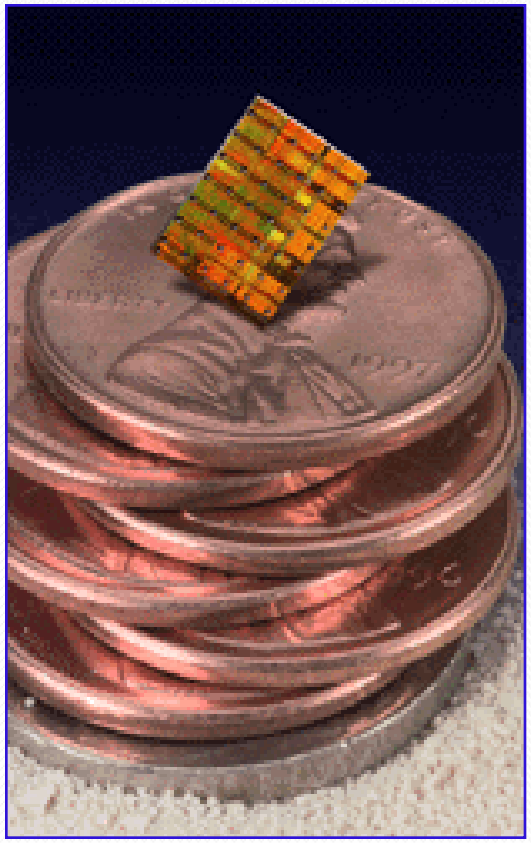
# Introduction to Nanotech & Clean Tech



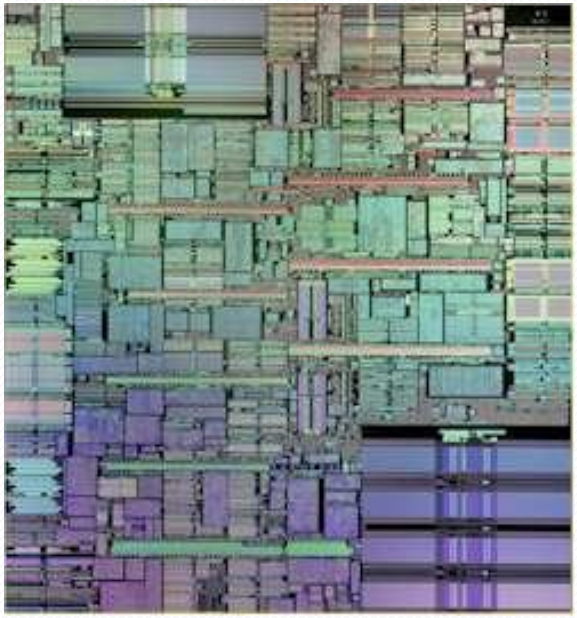
Lloyd L. Tran
President,
International Association of Nanotechnology
Director
California Institute of Nanotechnology
LTran@cinano.com


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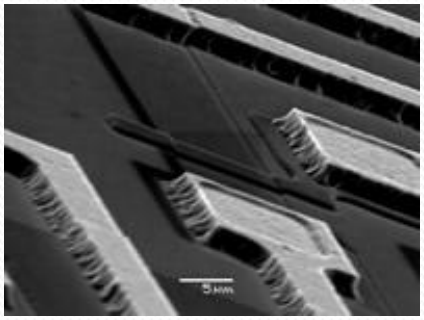
# Nanotechnology Makes Small Smaller



macroscale



microscale



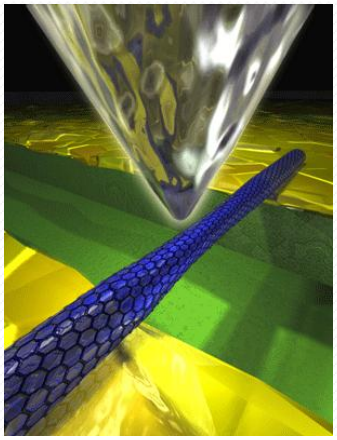
nanoscale

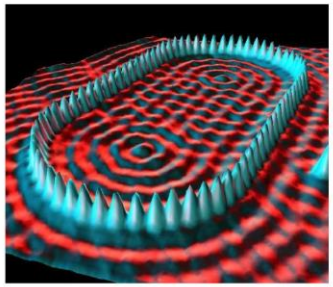
Sources: IBM


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# What is Nanotechnology ?





Nanotechnology deals with the manipulation of materials on an atomic or molecular scale measured in billionths of a meter (nanometers).

One nanometer is about 100,000 times smaller than the diameter of a human hair.

This ability to design and manipulate materials at the molecular level, atom per atom can result in changing the composition of materials and how the products are manufactured in a radical ways.


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# Nanotechnology

A very brief history



**Richard P. Feynman (*APS Meeting* 1959):**

*"Why cannot we write the entire 24 volumes of the Encyclopedia Brittanica on the head of a pin?"*

*"There is plenty of room at the bottom"*

1974: **Norio Taniguchi** first used the word "nano-technology refer to "production technology to get the extra high accuracy and ultra fine dimensions

**1981: Scanning Electron Microscope** invented

**1985: Buckyball** discovered

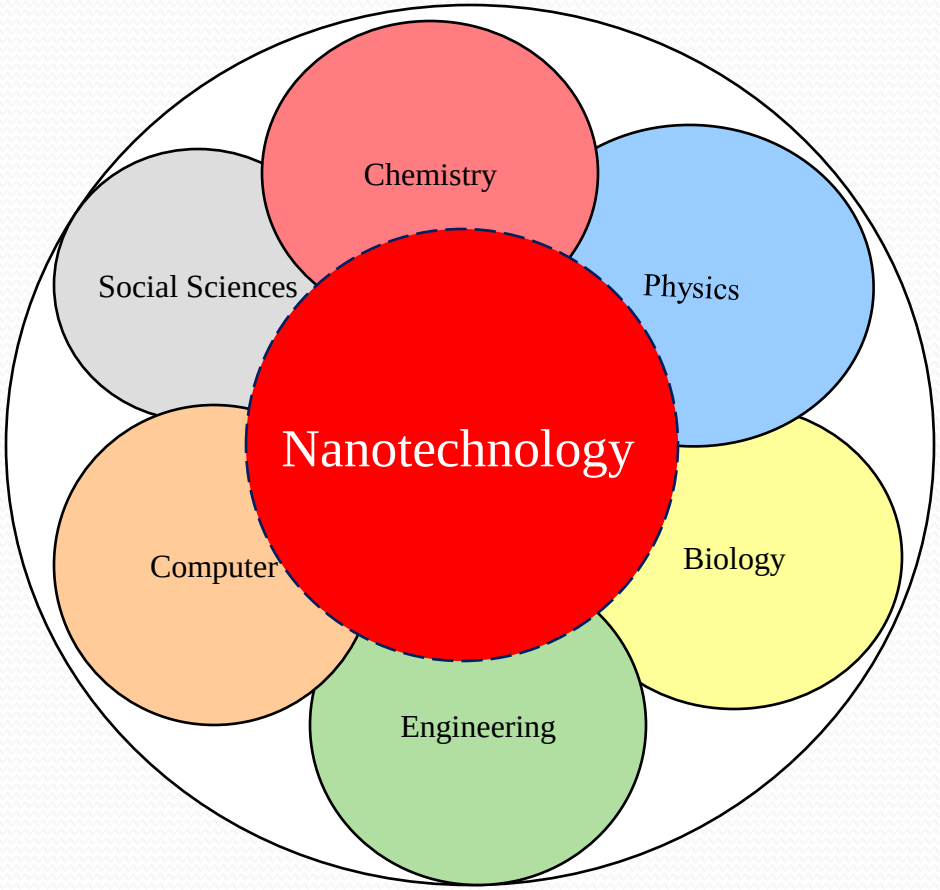
**1986: Atomic Force Microscope i**nvented

**2000:** President Clinton announces the US National Nanotechnology Initiative


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# Multi-Disciplinary Nature of Nanotechnology

*Nanoscience: the Unifying Science*

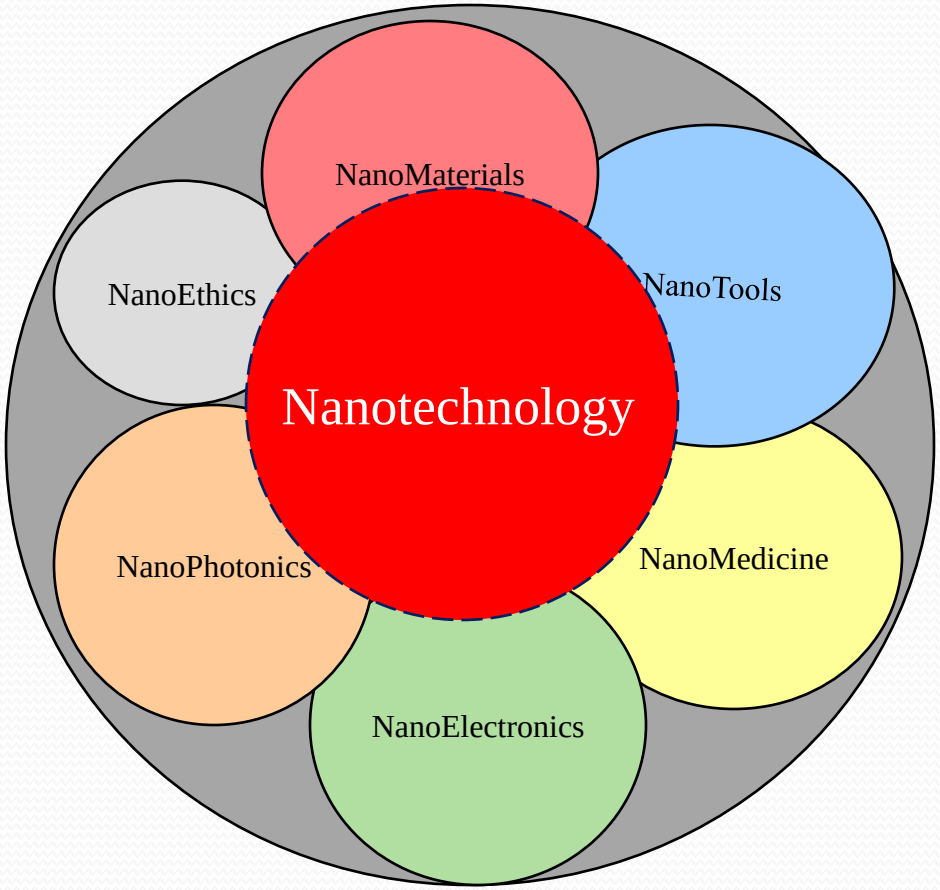




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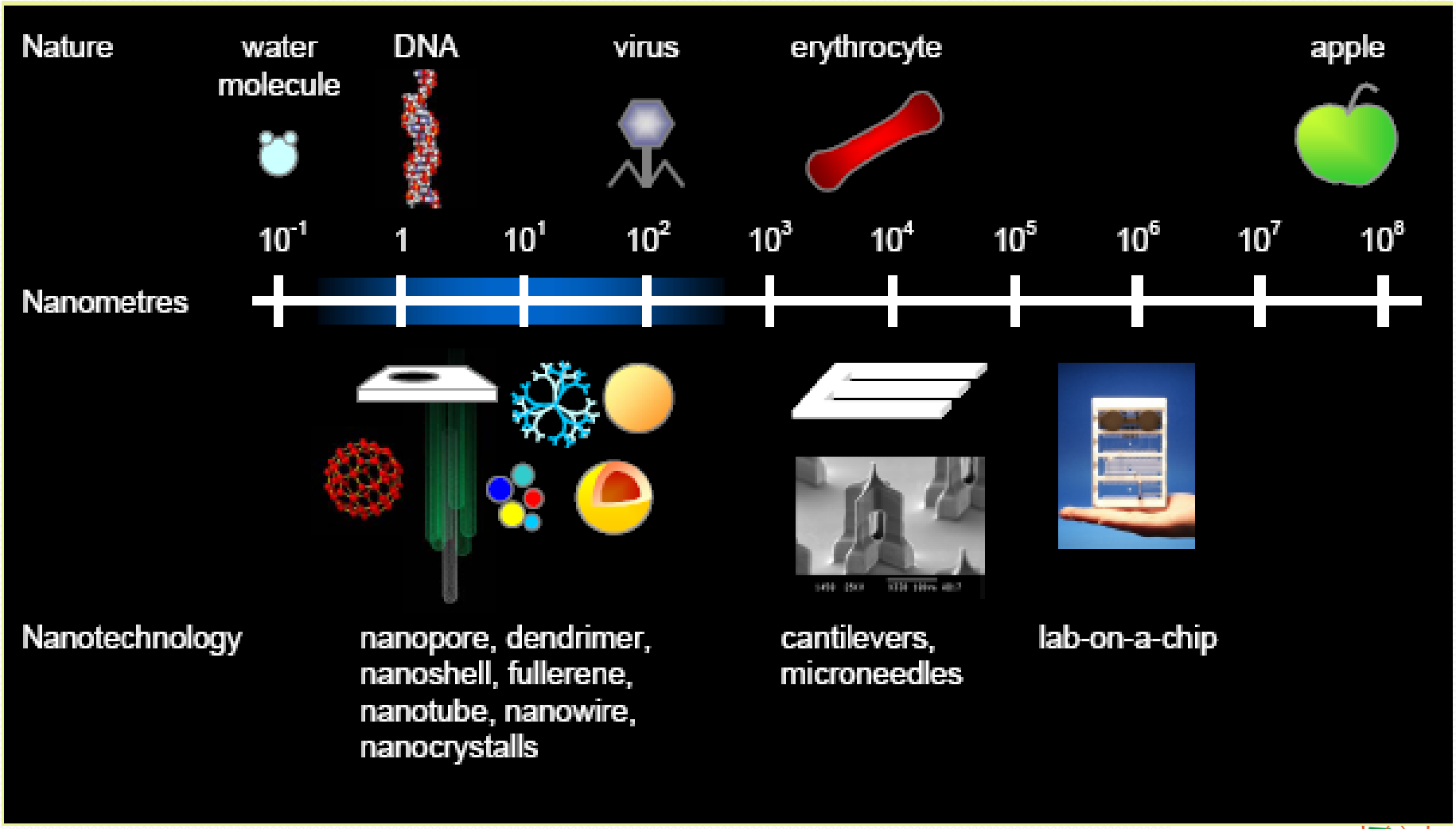
# Multi- Disciplinary Nature of Nanotechnology

*Nanoscience: the Unifying Science*





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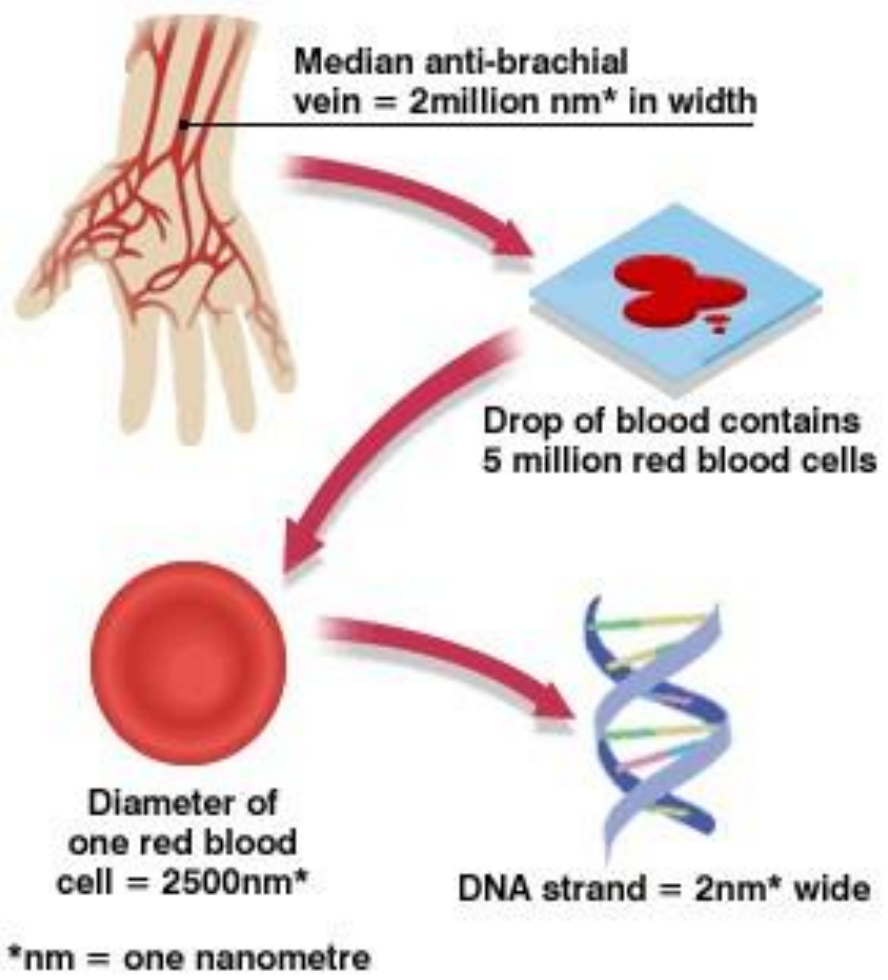




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# Biological Structures—Encompass Wide Spectrum of Sizes

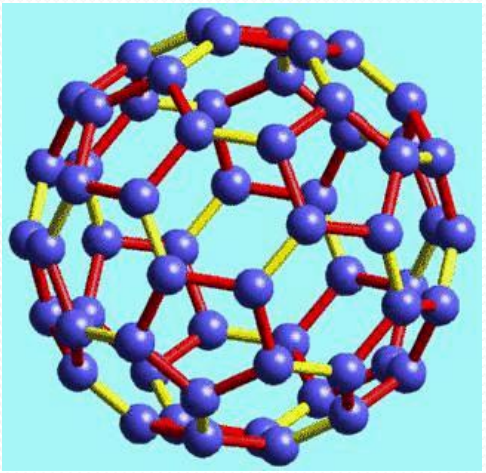



http://news.bbc.co.uk/1/shared/spl/hi/pop_ups/04/sci_nat_nanotechnology___building_from_the_bottom_up/html/2.stm

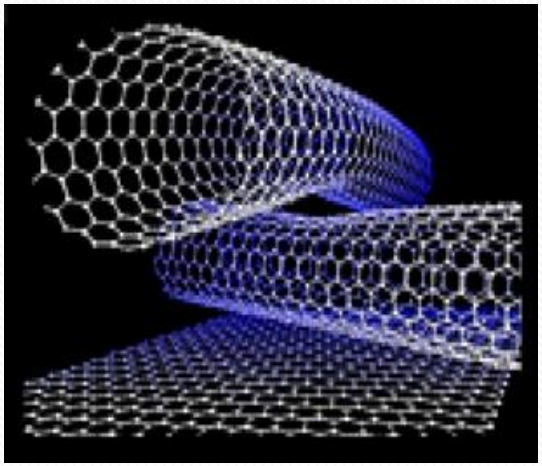

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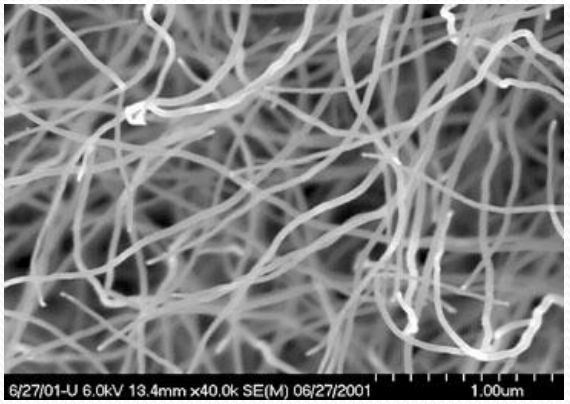
8

# Example: Fullerene and Carbon Nanotubes



Fullerene or C60. All sixty carbon atoms are equivalent, and lie on the surface of a sphere of close to 7 Å in diameter (1 Å = 10-10 m).






High-resolution scanning electron microscope image of multiwall carbon nanotubes. One tube is approximately 1/10,000th the diameter of a human hair. *(NASA)*


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# Nanotechnology: Why?

- Need to understand sciences at molecular & atomic levels to design, build and manipulate physical substances at macro-levels
- Limitation are imposed by technology (ability to make extremely small things). It is not limited by physical laws.
- At nano-scale levels many substances may possesses unique characteristics
- Miniaturization impacts:
  - Design and manufacture products and machinery
  - Storage and process of information
  - Storage and transport of energy


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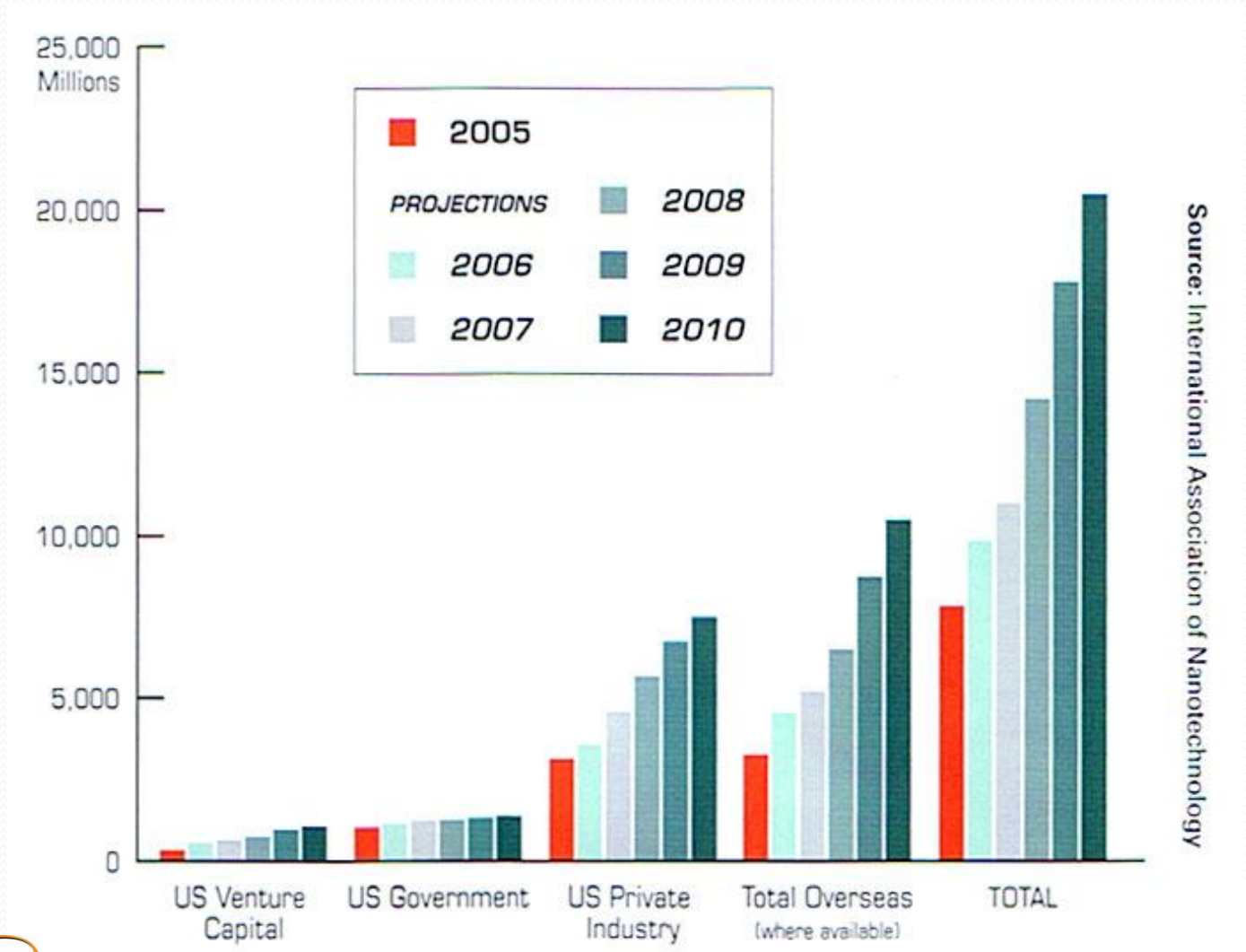
# Nanotechnology R&D Funding by Agency

| NNI Budget, 2007 - 2009 (dollars in millions) | | | |
|---|---|---|---|
| | **2007 Actual** | **2008 Estimate*** | **2009 Proposed** |
| DOD | 450 | 487 | 431 |
| NSF | 389 | 389 | 397 |
| DOE** | 236 | 251 | 311 |
| DHHS (NIH) | 215 | 226 | 226 |
| DOC (NIST) | 88 | 89 | 110 |
| NASA | 20 | 18 | 19 |
| EPA | 8 | 10 | 15 |
| DHHS (NIOSH) | 7 | 6 | 6 |
| USDA (FS) | 3 | 5 | 5 |
| USDA (CSREES) | 4 | 6 | 3 |
| DOJ | 2 | 2 | 2 |
| DHS | 2 | 1 | 1 |
| DOT (FHWA) | 1 | 1 | 1 |
| **TOTAL** | **1,425** | **1,491** | **1,527** |

Sources: National Nanotechnology Initiative- USA


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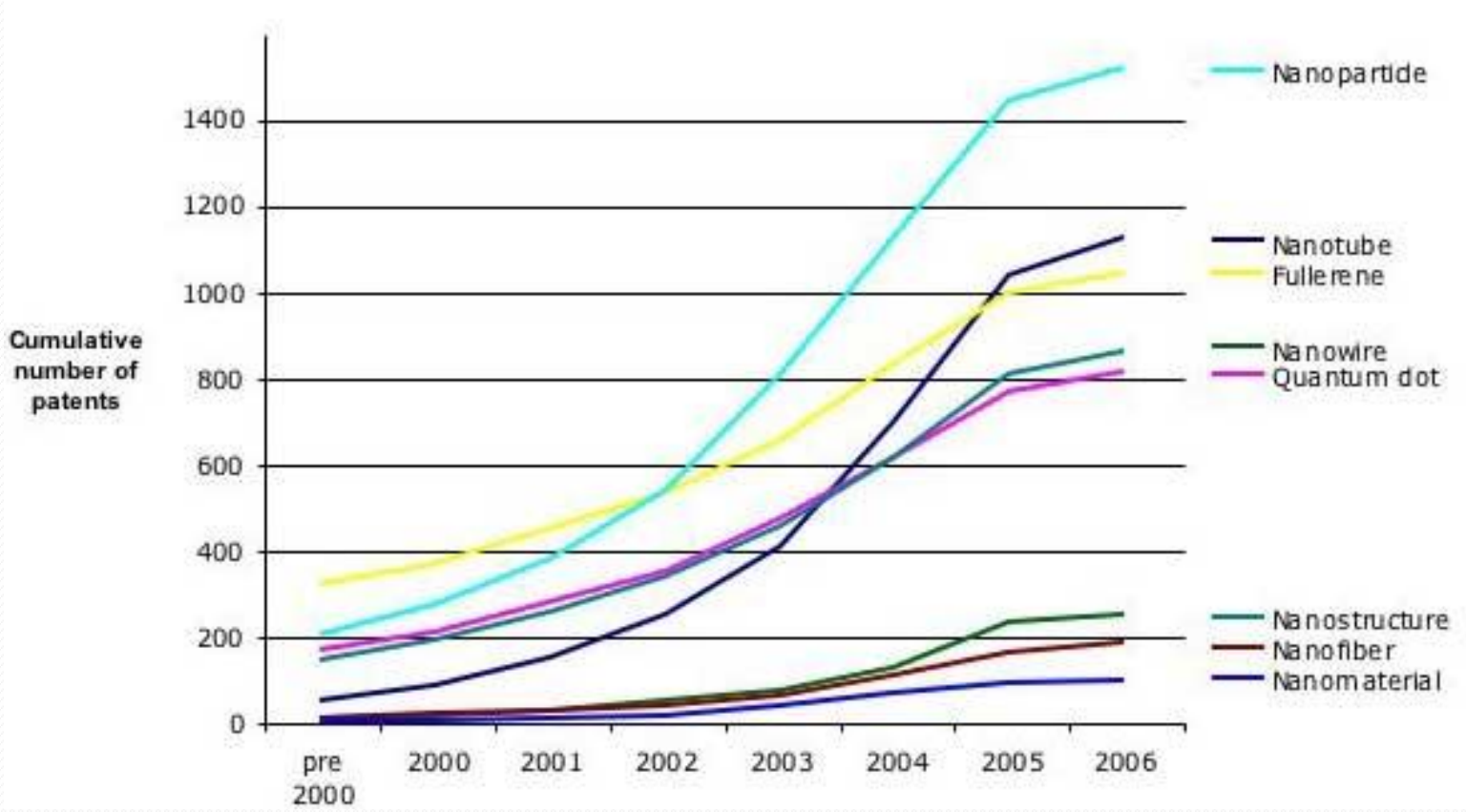
# Investment in Nanotechnology 2005-2010





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# The Patent Landscape

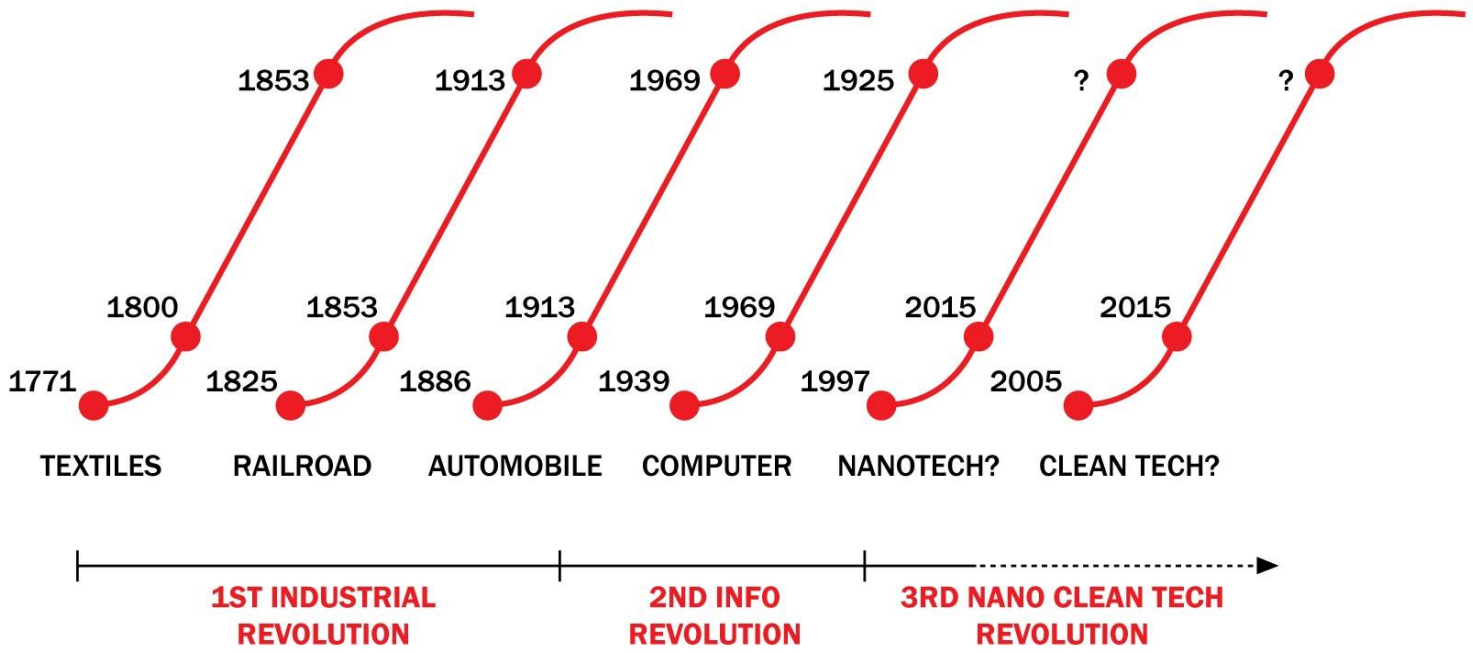



*Number of patents issued by the United States Patent and Trademark Office (USPTO) every year since 2000 that contain one of the charted terms (as of March 24, 2006). (Source: Base data from the USPTO database; compilation and graphic: Nanowerk)*


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# The Growth Innovation

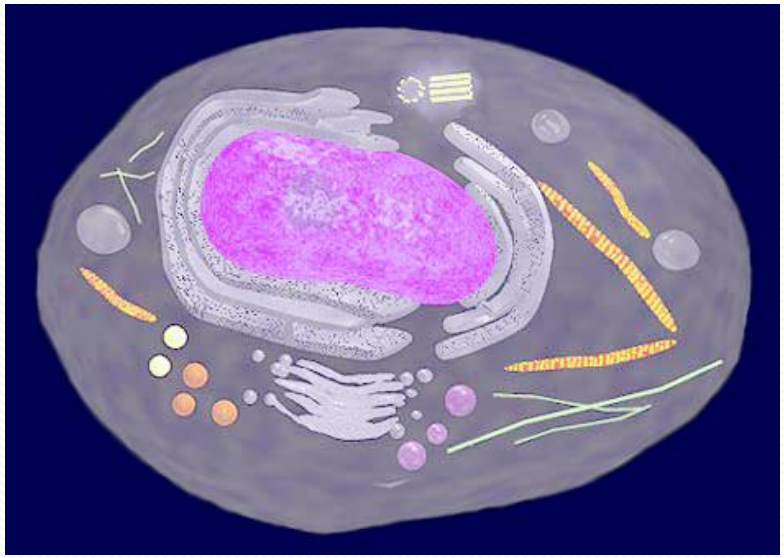



Economist Norm Poire at Merrill Lynch tracks a series of historical growth innovations. Poire observes that it takes about 28 years for a new technology to become widely accepted, which then fuels a period of rapid growth lasting about 56 years.


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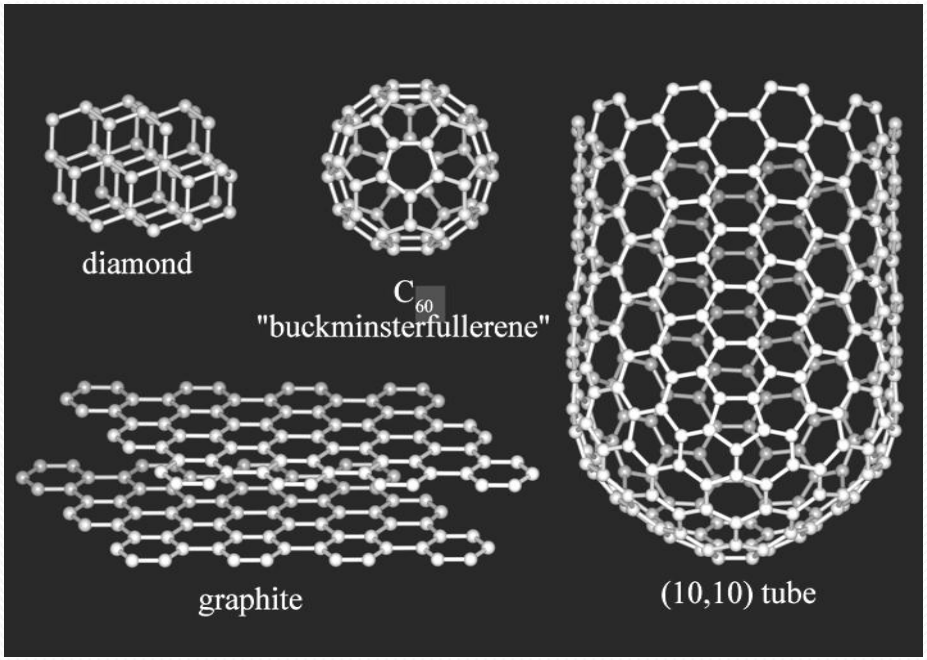
# The Wet Side of Nanotechnology



- All the nano-machinery of cellular life (and viruses)
- Biotechnology is a form of Nanotechnology (the wet side)


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# The Dry Side of Nanotechnology

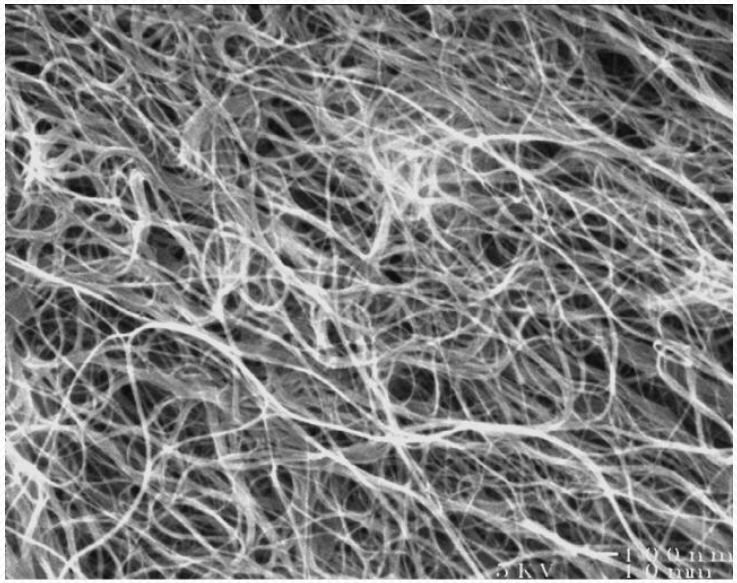


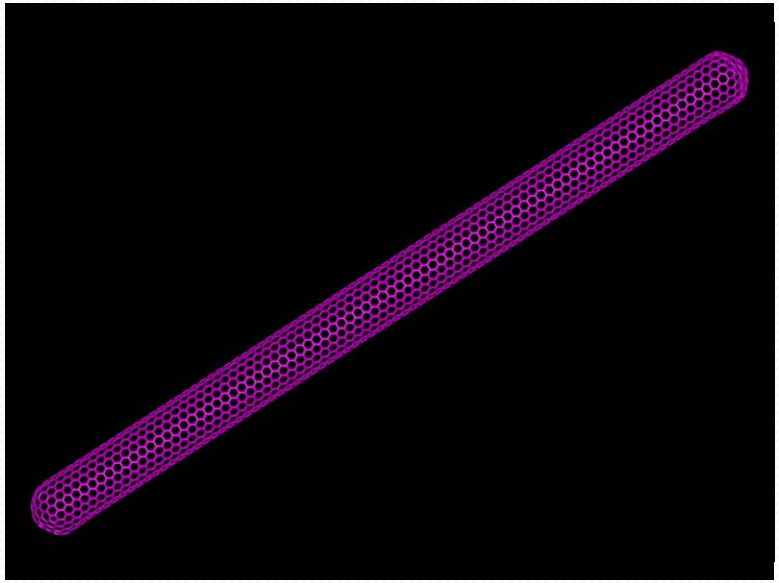

- Electrical & thermal conduction
- Great strength, toughness, high temperature resistance

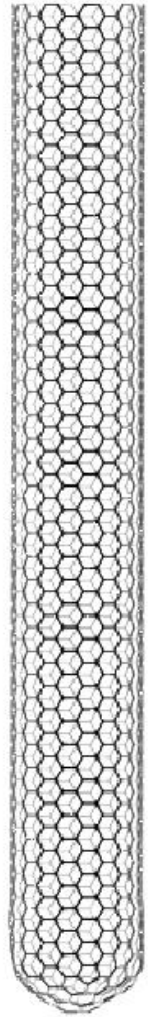

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# Molecular Perfection: FULLERENE

- The Strongest fiber that will ever be made.
- Electrical Conductivity of Copper or Silicon.
- Thermal Conductivity of Diamond.
- The Chemistry of Carbon.
- The size and perfection of DNA.



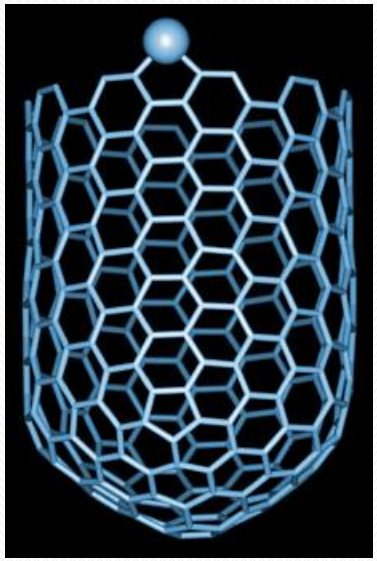




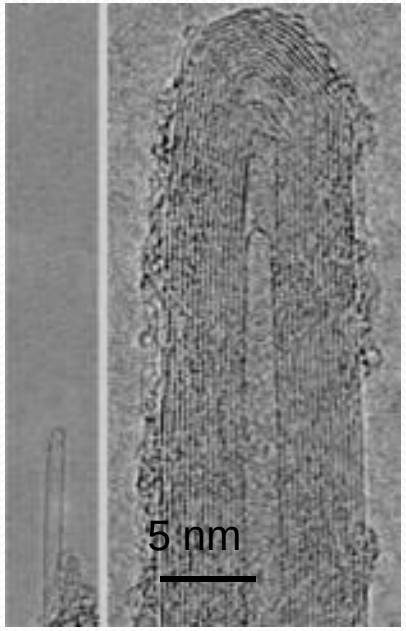

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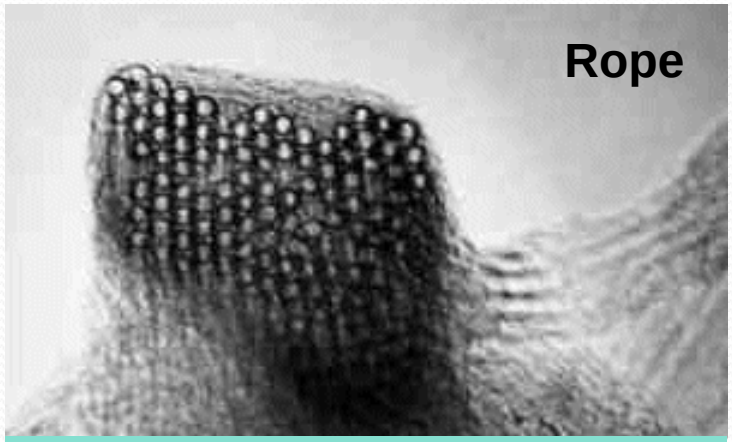
# Carbon Nanotubes



Single-Walled Tube
(SWNT)
Diameter ~ 0.5-2 nm



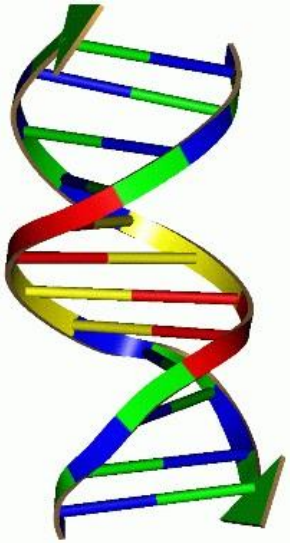

Multi-Walled Tube
(MWNT)
Diameter ~ 10 - 50 nm




Thess et. al, Science (1996)

# Why is this length scale so important?

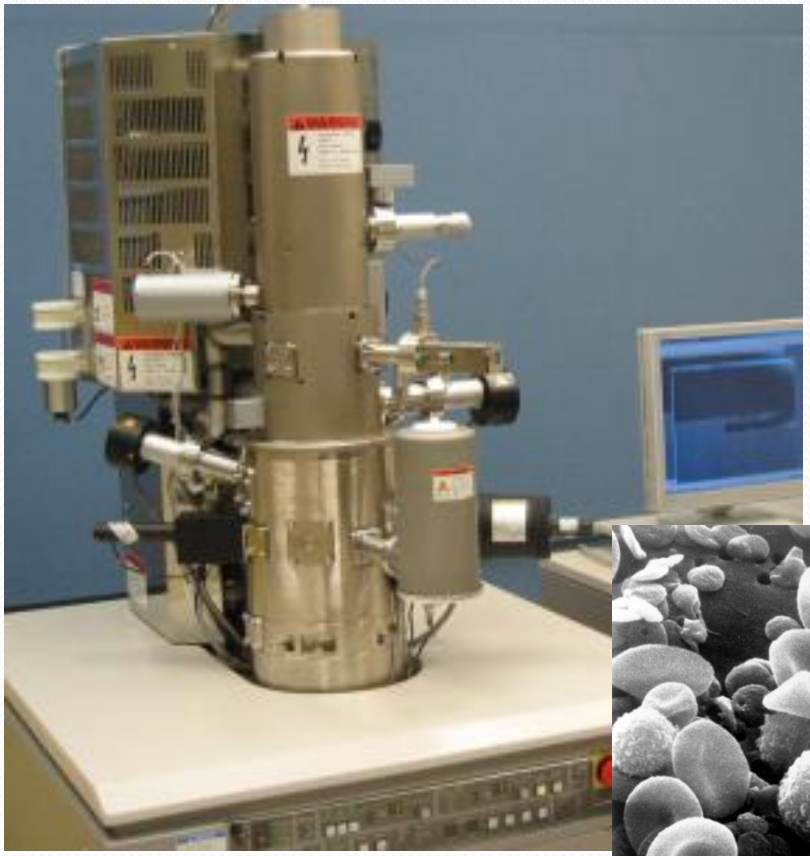
The *systematic* organization of matter on the nanometer length scale is a key feature of biological systems. Nanotechnology promises to allow us to place artificial components and assemblies inside cells, and to make new materials using the self-assembly methods of nature. This is a powerful new combination of materials science and biotechnology.

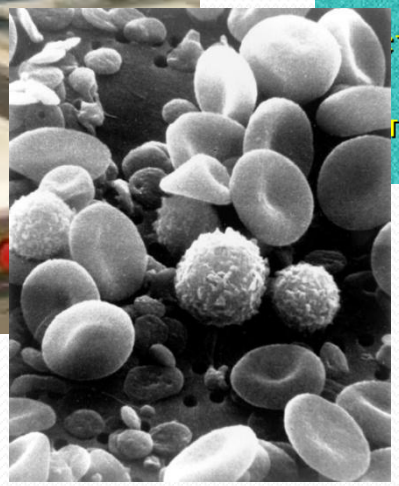


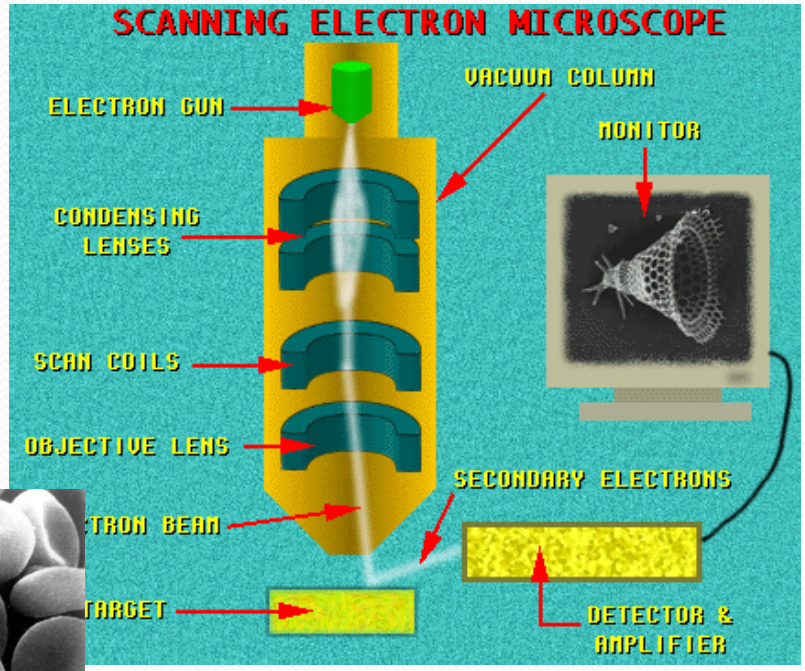
Self-Assembly in Nature: DNA Molecule


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# Scanning Electron Microscopy (SEM)



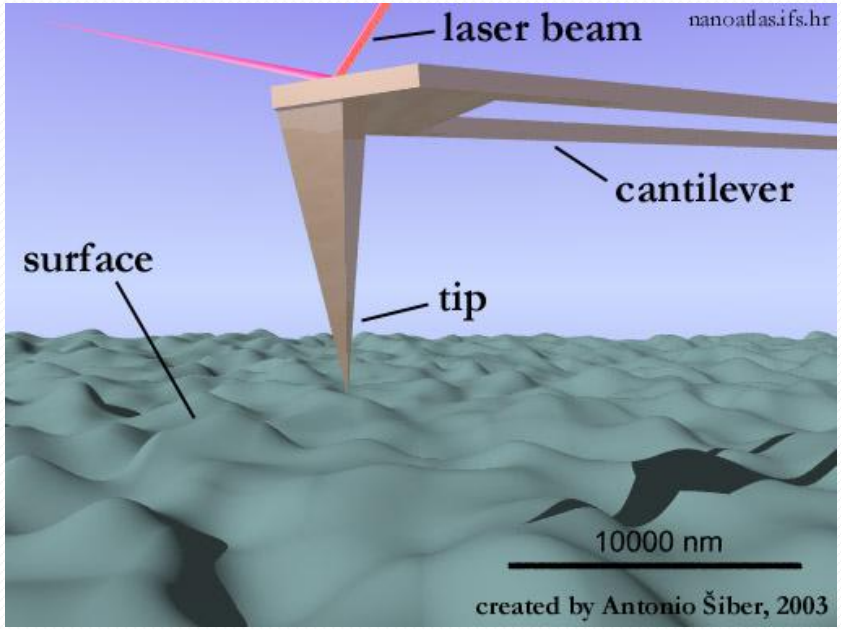






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# Atomic Force Microscope




The precursor to the AFM, the scanning tunneling microscope, was developed by Gerd Binnig and Heinrich Rohrer in the early 1980s, a development that earned them the Nobel Prize for Physics in 1986.

Binnig, Quate and Gerber invented the first AFM in 1986.

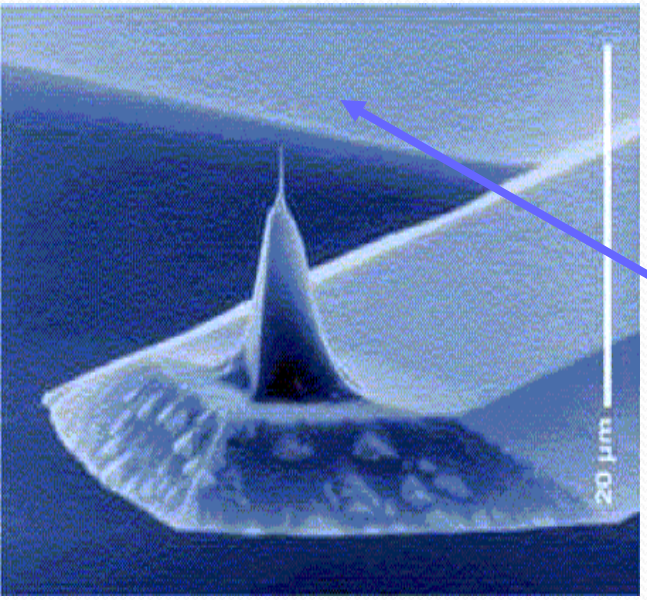
The term 'microscope' implies looking, but AFM information is gathered by "feeling" the surface with a mechanical probe.

Piezoelectric elements that facilitate tiny but accurate and precise movements on (electronic) command are what facilitates the very precise scanning.

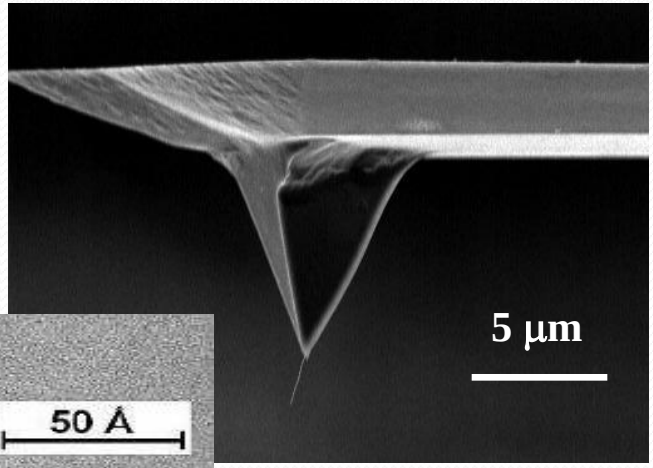

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# Atomic Force Microscopy

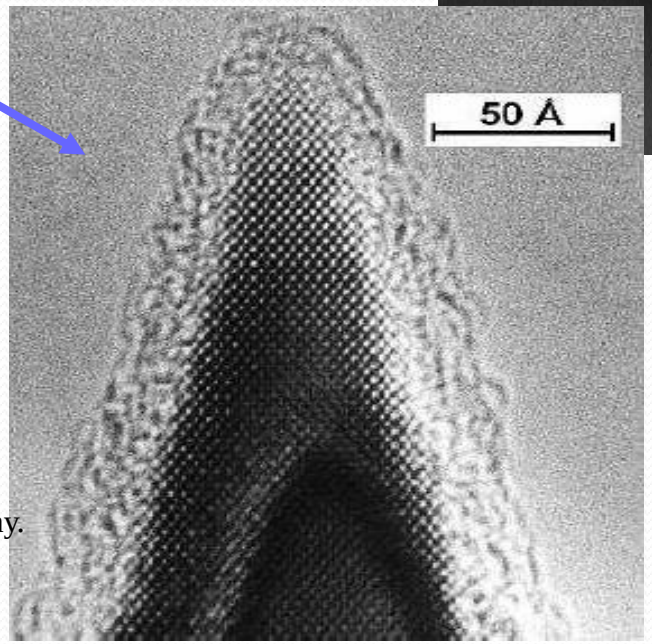
Silicon Cantilever with Integrated Tip




Nanosensors, 2002, POINTPROBE sensors, Nanosensors AG, NANOSENSORS GmbH und Co. KG, Koogstraat 4, 25870 Norderfriedrichskoog, Germany.

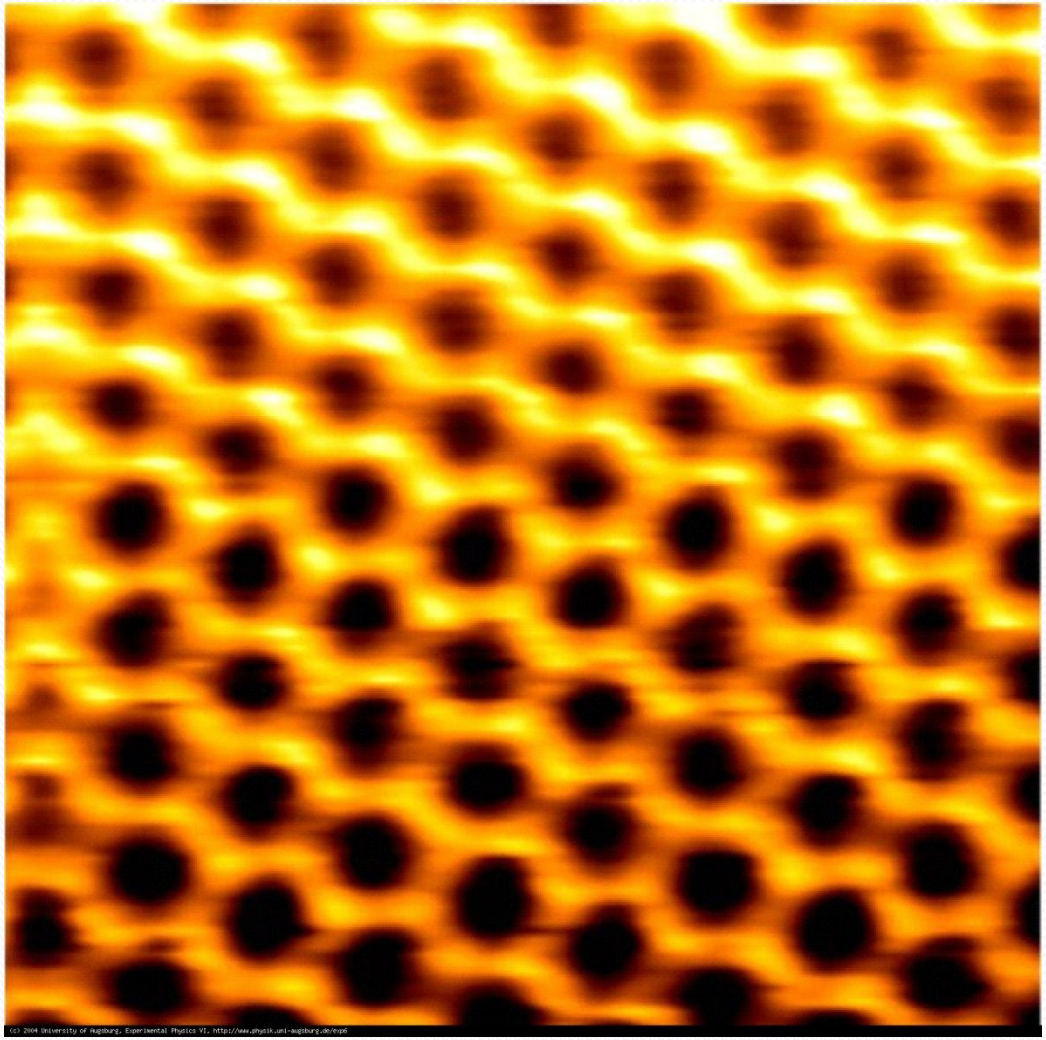



AFM Probe with Carbon Nanotube Tip




Marcus, R et al. 1990, "Formation of silicon tips with <1 nm radius", Appl. Phys. Lett. 56(3), 236–238.


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Revealing the hidden atom in graphite with AFM showing all atoms within the hexagonal graphite unit cells. Image size 2×2 $nm^2$.

F. J. Giessibl
Faculty of Physics
University of Regensburg


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# SEM and AFM



SEM analysis requires a metallization step and vacuum exposure, both of which could potentially induce modifications to the surface details.

AFM is a suitable technique to evaluate any effect resulting from sample manipulation because it can be applied without any specific treatment.

Poletti G. et al Journal of microscopy , 2003, vol. 211 (3), pp. 249-255


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# Applications of Nanotechnology

- Chemical Industry
- Electronics
- Semiconductor
- Biotechnology
- Clean Tech
- Automotive
- Aerospace
- Homeland Security
- Defense
- Textile
- Consumer Product Industry


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# Example Applications of Nanotechnology

- Sun screen
- Stain resistant textiles
- Sport goods
- Information recording layers
- Adaptive camouflage
- Body armor
- High hardness cutting tools
- Chemical and bio-detectors
- Targeted drug delivery systems
- Nanoparticle Drug Formulations


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# Nanotech Consumer Products




New nanotechnology consumer products are coming on the market at the rate of 3-4 per week, a finding based on the latest update to the nanotechnology consumer product inventory maintained by the Project on Emerging Nanotechnologies (PEN).

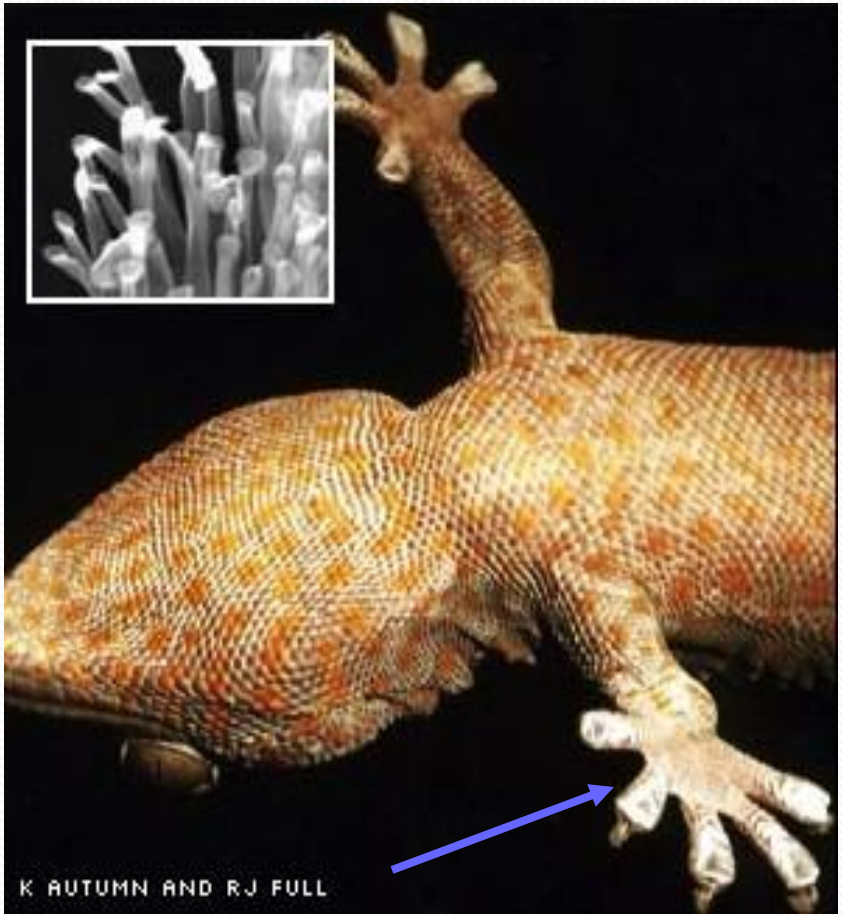
As of April 24, 2008, the number of consumer products using nanotechnology has grown from 212 to 609 since PEN launched the world's first online inventory of manufacturer-identified nanotech goods in March 2006


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# Earliest Nanotechnology Applications—Nature knows

- The gecko can walk up glass and even hang upside down. The hairs (spatulae) on its feet are so small they can exploit forces that pull molecules together, *sticking* the gecko to the ceiling.

- Nanotech can make sticky tape lined with gecko-like synthetic hairs that do the same job.




http://news.bbc.co.uk/1/shared/spl/hi/pop_ups/04/sci_nat_nanotechnology___building_from_the_bottom_up/html/2.stm


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# Early Nanotechnology Applications—No Spots

- The clothing industry uses nanotech to make stain-repellent fabrics.

- A chemical process during manufacture forces liquids to bead up when spilled on a garment for easy wiping away.

- Socks that are made with nano-silver particles give anti-microbial protection, preventing bacteria and fungus that cause itchiness and smells.




http://news.bbc.co.uk/1/shared/spl/hi/pop_ups/04/sci_nat_nanotechnology___building_from_the_bottom_up/html/2.stm


© California Institute of Nanotechnology

# Early Nanotechnology Applications— Little bits

- The cosmetics industry already puts nano-particles in lotions, creams and shampoos.

- Nano-sized zinc oxide particles are used in sun creams.
  The particles are particularly good at absorbing ultra-violet rays, but make the lotion *transparent* and *smooth* instead of sticky and white.



http://news.bbc.co.uk/1/shared/spl/hi/pop_ups/04/sci_nat_nanotechnology___building_from_the_bottom_up/html/2.stm


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# Example of Nanocoatings



Self-cleaning surfaces - like a Lotus leaf (ultrahydrophobic)

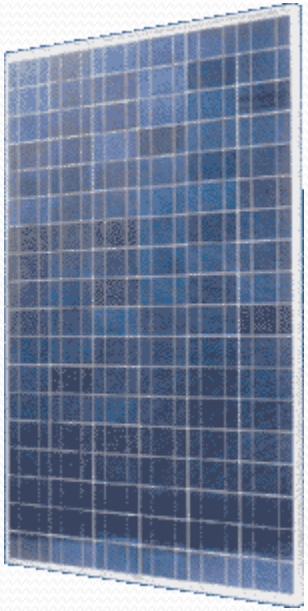


Biocompatible coatings for long lasting orthopedic joints


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# Nanotechnology applications in Solar Cells

- Organic/Inorganic solar cells
- Silicon solar cells are most common and efficient right now.
- **Reflection** of incoming light is a big natural limitation for efficiency.



Evergreen Solar, Inc.





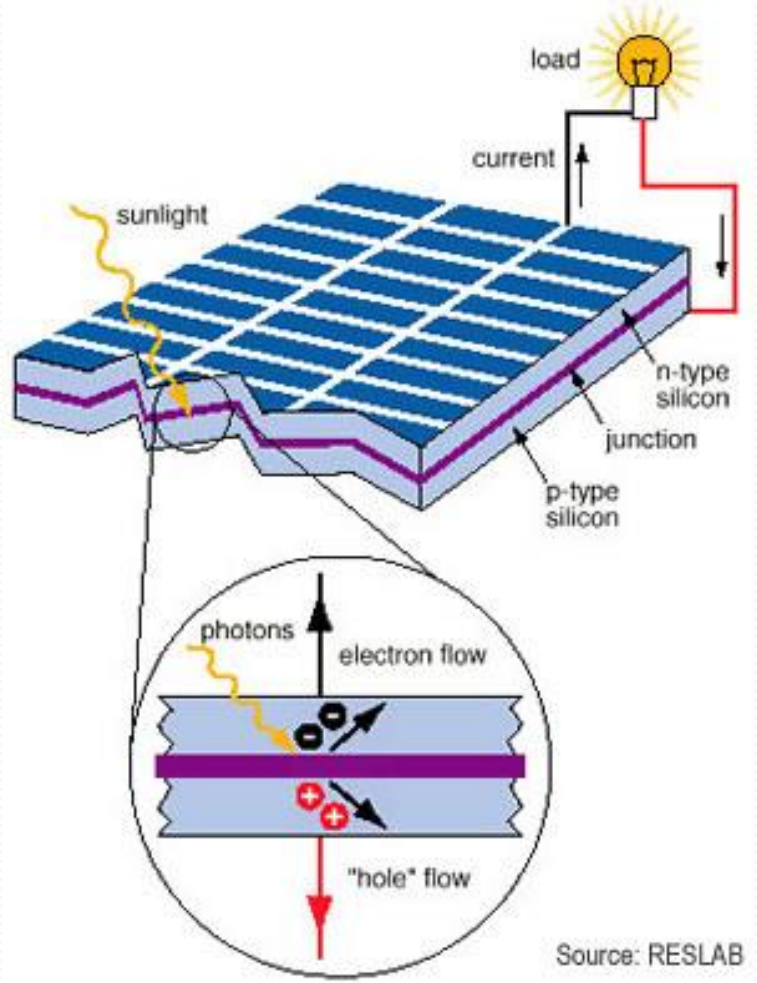

Konarka


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# Solar Photovoltaic Cell

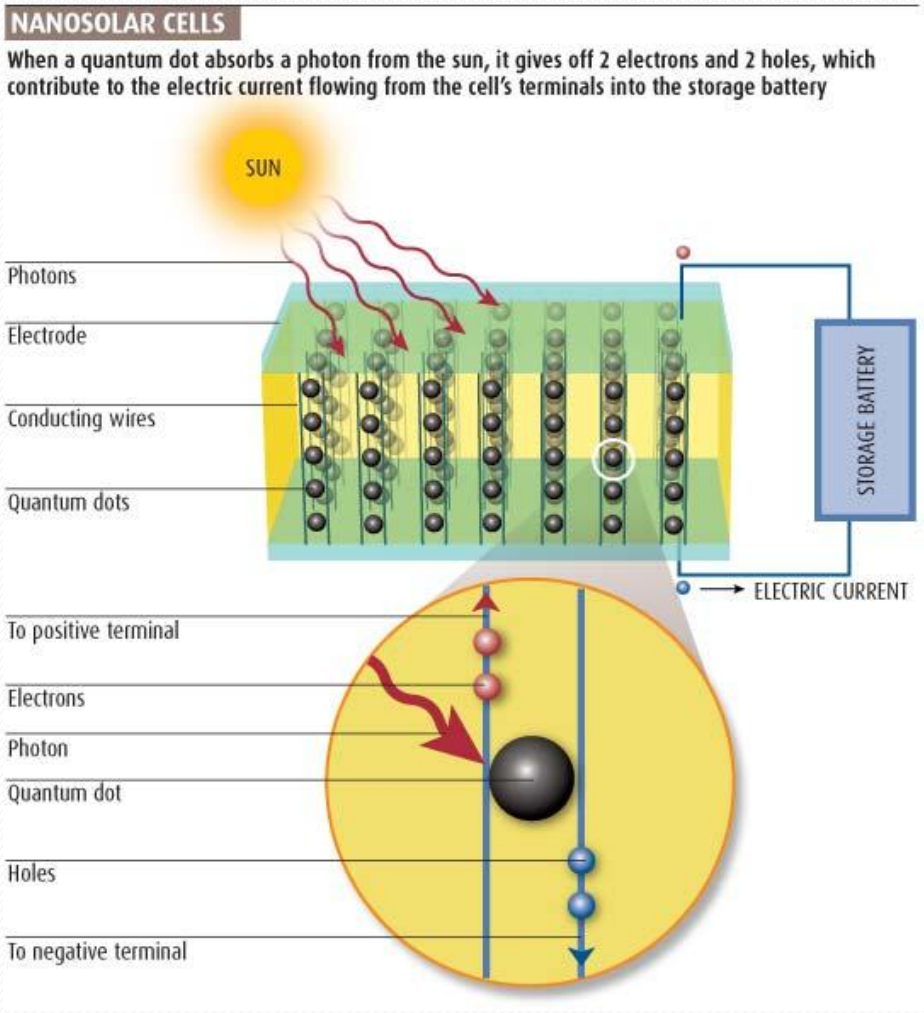






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# Nanotech  applications in Solar Photovoltaic




Sources: Nanosolar Inc.

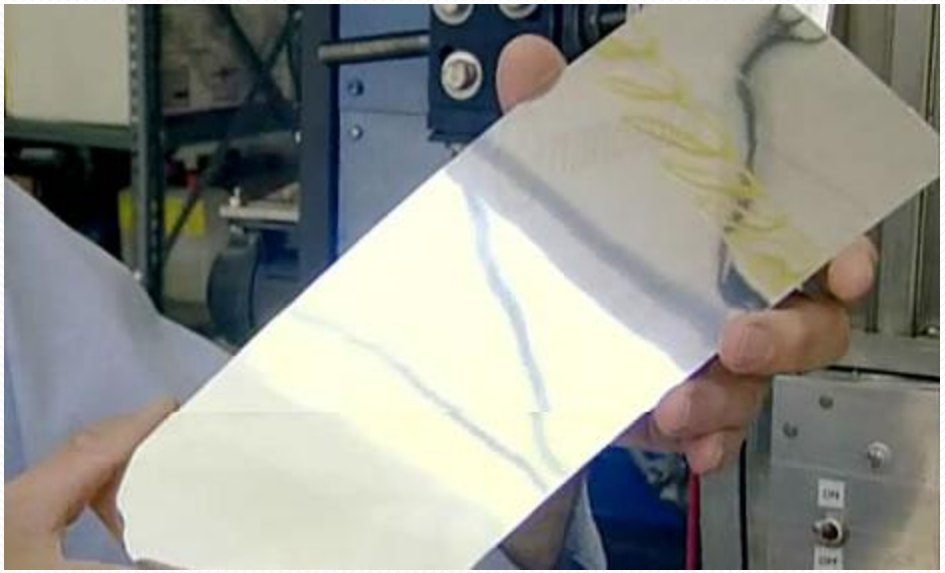

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# Nanotech  applications in Solar cell

Nanosolar's approach to manufacturing thin-film solar photovoltaics takes advantage of a roll-based process similar to a printing press.



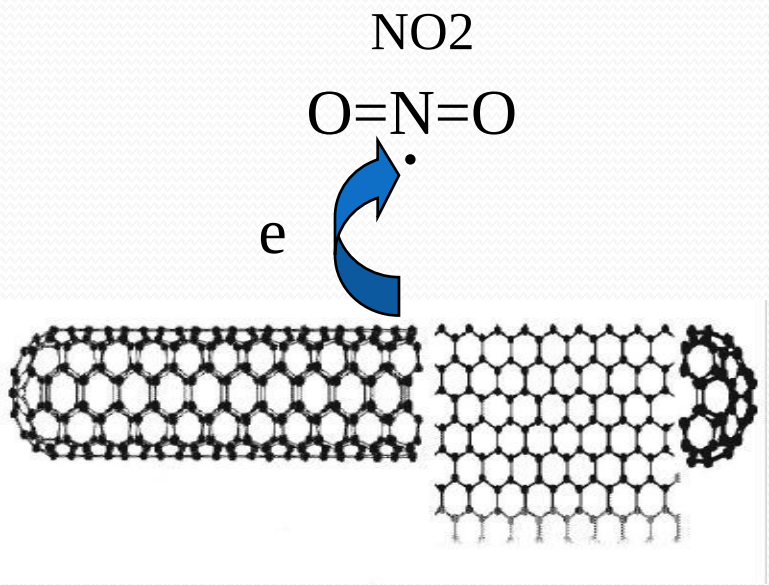


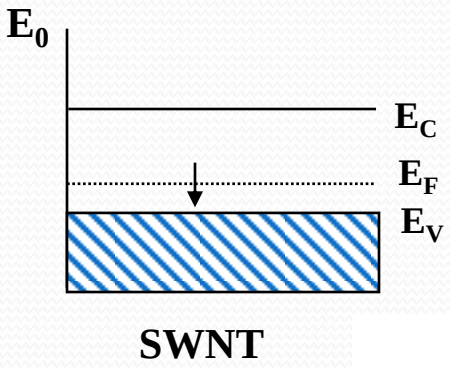
Sources: Nanosolar Inc.


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# Applications of Carbon Nanotubes for Chemical Sensors

- Every atom in a single-walled nanotube (SWNT) is on the surface and exposed to environment
- Charge transfer or small changes in the charge-environment of a nanotube can cause drastic changes to its electrical properties





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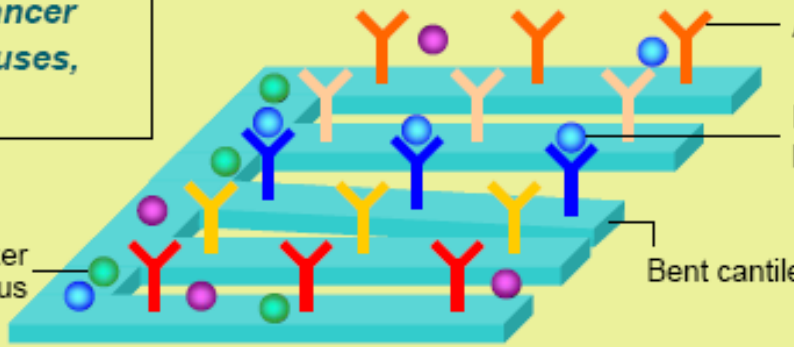
# Biosensors / biodetection (1)

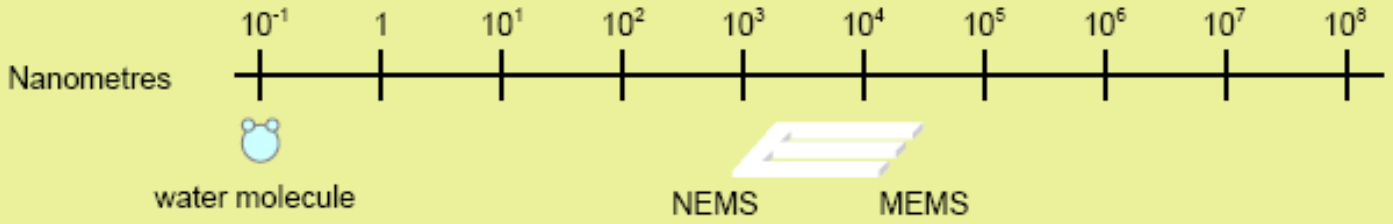
## *Cantilever array sensors (NEMS/MEMS)*

Ultrasensitive mass detection technology:detection limit attogram ($10^{-18}$)

Multiplexing modality: sensing large numbers of different molecules in real time

***Applications:***
***Diagnosis diabetes, cancer***
***Detection bacteria, viruses, fungal spores***




Ref: Roszek- Medical Nanotechnology


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# Currently Marketed Prescription Drugs with Nanoparticles

| Product | Type of Nanoparticles | Indication | Particle Size |
|---|---|---|---|
| Magenvist | Gadolinum Dimeglumine | MRI contrast agent | < 1nm |
| Feridex | Superparamagnetic Iron Oxide | MRI contrast agent | 120- 180 nm |
| Rapamune | Nano-crystal/ Sirolimus | Immunosuppressant | 100-180 nm |
| Emend | Nano-crystal/Aprepitant | Anti-emitic | 100-1000 nm |
| TriCor | Nanocrystal/Fenofibrate | Hypolipidemic | |
| Doxil | Liposome/Doxorubicin | Antineoplastic | ~100 nm |
| Abraxane | Albumin-coated nanoparticles | Antineoplastic | ~130 nm |
| Megace ES | Nanocrystal/Megesterol Acetate | Appetite enhancer | |
| AmBisome | Liposome/Ampotericin | Antifugal | |
| Diprivan | Albumin-coated nanoparticles | Anesthetic | |
| Definity | Lipid coated gas particles | Echography contrast agent | |


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# Paclitaxel

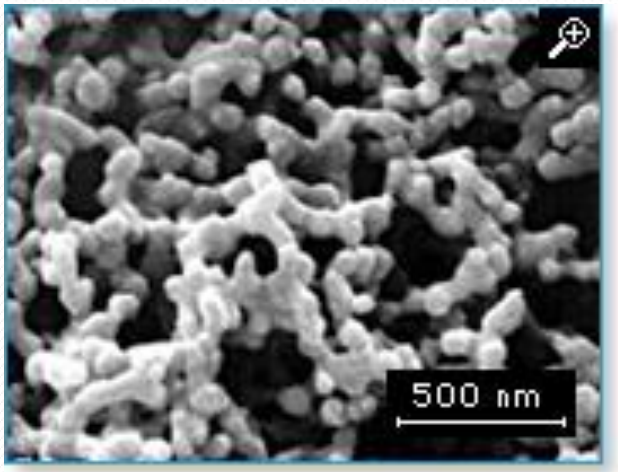



- Paclitaxel is one of the best antineoplastic drugs found in nature.

- Paclitaxel s highly hydrophobic with water solubility less than 0.03 mg/L. Its current clinical dosage from Taxol® is formulated in Cremophor EL, which has been found to be responsible for serious side effects including hypersensitivity reactions, nephrotoxicity, neurotoxicity and cardiotoxicity.


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# Paclitaxel Nanoparticles




Paclitaxel Nanoparticles

- New formulation of Paclitaxel contained in poly(lactic-co-glycolic acid) (PLGA) nanoparticles (NPs)
- Nanoparticles Paclitaxel can be are prepared by the solvent extraction/evaporation method with d-α-tocopheryl polyethylene glycol 1000 succinate (TPGS) as a novel emulsifier.
- Nanoparticles Formulation of Paclitaxel was found to be 1.37 times more effective than Taxol® after 24 hour culture at 500 ng/ml Paclitaxel concentration.
- The drug loaded PLGA nanoparticles can be used either for local delivery by balloon catheter or for development of a novel type of cardiovascular stent which is coated by nanoparticle formulation instead of the pristine drug.


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# Current Nanotechnology Issues

- Development of International Standards
- Workforce Training for Nanotech Workers
- Environmental, Health and Safety
- Societal and Ethical Implications
- Pending Regulations
- Public Engagement


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# Nanotechnology Roadmap

*8 key points for a safe and beneficial Nanotechnology*

1. Foster advanced scientific research & business collaboration worldwide
2. Develop international nomenclature and standards
3. Forming a consortium to facilitate supply chain collaboration and integration
4. Ensure safety & quality assurance of nano-manufacturing processes and products
5. Develop Nanotechnology education and workforce training
6. Nurture & provide capital investment in promising technologies & companies
7. Outreach to stake-holders and upstream public engagement
8. Focusing on developing solutions for clean sustainable energy


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# The International Association of Nanotechnology
# Nanotechnology Roadmap

## Road map # 1:

Foster advanced scientific research & business collaboration worldwide





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## Selected research projects for collaboration: Nano Bio Clean Tech

1. Improvement of purification and quality control of uniformity of carbon nanotubes .
2. Manufacturing scalability of carbon nanotubes in partnership with industry partners.
3. Bio-Sensors: development of a bio-nano-sensor system for detecting of toxin and toxic nanoparticles in food and biological products.
4. Targeted Nanoscale Drug Delivery Sustem: development of a novel Nano Drug Delivery System to carry potent anti-cancer anti-biotics to certain targeted cancerous areas to optimize therapeutic treatment while minimizing the toxic effect of chemotherapy.
5. Fuel Cells: Further development electro-catalysis replacement of Platinum based electrodes to improve yields and cost of large scale production.
6. Nanoscale thin-film materials and Nano-Organic materials for the development of solar energy system products.


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# The International Association of Nanotechnology Nanotechnology Roadmap

## Roadmap # 2:

## Develop international nomenclature and standards

1. Metrology and test methods:
2. Properties and characteristics of nanomaterials
3. Risk assessment and management
4. Toxicology study
5. Environmental impact


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# Actions by Standards Organizations

**Nomenclature**

ASTM E2456-06, Terminology for Nanotechnology

**Metrology**

ASTM E2456
ISO Technical Committee (TC) 229
OECD WPMN

**Environmental Health Safety:**

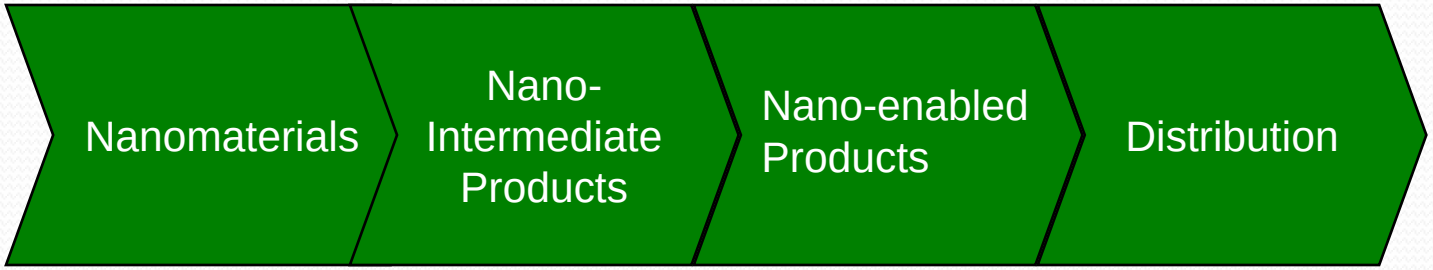
International Council of Nanotechnology (ICON) EH&S database
Nanotechnology Characterization Laboratory (NCL)
NIOSH Voluntary Frameworks


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# The International Association of Nanotechnology
# Nanotechnology Roadmap

## Roadmap # 3:

Forming  a consortium to facilitate supply chain collaboration and integration





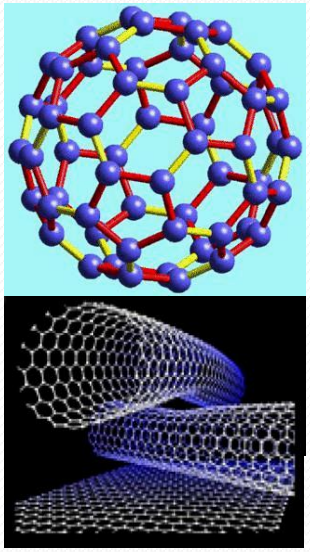
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# The International Association of Nanotechnology Nanotechnology Roadmap

## Road Map # 4:

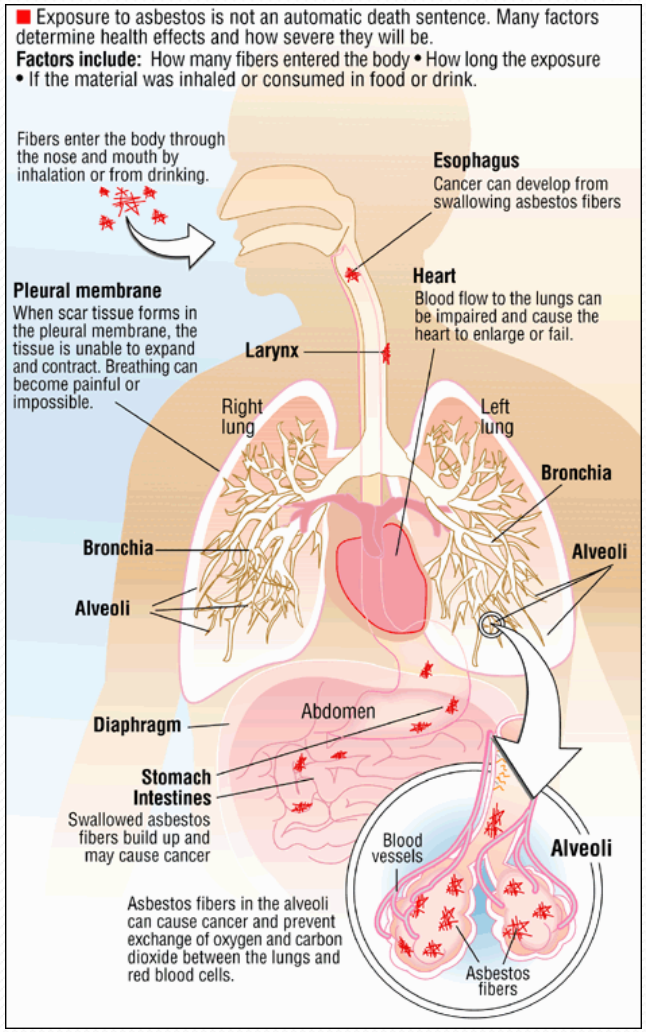
## Ensure safety & quality assurance of nano-manufacturing processes and products






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# Nanoparticle Safety




- What are the nanoparticle' pathways inside the human body?
- How long do the nanoparticles remain in the tissues and how are they cleared?
- What effects do nanoparticles have on cellular and tissue functions?
- Can nanoparticles gain access to the systemic circulation from dermal exposure? If nanoparticles enter skin cells, is there an effect on cellular functions?
- What are unanticipated reactions in vivo?


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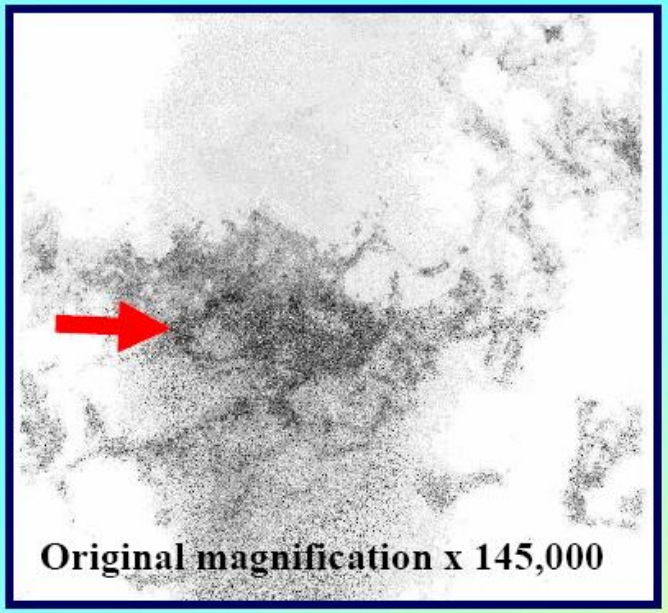
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# Single Wall Carbon Nanotube contains Redox-Active Iron

## Metal Components of SWCNT

| Component | (μg/gram) | Component | (μg/gram) |
|---|---|---|---|
| Aluminum | 233 | Molybdenum | 1070 |
| Calcium | 164 | Sodium | 8750 |
| Cadmium | 23.4 | Nickel | 8,750 |
| Chromium | 13.1 | Palladium | 28 |
| Copper | 2,530 | Selenium | <2.001 |
| Iron | 239, 000 | Titanium | 6.92 |
| | | Zinc | 85.9 |

## Transmission Electron Microscopy of SWCNT



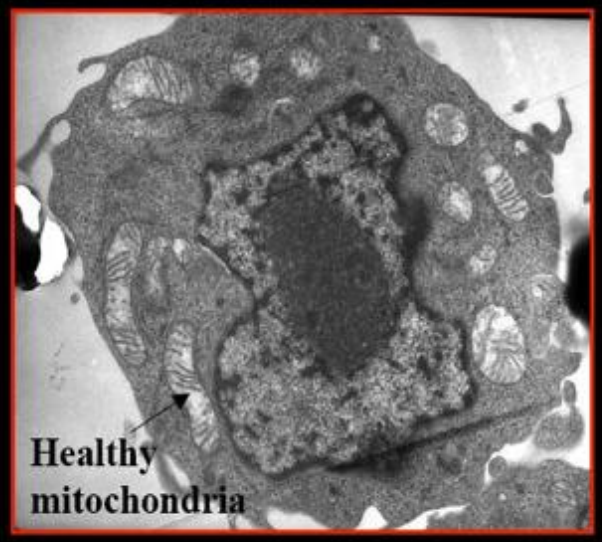

Source: Valerie E. Kagan, Dept. Environmental & Occupational Health, University of Pittsburgh


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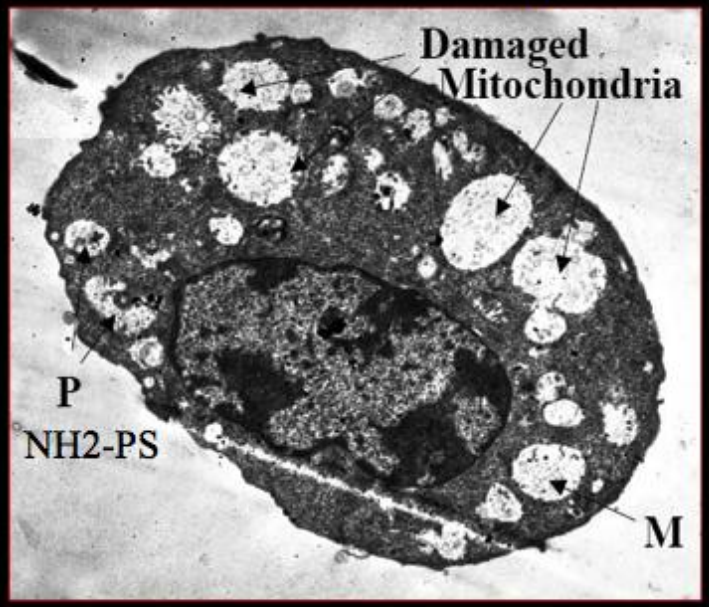
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# Cellular uptake and damage by a highly charged Nanoparticle that targets mitochondria

Untreated healthy cell




Cell treated with toxic nanoparticle



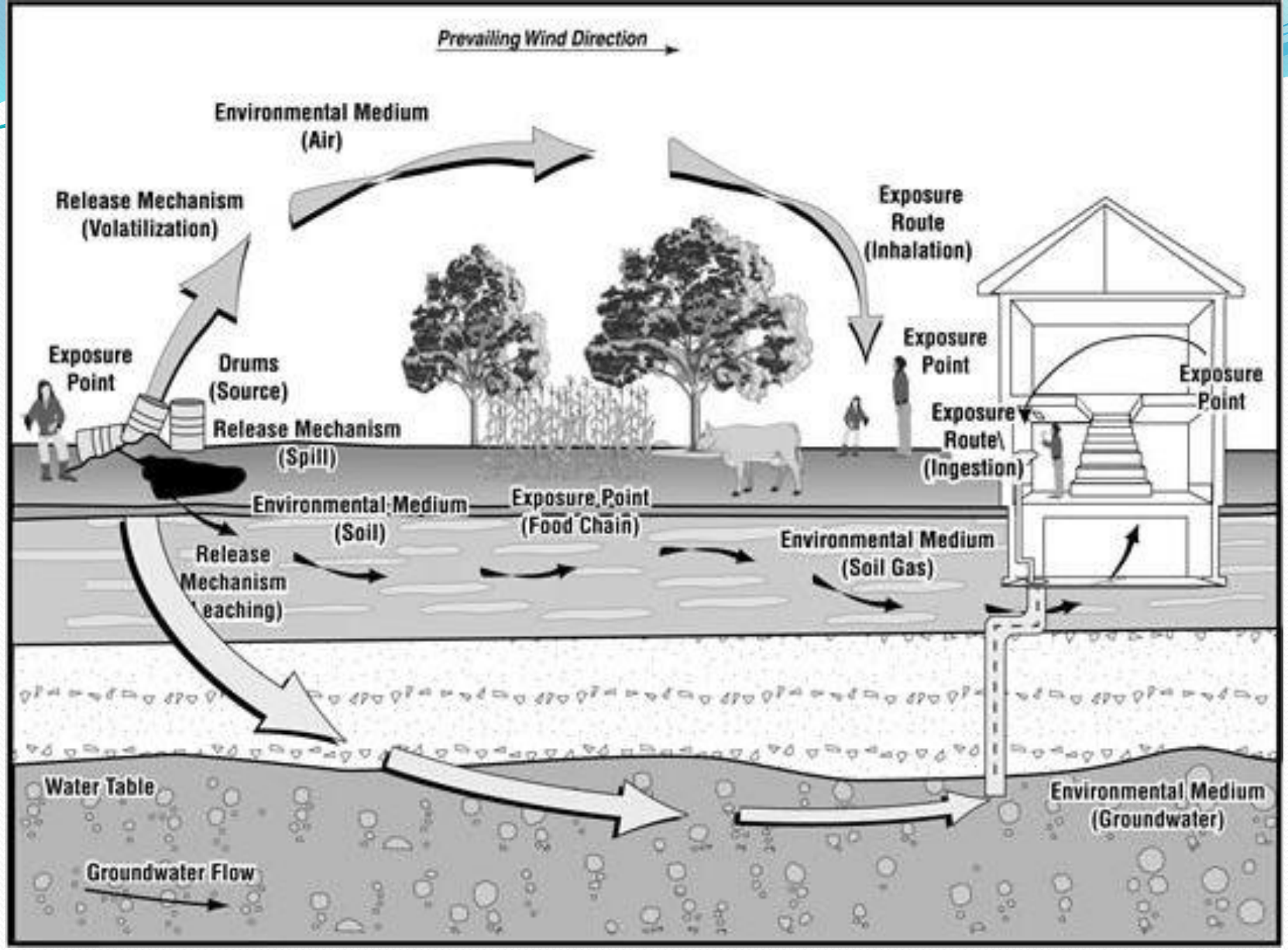

M = mitochondria; P = particles

Mitochondrial injury and cell death

Nel et al., Nano Letters, 2006


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From the ATSDR Public Health Assessment Guidance Manual, January 2005


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# The International Association of Nanotechnology
# Nanotechnology Roadmap

## Road Map # 5:

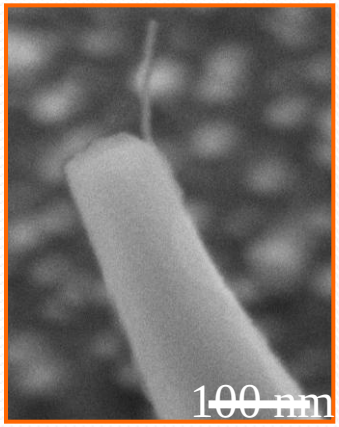
## Develop Nanotechnology education and workforce training

- California lost 318,000 high paying jobs over the past 5 years
- Economists predict a $1.5 trillion dollars global multi-industry market for nanotech products in 10 years
- Nanotechnology could create as many as 2 million jobs by 2015 in the USA.
- Productivity impacts from nanotechnology are expected to be similar to those associated with information technology.


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# Challenges Facing Nanotech Companies

- Substantial start-up capital
- Capital intensive R & D and Nano-Manufacturing
- Lack of highly trained and skilled workforce
- Costly Intellectual property protection
- Global competition









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# Nanotechnology Workforce Challenges

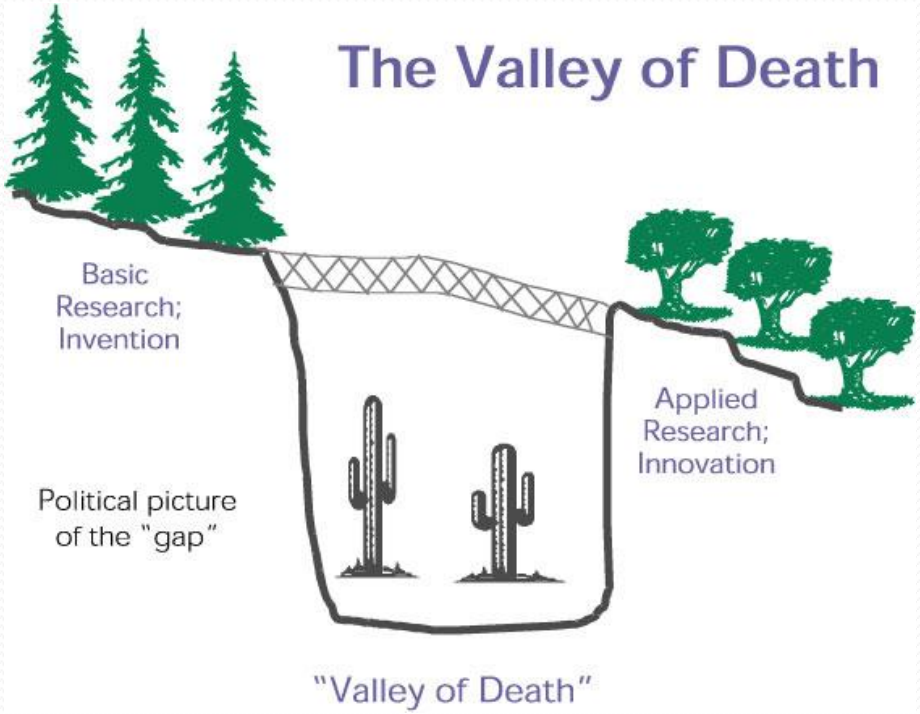
- Insufficient utilization of existing workforce training resources required for advanced manufacturing industries;
- Lack of high technology workforce training programs in Nanotechnology
- Absence of comprehensive nanotechnology training curriculum
- Lack of an acceptable standard for industry-driven Nanotechnology curriculum development;


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# The International Association of Nanotechnology
# Nanotechnology Roadmap

## Road Map # 6:

Nurture & provide capital investment in promising technologies & companies





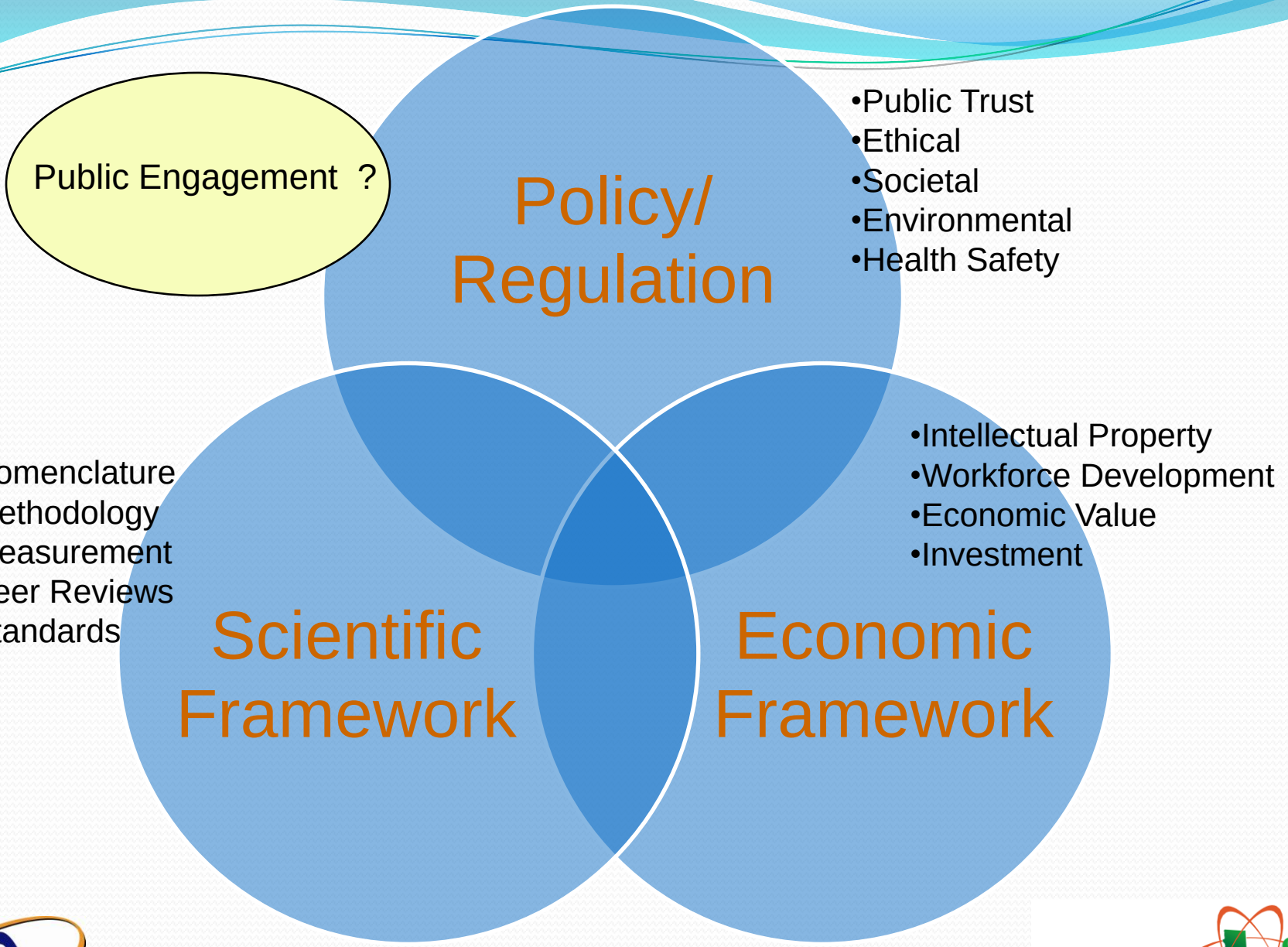
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# The International Association of Nanotechnology
# Nanotechnology Roadmap

## Road map # 7:

## Outreach to stake-holders and upstream public engagement


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**EPA Guidance on Examples of Engineered Nanoscale Materials Included in the Nanomaterials Stewardship Program:**

- Metals (Au, Ag)
- Metal Oxides (TiO2, SiO2,ZnO2)
- Quantum Dots
- Nanotubes, Nanowires
- Fullerenes
- Polymeric Dendrimers
- Materials derived from natural sources and further processed to produce nanoscale-sized materials


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# Toxics Release Inventory (TRI)

•The Emergency Planning and Community-Right to-Know Act (EPCRA) was enacted in 1986

•Question: Could the Toxics Release Inventory (TRI) in (EPCRA)1 could be applied to nanomaterials?

• The City of Berkeley, California enacted a law in 2006 that specifically addresses environmental, health, and safety of nanomaterials by the "right-to-know" approach that requires facilities that manufacture or use "manufactured nanoparticles" to disclose both the known toxicology of those materials and the facility's plan for material handling, monitoring, containment, disposal, inventory tracking, release prevention, and mitigation.


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The primary goal of the consortium is to optimize the beneficial applications of nanotechnology by expanding the knowledge of the health and environmental implications of nanoparticles.

The Consortium will foster communication between a number of regional, national and international initiatives, and facilitate the collaboration amongst stakeholders in this effort worldwide.


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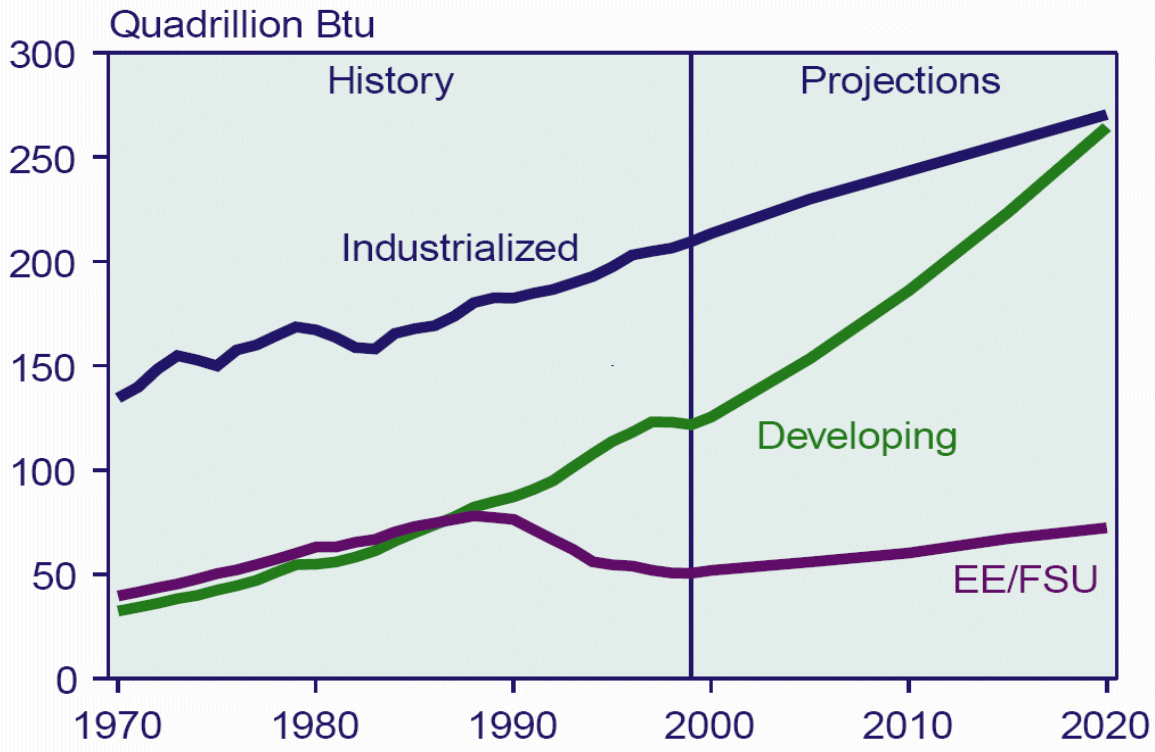
# The International Association of Nanotechnology Nanotechnology Roadmap

## Road map # 8

## Focusing on developing solutions for one of major problems facing mankind: shortage of energy


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## Figure 3. World Energy Consumption by Region, 1970-2020




Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).


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# Global Warming by the Numbers

**Rank 1**: 2006 as **hottest year on record** in the continental United States.

**Rank 1**: America as **top global warming polluter in the world**.

**20% increase of America's carbon dioxide emissions** from the burning of fossil fuels since 1990.

**15% increase of America's carbon dioxide emissions forecasted** by 2020 if we do not cap pollution.

**80% decrease in U.S. global warming pollution required** by 2050 to prevent the worst consequences of global warming.

**358** U.S. mayors (representing 55 million Americans) **who have signed the U.S. Mayors Climate Protection Agreement** pledging to meet or beat Kyoto goals in their communities.

**0** Number of **federal bills passed** to cap America's global warming pollution.


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# Summary and Perspective

- Nanotechnology is the unifying science and enabling platform to develop advanced solutions to major technical challenges.
- Nanotechnology has a wide spectrum of applications with significant impact to industries, business, government, and society at large
- Nanomaterials and Nanoelectronics will provide innovative products, energy and storage system using nanotechnology over the next 3-5 years.
- Nanomedicine potentially offers breakthrough solutions for treatment of diseases such as Cancer, Alzheimer's over the next 5-7 years.
- International Standards are in the developmental stage
- Education and workforce training urgently needed for the emerging industry
- Health safety, environmental, and societal implications to be addressed


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# Thank You!




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