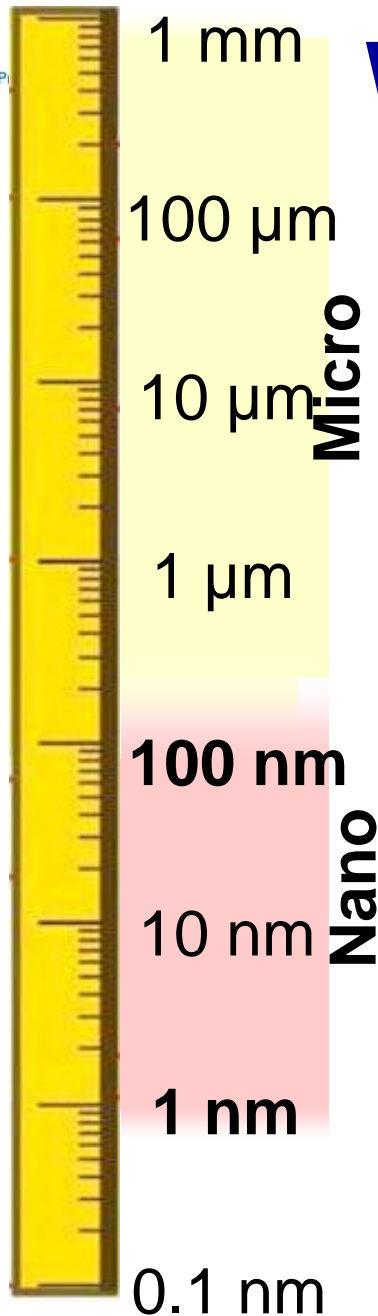


# Introduction to the world of Nano

*Amy Wang, PhD*



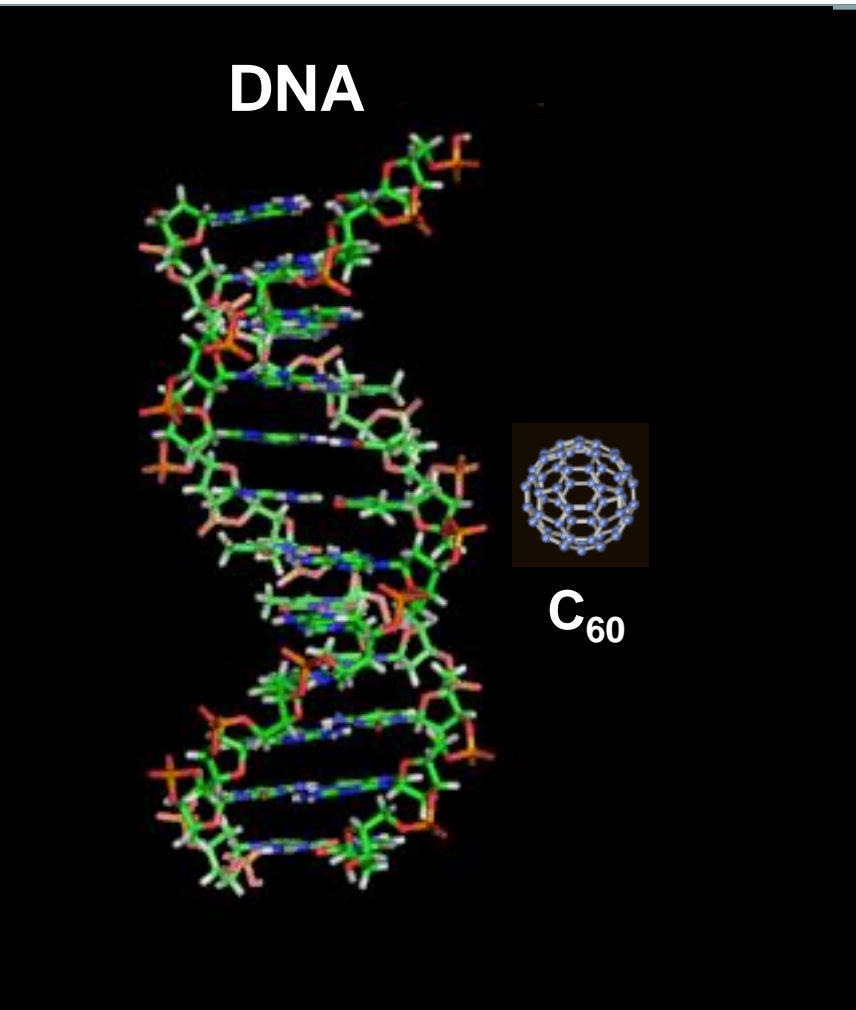
*The views expressed in this presentation are those of the author(s) and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.*

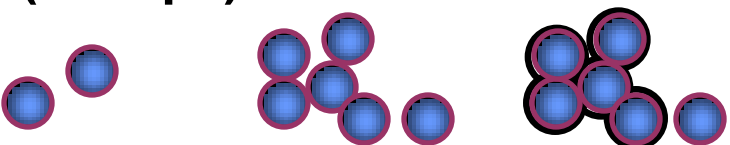


# What is Nano-

- “Dwarf” in Greek (nanos)
- In International System of Units (SI), nano =  $10^{-9}$
- 1 nanometer (nm) = one billionth ( $10^{-9}$ ) of a meter
- Nanoscale = approximately 1 – 100 nm

# Nanomaterials



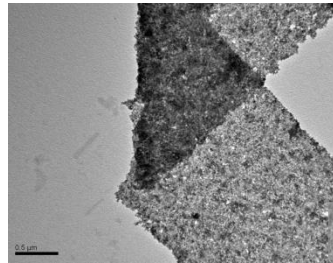
- **Engineered Nanomaterials**
  1. Are **intentionally** produced
  2. Have one or more dimension in nanoscale (**~ 1-100 nm**)
  3. Have **unique properties** due to their small size (compared to bulk materials of the same chemical composition)
- **Include**
  - aggregates and agglomerates (clumps) that are >100 nm
  - composites containing nanomaterials

# Like pasta, nanomaterials come in all shapes



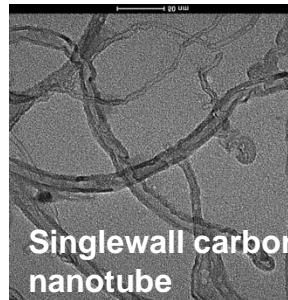
# # of dimensions in nanoscale (1-100 nm)

1      Nanosheet  
        Nanofilm

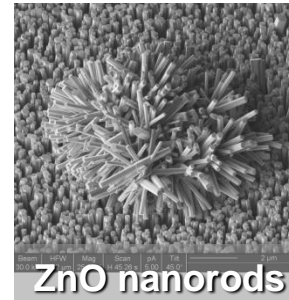


Nanosheet (polyamines and FeO<sub>3</sub> NP)

2      Nanotube  
        Nanorod  
        Nanowire



Singlewall carbon  
nanotube

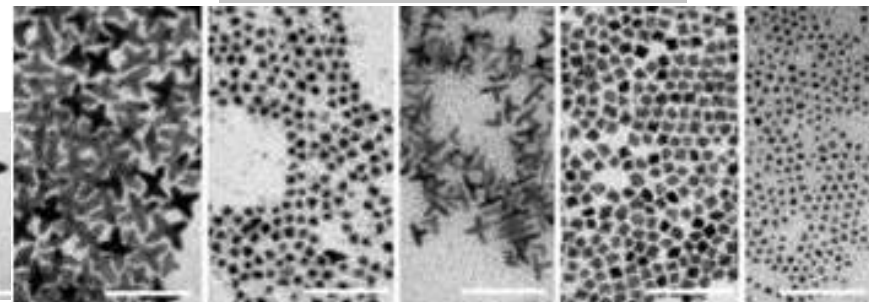
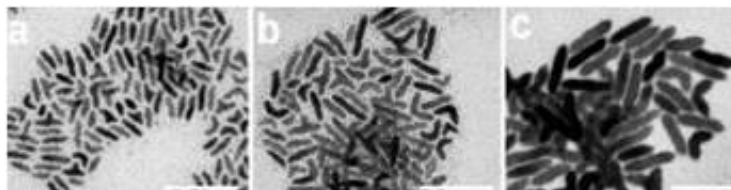


ZnO nanorods



Branched composite  
nanorods (Bi<sub>2</sub>Te<sub>3</sub>,  
Bi<sub>2</sub>S<sub>3</sub>)

3      Nanoparticle  
        (NP)



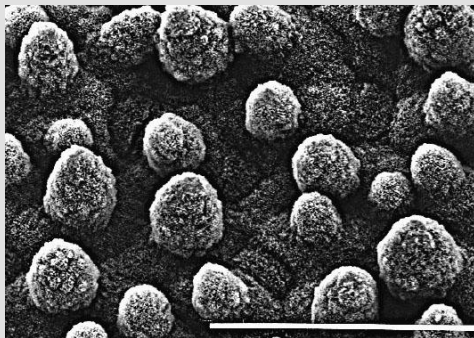
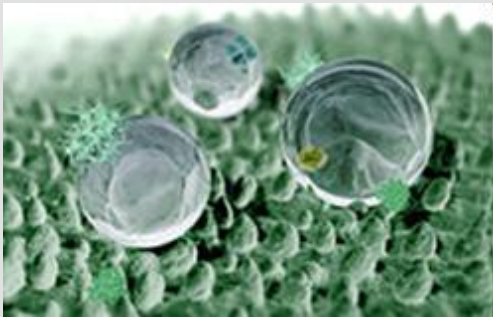
PbSe nanocrystals

# Nanotechnology

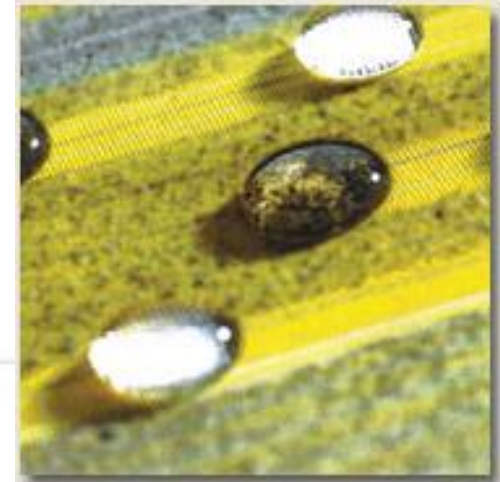
- **“Nanotechnology is the understanding and control of matter at dimensions of roughly 1-100 nm, where unique physical properties make novel applications possible”** (National Nanotechnology Initiative)
  - Enabling technology
  - Novel properties and functions due to size

# Enabling technology – one property, many uses

## Nature lotus effect



## Lotus effect from nanomaterials



**Normal masonry paint**

With normal masonry paint, water droplets slide down the surface, re-arranging the particles of dirt



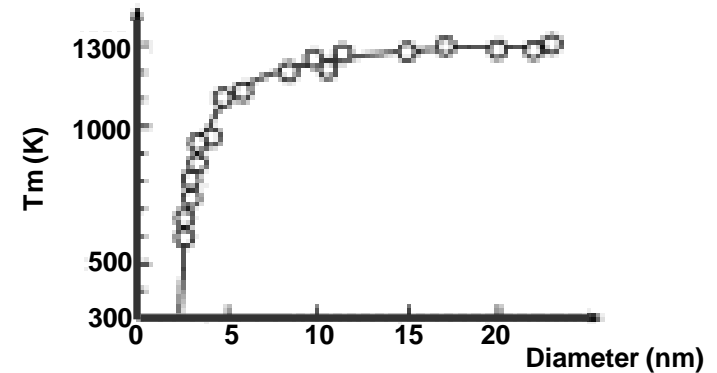
**Nano-coated paint**

With Water Shield, water droplets roll down the surface and particles of dirt stick to the droplet

# Unique properties of nanomaterial (1 of 3)

## 1. Physical

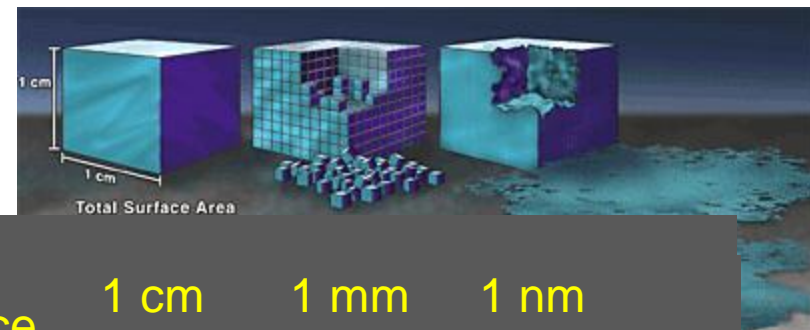
- Lower melting point with smaller size (gold)
- Stable materials become combustible (aluminum)



Melting temperature of gold nanoparticles vs. size (Dosch, 2001)

## 2. Chemical

- Higher reactivity due to **large surface area to volume/mass ratio**
- Inert materials become catalytic (platinum, gold)



Cube size:	1 cm	1 mm	1 nm
Total surface area (cm <sup>2</sup> ):	6	60	60,000,000

# Unique properties of nanomaterials (2 of 3)

## 3. Electrical

- Insulators become conductors (silicon, carbon)
- rechargeable batteries

## 4. Magnetic

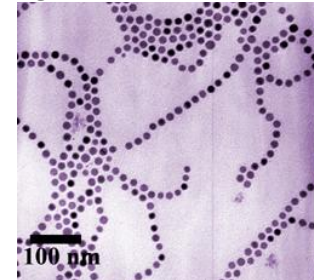
- Highly magnetic (cobalt)
- Small motors, ultra-sensitive analytical instruments

## 5. Mechanical

- Multiwall carbon nanotubes showed extremely high tensile strength
- Sports equipment, automobile components



Nanotechnology-enabled rechargeable batteries



Cobalt nanoparticles in magnetic filed



CNT in the bicycle frame

# Unique properties of nanomaterials (3 of 3)

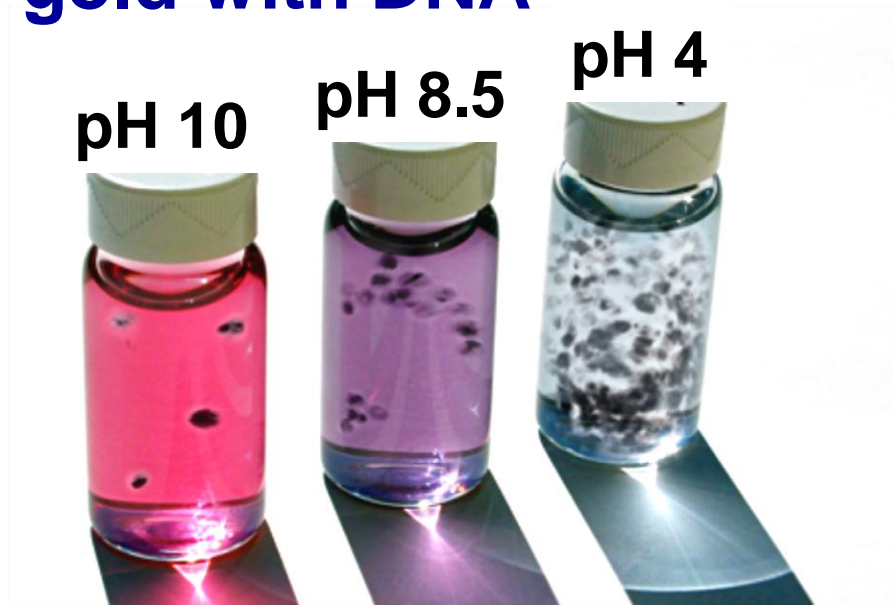
## 6. Optical

- Opaque substances become transparent
- Size-dependent or shape-dependent color for the same chemical component



Colors of silver nanoplates with various thickness and size

# Determine protein folding/unfolding by nano-gold with DNA



Protein

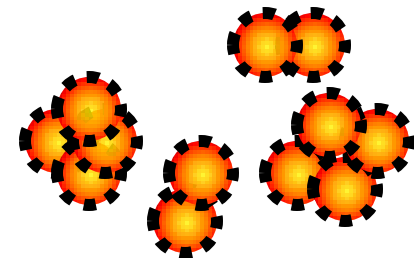
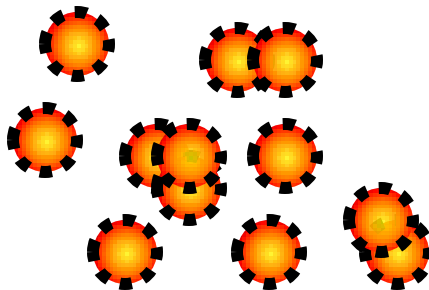
(Cytochrome c):

fold



unfold


Nano-gold coated  
with cytochrome C:



# Nanomaterials may have unique behaviors and effects

- **Novel properties may lead to new implications**
  - Ex: Small – new biodistribution; Highly catalytic – high oxidative stress
- **Nanomaterials change**
  - **Depending on the material and environment**
    - Aggregate and agglomerate (clump) bigger in water with organic matter than in pure water
  - **With time**
    - Some nano-silver lose its activity quickly due to oxidation
  - **Effects change**

# Four generations of nanomaterials



1<sup>st</sup>: Passive nanostructures

- a. Dispersed and contact nanostructures . Ex. Aerosols, colloids
- b. Products incorporating nanostructures. Ex. Coating, nanoparticle reinforced composites; nanostructured metals, polymers, ceramics

~ 2000

2<sup>nd</sup>: Active nanostructures

- a. Bio-active, health effects. Ex: targeted drugs, biodevices.
- b. Physico-chemical active. Ex: 3D transistors, amplifiers, actuators, adaptive structures

3<sup>rd</sup>: Systems of nanosystems

Ex: guided assembling; 3D networking and new hierarchical architectures, robotics, evolutionary

4<sup>th</sup>: Molecular nanosystems

Ex: molecular devices “by design”, atomic design, emerging functions



# First generation nanoproducts

## Pencil Leads

Nanotechnology + Aromatherapy!



<http://thegloss.com/odds-and-ends/pencil-leads-of-the-future-nanotechnology-aromatherapy/>

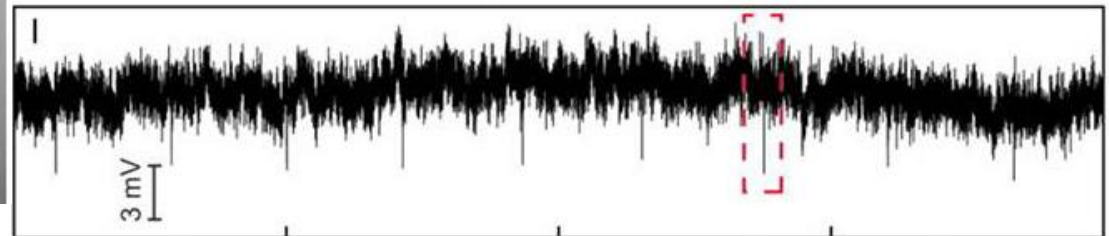
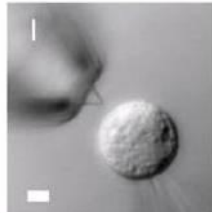
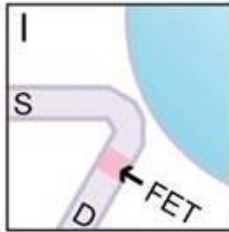
## FDA-approved iron nanoparticles for iron supplementation



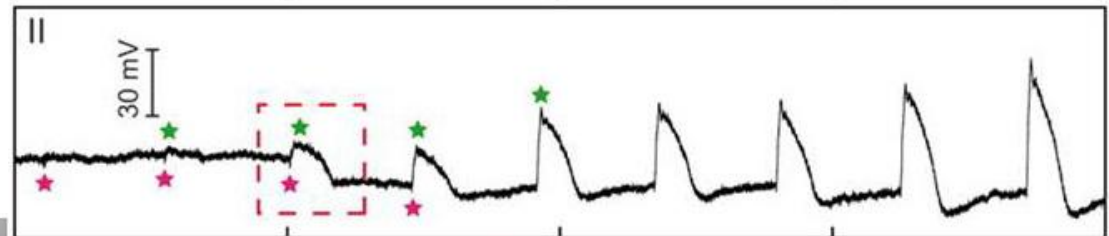
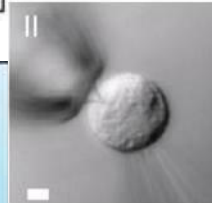
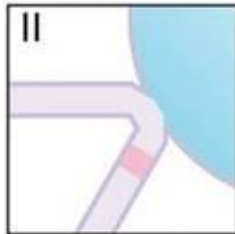
$\text{Fe(III)(OH)}_3$  core +  
sucrose coating

# Virus sized probe for cardiac intracellular potential

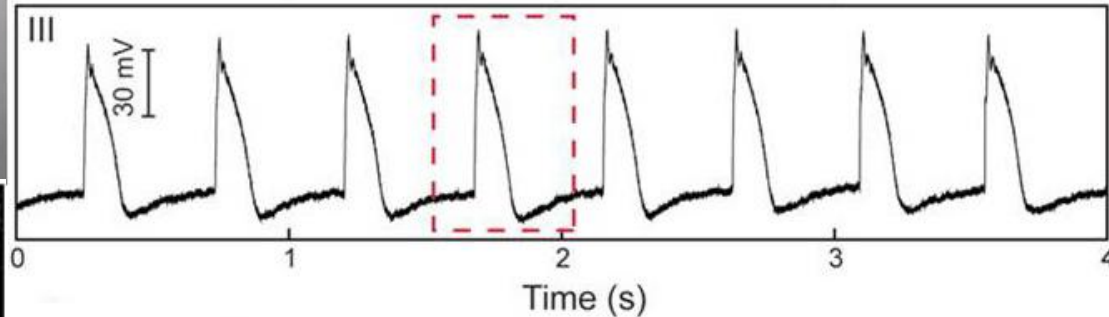
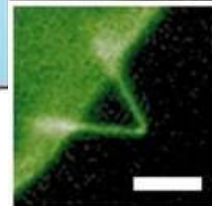
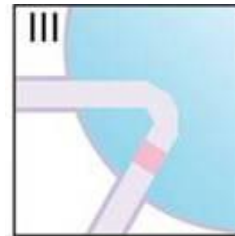
Outside  
the cell



Entering  
the cell

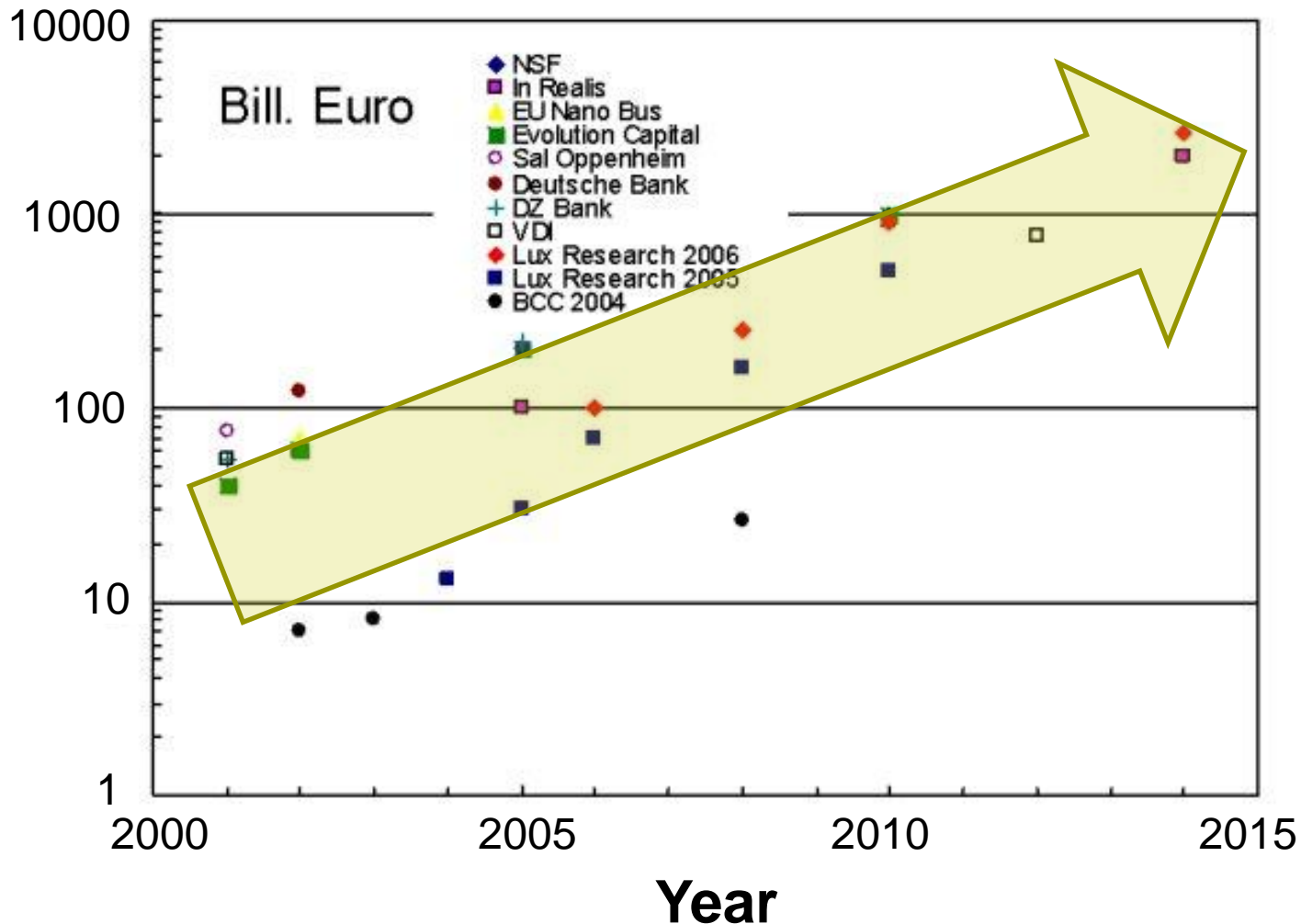


Inside  
the cell



B Tian et al. Science 2010;329:830-834

# Economic potential of nanotechnology (estimated, global)



# Summary

- **Engineered nanomaterials are intentionally-made materials at ~1-100 nm**
- **Nanomaterials may have unique properties, behaviors, and effects**
  - **Enable novel applications**
  - **Possible new implications**
- **Nanotechnology is an enabling technology, and is used in many fields**

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