The World of Nanotechnology: An Introduction

The NACK Center was established at the Pennsylvania State College of Engineering, and is funded in part by a grant from the National Science Foundation.

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Welcome to NACK's Webinar

Presenter

Stephen J. Fonash, Ph.D.
Director, Center for Nanotechnology Applications & Career Knowledge (NACK)

Webinar Desired Outcomes

Participant understanding of:

- What is nanotechnology ?
- What is so unique about the nanoscale?
- Where did nanotechnology come from and why is it so “big” now?
- How is nanotechnology impacting us today?
- How will nanotechnology impact us in the future?

Nanotechnology

What Does the Word Mean?

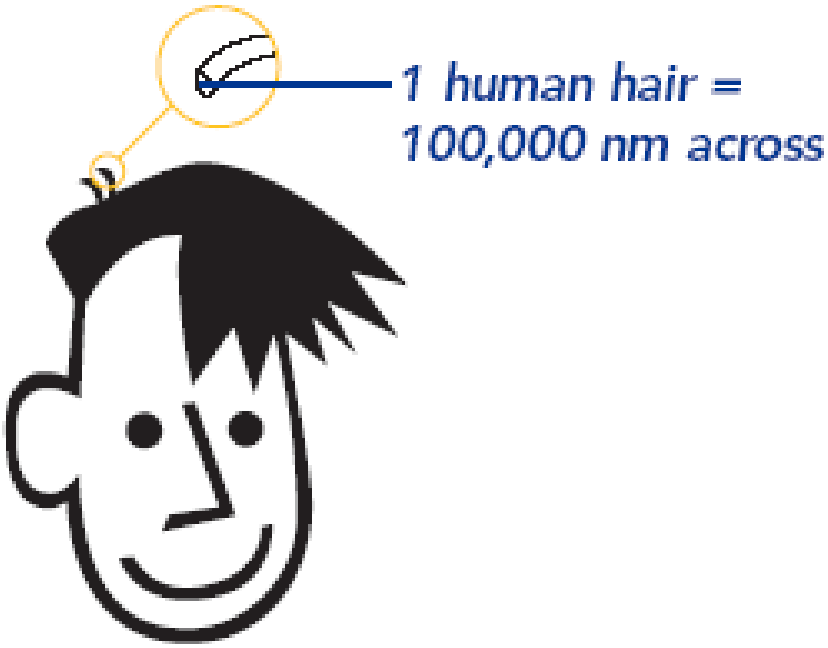
It refers to technology based on “things” that are really, really, really small

or more precisely

It means technology based on particles and/or structures which have at least one dimension in the range of one billionth of a *meter*

How small is a Nanometer-

1 nanometer (nm) = one billionth of a meter

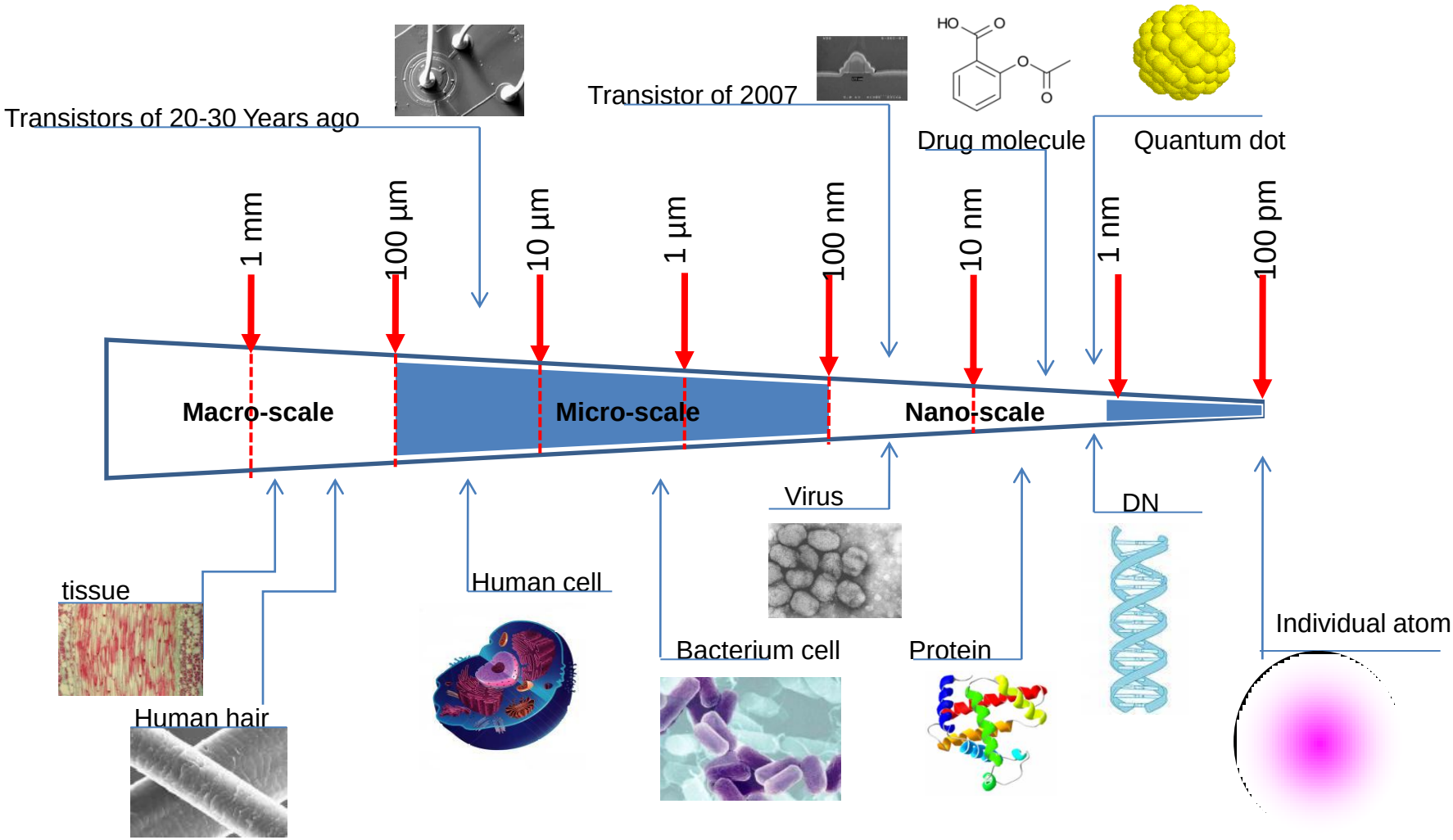


Courtesy of NanoHorizons, Inc.

Let’s look at the “small size” ranges pictorially

Let’s also get some idea of what nature makes and what man makes in these size ranges

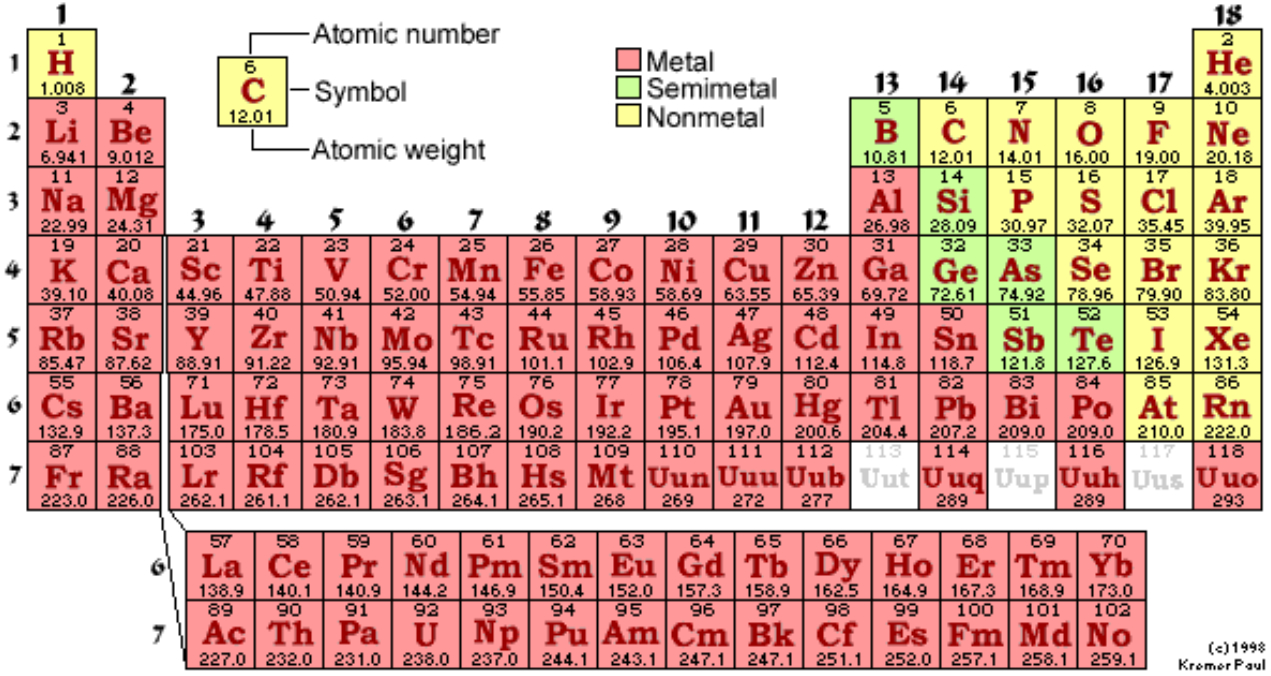
Sizes of Some Small Naturally Occurring and Man-Made Structures



Note from our pictorial representation of scales that the next size range that is smaller than the nano-scale is the pico-scale

Note that neither nature nor man builds anything at this pico-scale size range.

It is the size range of the basic “legos” used to build everything – individual *atoms*



What's After Nanotechnology – Is there a Picotechnology?

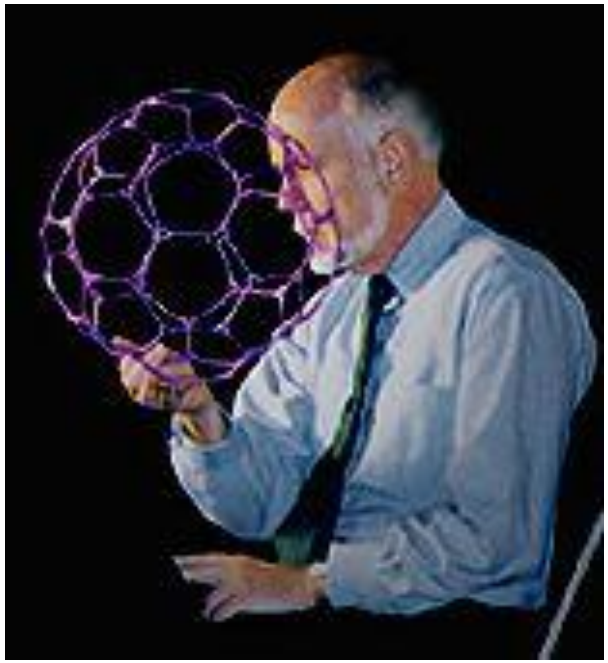
No, nothing to build at the pico-scale

Nano-Scale

- Lots to build at the nano-scale
- Atoms and molecules are the “legos” in the building
- The creating and using of ‘things’ at the nano-scale, for the benefit of mankind, is nanotechnology

“Nanotechnology is the builder’s final frontier.”

Richard Smalley
1996 Nobel Laurate in Chemistry, Rice University



Is Nanotechnology new?

Nanotechnology has actually been practiced by humans for quite a long time

We now know that a cup made by the Romans 1700 years ago used nanotechnology!

(We just found out because we just learned how to see the nanoparticles they used)

Is Nanotechnology new?

Source: British Museum

- Lycurgus Cup
  - 4th century Roman glass cup
  - In reflected light cup appears *green*; transmitted light appears *red*
- Nanoparticles of metals
  - Au nanoparticles & Ag nanoparticles embedded in silica glass causing plasmons

Barber, D J and Freestone, I C 1990, An investigation of the origin of the colour of the Lycurgus Cup by analytical transmission electron microscopy, *Archaeometry*, 32 (1), 33-45.

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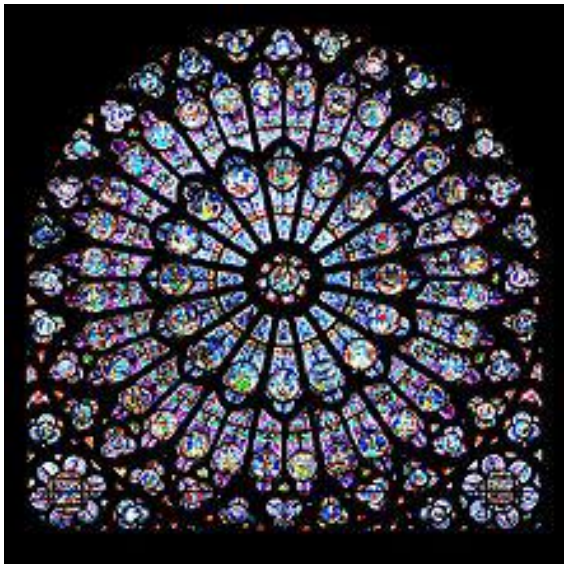
We now know that the beautiful stained glass windows used in European cathedrals as far back as 800 years ago employed nanotechnology

Is Nanotechnology new?



Gothic stained glass
rose window
Notre-Dame de Paris

We now know that beautiful plates made by the Renaissance Italians 500 years ago also used nanotechnology

(We just found out because we

just learned how to see the nanoparticles they used also)

Is Nanotechnology new?

16th century Renaissance pottery

Padovani et al. J. Appl. Phys. 2003

If nanotechnology has been around so long, why is it taking off now?

Why is it so “big” now?

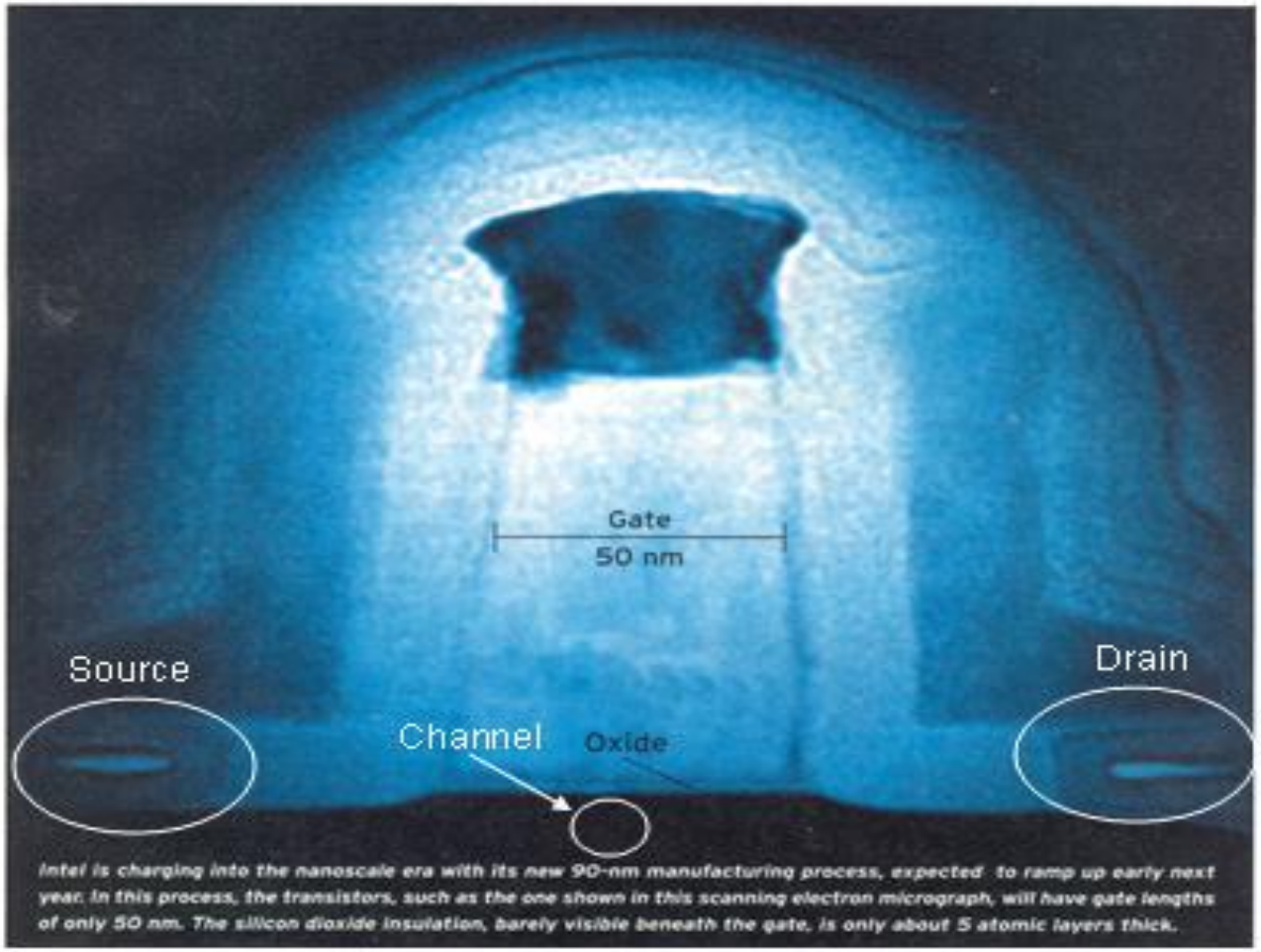
Because we have learned what's going on and how to control and see it-

- We can now controllably and repeatedly make things in the nano-size range

- And finally **we can now see what we have made**

We can controllably and repeatedly make things in the nano-scale range and we can "see" what we made

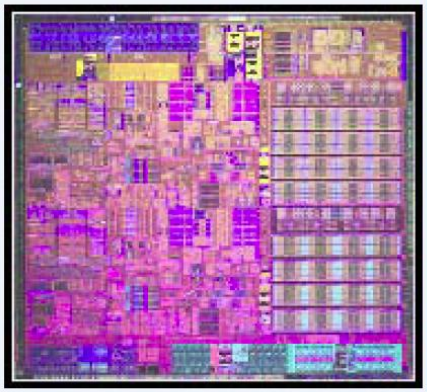
- For example, today's *transistors* are nano-scale structures---they are 45nm in length!
- Today more nano-scale transistors are made in a year than there are grains of rice grown in a year—now that's control and repeatability!
- We have really learned how to build at the nano-scale!



Adapted from Linda Geppert, The Amazing Vanishing Transistor Act,

IEEE Spectrum, October 2002, Vol. 39, Number 10, pg. 28-33

Nanoelectronic Applications

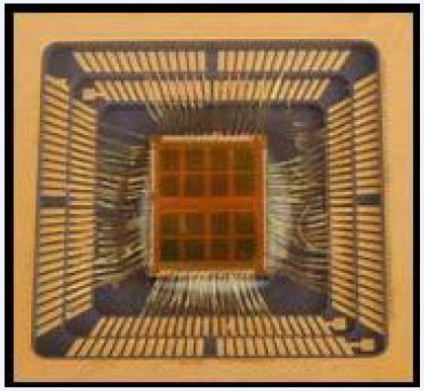


32 nm complementary metal oxide semiconductor (CMOS) processor technology by Intel (2009), (gate length of 30 nm) with high-K / metal gate. This technology is used to make integrated circuit (IC) chips that will be available in a wide variety of laptop, desktop, and server computer systems, giving higher speed, higher density, and lower power.

32 nm CMOS (2009)

90 nm thin-film storage (TFS) flash flexmemory by Freescale (2010) for next-generation microcontrollers, utilizing silicon nanocrystals as the charge storage layer. The nanocrystal layer enables higher-density arrays, lower-power operation, faster erase times, and improved reliability. Micro-controllers are the "brains" of a wide variety of industrial and consumer products.

Si Nanocrystal Flash (2010)



16 megabit magnetic random access memory (MRAM) by Everspin (2010) is based on nanometer-scale magnetic tunnel junctions. These memories have many industrial and commercial applications, such as saving data during a system crash, enabling resume-play features, quick storage and retention of data encryption during shutdown, and retention of vehicle data in an accident for later analysis.

Magnetic RAM (2010)

http://www.hersam-group.northwestern.edu/
http://chemgroups.northwestern.edu/mirkingroup

Questions?

Please type all questions into the Chat Box

We can now see what we have made!

We can even routinely see atoms now!

- Nanotechnology is now *manufacturable*
- Nanotechnology can now produce things in huge numbers and economically
- Nanotechnology products have new, unique properties/capabilities

- Nanotechnology is now *manufacturable*
- Nanotechnology can now produce things in huge numbers and economically
- Nanotechnology products have new, unique properties/capabilities

Why is Nanotechnology So Useful?

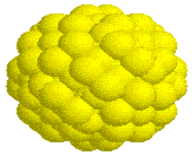
Because nanotechnology products have new, unique properties and capabilities

Why?

Because new “doors” open at the nano-scale

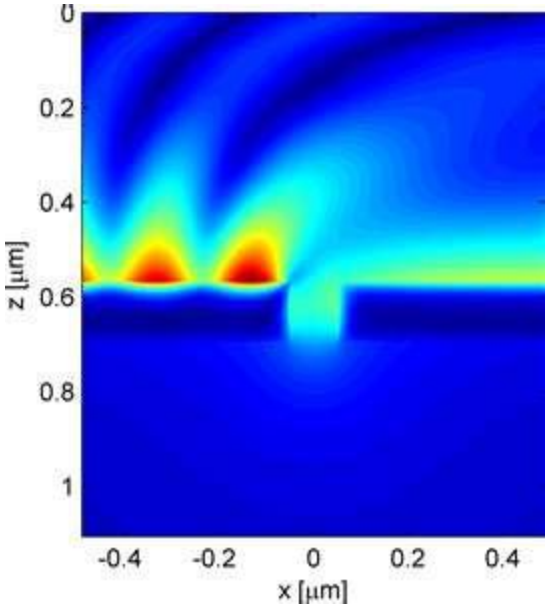
New phenomena and opportunities become accessible

The Sources of the Unique Properties

- Small size 
- High surface to volume ratio — unique environment of surface atoms
- Surface forces dominate over bulk forces (which dependent on volume) — for example, gravity is not important!
- Importance of quantum mechanical effects

The Sources of the Unique Properties

- Dominance of the wave properties of light (e.g., plasmons)



The Sources of the Unique Properties

- Sizes corresponding to basic biological structures
- Sizes corresponding to macro-molecules
- Unique chemical bonding configurations possible
- New epistemologies (i.e., new ways of knowing)

www.pezcyclingnews.com

What Are Some of the Accomplishments of Nanotechnology?

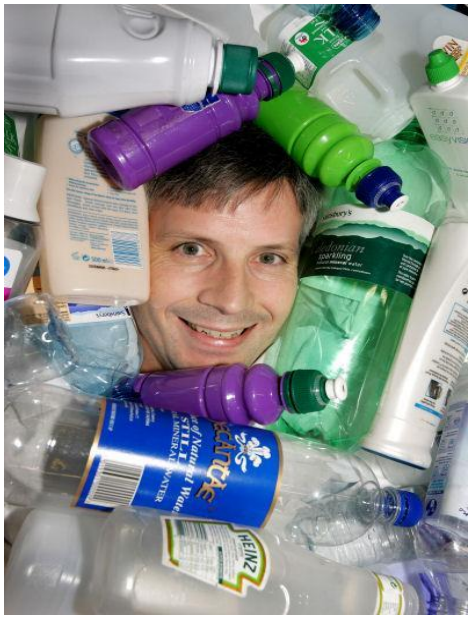
Questions?

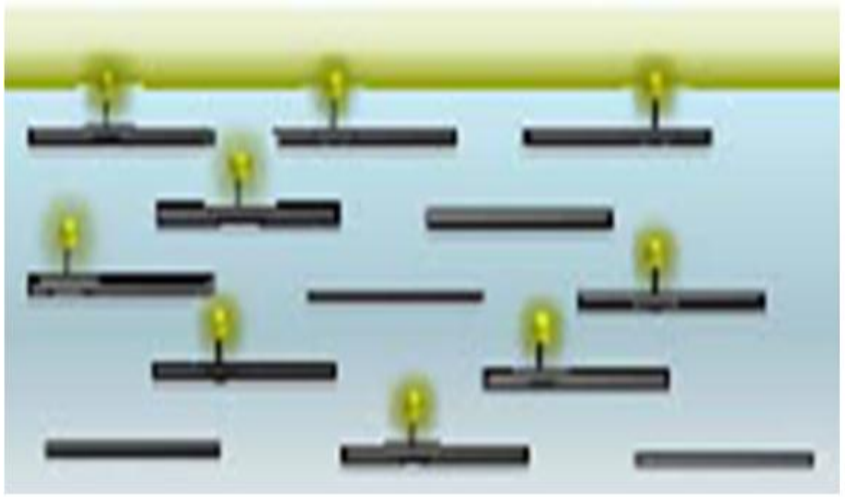
Please type all questions into the Chat Box

Example: Better Packaging

Example: Better Plastics and Polymers

Plastics and Polymers



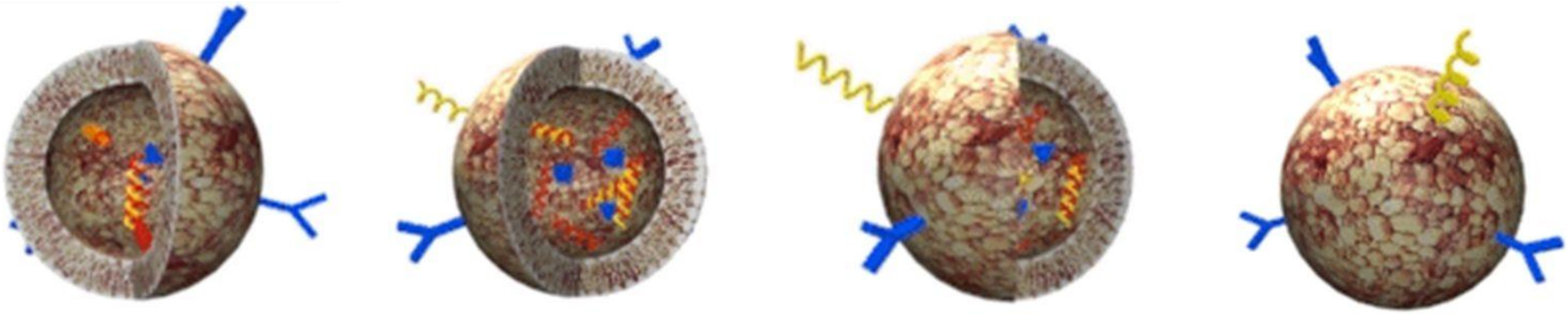


Courtesy Dr. ir. Marcel H. Van de Voorde,
University of Technology, Delft
The Netherlands

Example: Better

Research and
Advanced Engineering

Better Imaging Tools for Basic Biological Research

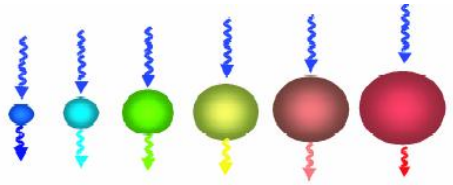


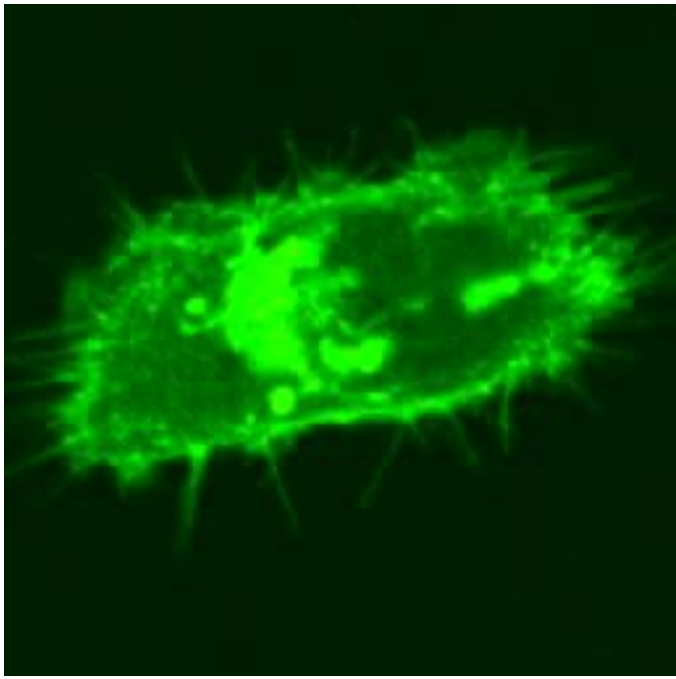
3D Model of a Functionalized Nanoparticle

From Dr. R. Rezka, MDC, Berlin

Using **Nanotechnology** to Study Cancer Cell Structure

In this movie, Hela cancer cells, genetically engineered so that protein in EGF receptor fluoresces in the green, are seen to be taking up the human growth peptide EGF. The EFG is tagged in the movie with red-fluorescing quantum dots so we can follow its movement. This taking up of EFG occurs at EGF receptors on filopodia which are extending from the cell wall. Before this work, it was not known that EGF receptors are positioned out on such extended filopodia in cancer cells. This is not the case in normal cells.





Lidke, D. S.; Jovin, T. M., et al. Nature Biotech. ***2004****, 22, 198*

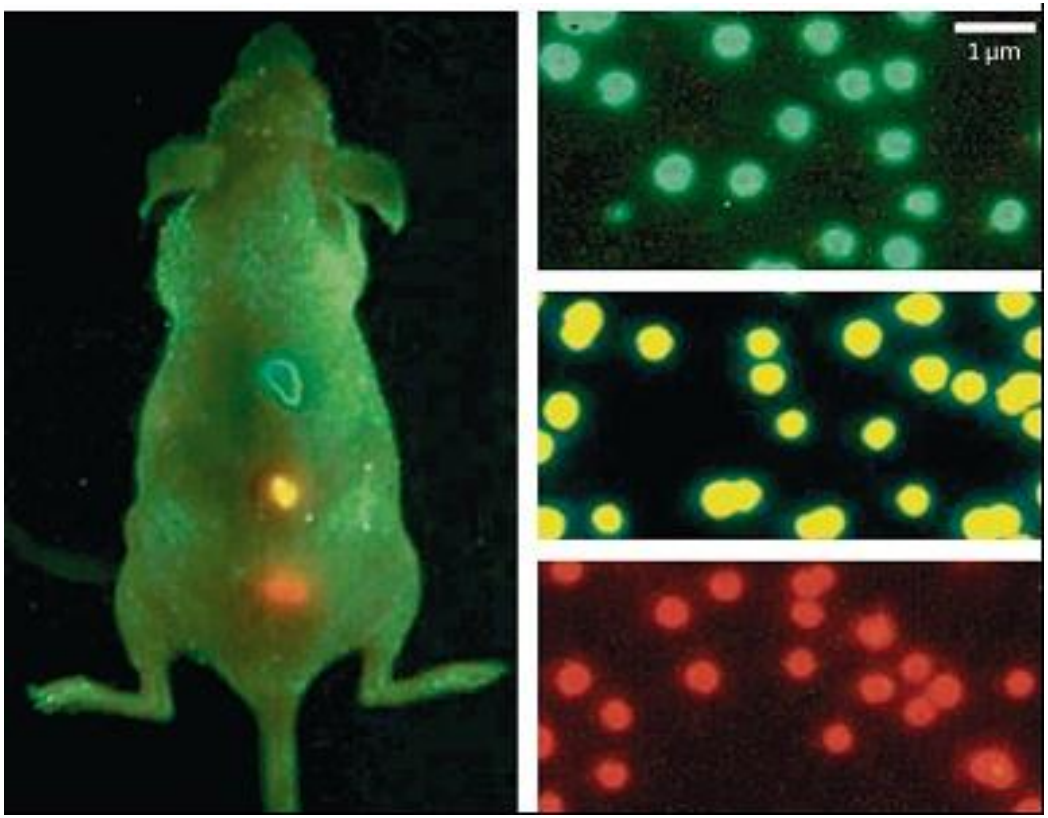
We now know this is how cancer cells can grab more than their share of the EGF peptide.

Functionalized Nanoparticles for Medical Applications

Nanoparticles for Better Fluorescence Imaging of Tumors

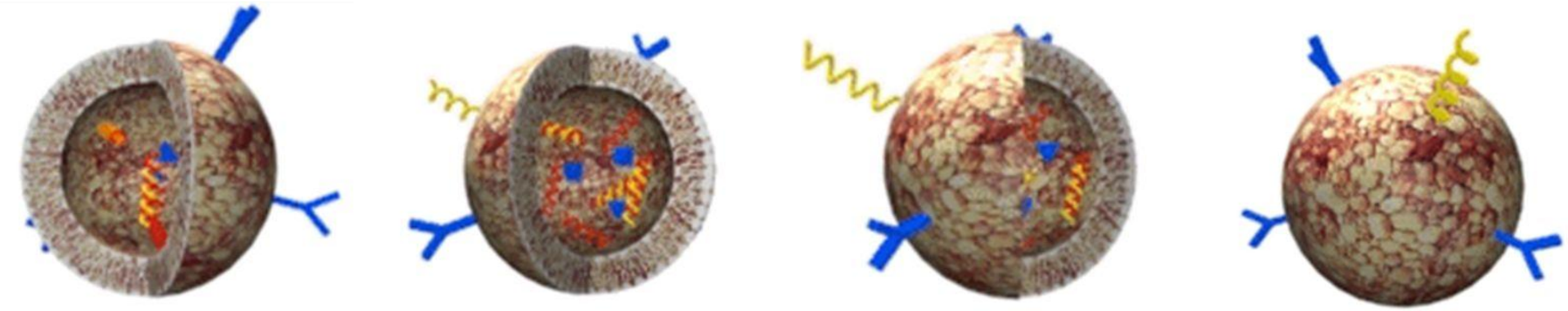
Fluorescent Nanoparticles

QD's can be functionalized to go to different types of tumors and then be used for Fluorescence Imaging of the tumor.



Yezhelyev, Emerging use of nanoparticles in diagnosis and treatment of cancer

Example: Functionalized Nanoparticles for Better Drug Delivery



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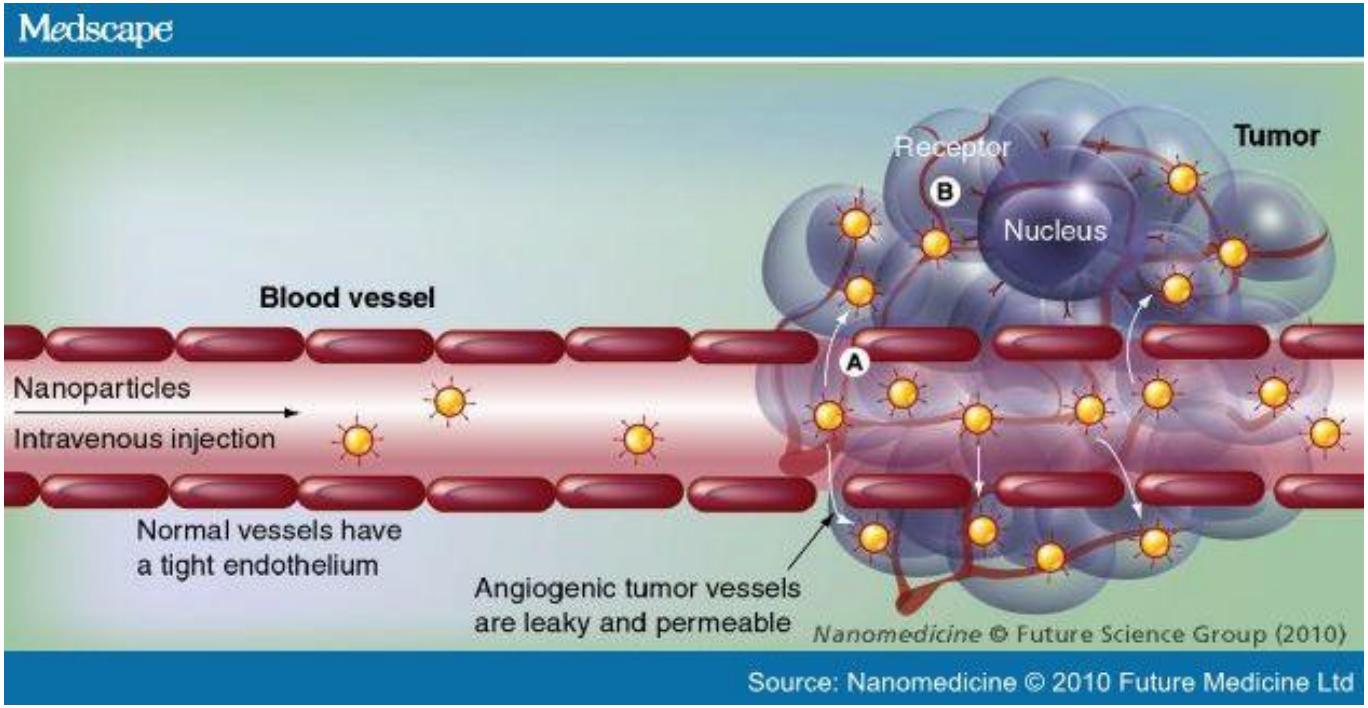
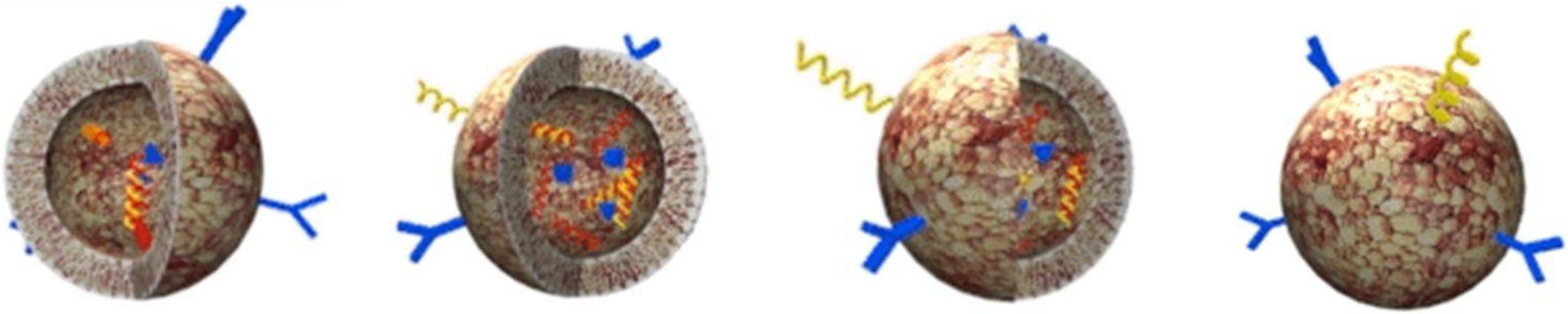
Active Tumor Targeting by Nanoparticles



The ligands (green triangles) on the surface of the nanoparticle fit into the cell receptors, allowing encapsulated drug molecules to enter the tumor cell after binding.

Example: Functionalized Nanoparticles for Cancer Radiation Treatment



3D Model of a Functionalized Nanoparticle

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Nanotechnology Examples – In Our Lives Today

Project on Emerging Technologies - partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts

The project is dedicated to helping ensure that, as nanotechnologies advance, possible risks are minimized, public and consumer engagement remains strong, and the potential benefits of these new technologies are realized.

www.nanotechproject.org

Examples of the information on this site:

- Site has products information at
  http://www.nanotechproject.org/inventories/consumer/
- Site has medical applications information at

  http://www.nanotechproject.org/inventories/medicine/apps/imaging/trilite_technology/

Can there be Dangers with Nanotechnology ?

Yes, care must be exercised with every new technology

There are dangers with <u>any</u> technology

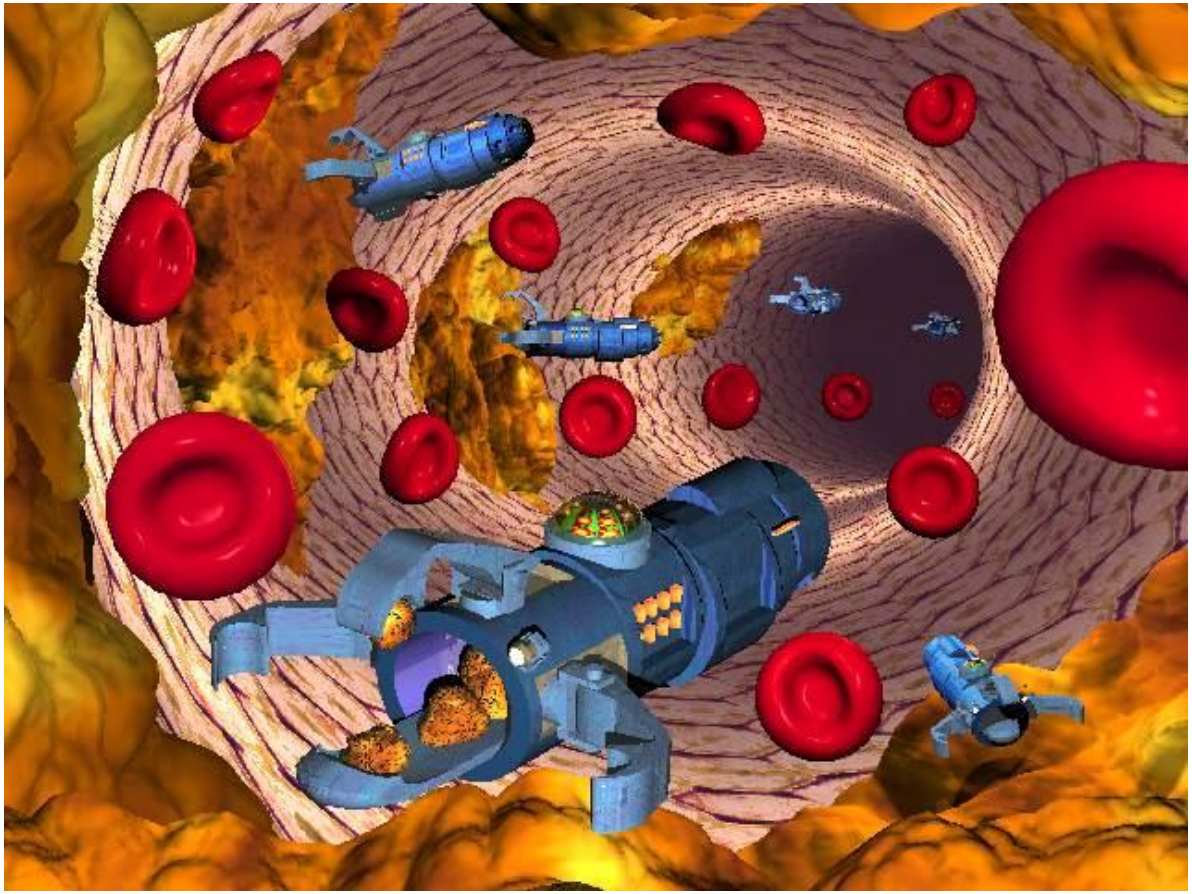
An Example: Fire—a technology we have been using for a long time

- On average in the United States in 2008, someone died in a fire about every 158 minutes, and someone was injured every 31 minutes
- Four out of five U.S. fire deaths in 2008 occurred in homes (Karter 2009)
- In 2008, fire departments responded to 403,000 home fires in the United States, which claimed the lives of 2,755 people (not including firefighters) and injured another 13,560, not including firefighters
- Fire and burn injuries cost $7.5 billion each year

Source:http://www.cdc.gov/HomeandRecreationalSafety/Fire-Prevention/fires-factsheet.html

Are all the Wonderful Things People are Saying About Nanotechnology Possible?

No, there are lots of things that are not feasible with nanotechnology
(at least not now)



"In this fanciful and colorful image, nanorobots are cleaning fatty deposits from the inside wall of an arteriosclerotic artery."

Tim Fonseca's Digital Paintings: http://artistnano.com/. "Speculative Nanobots": http://artistnano.com/speculativenanobots.html

What does Nanotechnology have to do with society and our lives ?

Top 10 World Issues

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism and war
7. Disease
8. Education
9. Democracy
10. Population

MRS Bulletin 2005, 30(6), 412.

Nanotechnology is 21st Century Materials and Manufacturing Technology

How Can We Better Serve You?

Whether you are joining us live or watching the recorded version of this webinar, please take 1 minute to provide your feedback and suggestions.

http://questionpro.com/t/ABkVkZLhD2

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Introduction to Nanotechnology