

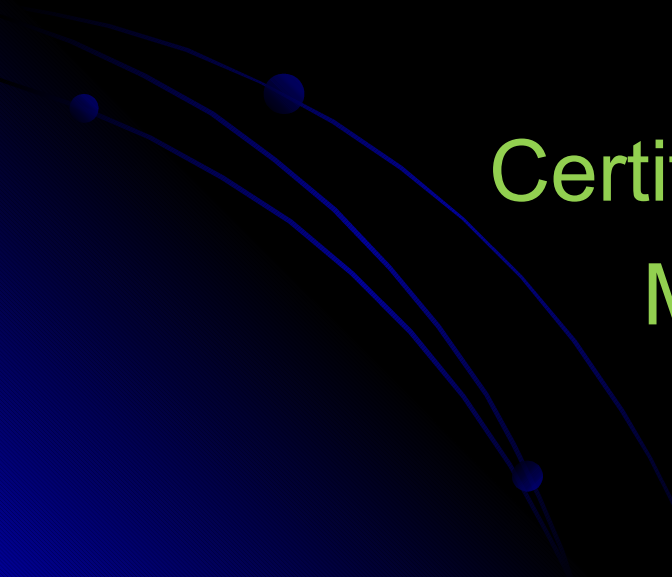
Nanotechnology and Wastewater Treatment

The new technology that could “save us, destroy us, or
something in between”

Kay Curtin

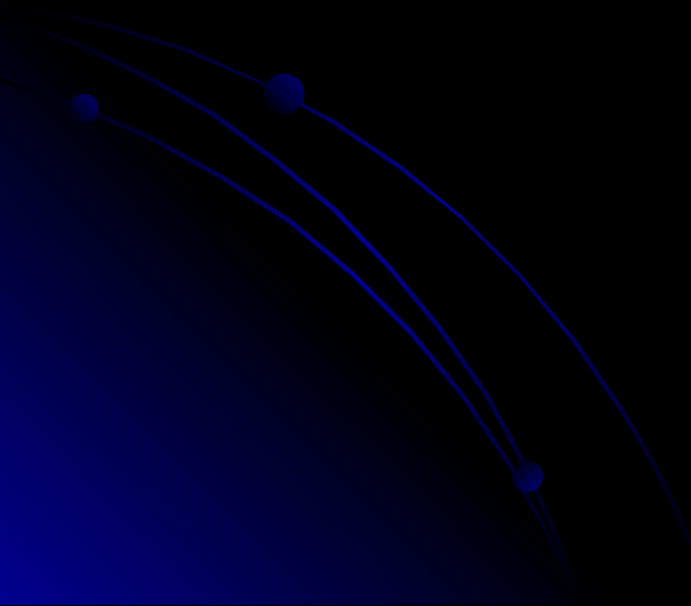
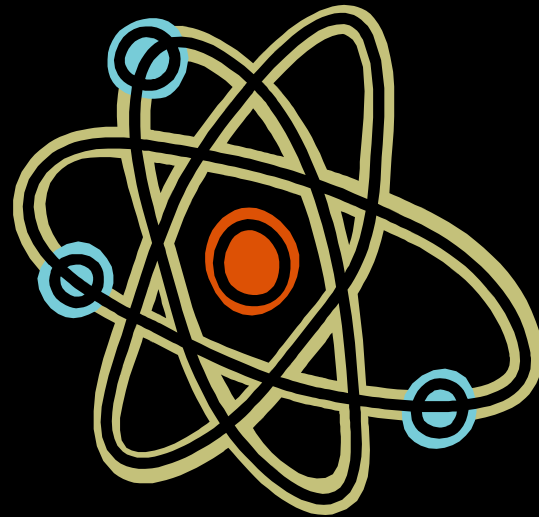
Certification and Training

MPCA – St. Paul

A decorative graphic in the bottom-left corner consisting of three curved, parallel lines in a dark blue color. Each line has a small, solid blue circular dot placed on it. The lines curve from the bottom-left towards the center of the slide.

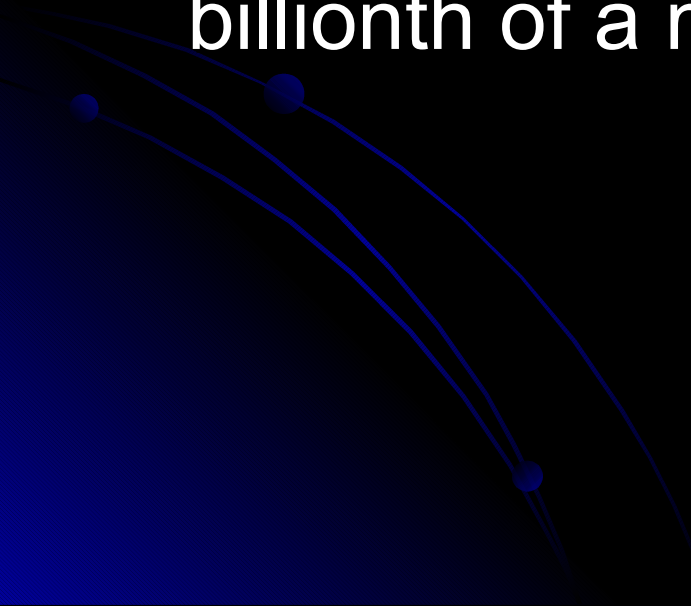
What is it?

- The manufacture of **extremely small** particles (atomic level) for uses in medicine, cosmetics, food, technology, electronics, etc.

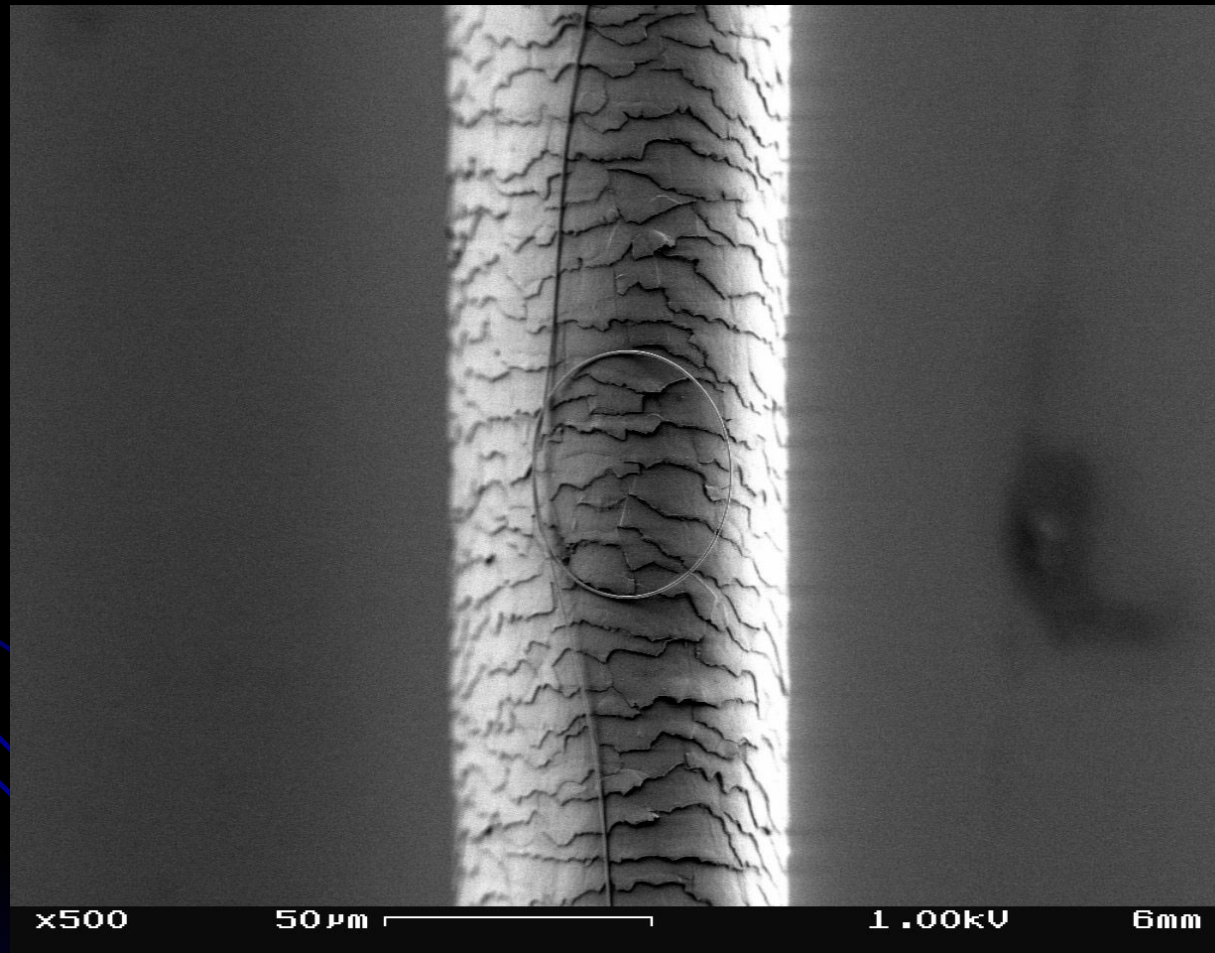


What is it?

- *Nano* is the Greek word for *dwarf*.
- Nanotechnology deals with objects on the order of a *nanometer* in size.
- 1 *nanometer* = 0.000000001 meters or 1 billionth of a meter



What is it?

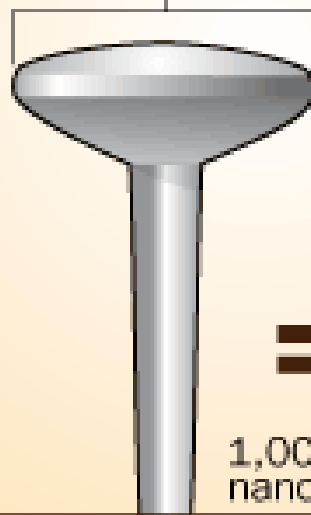


Human hair is between 17,000 to 181,000 *nanometers* thick

How Nanotechnology Works

©2007 HowStuffWorks

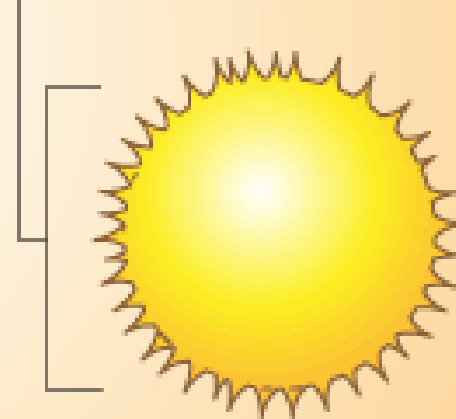
Head of a Pin is 1 millimeter



=

1,000,000
nanometers

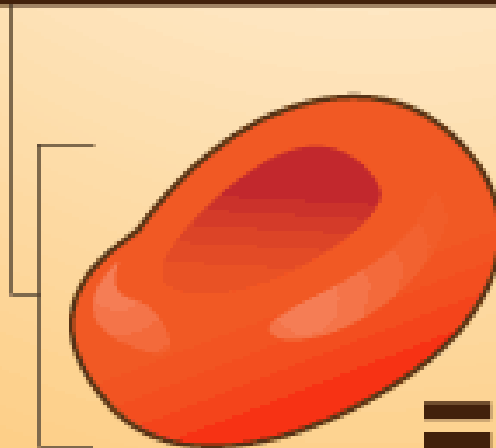
Ragweed pollen is 20 micrometers



=

20,000
nanometers

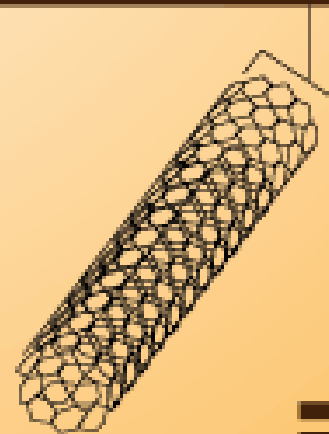
Red blood cell is 2.5 micrometers



=

2,500
nanometers

Carbon nanotube is 2 nanometers

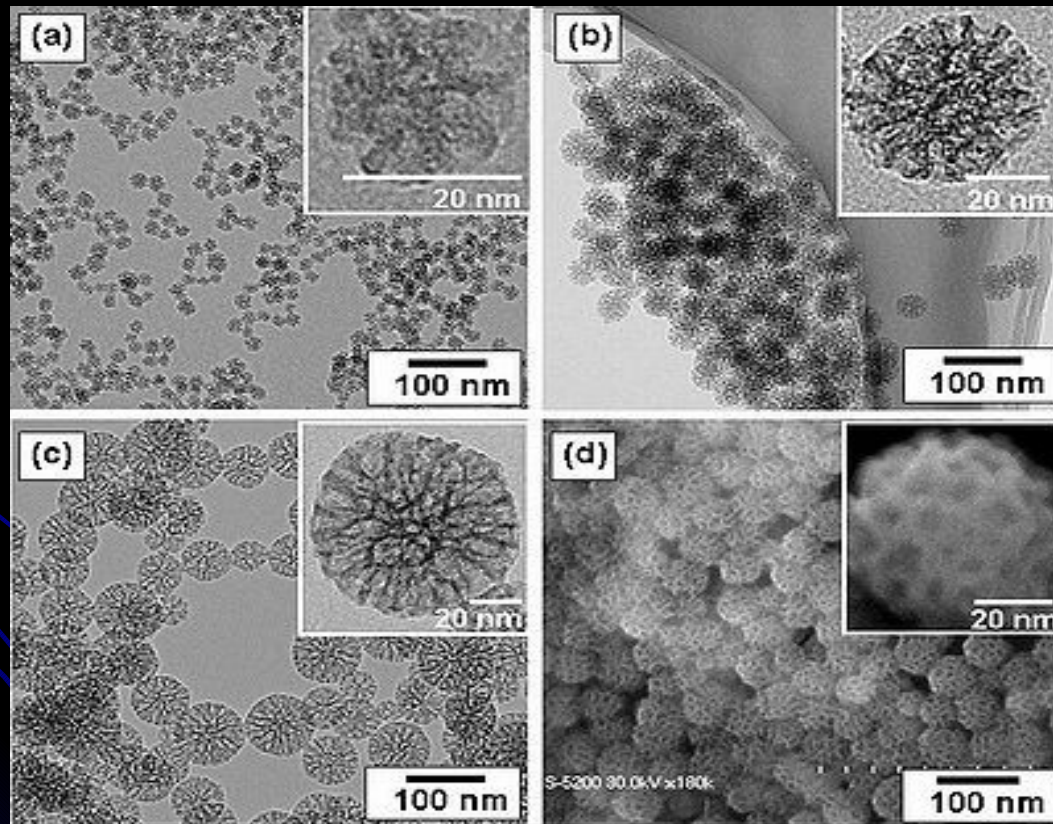


=

2 nanometers

Nanoparticles used in current technology

- Between 1 and 100 nanometers in size



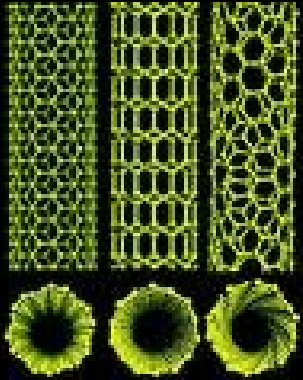
History

- 1959 – Richard Feynman “*There’s Plenty of Room at the Bottom*” at an American Physical society meeting at Caltech
- 1974 – term “nanotechnology” coined by Tokyo Science University professor Norio Taniguchi

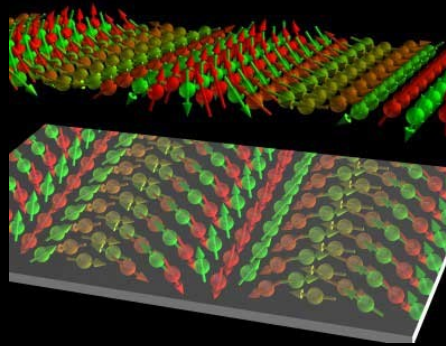
History

- Carbon fullerenes accidentally discovered by Richard Smalley (1943-2005) at Houston's Rice University in 1985
 - Called "fullerenes" from "Buckminsterfullerene" (named after Richard Buckminster Fuller)
 - Spherical are called "Buckyballs"
- 1980's – Dr. K. Eric Drexler promoted nanotechnology

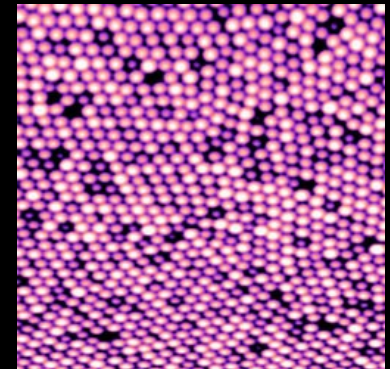
Types of Nanoparticles



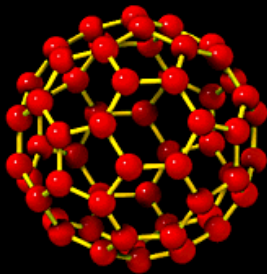
Carbon
Nanotubes



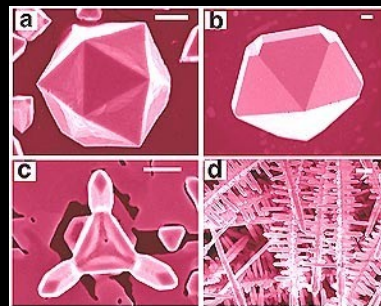
Nanolayers



Quantum
dots



Fullerenes
(buckyballs)



Nanocrystals

Nanotechnology Today

- *Fastest growing industry in the U.S.*



What's so special about the nanoscale?

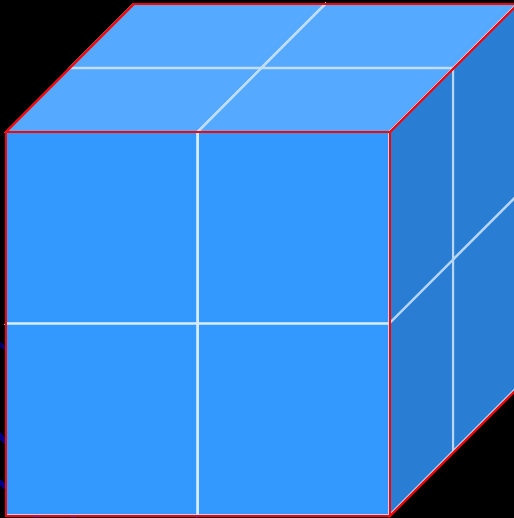
Surface Area to Volume ratio

- Carbon nanotubes have a HUGE surface area and a very tiny volume.
- The higher the SA:V, the stronger, more stable and durable the nanomaterial
- Materials can be developed from the “bottom up” or “top down”

What's so special about the nanoscale?

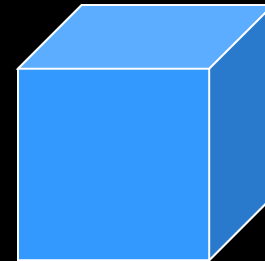
- Surface Area to Volume ratio

Volume = 8 blocks
Surface Area = 24 sides



S.A./Volume:
3

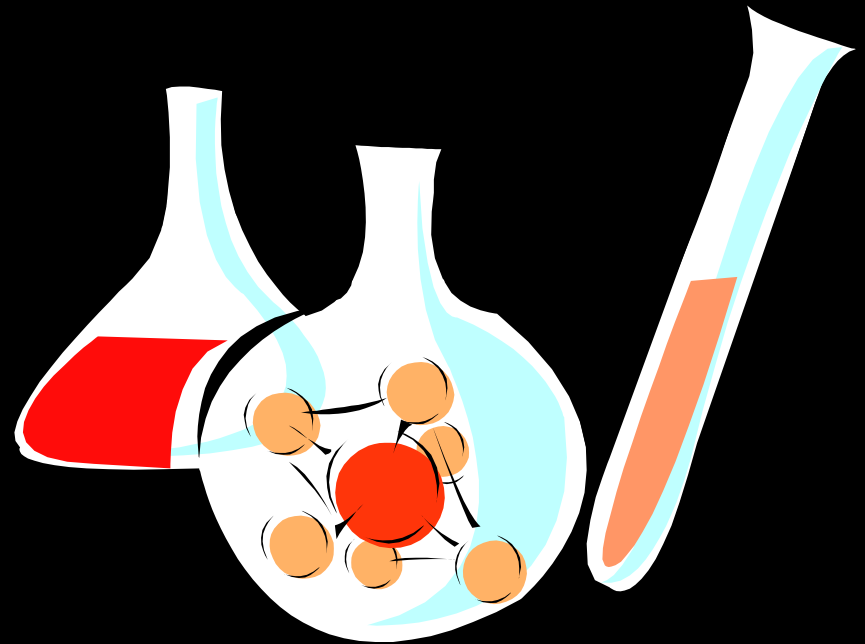
Volume = 1 block
Surface Area = 6 sides



S.A./Volume:
6

What's so special about the nanoscale?

- Materials may **change** optical, electrical, physical, chemical, or biological properties at the nanoscale level.



What's so special about the nanoscale?

- Materials obey different laws of physics as they approach the atomic scale:
 - Gold **changes color** in the nanoscale.
 - Zinc oxide **appears clear**
 - **Boiling temperatures** change
 - **Gravitational forces** become negligible
 - **Electromagnetic forces** become dominant

What's so special about the nanoscale?

- Makes material **stronger**, more durable
 - Makes chemical and biological reactions **easier**
 - Can **attach** enzymes, metal ions, etc. to nanomaterials for more **effective use and delivery**
- 

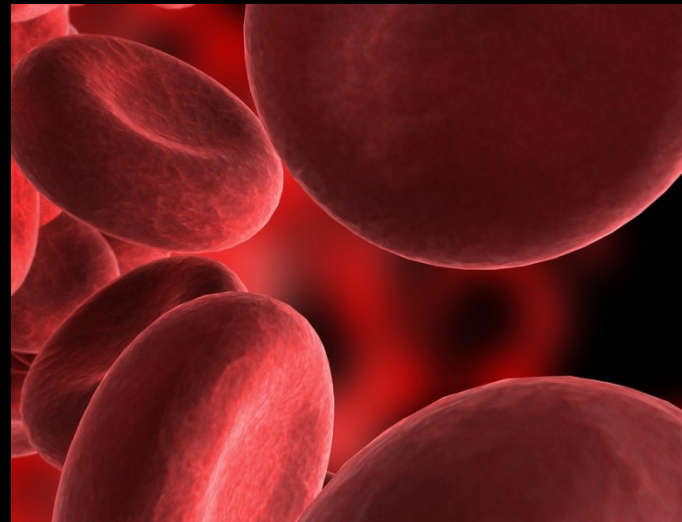
Quantum Dots

- Quantum dots are nanoparticles made from a semiconducting material.



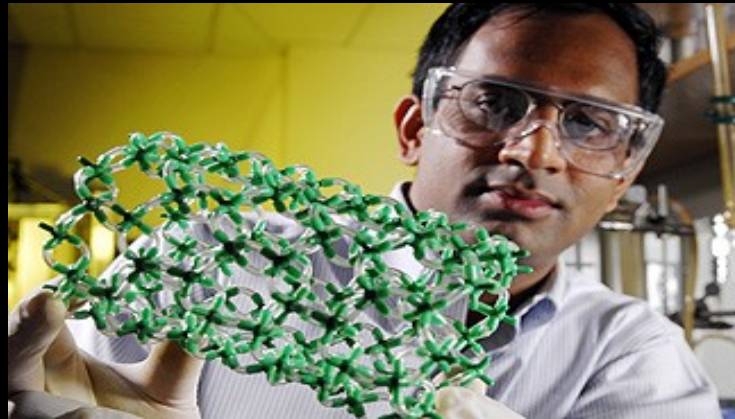
What's so special about the nanoscale?

- Small size is ideal for medicine :
 - Red blood cells are 7,000 nm wide
 - Ideal candidates for cancer detection
 - Ideal for drug delivery systems



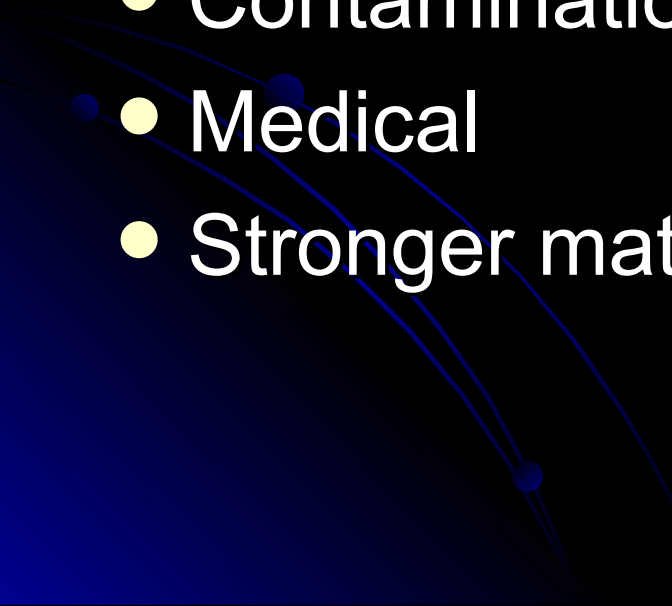
Beyond Carbon

- Metal Oxides



Sankar Nair, Georgia Tech School of Chemical and Biomolecular Engineering, with a model showing the structure of metal oxide nanotubes he is developing.

Nanotechnology Uses Now

- Food industry
 - Energy
 - Remediation
 - Filtration
 - Contamination clean-up
 - Medical
 - Stronger materials (graphene)
- 

Future Uses?

- Self-assembling products, systems and materials
- Computers billions of times faster
- Extremely novel inventions (fabric, optical, etc.)
- Realistic space travel and exploration
- Nanomedical discoveries
- Molecular food syntheses

NanoTechnology Industry Focus

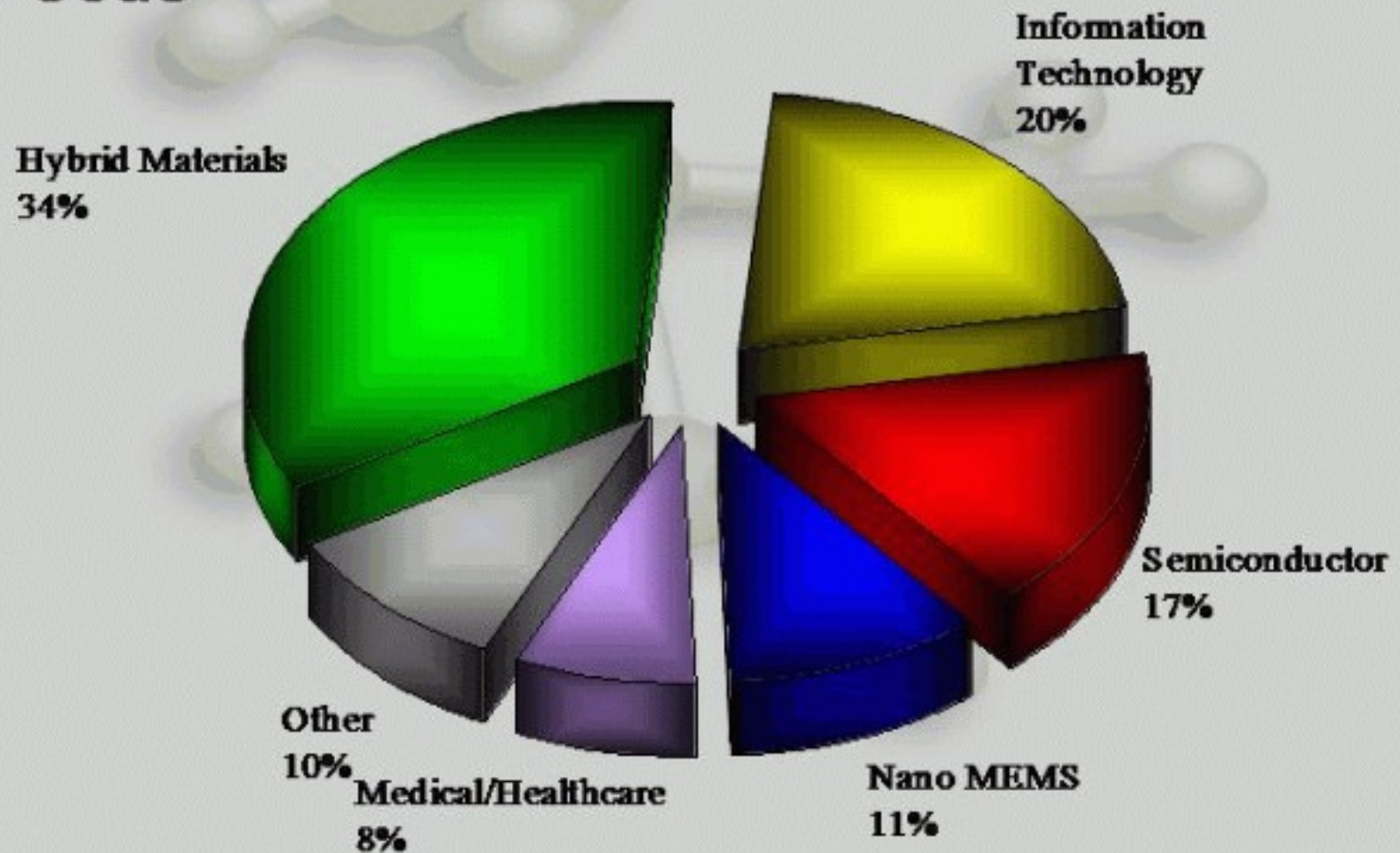
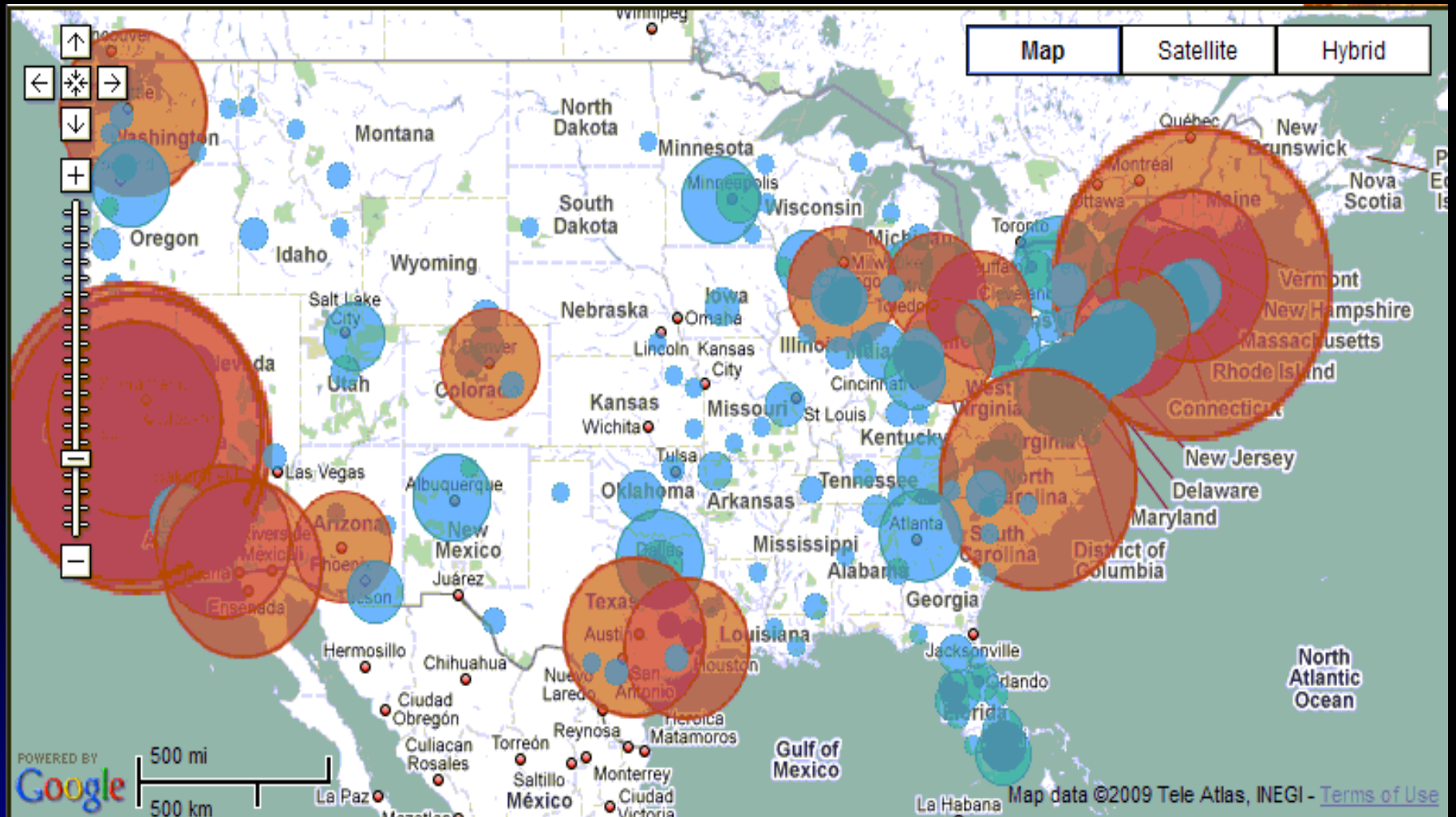


Figure 4

Blue – Energy and Environmental
Orange - Electronics



<http://www.nanotechproject.org/inventories/map/>
- Madison, WI

- Medicine and Health
- Tools and Instruments
- Academic and Government Research
- Imaging and Microscopy
- Electronics
- UW nanotechnology laboratory
- Trek developed a bike frame composed of graphene

Environmental Applications

- Sensors
- Water Treatment
- Remediation (clean-up sites)
- Green manufacturing
- Green energy



Environmental Promises of Nanotechnology

- Reduce waste production
- Clean-up industrial contamination
- Provide clean drinking water for third world countries
- Improve the efficiency of energy production and use



Examples of Environmental Applications

- Remediation
 - Use nano-sized rust particles to remove arsenic from drinking water.

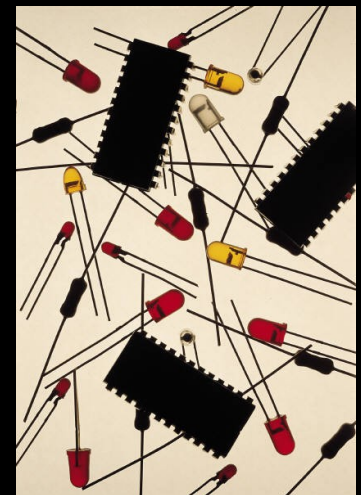


Resource: CBEN, Rice University, Texas

Examples of Environmental Applications

- Sensors

- Tel Aviv University is currently building and commercializing its water-testing mini-labs to measure water contaminants and monitor how genetically engineered bacteria respond to pollution such as *e. coli* in water.

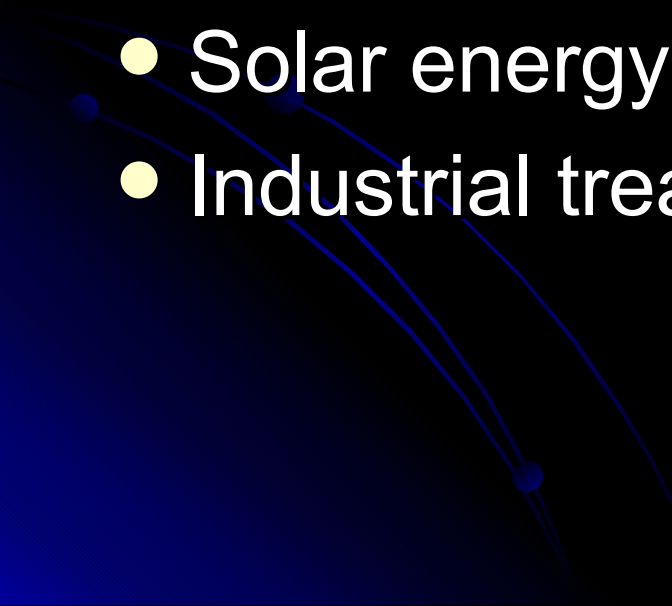


Examples of Environmental Applications

- EPA's Nation Risk Management Research Laboratory in Cincinnati developed a method using nano-zerovalent iron embedded with nanopalladium in activated carbon to clean up PCBs.
 - Being used in Hudson River, where General Electric dumped PCBs for decades

Resource: <http://pubs.acs.org/doi/full/10.1021/es803116t>

Wastewater Treatment Applications

- Make filters more effective
 - Sensors
 - Phosphorus removal
 - Metals removal
 - Solar energy
 - Industrial treatment
- 

Wastewater Treatment Applications

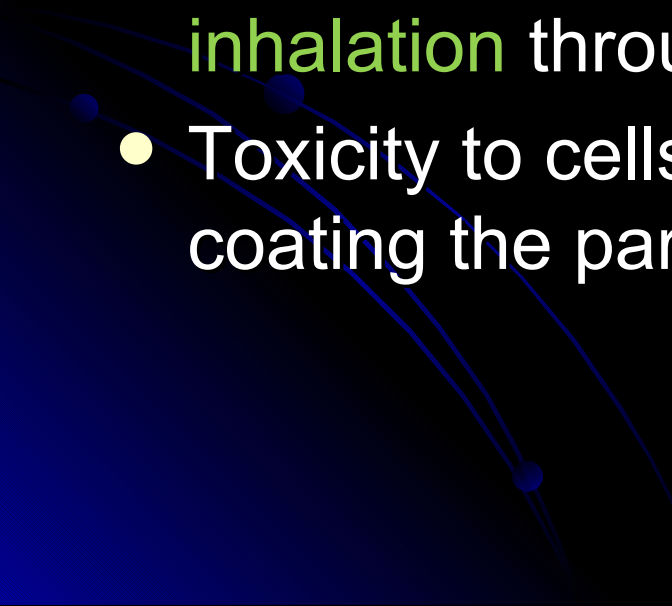
- The University of South Australia has is developing a new solar one-step nano-photocatalytic wastewater treatment process
- Replaces chlorination disinfection to disinfect micro-organisms while removing the organic compounds

Resource: <http://www.azonano.com/default.aspounds>

Now for the Bad News...



Potential Effects

- Nanoparticles may be **more toxic** than micron-sized particles in short-term animal tests
 - Nanoparticles may **translocate** to other organs in the body
 - Nanoparticles may enter the brain through **inhalation** through nasal neurons
 - Toxicity to cells may be modified or reduced by coating the particles
- 

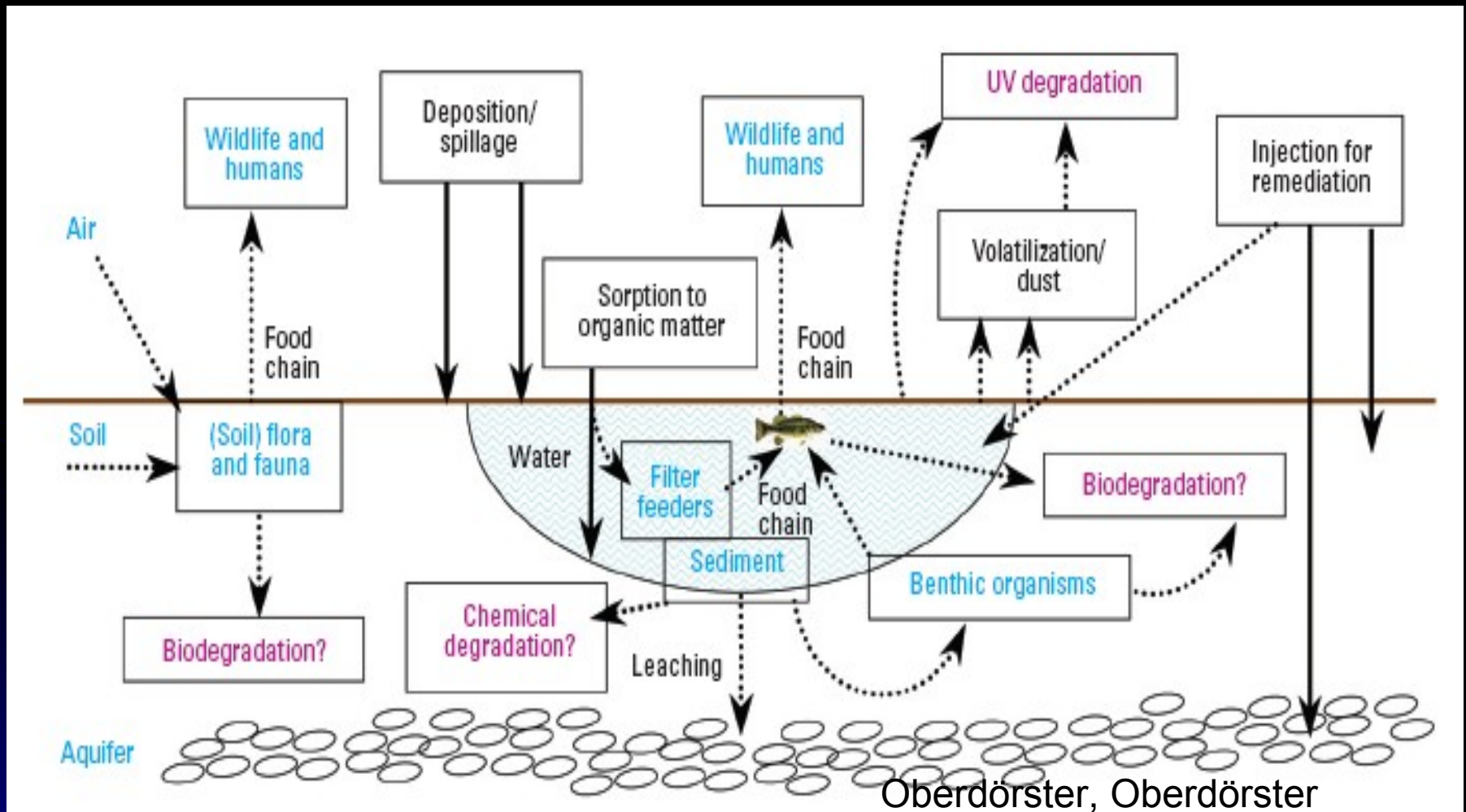
Potential Effects, cont.

- Buckyballs can cause **brain damage** in young largemouth bass
- Carbon nanotubes can cause **lung damage** in lab rats
- Copper nanoparticles can cause **gill injury and acute lethality** in zebra fish
- Some manufactured nanoparticles can **damage human DNA**, increasing the risk of cancer
- Silver nanomaterial can cause **liver damage** in rats

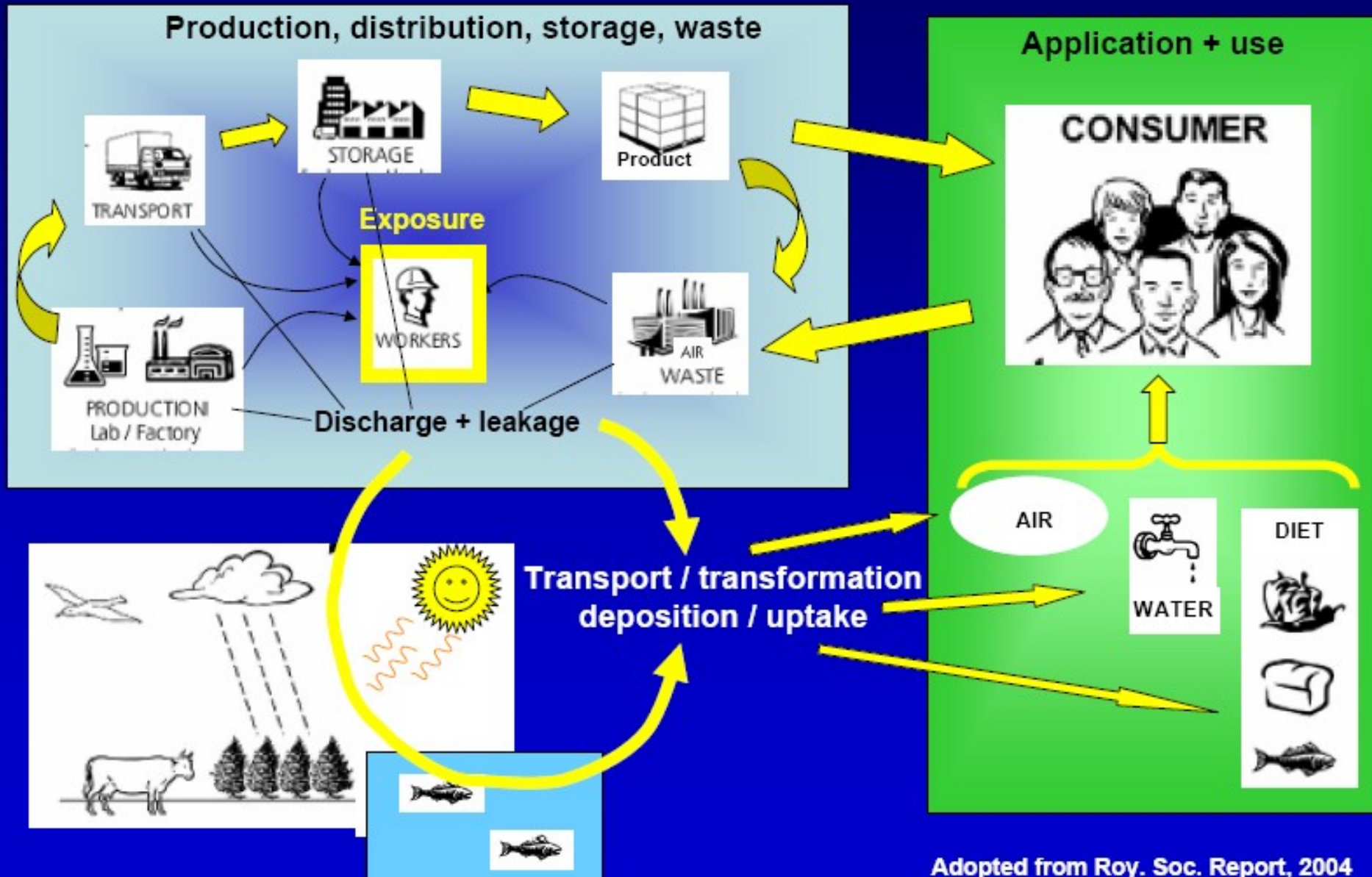
***Few Studies
Have Been
Completed***



Suggested Routes of Exposure, Uptake, Distribution, and Degradation of Nanoparticles in the Environment

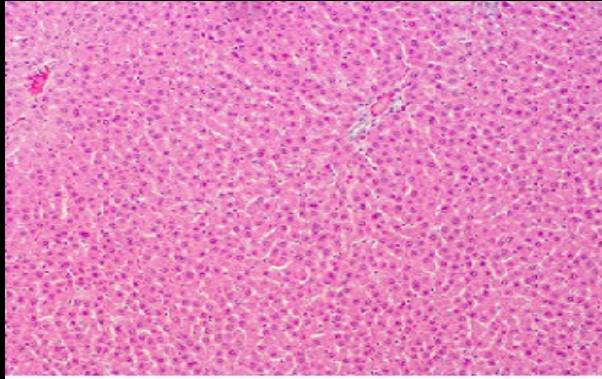


Risks During Life Cycle of Nanoparticles (Kreyling 2006)

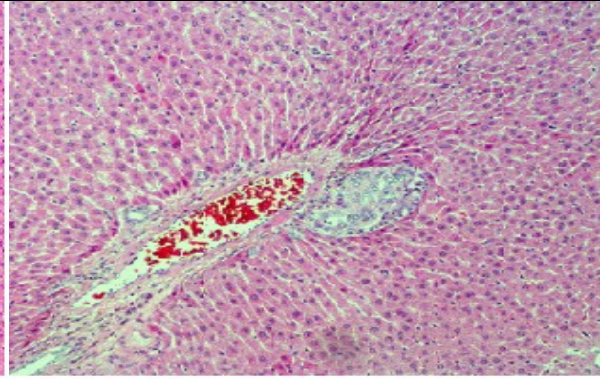


Histopathology of Liver (Rodent) (Oral)

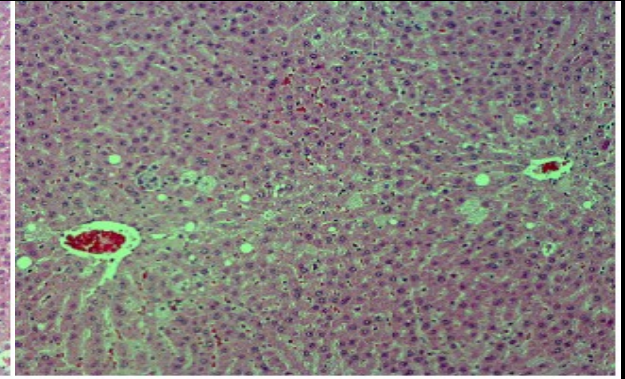
Liver



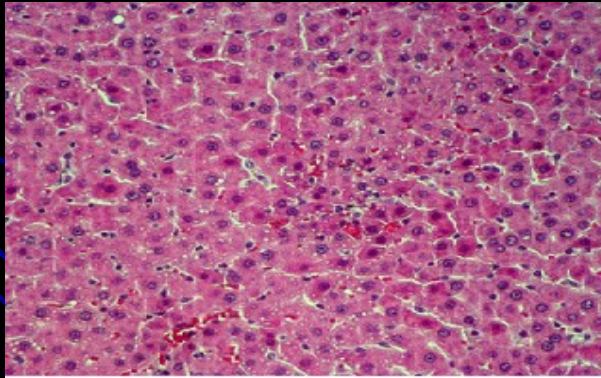
Control x100



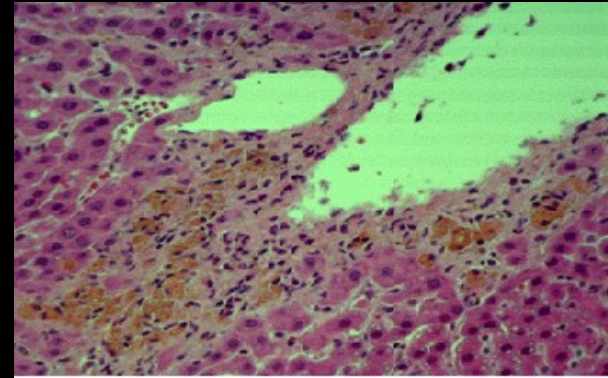
Bile duct hyperplasia x100



Vacuolization x100



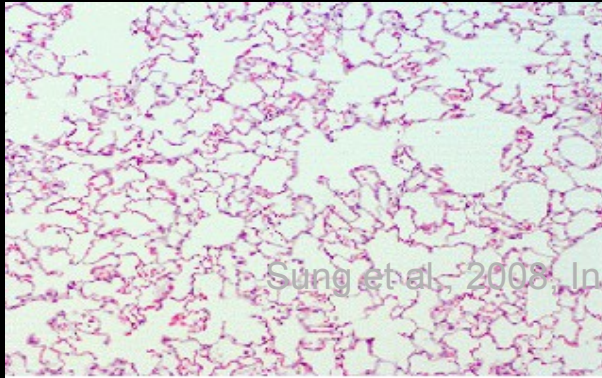
Hepatocytes swelling x200



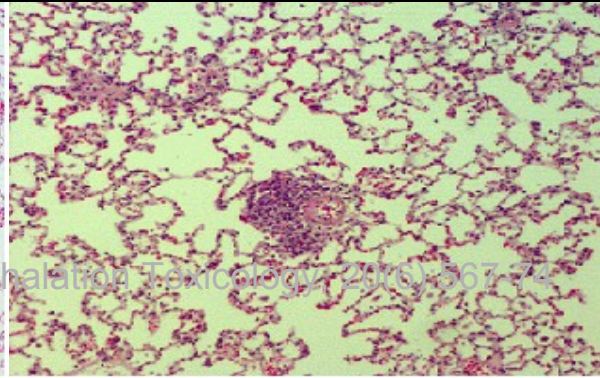
Siderotic near central vein x200

Histopathology of Lung (Rodent) (Inhalation)

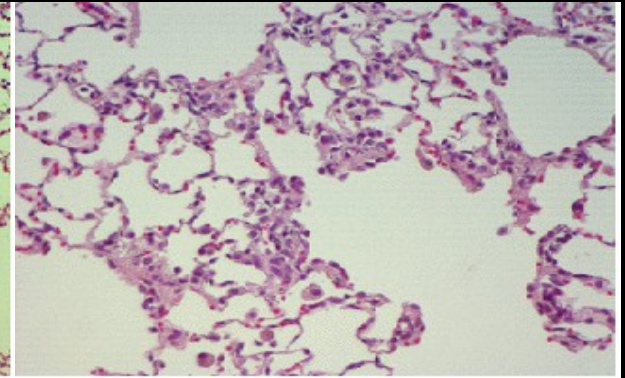
Lung



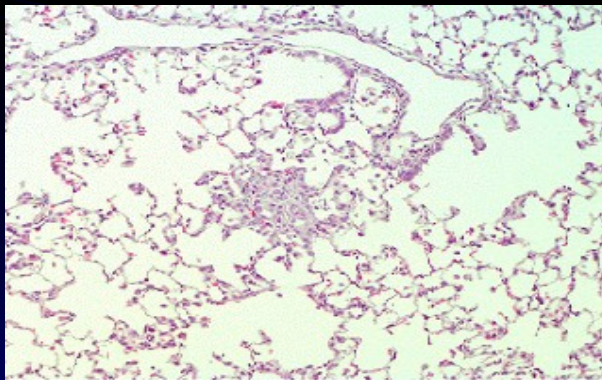
Control x100



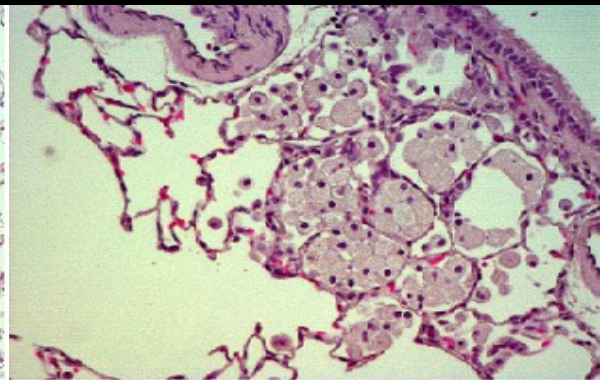
Perivascularitis x100



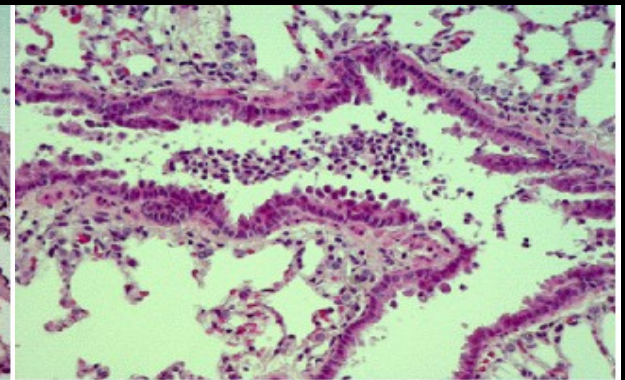
Alveolitis x200



Granulomatous lesions x100

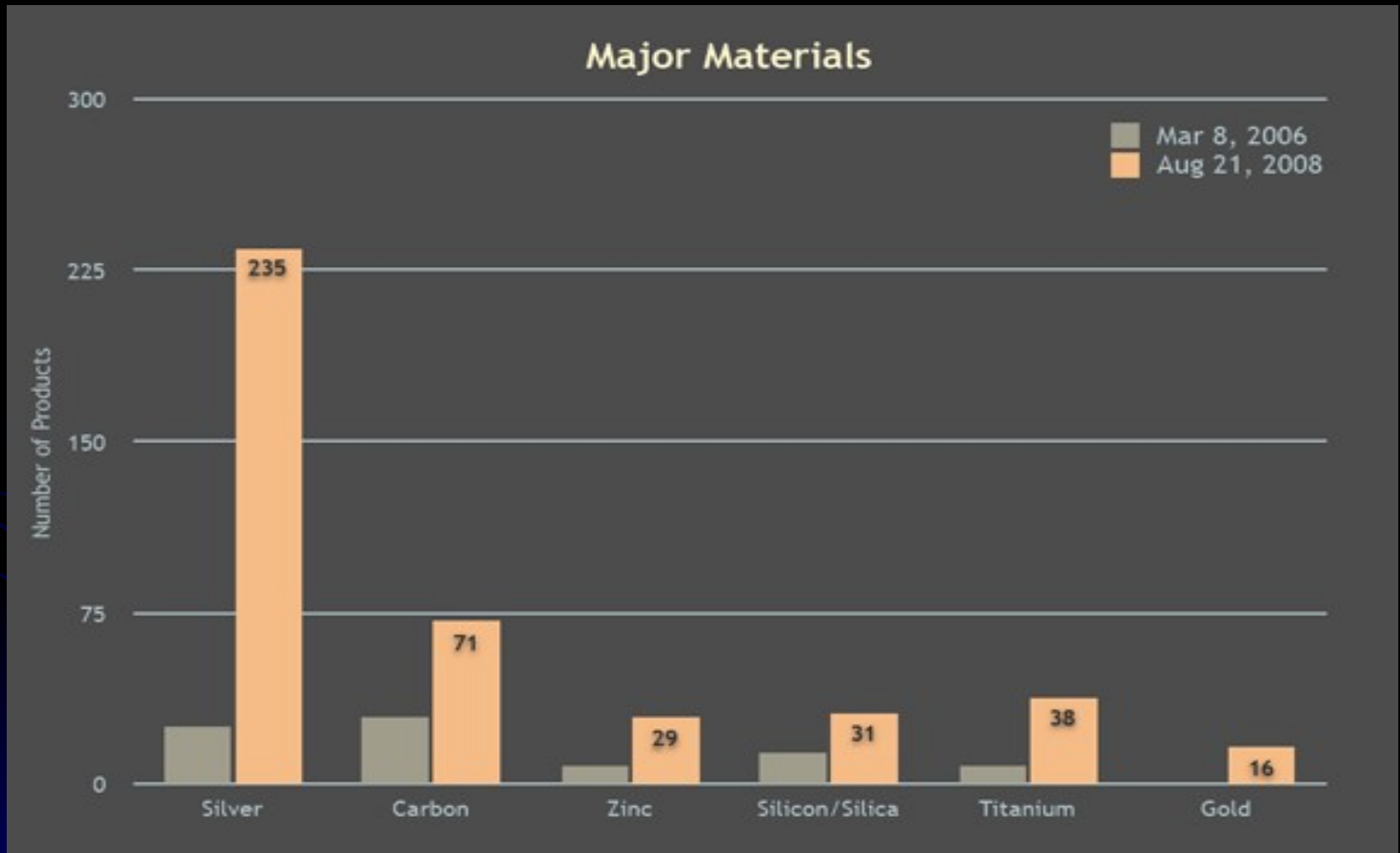


Histiocytosis x400



Inflammation x100

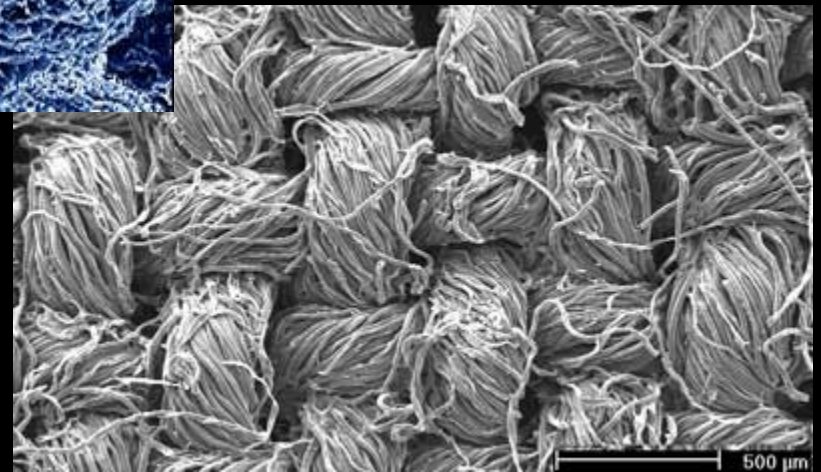
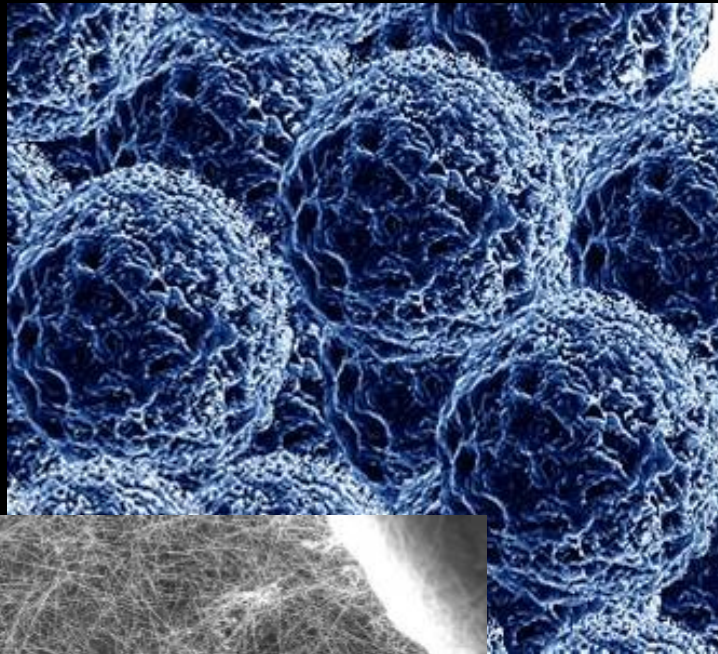
Silver nano consumer product



Silver nano applications

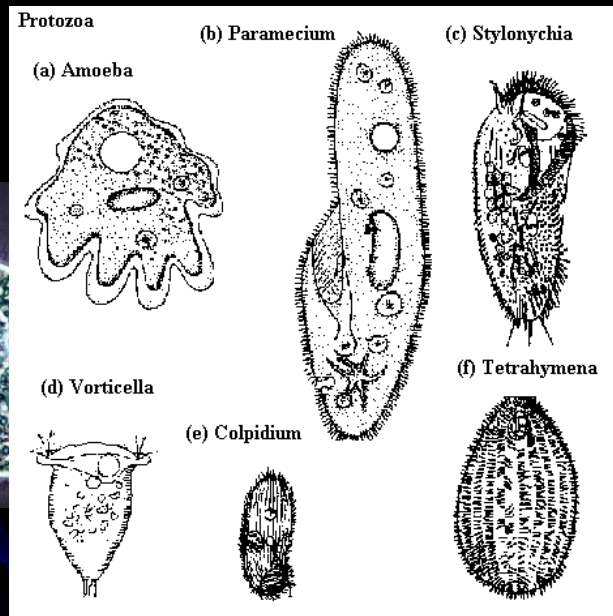
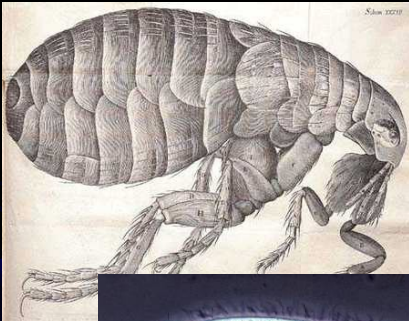
- Bedding
- Washing machines
- Water purification
- Tooth paste
- Shampoos
- Conditioners
- Baby bottles
- Fabrics
- Socks
- Deodorant
- Filters
- Kitchen utensils
- Toys
- Mattresses
- Humidifiers

Silver Nanomaterial Grafted to Cotton



Silver

- Antimicrobial =
Anti- wastewater
treatment organisms



Ag Silver

Atomic Number: 47
Atomic Mass: 107.87

Current Studies

- Dr. Zhuhua Liang, Atreyee Das, Zhiqiang Hu of University of Missouri Columbia conducted a recent study on the inhibitory effects of nanosilver on activated sludge:
 - Ammonia-oxidizing bacteria *nitrospira* were inhibited
 - Nitrite-oxidizing *nitrobacter* were completely washed out

Resource: "Bacterial response to a shock load of nanosilver in an activated sludge treatment system"
Liang, Das, Hu, 2010

Current Studies

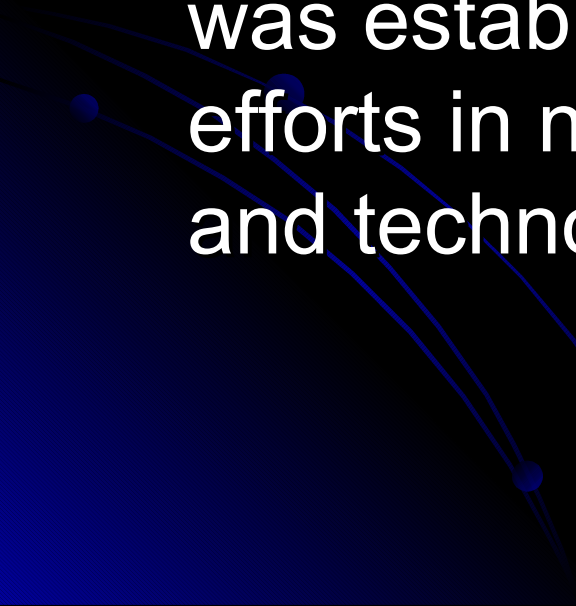
- Michael Hochella and colleagues at Virginia Tech, United States, which identified and characterized silver nanoparticles in the sewage sludge of an operating municipal wastewater treatment plant.
- Study showed that silver may be chemically transformed in the course of wastewater treatment.

Source: Richard Denison, a senior scientist with the Environmental Defense Fund (EDF) quoting Environmental Science & Technology

Federal Oversight of Nanotechnology

- Not everyone agrees existing federal laws are adequate for nanotechnology
 - Materials change at nano levels
 - Nanomaterials are below most content thresholds
- Many different government agencies need to be involved.
- In the absence of federal rules, nanotech companies have developed their own voluntary standards of care.

Federal Oversight

- The FDA and USDA currently have no regulations on nanomaterials
 - The National Nanotechnology Initiative was established to coordinate multiagency efforts in nanoscale science, engineering, and technology (www.nano.gov)
- 

WEF Publications

- 2008 - Technical Practice Update ‘Effects of Nanoparticles on the Wastewater Treatment Industry’



NIOSH

- Published Current Intelligence Bulletin 60:

“Interim Guidance for Medical Screening and Hazard Surveillance for Workers Potentially Exposed to Engineered Nanoparticles”

www.cdc.gov/niosh

New Regulations

- 2009 – EU approved regulations for cosmetics industries to **disclose** all nanoparticles in product ingredient list
- September 2010 - EPA published **significant new use rules** – SNURs – for both single- and multi-walled carbon nanotubes dealing with worker protection.

New Regulations

- The Government Accounting Office (GAO) made Recommendations for Executive Action by the EPA for **new use rules, registration and disclosure guidelines, implementation of studies, etc.** for nanomaterials
- <http://www.gao.gov/products/GAO-10-549>

What about Wisconsin?

- White Paper developed by DNR task force in 2006

http://www.nsec.wisc.edu/NanoRisks/Nano_WhitePaper.pdf

Recommends that the “Department articulate a clear position statement that can be used as a framework for addressing emerging nanotechnology issues”



How about Wisconsin?

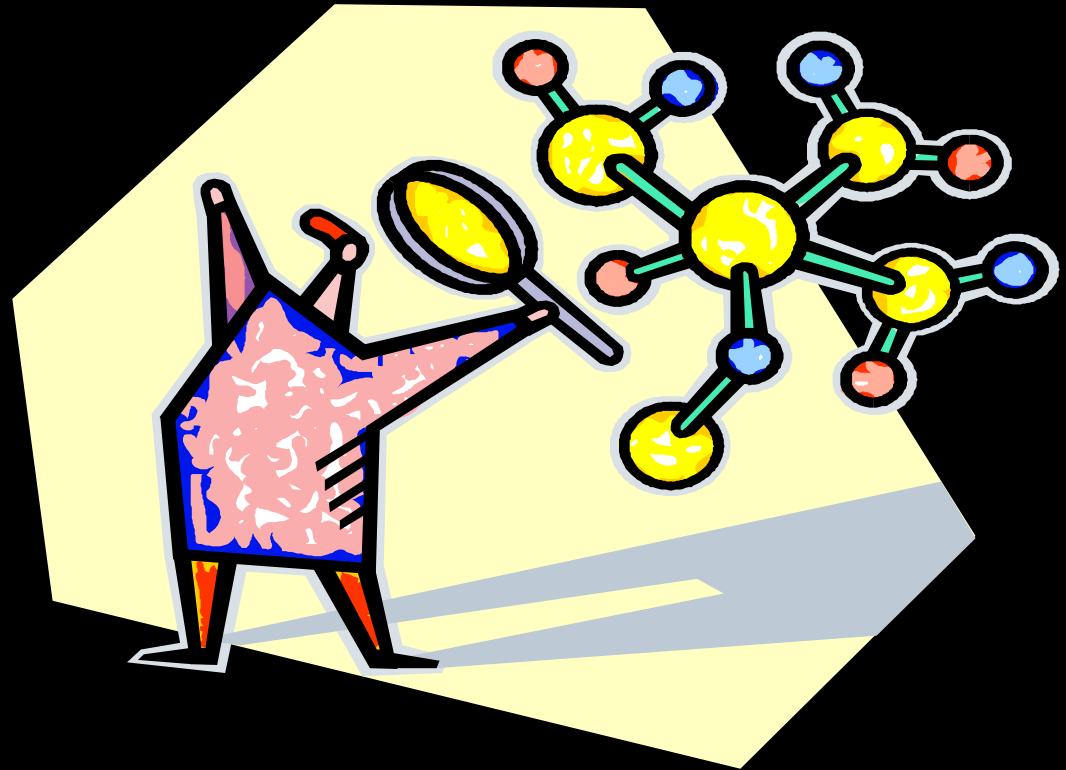
- Oct. 2010 - Public Health Committee hearing in October- Chief Science Advisor cautioned that **proactive steps** to avoid possible harm need to be implemented
- Three members of the Wisconsin State Legislature have requested a Legislative Council study on the **feasibility of developing a registry**



resource: <http://www.nanotechproject.org/>

What needs to be done?

- Studies/research
- Registry/disclosure
- **More studies**



The future of nanotech?



Many Thanks

- Dr. Judy Crane, MPCA – St. Paul
 - Dr. Zhiqiang Hu, University of Missouri - Columbia
 - George Gruetzmacher, Wisconsin State Laboratory of Hygiene
 - Martin Griffin, Wisconsin Department of Natural Resources
- 

For Further Information

- Judy Crane, Ph.D. (MPCA): 651-757-2293 (voice) or judy.crane@state.mn.us.
- Martin Griffin – Wisconsin DNR
Martin.Griffin@wisconsin.gov
- Dr. Zhiqiang Hu, Department of Civil and Environmental Engineering, University of Missouri Hu, huzh@missouri.edu 573-884-0497

For Further Information

- U.S. EPA Web Site: www.epa.gov/ncer/nano
 - National Nanotechnology Initiative:
www.nano.gov
 - Project on Emerging Nanotechnologies of the
Woodrow Wilson International Center for
Scholars: www.nanotechproject.org/
- 

For More Information

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Certification and Training

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