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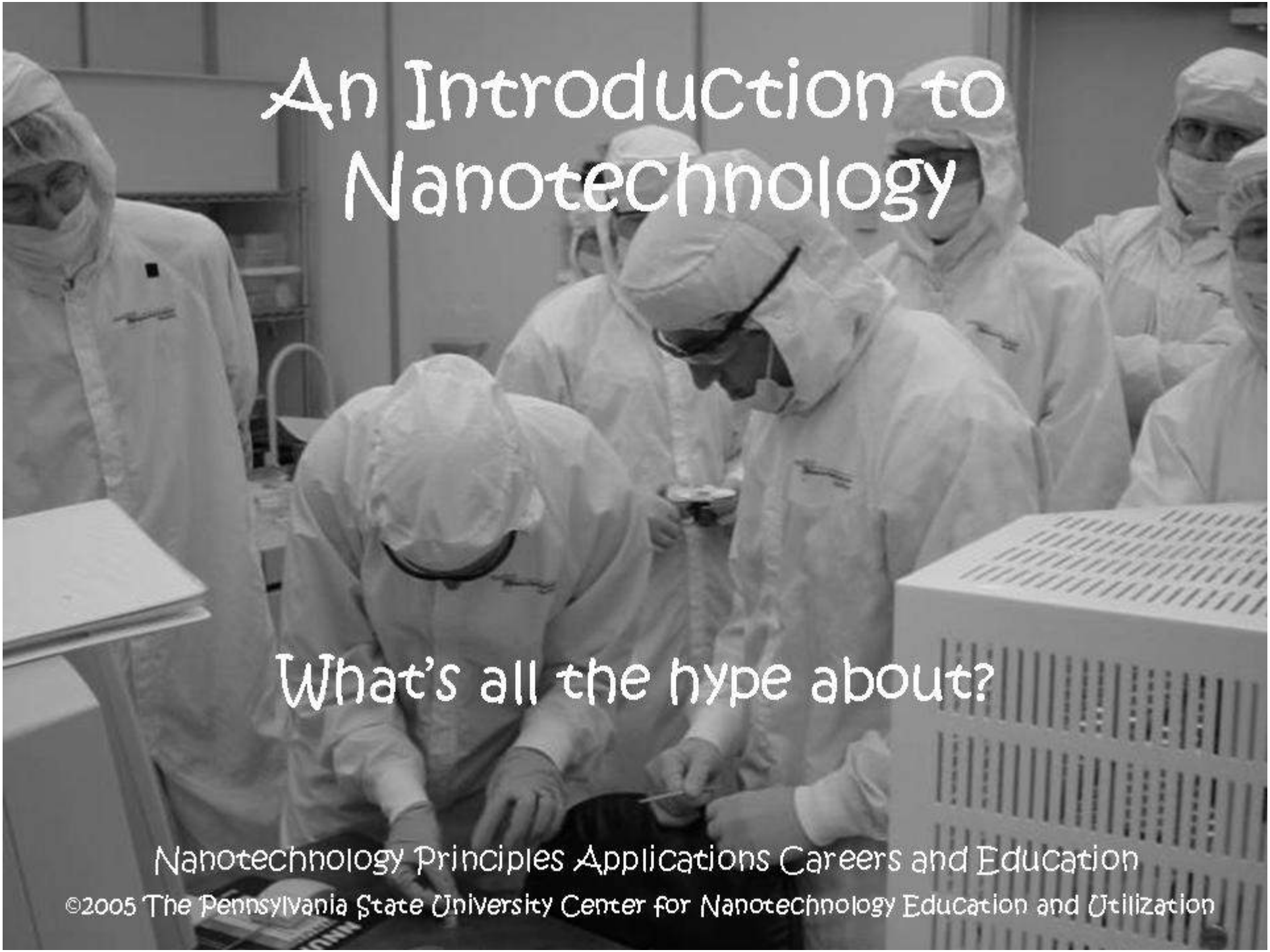


# An Introduction to Nanotechnology

## What's all the hype about?

Nanotechnology Principles Applications Careers and Education

# Outline

- What is Nanotechnology?
- How Small is a Nanometer?
- What's New, Cool, and Different about the Nanoscale?
- Current Applications in Nanotechnology
- Nanotechnology as a Career Choice
- Educational Pathways

# What is Nanotechnology?

- Based on what you know about the micrometer size scale, and microtechnology...

Intel Corp.

- Write down in your own words a definition of nanotechnology...

# What is Nanotechnology?

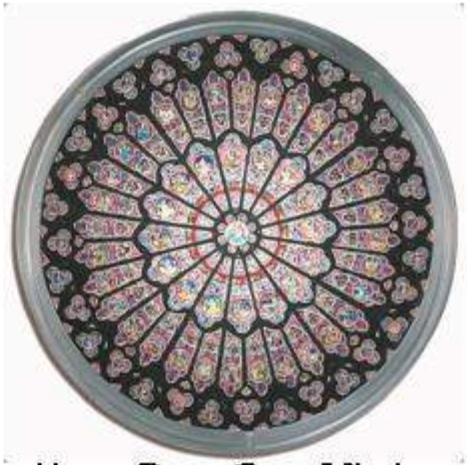
- Nanotechnology is the creation of functional materials, devices and systems through control of matter at the scale of 1 to 100 nanometers, and the exploitation of novel properties and phenomena at the same scale

- Nanofabrication is "machining at an atomic scale" used to create materials, devices, and systems

# What is Nanotechnology?

- Nanotechnology is nothing new.
  - Medieval artists used nanoscale gold salts to make vibrant colors for stained glass windows
    - They knew it worked...but didn't know why.

Courtesy Nanopedia
Case Western Reserve University



Notre Dame Rose Window
Cathedral Notre-Dame de Paris, France

# What is Nanotechnology?

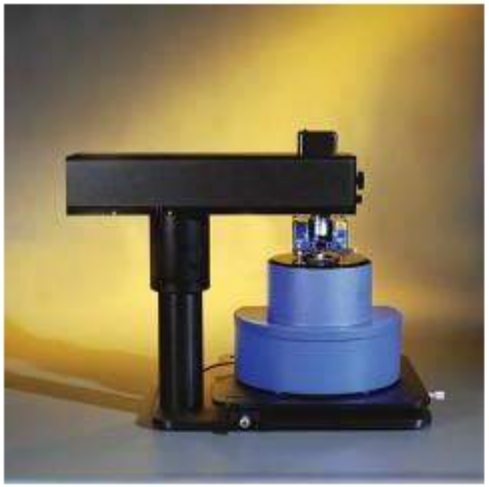
- *Using* nano-scale materials and *understanding* them are two different things!

Courtesy of R. J. Lee Group, Inc.

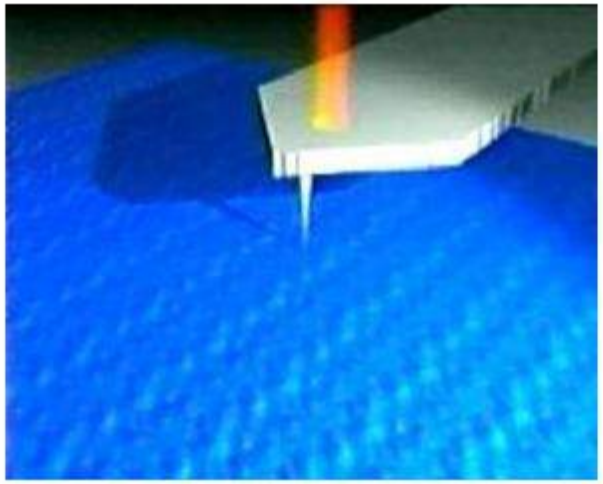
## Modern tools:

- Help us to see and manipulate matter at the nano-scale
- Allow us to understand how the small structures we are creating work, and why.

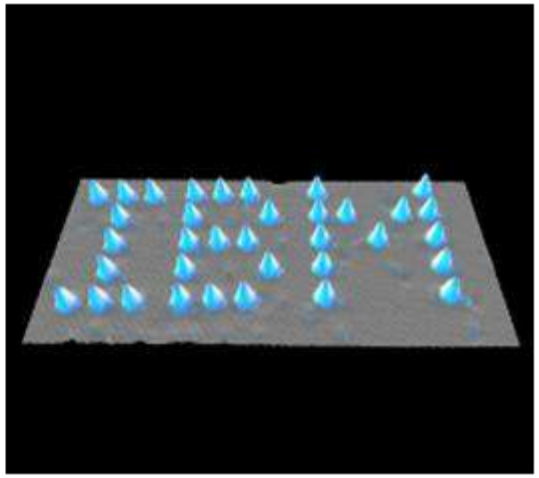
# What is Nanotechnology?



Atomic Force Microscope (AFM) Veeco Model CP-II



Depiction of AFM probe tip

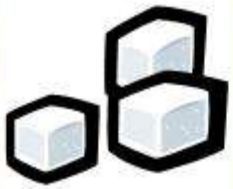


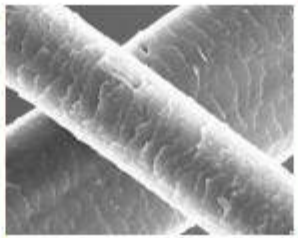
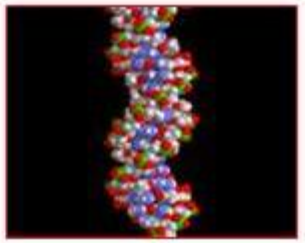
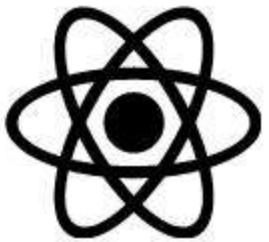
I B M spelled out with Xenon Atoms on a Nickel Surface by an AFM based tool

Nanotechnology is manipulating matter at the atomic scale!

# How BIG is a Nanometer?

| | | | |
|---|---|---|---|
| 1 meter | = | 3.28 feet | |
| | = | 100 Centimeters | ($1X10^{-2}$ m = 1 cm) |
| | = | 1000 Millimeters | ($1X10^{-3}$ m = 1 mm) |
| | = | 1,000,000 Micrometers (Microns) | ($1X10^{-6}$ m = 1 µm) |
| | = | 1,000,000,000 Nanometers | ($1X10^{-9}$ m = 1 nm) |
| | = | 10,000,000,000 Angstroms | ($1X10^{-10}$ m = 1 Å ) |

# How BIG is a Nanometer?


| | | | | | |
|---|---|---|---|---|---|
| METER<br>(1 x $10^{0}$ m) | A student is approximately<br>1 meter = 3.28 feet | ____m tall | MICROMETER<br>(1 x $10^{-6}$ m) | A strand of hair is approximately<br>1 meter = 1,000,000 µm | ___µm thick |
| CENTIMETER<br>(1 x $10^{-2}$ m) | A pencil is approximately<br>1 meter = 100 cm | ____cm wide | NANOMETER<br>(1 x $10^{-9}$ m) | DNA is approximately<br>1 meter = 1,000,000,000 nm | ___nm wide |
| MILLIMETER<br>(1 x $10^{-3}$ m) | A dime is approximately<br>1 meter = 1000 mm | ____mm thick | ANGSTROM<br>(1 x $10^{-10}$ m) | Atoms are approximately<br>1 meter = 10,000,000,000 Å | ___Å wide |

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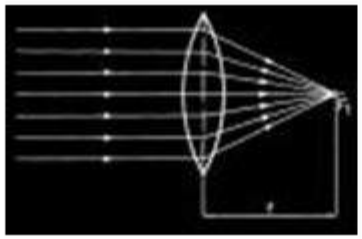
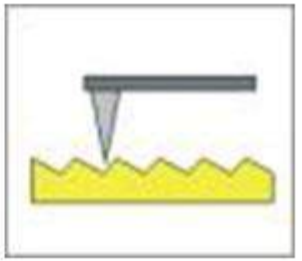
# How BIG is a Nanometer?

| meter<br>centimeter | millimeter | micrometer | nanometer<br>Angstrom |
|---|---|---|---|
|  |  |  |  |
|  |  |  |  |
| ruler and/or caliper | optical microscope | electron microscope | atomic force microscope |

# How BIG is a Nanometer?

- Count your Nanometers!

A 2 meter (6 ft. 6 in.) tall person is 2 billion nanometers tall.

Q: If he/she counts 3 nm every second, how long will it take to count all 2 billion nm?

# The Powers of Ten!

These websites offer different visual explanations of the powers of 10 and the concept of scale.

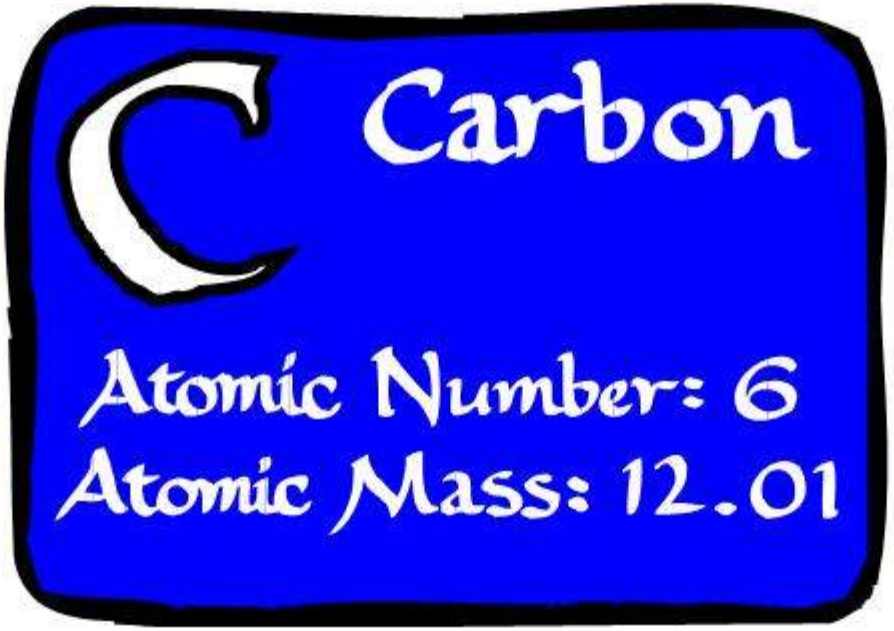
It helps to clarify the sizes of the structures we can fabricate.

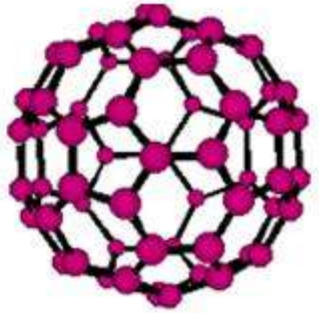
http://www.powersoften.com/


http://www.wordwizz.com/pwrsof10.htm

# What's new, cool, and different about the Nanoscale

- Material Properties *Change*
  - The materials that we thought we knew all about act much differently at the nanoscale.
  - An Example: Carbon



# What's new, cool, and different about the Nanoscale?



The gold we know:

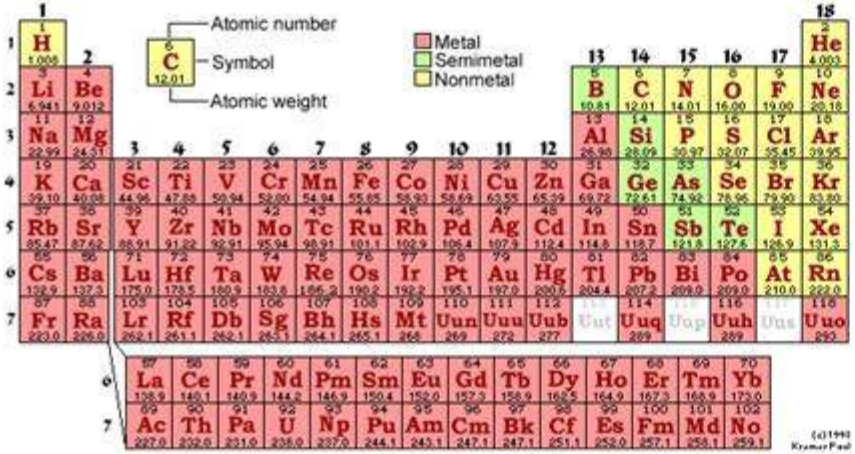
Material properties don't change with size
- resistivity
- melting point
- optical absorption
- etc.

The gold we are discovering:

Material properties (such as optical absorption, shown here) change with the size of the gold nanoparticle.

# What's new, cool, and different about the Nanoscale

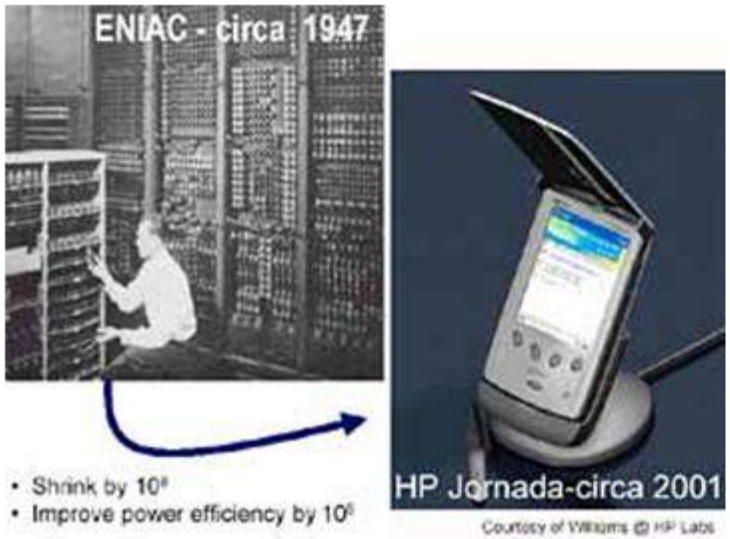
- We have a whole new treasure chest of material properties to discover, explore, and use!




http://www.vcs.ethz.ch/chemglobe/ptoe/periodic.gif

# Why is making things small so good?

- More functionality per sq. cm.
  - Nano-electronics



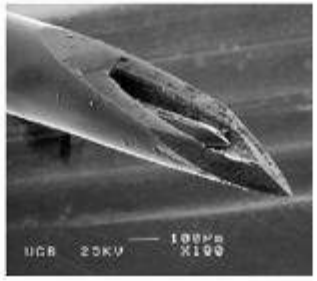

1993 2004

Smaller circuits lead to smaller cell phones.

# Why is making things small so good?

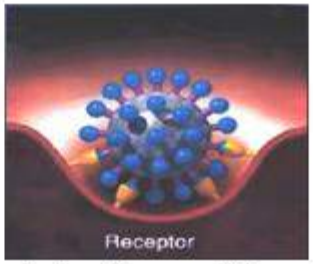
- We can make medical devices that are less invasive
  - Smaller medical sensors and tools

Hollow Micro-scale needle by itself (Verimetra, Inc.)



Hollow Micro-scale needle in an ordinary needle (Verimetra, Inc.)

- Don't need as much of expensive or toxic substances
  - Targeted Drug molecules




Buckyball used for drug delivery structure

# Why is making things small so good?

- Biomimetics
  - Man made systems can be made the same size as nature's systems.
  - We can mimic natures structures
  - A Large scale example — Velcro
    - In the early 1940's, Swiss inventor George de Mestral went on a walk with his dog... Upon his return home, he noticed that his dog's coat and his pants were covered with cocklebur s.
    - Curiosity led him to study the burrs under a microscope, where he discovered their natural hook-like shape.
    - This was to become the basis for VELCRO® brand hook and loop fasteners.

Scanning Electron Microscope (SEM) Image of Velcro
Courtesy www.about.com

Gecko Tape- plastic pillars on substrates.
Courtesy of Popular Science and National Geographic News

# Products Influenced by Nanotechnology

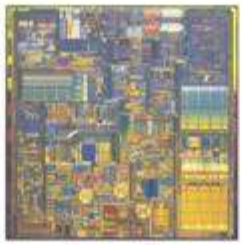
# Directions for the Activity

1. Open the bag
2. Pass out the reading material to each group member
3. Read the material and study the product
4. Discuss in your groups and prepare a short presentation about the nano-enhanced product
5. Be able to tell the class:
    1. What the product is
    2. What is it used for
    3. What is "nano" about it
    4. How does it work
    5. How is it different from it's "non-nano" counterpart
    6. Any other information
6. Divide the above work amongst your group members
7. Deliver your presentation to the class

# Electronics

www.eink.com


Sony Corp.


Intel Corp.

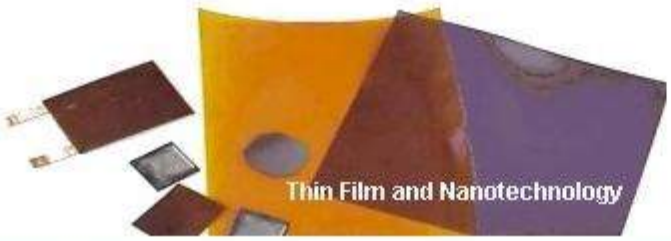

PalmOne, Inc.

Dell, Inc.


Addison Engineering, Inc.


Eastman Kodak Co.


www.nature.com




Power Paper Ltd.

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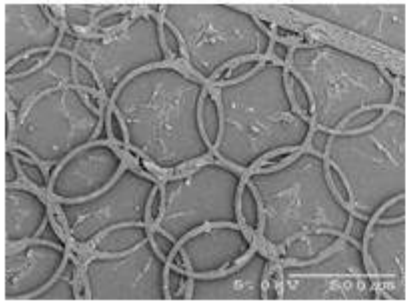
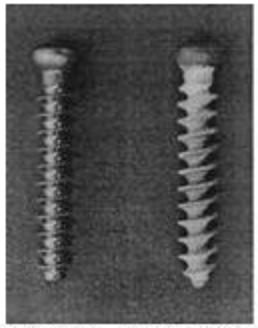
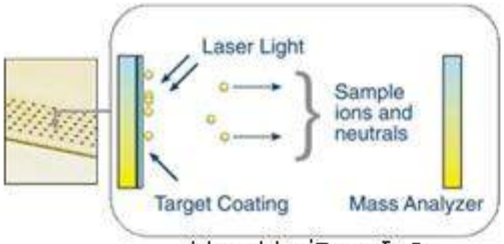
# Biotechnology



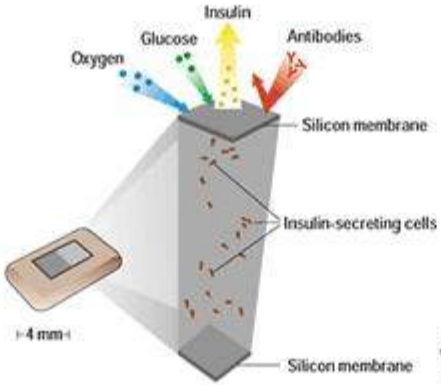

CuradUSA



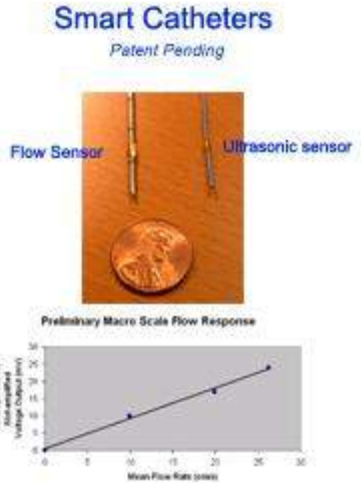
Piveteau et al., 1999

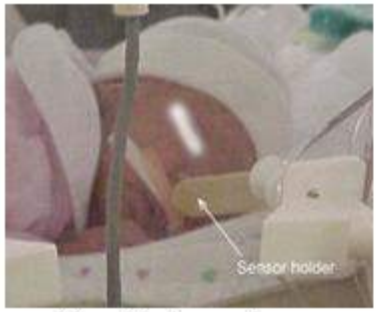



Nano Horizons Inc.

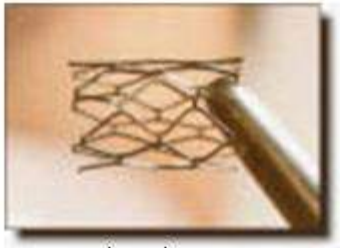



pubs.acs.org



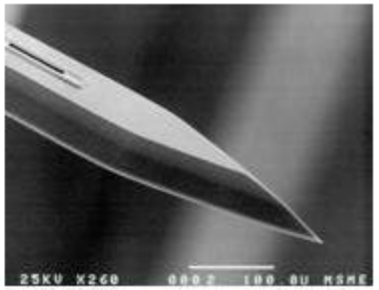




Nano Horizons Inc.



www.harthosp.org

www.additec.de



# Consumer Applications

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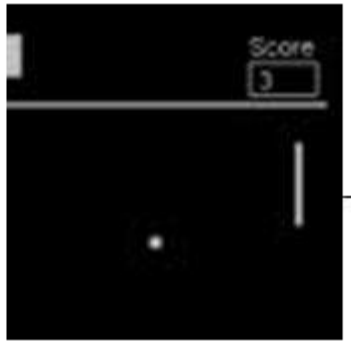
# Then and Now: The Nano-Impact

- Discuss how the following items have advanced over the years

Pentium 8086
Circa 1978
29,000 transistors


42,000,000 transistors




So.....

# Why Should I Consider a Nanotechnology Career Path?

# Why Consider Nanotechnology?

- We're on the Edge of a New Technological Frontier
- Governments and Others are Investing
- Educational Opportunities are being Created
- Job Projections are Excellent

# Investing in Nanotechnology Development

- While private investors are looking for short term returns, governments are investing in research that may take decades in order to maintain a competitive research edge globally.

- The US government has increased funding in Nanotechnology from roughly 460 million dollars in 2001 to over a billion dollars in 2005.

# Nanotech Job Projections

- It is estimated that about 2 million nanotechnology workers will be needed worldwide by 2015.

- ...an approximate distribution of nanotechnology workers needed in various areas by 2015 would be: 0.8-0.9 million in the US, 0.5-0.6 million in Japan, 0.3-0.4 million in Europe, about 0.2 million in the Asia-Pacific region excluding Japan and 0.1 million in other regions.

- ...nanotechnology has the potential to create 5 million additional related jobs overall by 2015 in the global market.
  - Source: Mihail C Roco, Nature Biotechnology Vol. 21, No. 10, Oct. 2003

# Where are "things" being made at the Nanoscale?

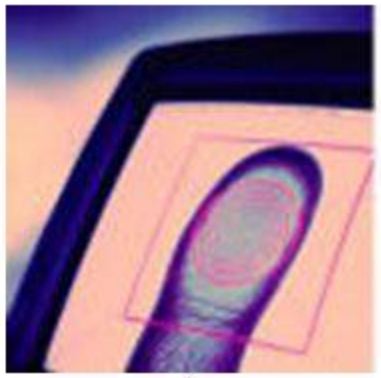
- Industry
- Universities
- National facilities

## So.....Tell me About Jobs

# Industries Related to Nanotechnology

www.scsolutions.com

- Electronic/Semiconductor Industry
- Biotechnology and Medical Fields
- Pharmaceutical Industry
- Optoelectronics
- MEMS
- Water Purification/Food Industry
- Forensics
- University Research & Teaching
- Many More!



www.rkon.com

Pard.technion.ac.il

www.monash.edu.au

# What might I be doing at work in a Nanotechnology Career?

- Design
- Development
- Distribution
- Fabrication
- Management
- Packaging

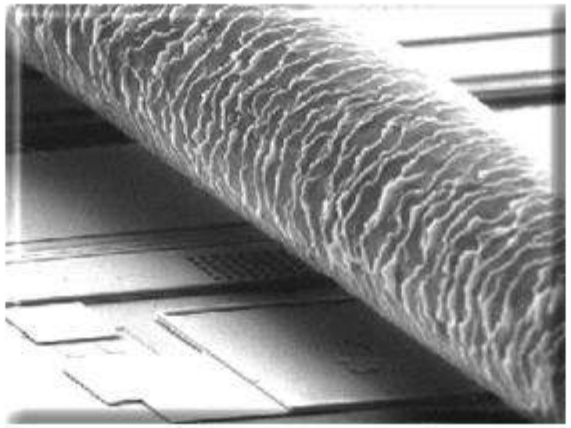
- Patent Law
- Public Service
- Research
- Sales
- Teaching
- Testing
- Tech Support

...and more!

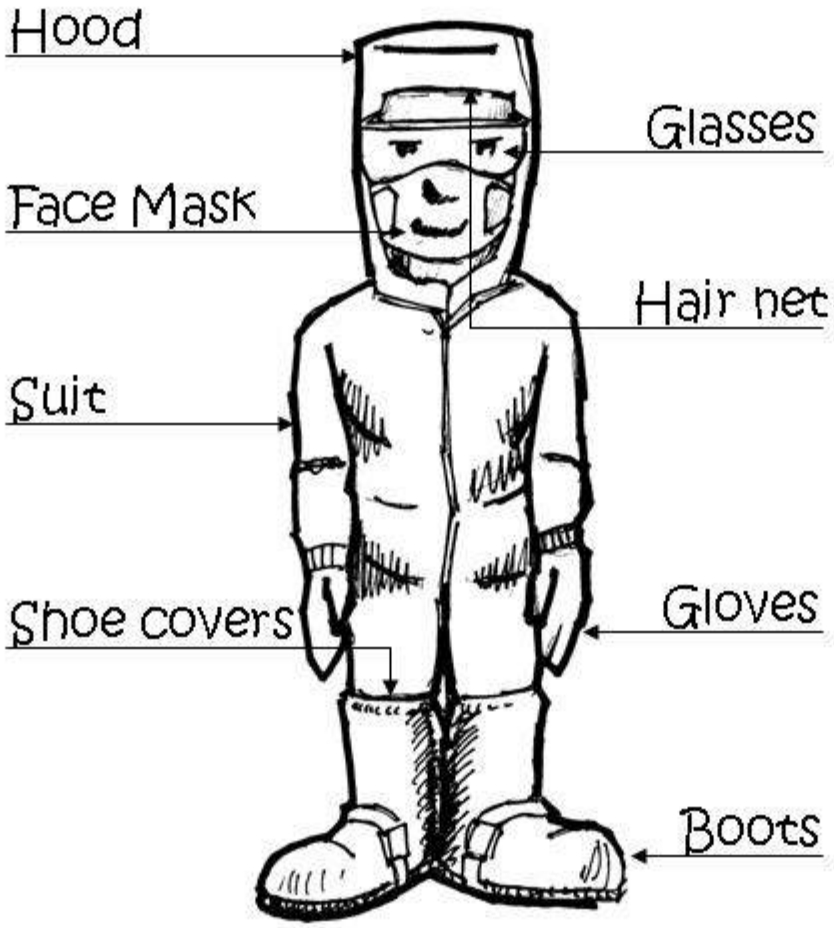
Some of these jobs might require you to work in a *cleanroom*.

# What is a cleanroom?

- A cleanroom is where scientists and engineers build structures at the nano scale.
- We wear suits to protect the cleanroom from the dirt we may carry in on our clothes, our bodies, and our shoes.



# Here's a cleanroom suit!



# Educational Opportunities are being Created

- A key challenge for nanotechnology development is the education and training of a new generation of skilled workers in the multidisciplinary perspectives necessary for rapid progress of the new technology.
  - » Source: Mihail C Roco, Nature Biotechnology Vol. 21, No. 10, Oct. 2003.

# So…. How Far could I go in in my Nanotechnolgy Education?

- Technical Programs
- Associates (2 years*)
- Bachelors (4 years*)
- Masters (6 years*)
- Doctorate (8 years*)

*As a full time student it should take approximately this long to complete degree requirements after high school.

# Fields of Study
# Where can I enter the Nanotechnology Arena?

- Biology
- Business
- Chemistry
- Forensic Science
- Law
- Physics
- Science Education

- Engineering
  - Aerospace
  - Agricultural
  - Biotechnology
  - Ceramic
  - Chemical
  - Computer
  - Electrical
  - Industrial
  - Nuclear
  - Materials

# What Should I do Now to Prepare for a Nanotechnology Career

- Develop your Technical Foundation
  - Science and / or Tech Courses
    - Depends on your Goal
- Search for Schools that Offer Diverse Opportunities & Nanotechnology Curriculum
  - www.nnin.org
  - www.cneu.psu.edu
  - www.dctc.edu
- Do Personal Web Research on Nanotech and it's Applications

# Some Additional Resources


- Education & Outreach
  - www.nnin.org
  - www.nano4me.org
- Current Events in the Nano-World
  - www.smalltimes.com
- Job Sites
  - www.tinytechjobs.com
  - www.workingin-nanotechnology.com