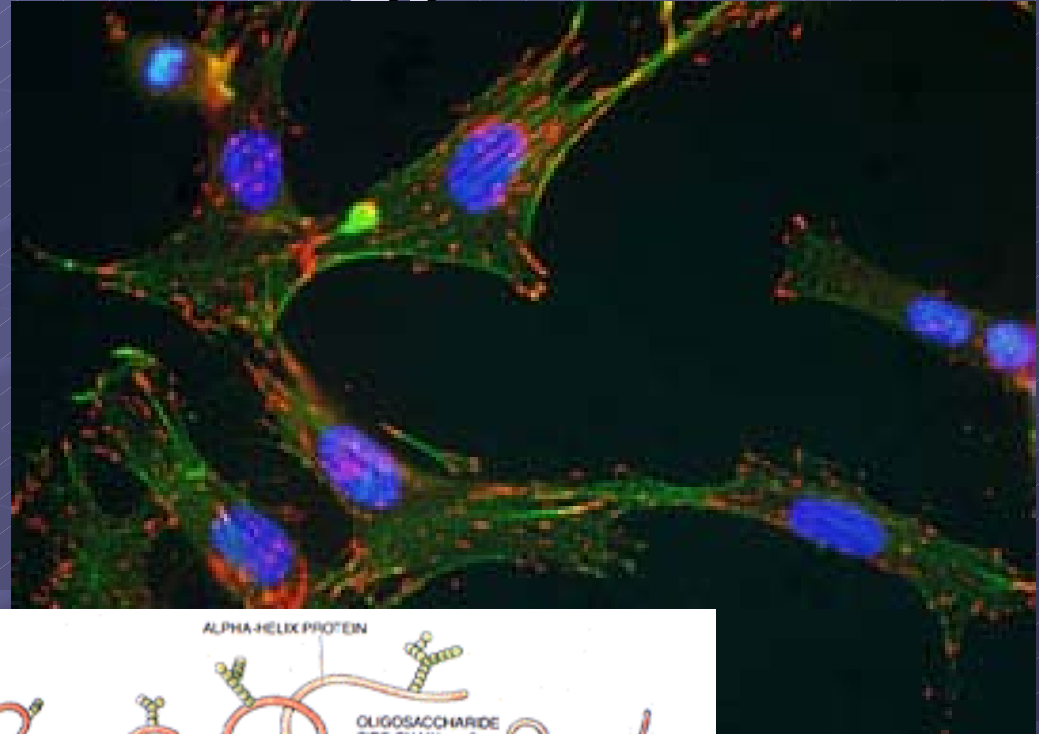
# Consumer products and nano



<http://www.nanotechproject.org/44/consumer-nanotechnology>

# Nanoscale cell biology

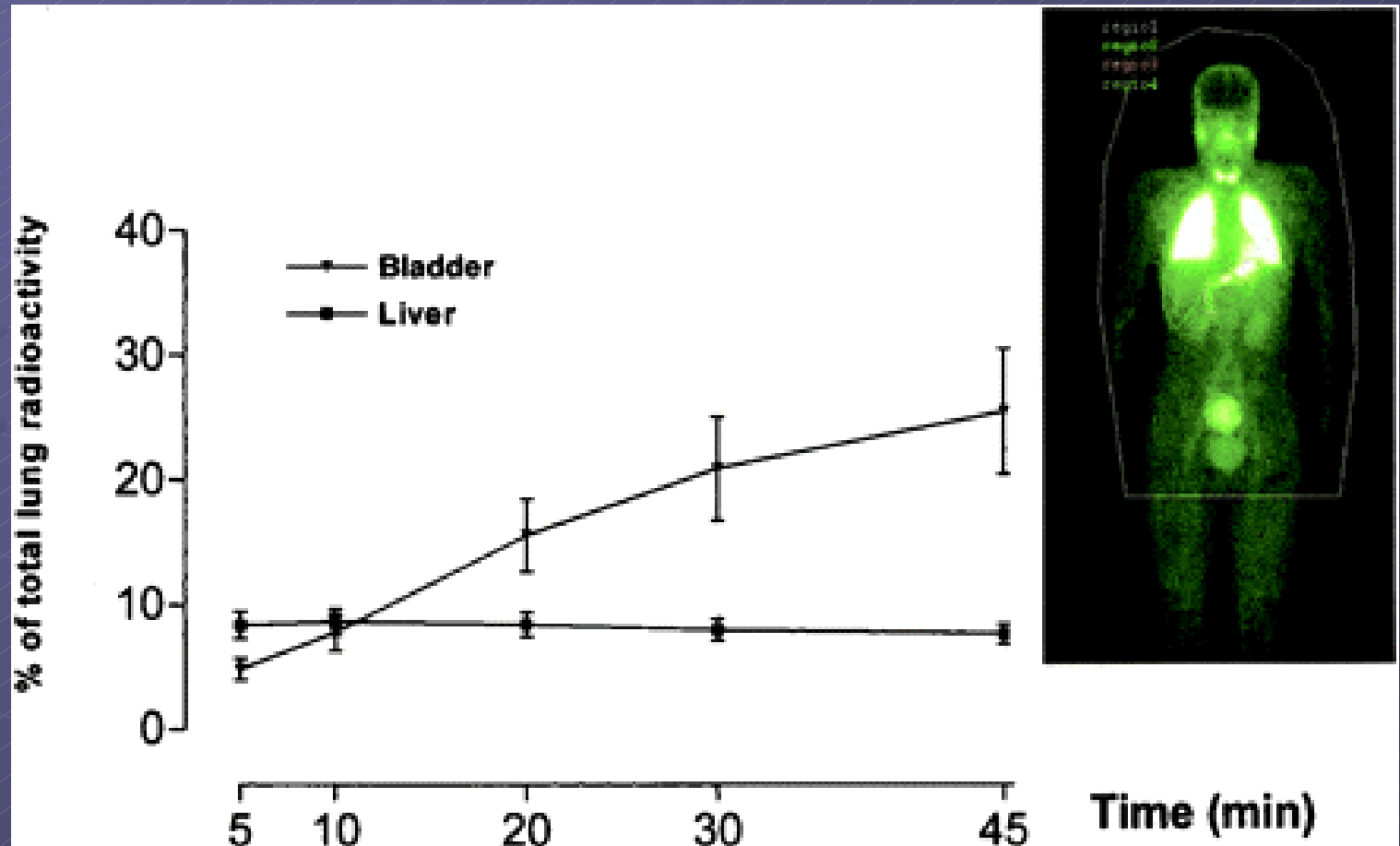
A cell membrane is about 7-10 nm thick.





# Inhaled carbon nanoparticles pass rapidly into the blood stream

(Nemmar et al, 2002)

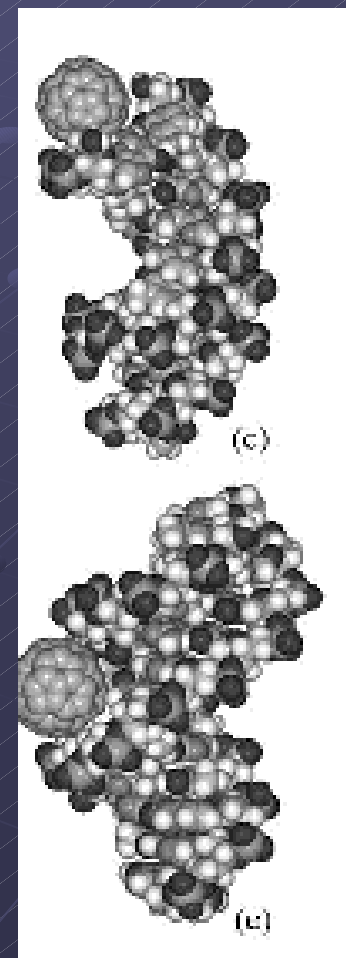
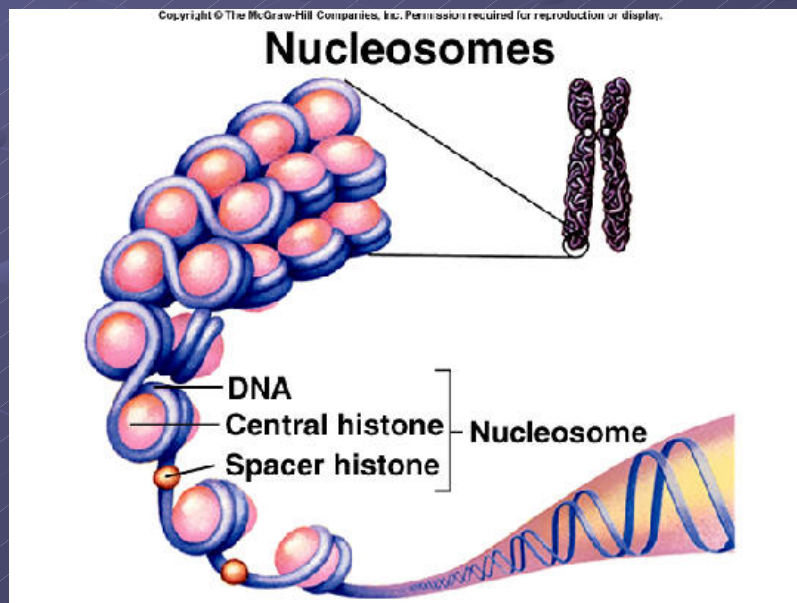


## $C_{60}$ Binds to and Deforms Nucleotides

Xiongce Zhao,\* Alberto Striolo,<sup>†</sup> and Peter T. Cummings\*<sup>†</sup>

\*Nanomaterials Theory Institute, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, Tennessee; and <sup>†</sup>Department of Chemical Engineering, Vanderbilt University, Nashville, Tennessee

DNA is about  
2.5 nm wide.



# Manufactured Nanomaterials (Fullerenes, C<sub>60</sub>) Induce Oxidative Stress in the Brain of Juvenile Largemouth Bass

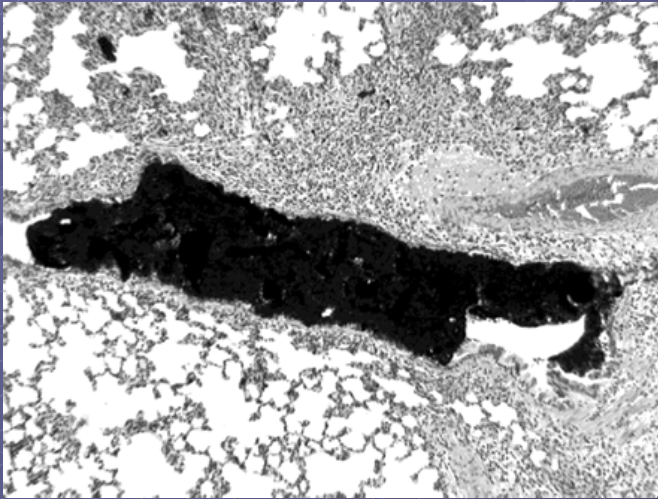
*Eva Oberdörster*

Duke University Marine Laboratory, Beaufort, North Carolina, USA; Department of Biology, Southern Methodist University, Dallas, Texas, US.\*

Environmental Health Perspectives • VOLUME 112 | NUMBER 10 | July 2004

Significant brain damage was found in brains of largemouth bass after 48 hr of exposure to 0.5 ppm uncoated nano (C<sub>60</sub>) buckyballs.

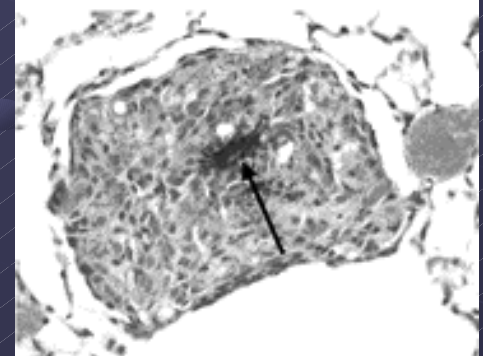
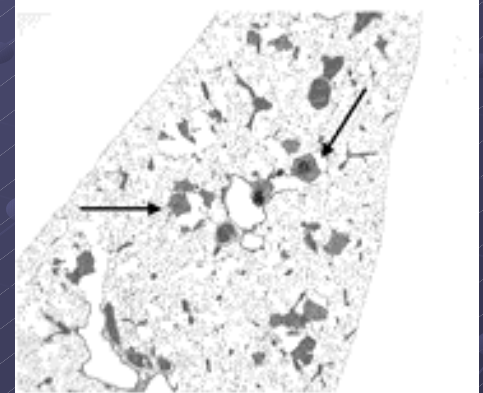
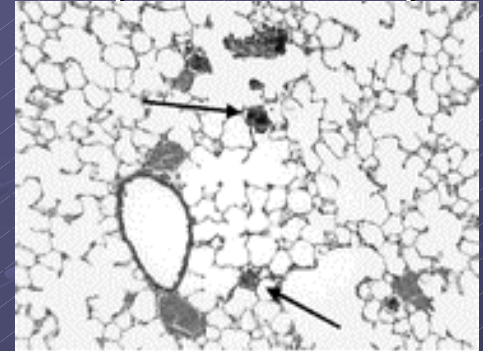
# Single walled carbon nanotubes cause lung fibrosis, death at high levels (NIOSH, DuPont, NASA...)



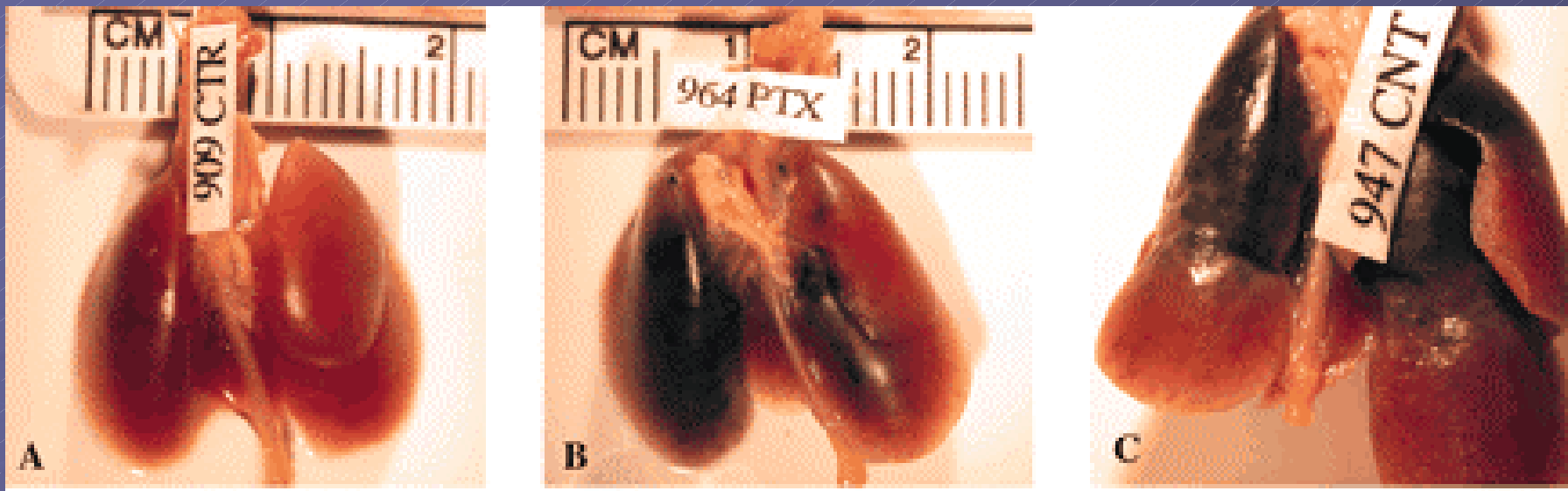
1 mg/kg  
SWCNT led  
to fibrosis  
after 1 week

5 mg/kg SWCNT led to suffocation in 15% of the CNT-exposed rats within 1 day of exposure.

Warheit et al, Toxicological Sci 77, 117-125 (2004)







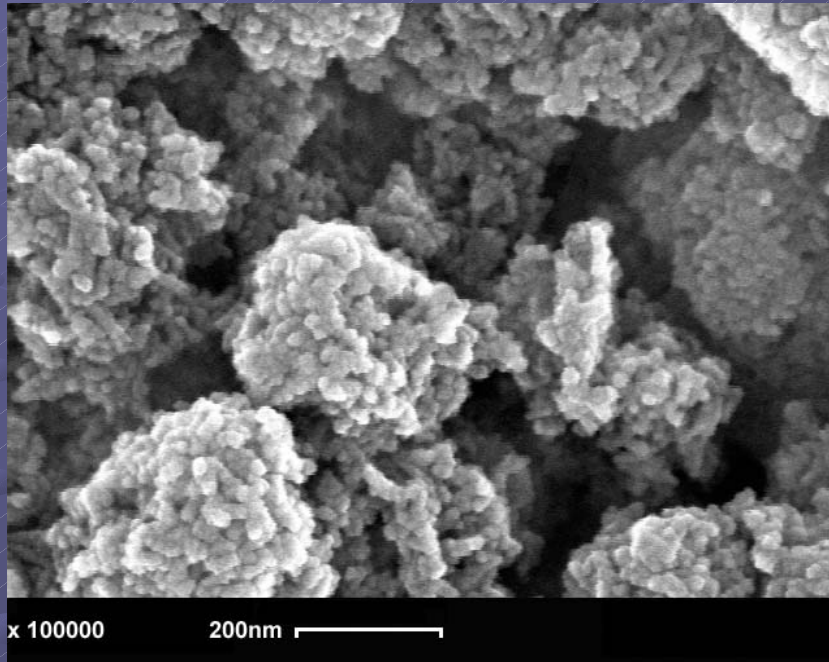
Lungs from mice instilled with 0.5 mg per mouse 90 days after the single treatment. (A) Serum control. (B) Carbon black (Printex). (C) carbon nanotubes.

This level is equivalent to a mouse breathing graphite dust at the OSHA PEL (5 mg/cu.m) for 17 days. Lam et al, Toxicological Sciences 77, 126-134 (2004)

# PM10 (10,000 nm) is linked to increased lung cancer and cardiopulmonary disease



Nano cerium oxide used as a fuel additive to reduce diesel emissions by 15% and increase fuel efficiency by 10% (Oxonica)



What are the health hazards?

# What makes nano toxic?

- Large surface-area-to-mass ratio
- Ability to penetrate biological tissues
- biopersistence

Nel et al, Science, 2006

**Table 1.** Particle number and particle surface area for 10  $\mu\text{g}/\text{m}^3$  airborne particles (5).

Particle diameter ( $\mu\text{m}$ )	Particles/ml of air	Particle surface area ( $\mu\text{m}^2/\text{ml}$ of air)
2	2	30
0.5	153	120
0.02	2,390,000	3000

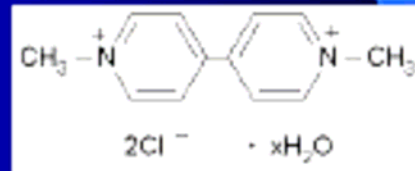


# Health Risk Assessment of Nanomaterials

## Comparative In Vitro Toxicity of Fullerenes

Toxicants	LC <sub>50</sub> , mg/kg
C <sub>60</sub> (OH) <sub>24</sub>	> 100,000
Ethanol*	17,000
THF	11,000
Toluene	1,600
Paraquat	100
Benzo[a]pyrene*	10
nano-C <sub>60</sub>	0.02
Dioxin*	0.001

\*National Institute of Health,  
Registry of Cytotoxicity Data (ZEBET)

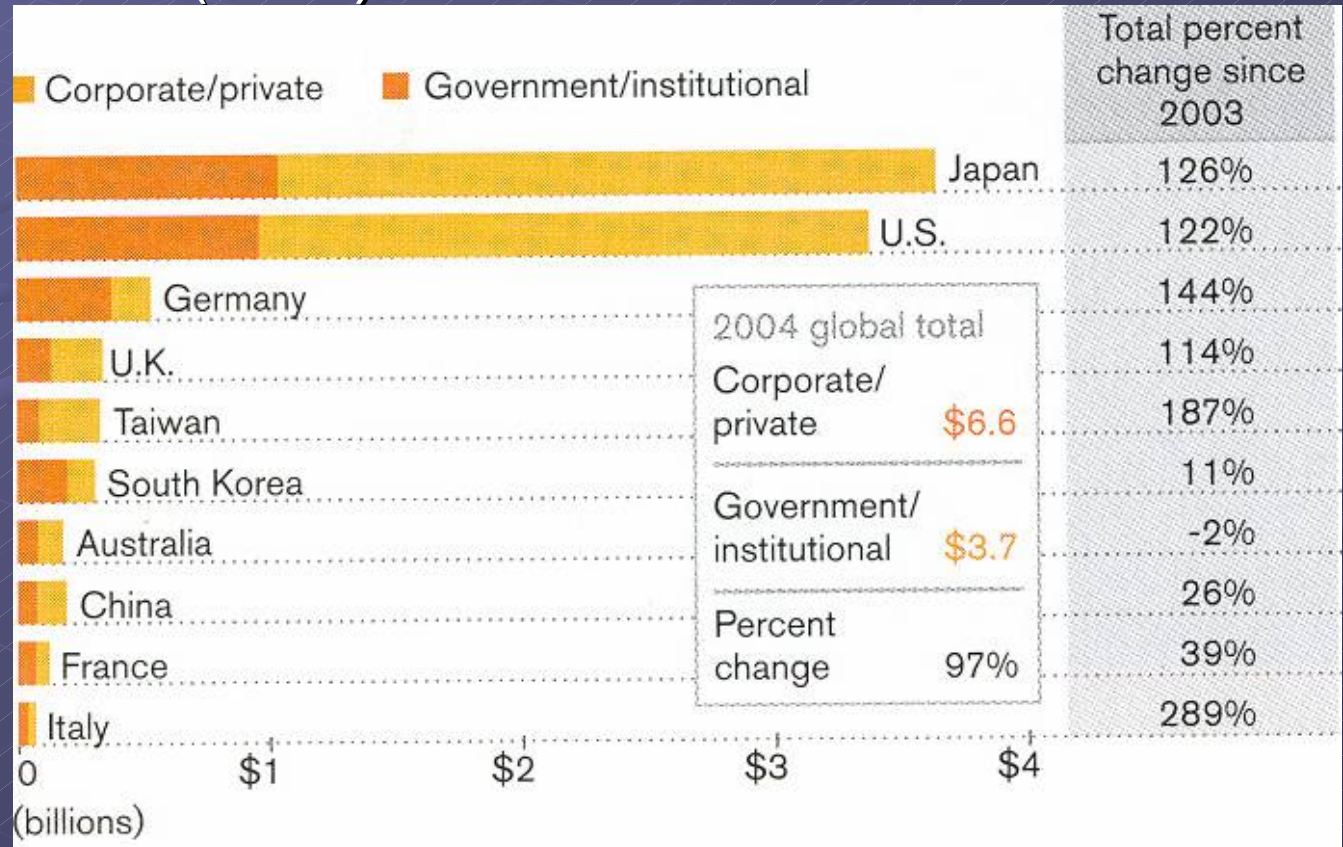


**Paraquat**

Courtesy of C. M. Sayes, Rice University, CBEN

Kevin Dreher, EPA, October, 2005

FY07 US federal NANO budget (total \$1.2B):  
 27% for DOD (\$345M),  
 20% for DOE (\$258M),  
 7% for EPA (\$9M)



# NRDC POSITION

- Prevent dispersive uses
- Label products
- public risk information
- Independent safety testing
- comprehensive life-cycle assessment

# NRDC Action Plan

- case studies of risks (cosmetics, pesticides, food)
- framework for regulation based on performance standards
- cost benefit analysis of regulatory compliance versus liabilities using above info
- Identify sectors to support a regulatory framework