

Basics of Nanotechnology

created by
Antonio Šiber
2003.

erythrocyte
(6000 nm)

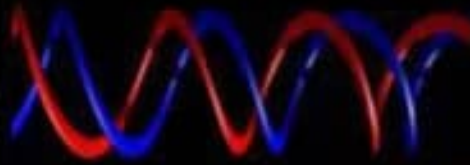


hand (10 cm)



Earth (10000 km)

DNA
(2.5 nm)



10^{-15}

10^{-9}

10^{-5}

10^{-1}

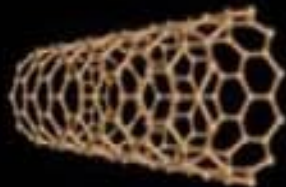
10^3

10^7



proton

(hydrogen nucleus, 1 fm)



carbon nanotube
(1 nm)

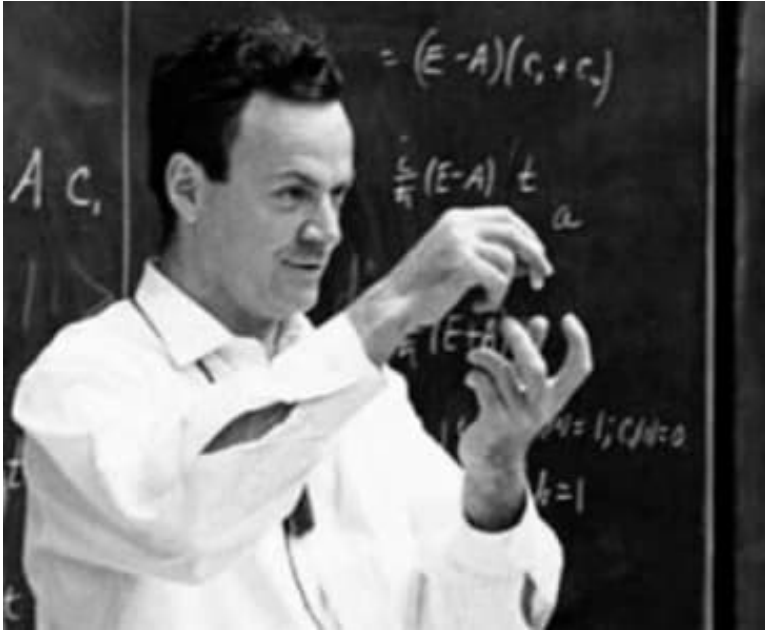


hydrogen atom
(0.1 nm)



CD (10 cm)

Richard Feynman: Father of Nanotechnology




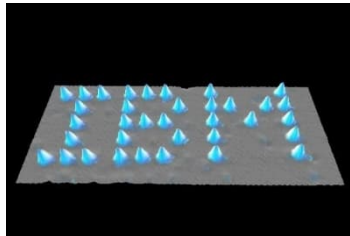

In 1959, the late Nobel Prize – winning physicist **Richard P. Feynman** presented a talk entitled “**There’s Plenty of Room at the Bottom**” at the annual meeting of the American Physical Society.

Feynman proposed using machine tools to make smaller machine tools, which, in turn, would be used to make still smaller machine tools, and so on all the way down to the molecular level.

Richard P. Feynman (Nobel prize in QED 1965)

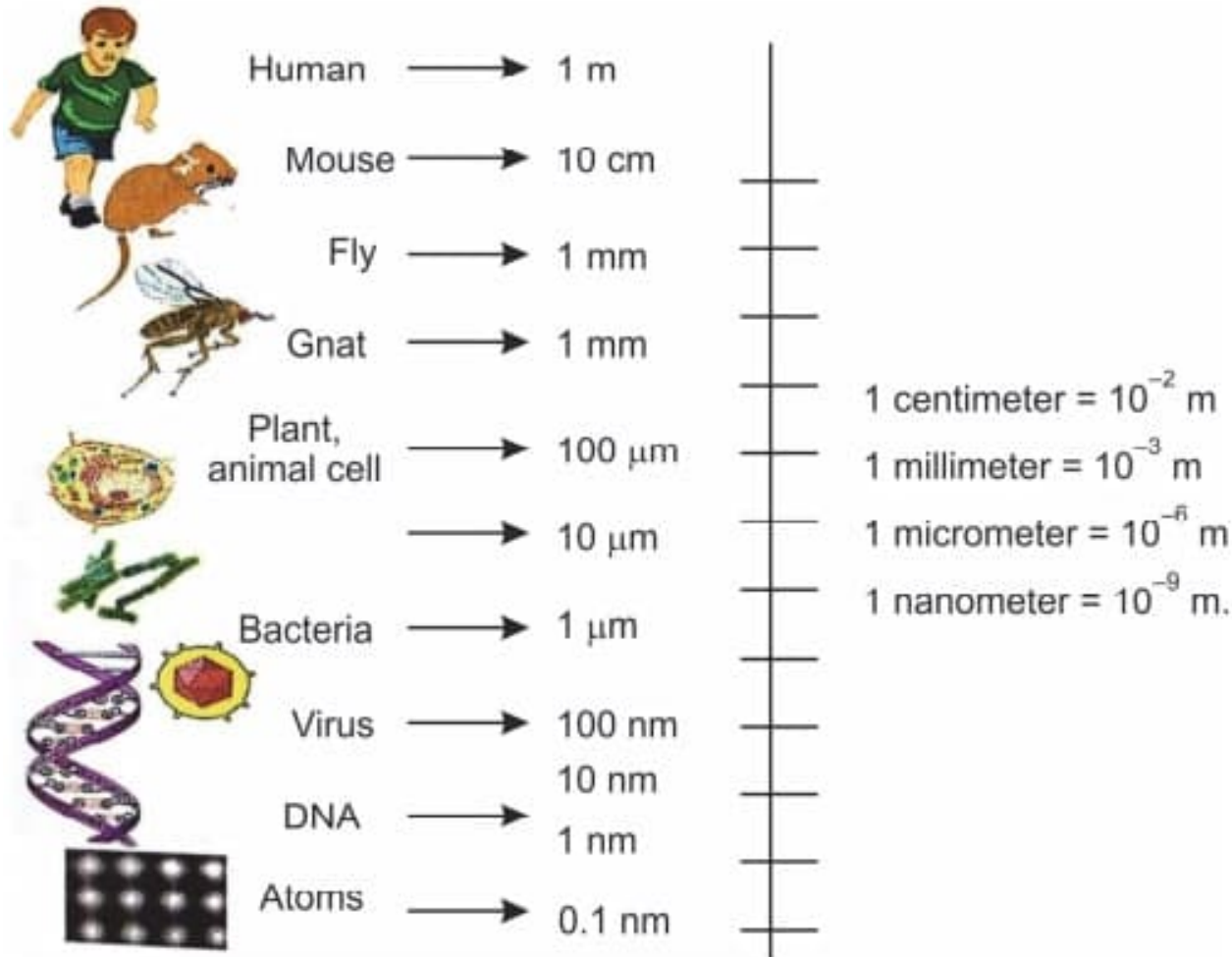
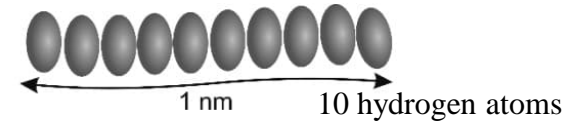


History of Nanotechnology

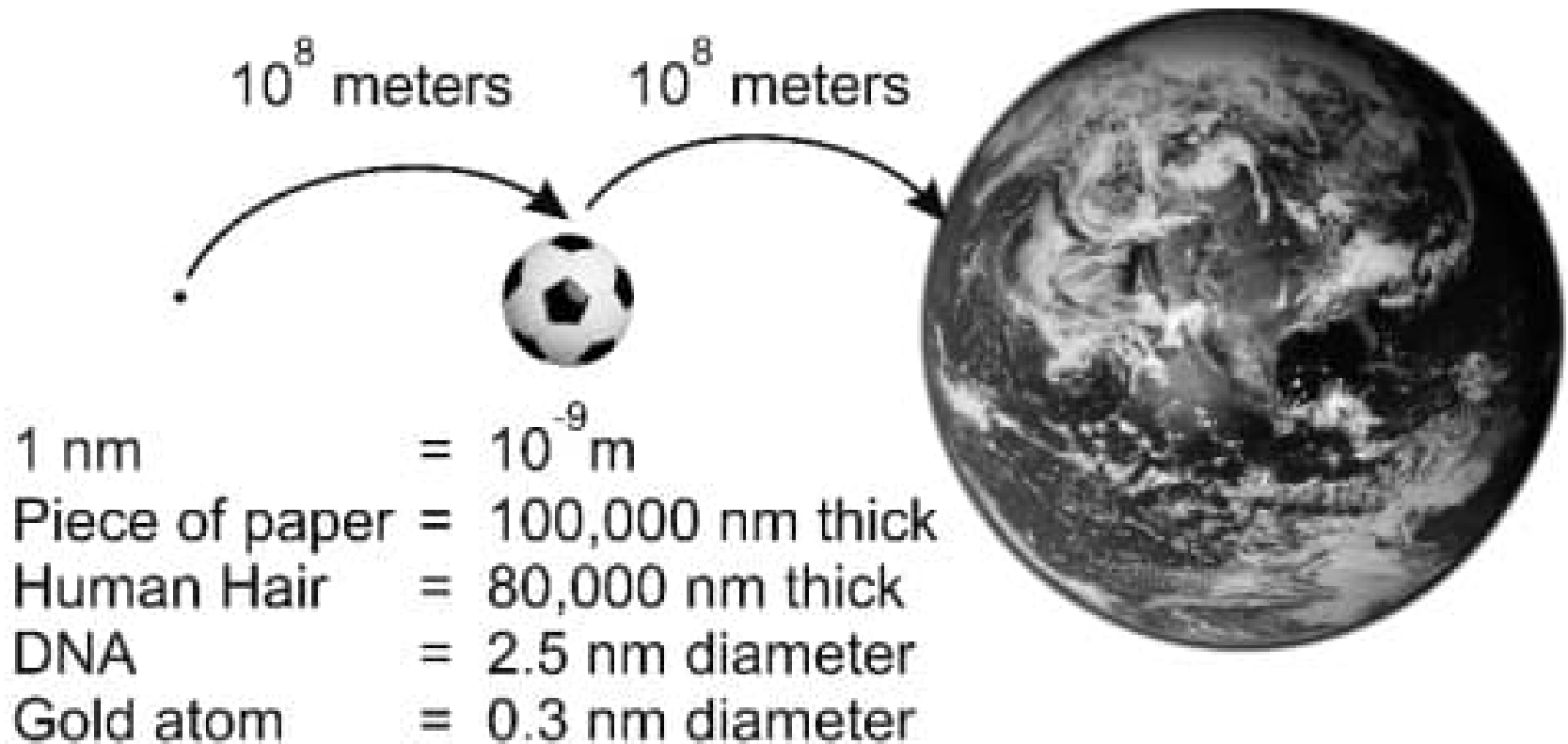
- ❖ 1959 – “There is plenty of room at the bottom” by R. Feynman
- ❖ 1974 – “Nanotechnology” Nori Taniguchi uses the term nanotechnology for the first time
- ❖ 1981 – IBM develops Scanning Tunneling Microscope (Rohrer & Binnig) 
- ❖ 1986 “Engines of Creation: The coming era of Nanotechnology” first book on nanotechnology by K. Eric Drexler
- ❖ 1989 – IBM logo made with individual atoms 
- ❖ 1991 – Carbon nanotube discovered by Sumio Iijima
- ❖ 1999 – “Nanomedicine” – 1st nanomedicine book by R. Freitas
- ❖ 2016 – “Turning molecules into machines” Nobel prize for J.-P. Sauvage, F. Stoddart & B. Feringa 

Definition of Nano

Nano comes from the Greek word “nanos”, meaning “dwarf”, but nano is infinitely smaller than a dwarf. Nano means 10^{-9} .



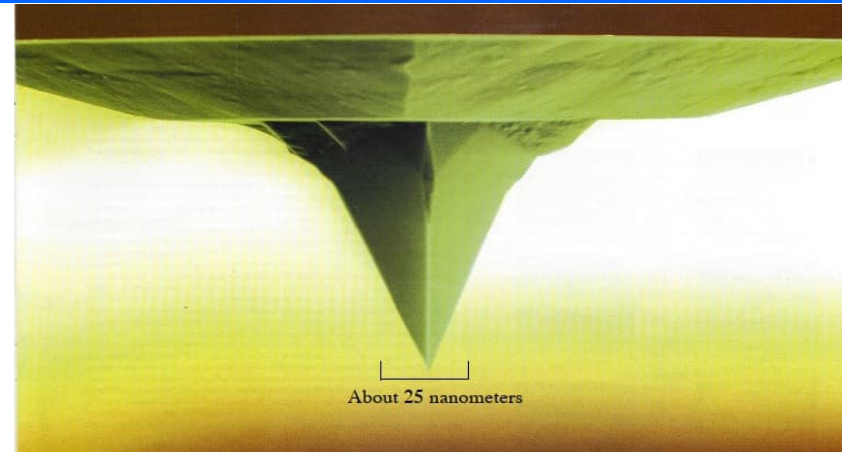
How small is Nano?



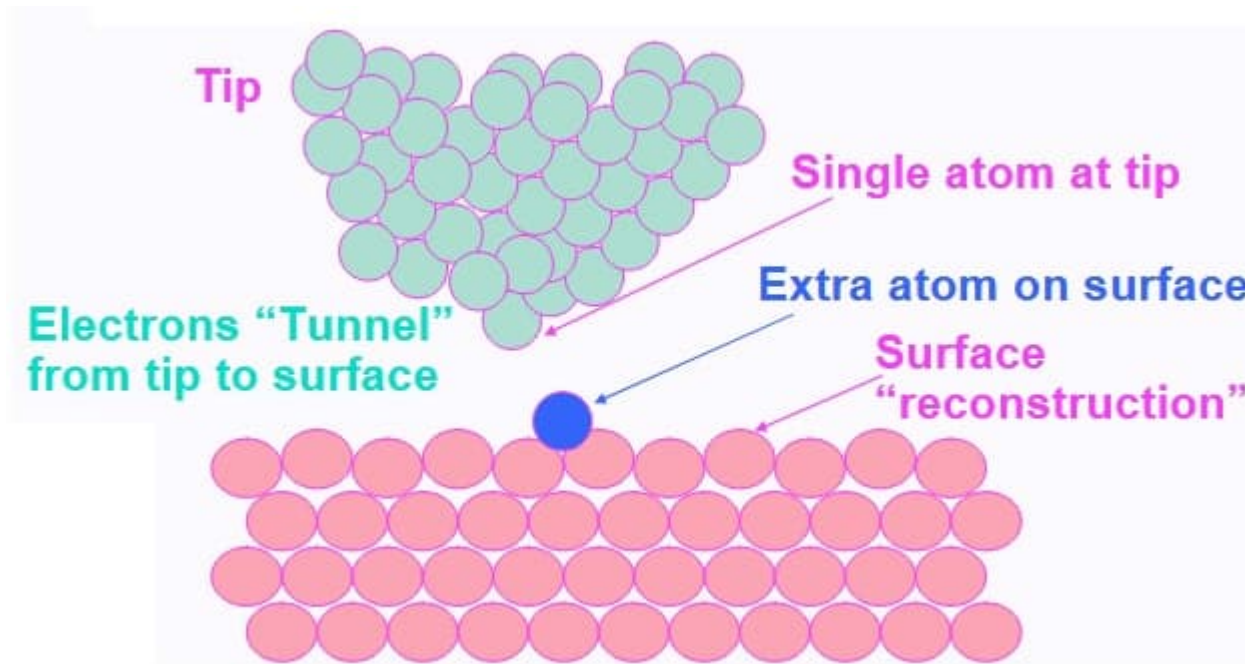
Scanning Tunneling Microscope



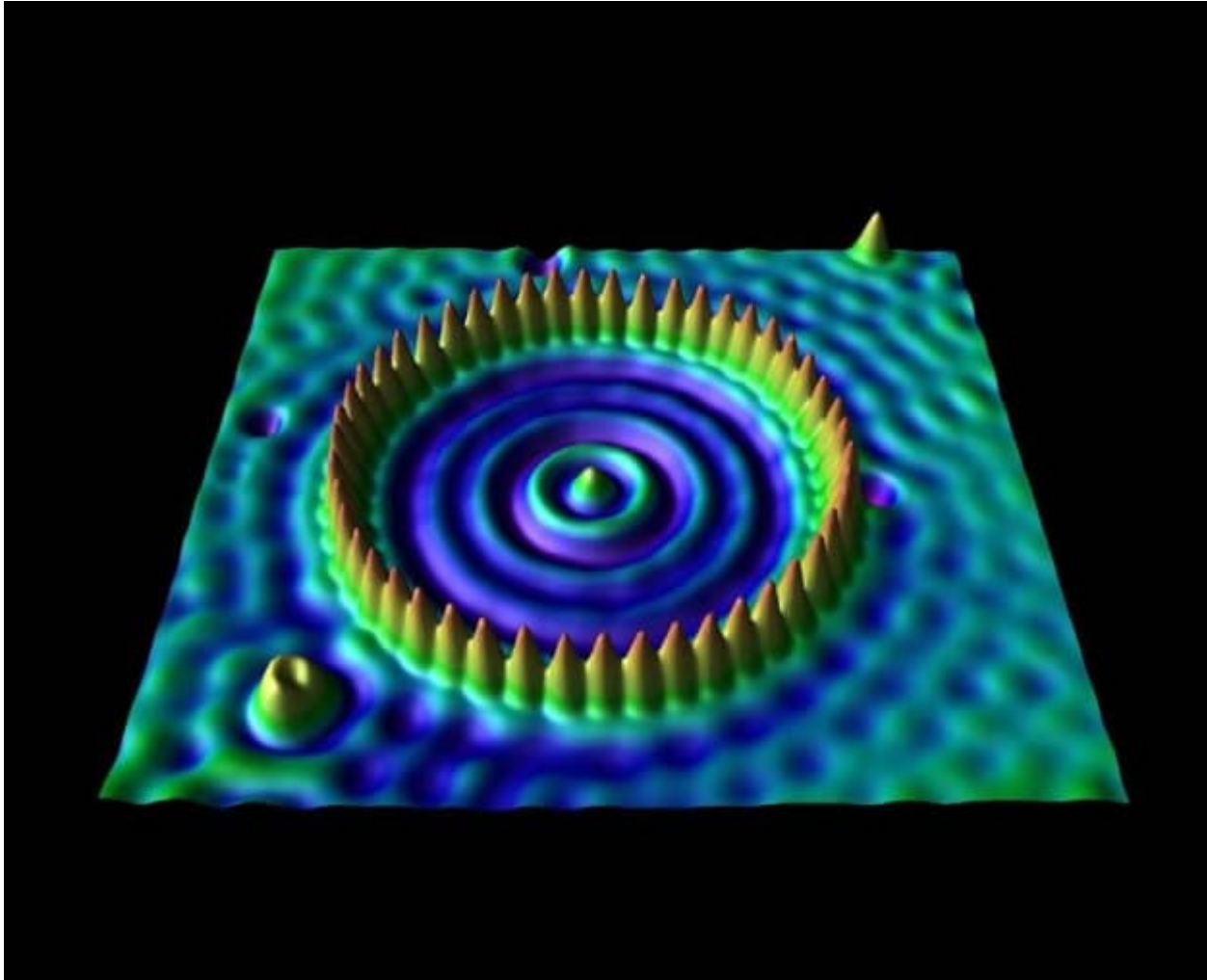
Heinrich Rohrer & Gerd Binnig



Touching the surface



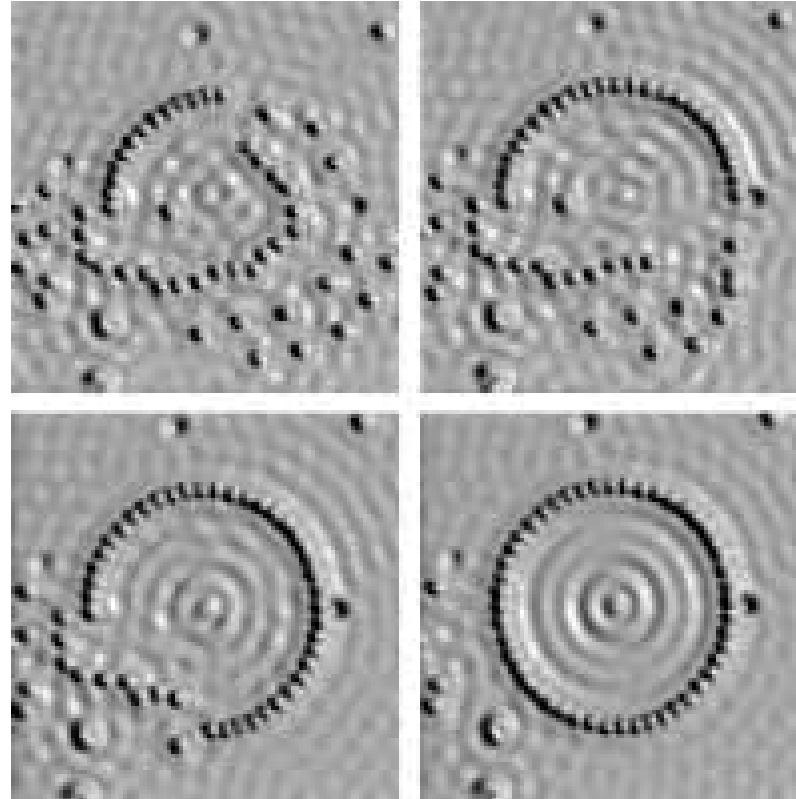
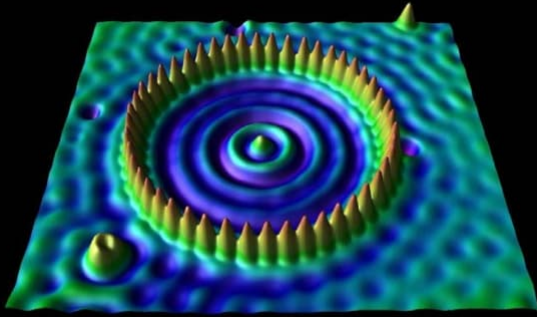
Scanning Tunneling Microscope



Quantum-corrall of 48 Fe-atoms **placed** one at the time **by maneuvering atoms with STM** (*D. Eigler 1993*)

Atomic Force Microscope AFM, 2006

Nano-objects


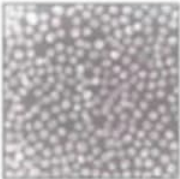

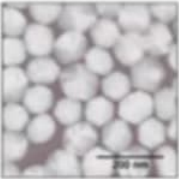

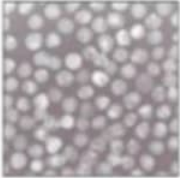

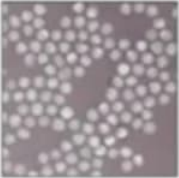

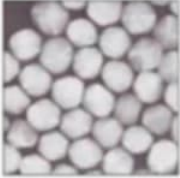




A series of STM images showing formation of a “quantum corral” from 48 Fe atoms absorbed on the surface of Cu (111).

History of Nanotechnology



Lycurgus cup (4th century A.D.)

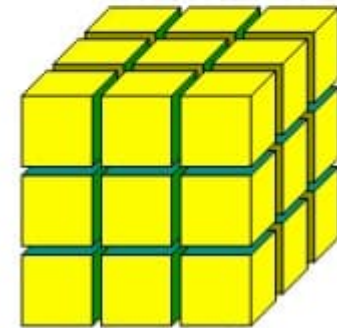
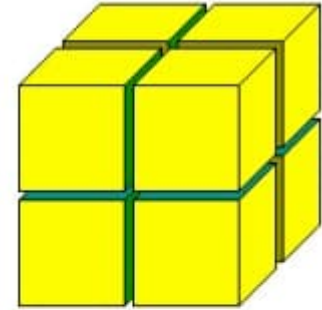
Gold particles in glass		Silver particles in glass	
Size: 25 nm Shape: sphere Color reflected: 		Size: 100 nm Shape: sphere Color reflected: 	
Size: 50 nm Shape: sphere Color reflected: 		Size: 40 nm Shape: sphere Color reflected: 	
Size: 100 nm Shape: sphere Color reflected: 		Size: 100 nm Shape: prism Color reflected: 	

Is nanoscience just seeing and moving really small things?

Properties of materials change at nanoscale!

❖ Cutting down a cube of gold

- If you have a cube of pure gold and cut it, what color would the pieces be?
- Now you cut those pieces. What color will each of the pieces be?
- If you keep doing this – cutting each block in half – will the pieces of gold always look “gold”?



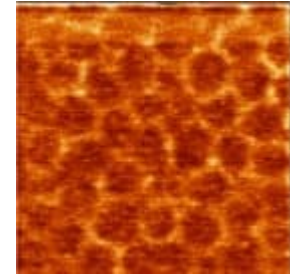
Is Gold always “Gold”?

❖ Strange things happen at the small scale

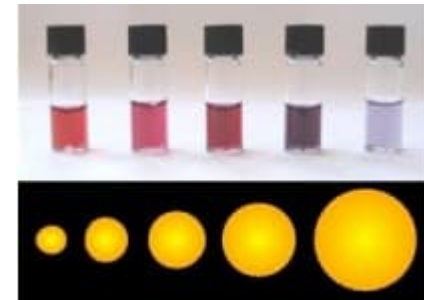
- If you keep cutting until the gold pieces are in nanoscale range, they don't look gold anymore... They look **RED!**
- In fact, depending on size, they can turn red, blue, yellow, and other colors

❖ Why?

- Different thicknesses of materials reflect and absorb light differently

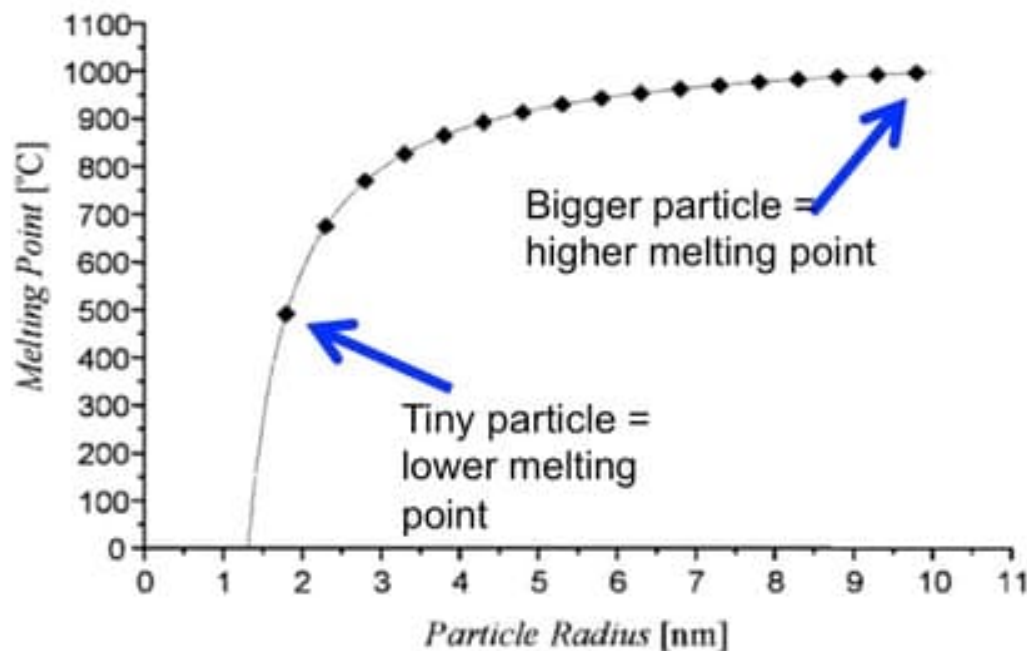
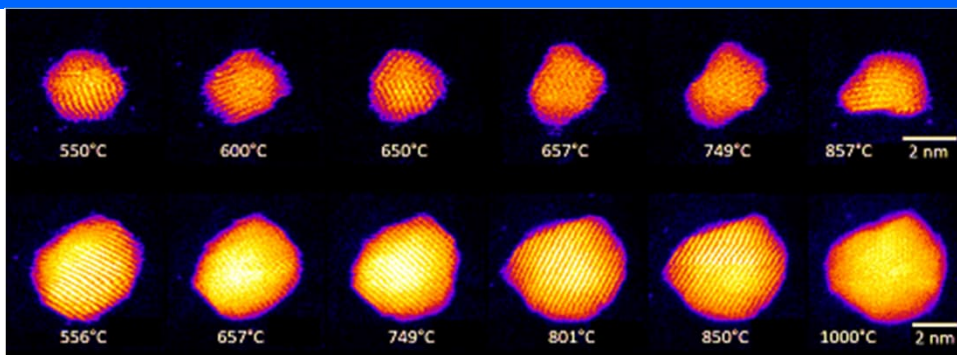


*12 nm gold particles
look red*

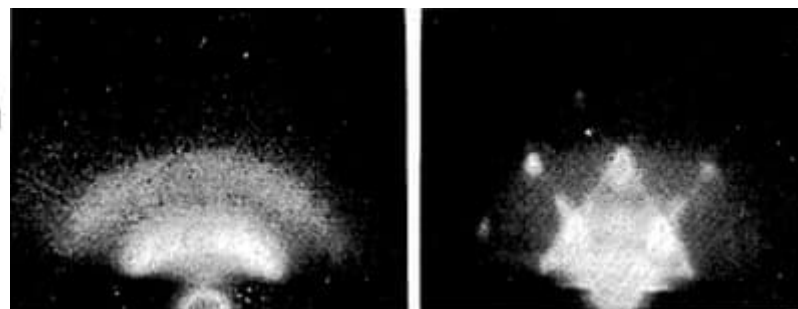


*Other sizes are other
colors*

Particle size and melting point of Gold size matters



diffraction pattern

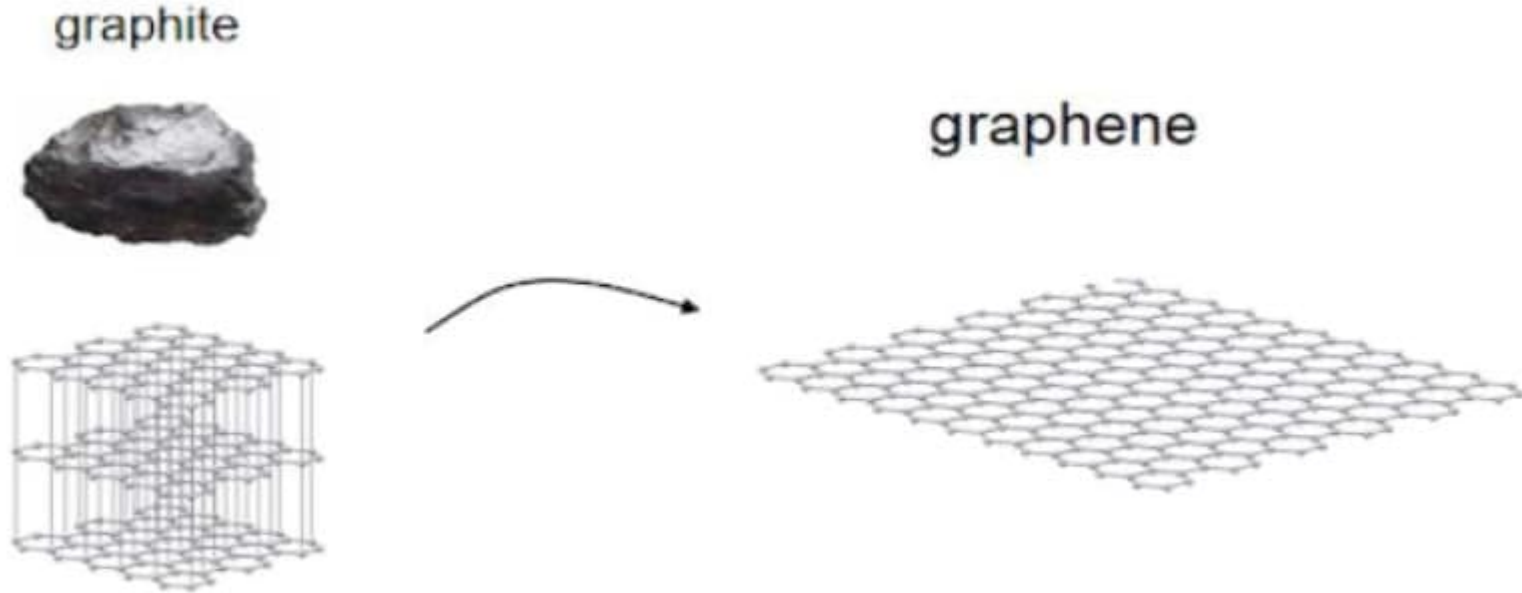


fluid

solid

Gibbs-Thomson equation

Graphite: a layered structure

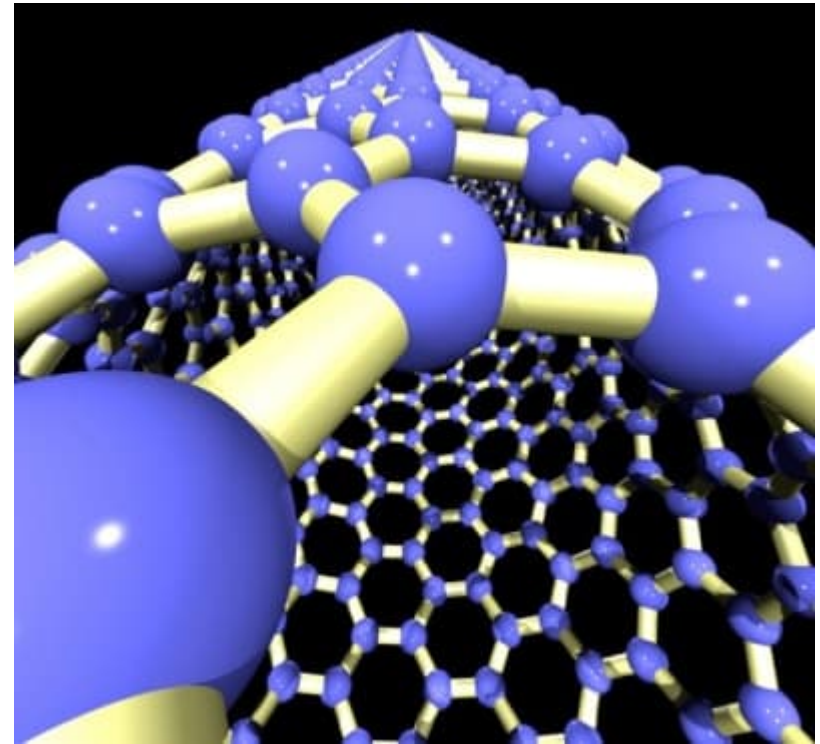


Graphene is one carbon sheet, **singular flat carbon bonds** are very strong which makes Graphene the super-material that it is; **atoms behave different at the nanoscale producing different physical properties.**

- ❖ 200 times stronger than steel
- ❖ 6 times lighter
- ❖ Superconductive
- ❖ Can stretch up to 20% its length
- ❖ Endlessly bend without breaking

❖ **Using new techniques, we've created amazing structures like carbon nanotubes**

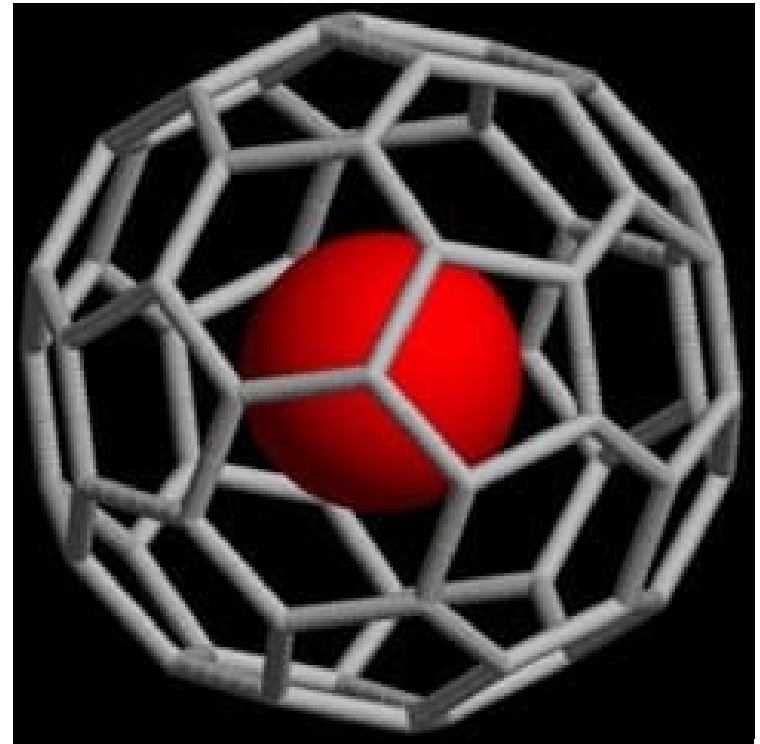
- 100 times stronger than steel and very flexible
- If added to materials like car bumpers, increases strength and flexibility



model of a carbon nanotube

Carbon Buckyballs (C60)

- ❖ **Incredible strength due to their bond structure and “soccer ball” shape**
- ❖ **Could be useful “shells” for drug delivery**
 - Can penetrate cell walls
 - Are nonreactive (move safely through blood stream)



model of a carbon buckminsterfullerene

❖ Atom-by-atom assembly

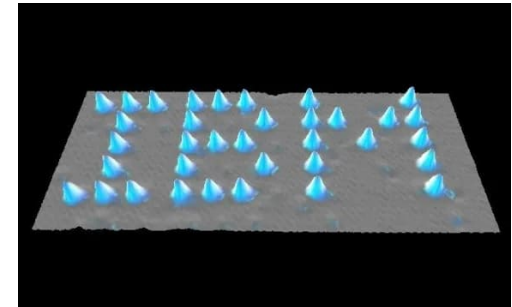
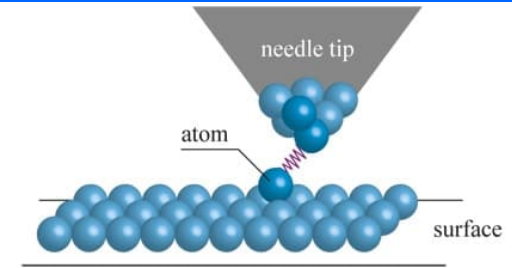
- Like bricklaying, move atoms into place one at a time using tools like the AFM and STM

❖ Chisel away atoms

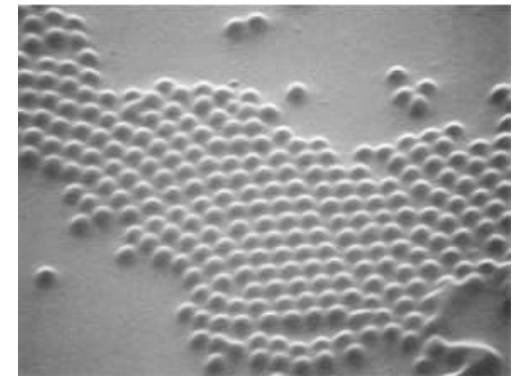
- Like a sculptor, chisel out material from a surface until the desired structure emerges (laser pressure)

❖ Self assembly

- Set up an environment so atoms assembly automatically. Nature uses self assembly (e.g. cell membranes)

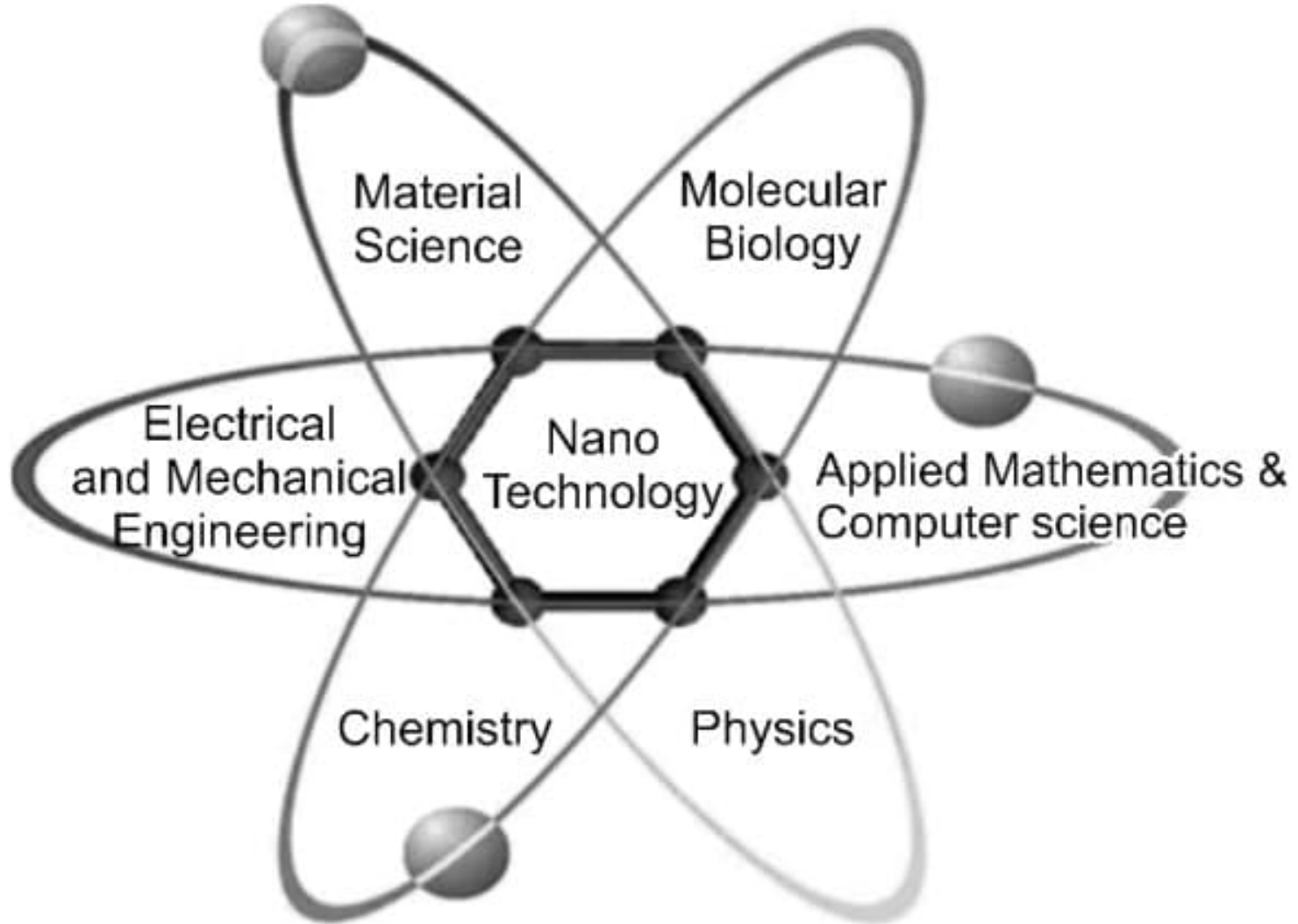


IBM logo assembled from individual xenon atoms



Polystyrene spheres self assembling

Nanoscience multidisciplinary subject



❖ Kinesin

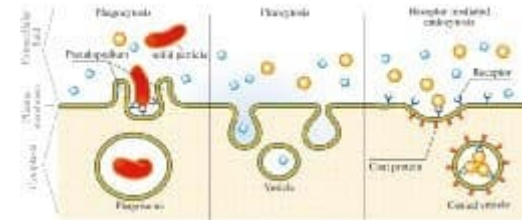
- they mainly carry out transport from the centre of the cell in the direction of the cytoplasmic membrane

❖ Endocytosis

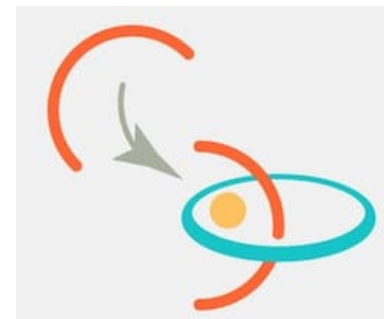
- is the central process in the delivery of nanodrugs and therapeutic genes to a cell

❖ Macromolecule

- examples of linear macromolecules of natural rubber, cellulose, some proteins etc



Biological motors



❖ Jean-Pierre Sauvage

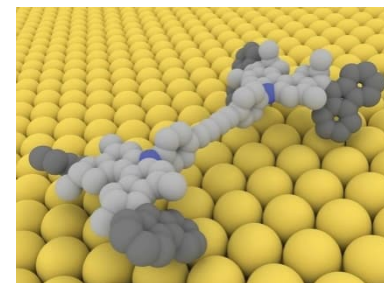
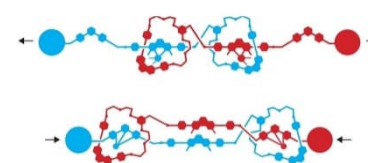
- creation of molecule chains with mechanical connections

❖ Fraser Stoddart

- invented axis, wheel and elevator

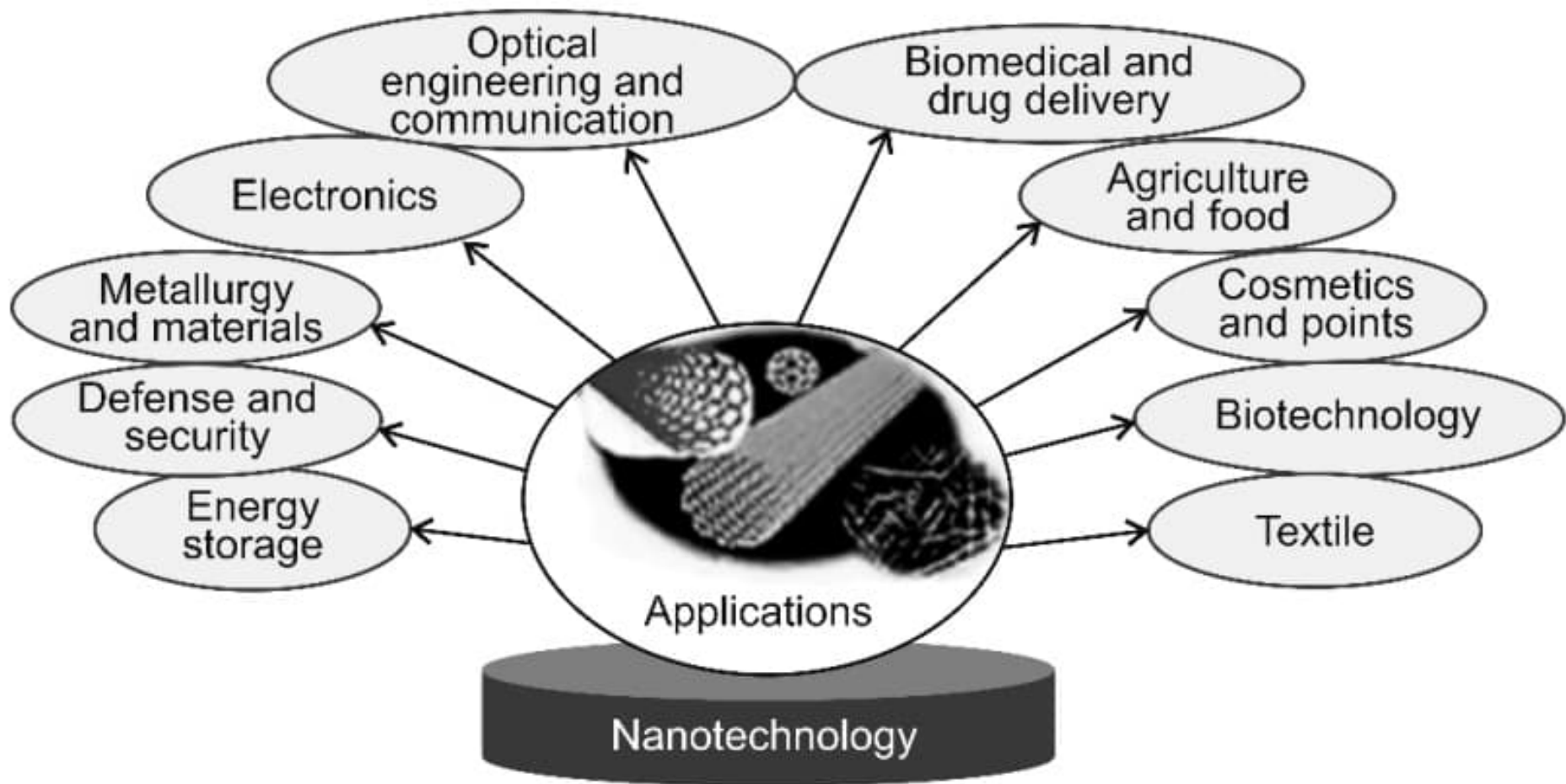
❖ Bernard Feringa

- created an engine and a molecular car



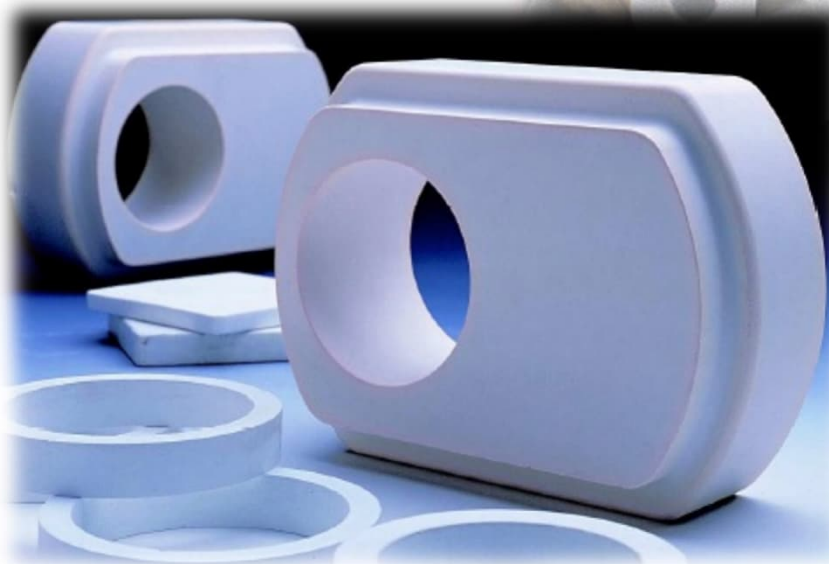
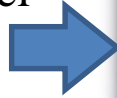
eng.thesaurus.Rusnano.com/wikw/article2193

Applications of Nanomaterials



Nanomaterials manufacturing

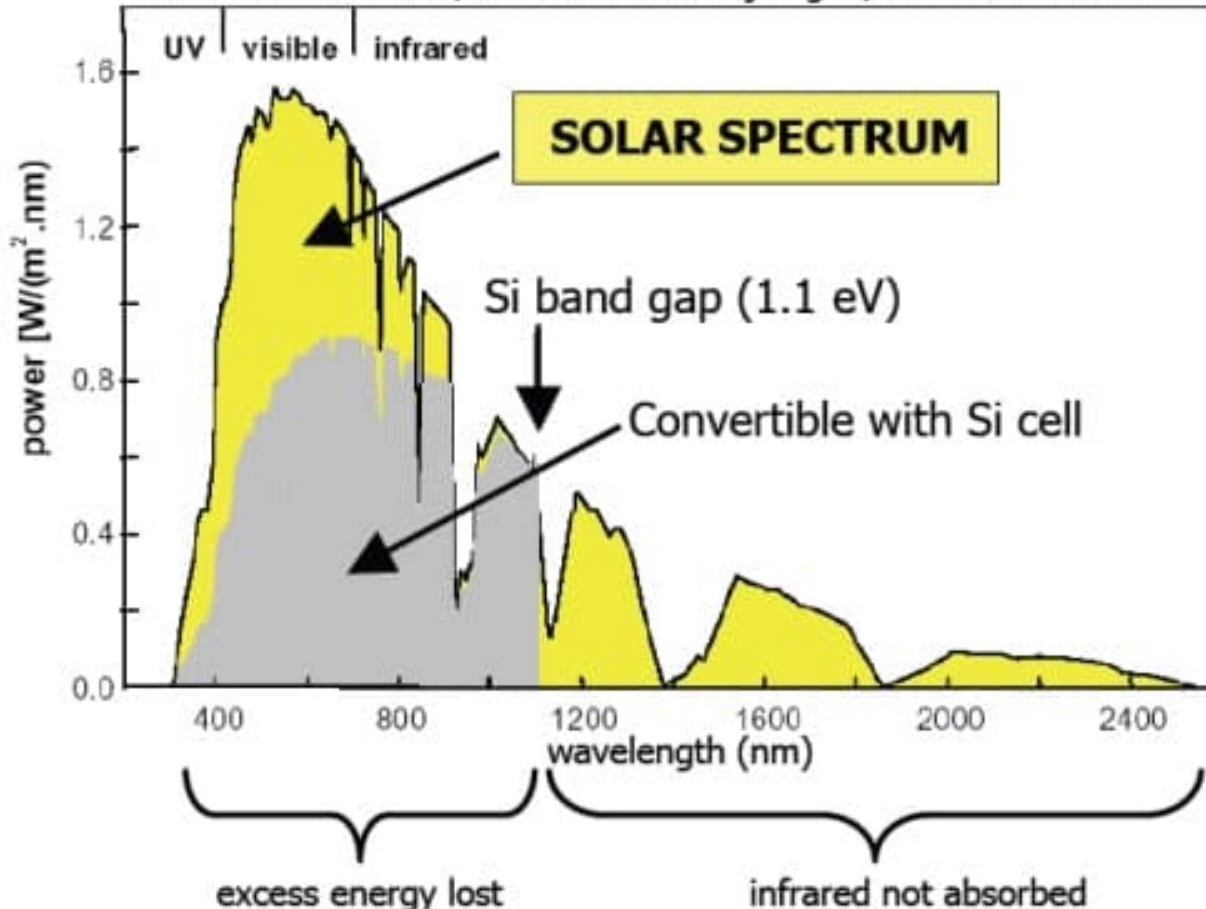
- Carbon Nanotubes
- Nanostructure Polymers
- Optical fiber performs through sol-gel processing of nanoparticles
- Nanoparticles in imaging systems
- Nanostructure coatings
- Ceramic Nanoparticles for netshapes



Solar Cells - Silicon

Efficiency limited: not all incident solar energy convertible to electricity

From J.J. Schermer, Radboud Univ. Nijmegen, The Netherlands



Efficiency:

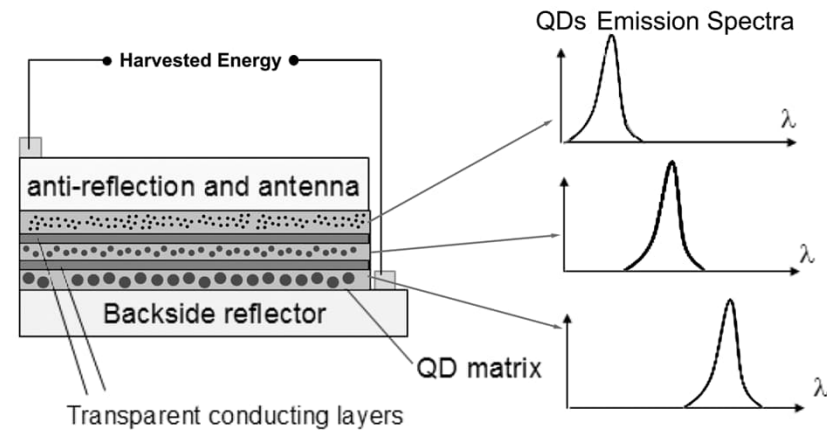
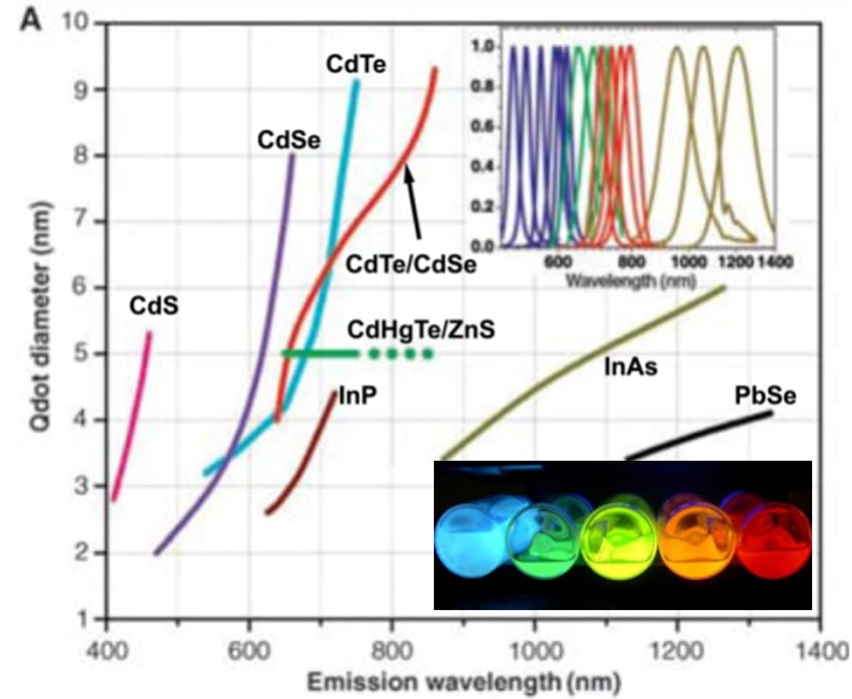
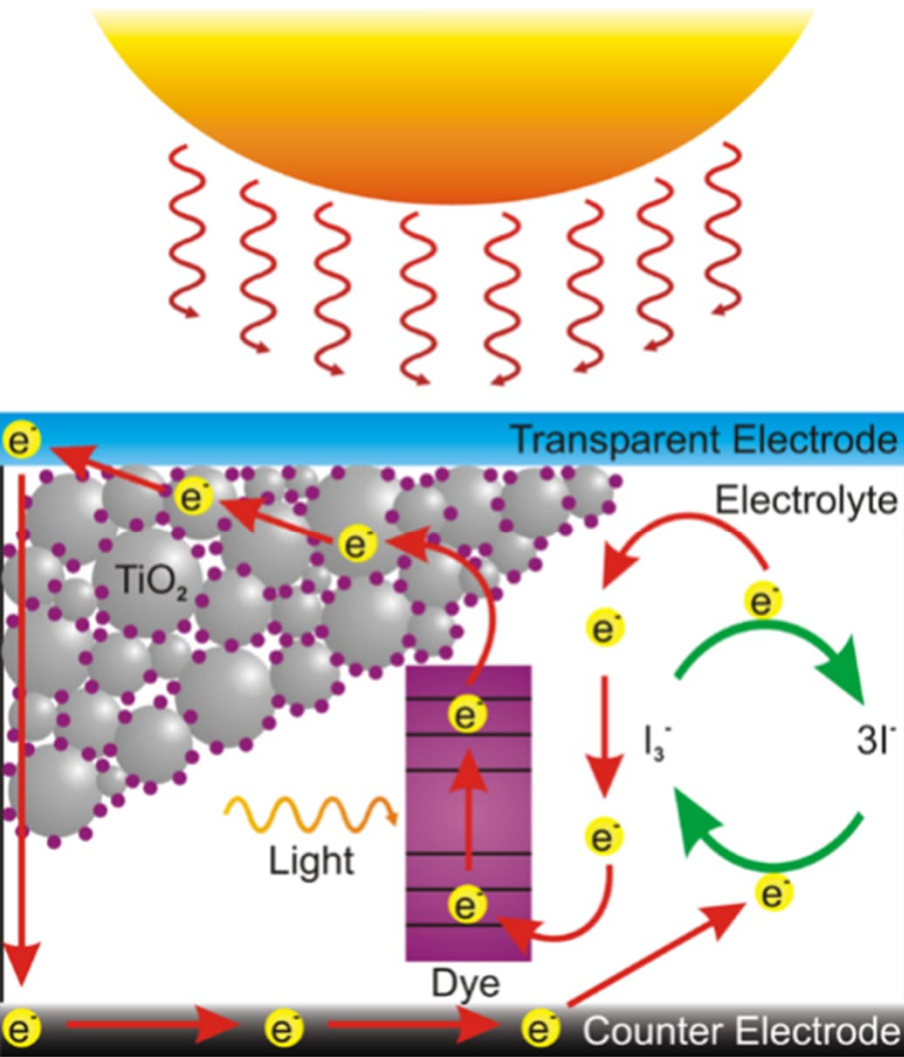
Theor. (AM1.5G)	33 %
Max. achieved	24 %
Usual	15-20 %

Theoretical losses:

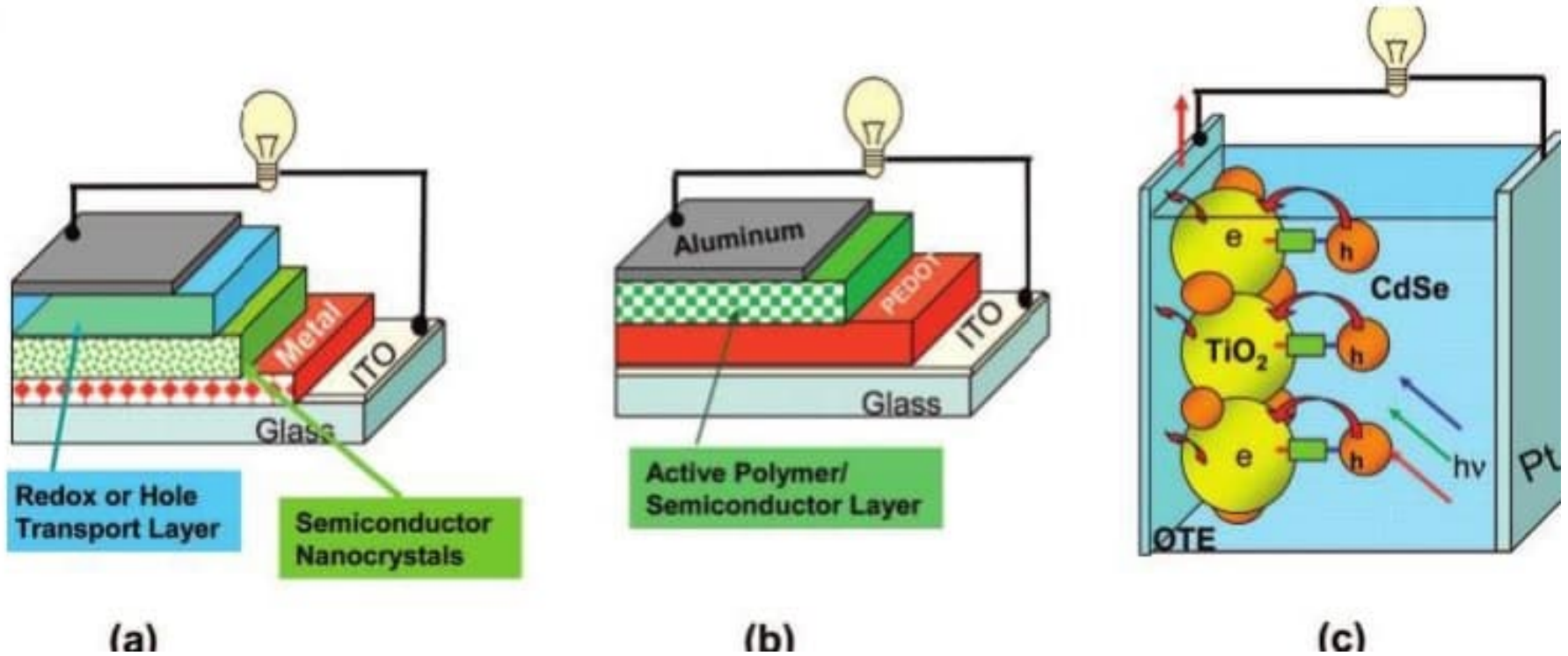
- 47 % thermalization
- 18 % not absorbed IR
- 2% rad. recombination/
thermodynamic loss

Solar Cells – Harvesting of Light

Dye-sensitized Solar Cells w/ TiO_2



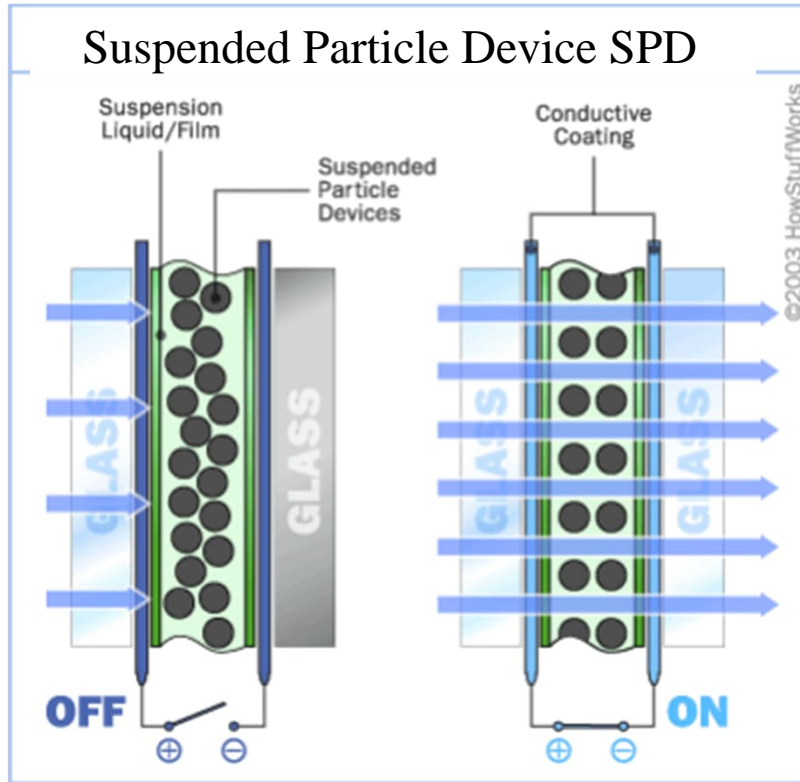
Quantum Dot Solar Cells – Semiconductor Nanocrystals as Light Harvesters



The strategies to develop QD based on solar cells: (a) metal-semiconductor junction (b) polymer-semiconductor, and (c) semiconductor-semiconductor system

Optical Applications – Smart Window

Needle shaped nano-particles of polyiodides



The electric field causes the particle material to polarize /induced electric dipoles)
The induced electric dipoles interact and the particles align in chains with maximizes their attraction

Nanotechnology in Transportation

More efficient catalytic converters

Thermal barrier and wear resistant coatings

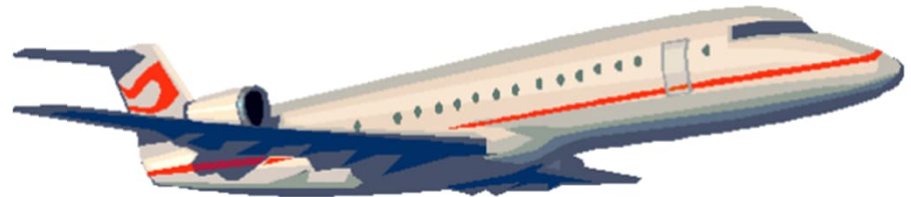
Battery, fuel cell technology

Improved displays

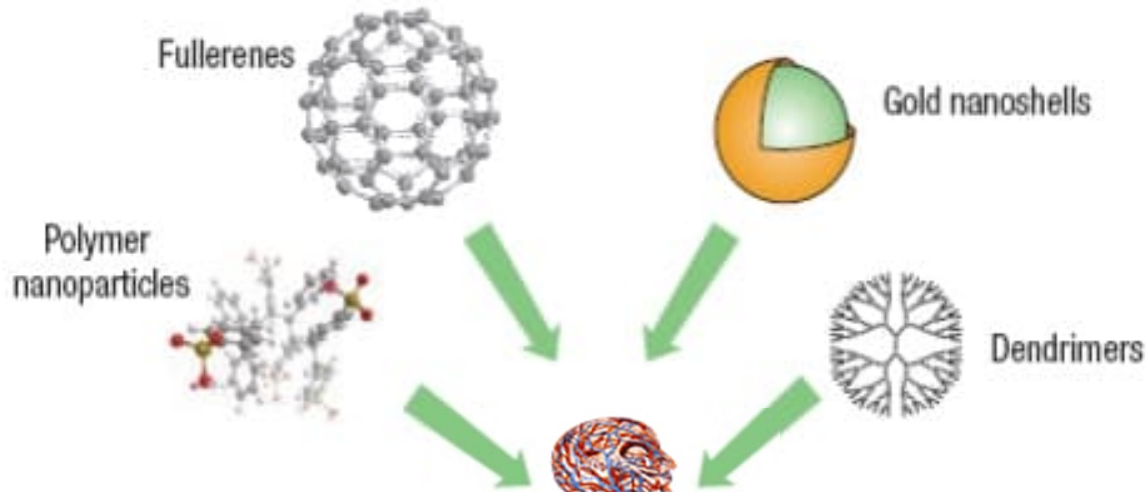
wear-resistant tires

High temperature sensors for 'under the hood' novel sensors for "all electric" vehicles

High strength, light weight composites for increasing fuel efficiency



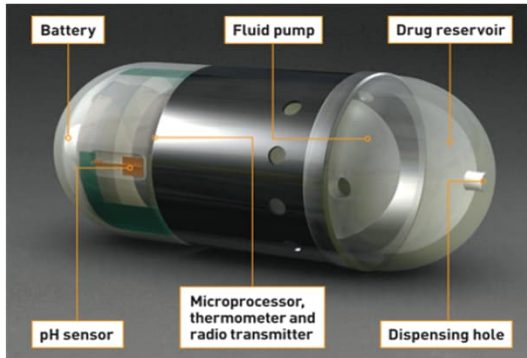
Nanomedicine



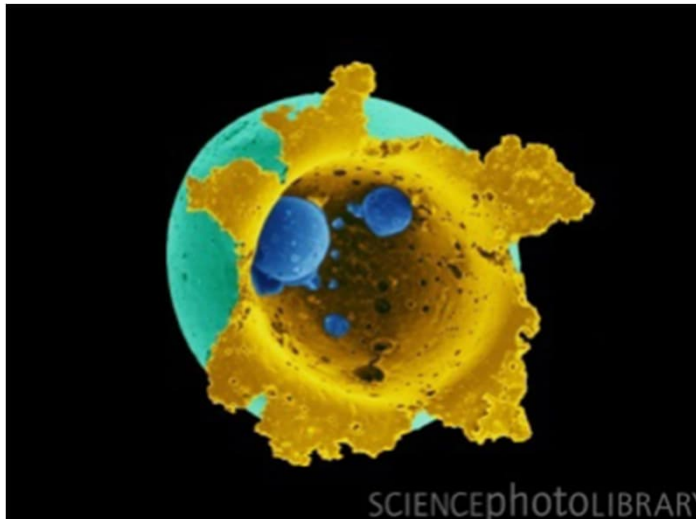
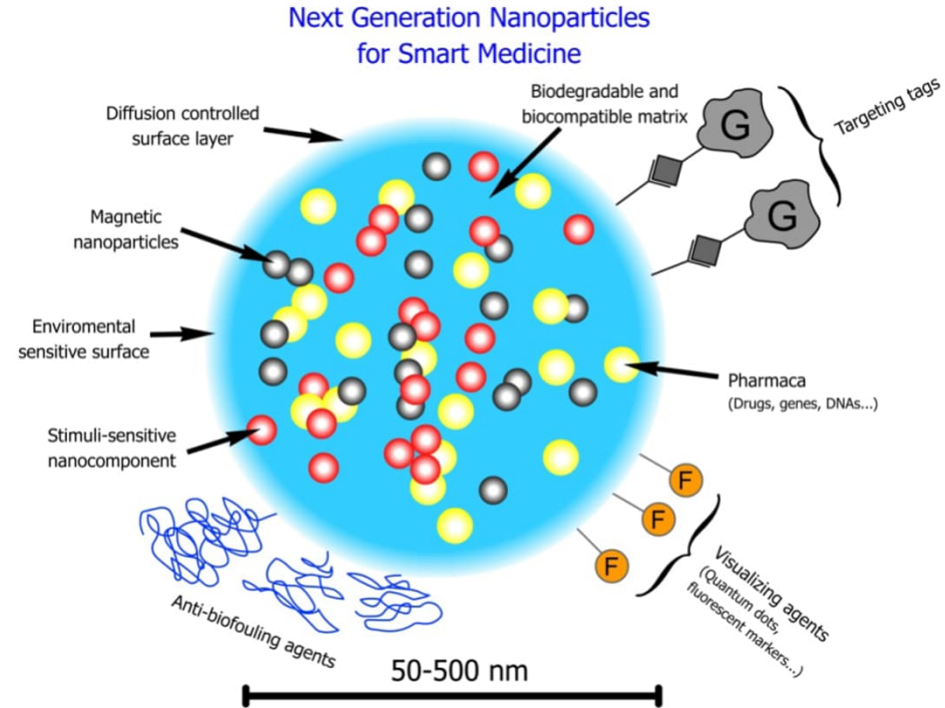
- Fast and more efficient biosensors
- Targeted drug delivery to specific cells
- Novel cancer therapy and hyperthermia treatments

- Magnetic resonance imaging enhancement
- Single cell study and bio-manipulation
- Novel diagnostic tools for early stage detection of diseases

Nanomaterials in biology and medicine



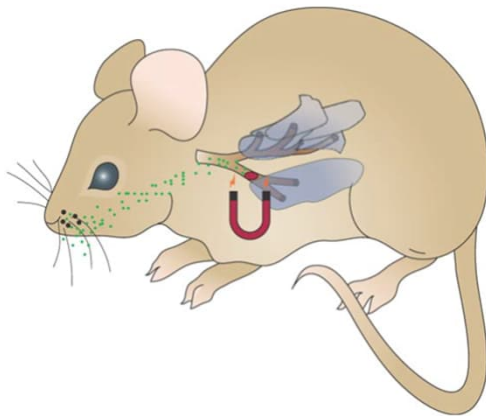
Pill is designed to deliver medicine



Targeted drug delivery using a multicomponent nanoparticle containing therapeutic as well as biological surface modifying agent

Drug Delivery

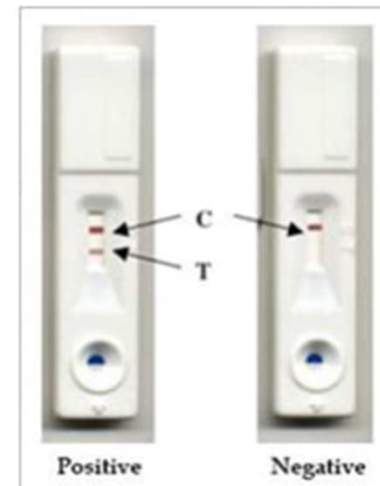
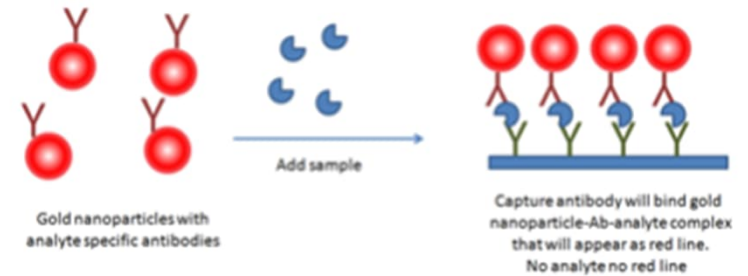
Magnetic-field guided drug delivery with magnetic aerosols



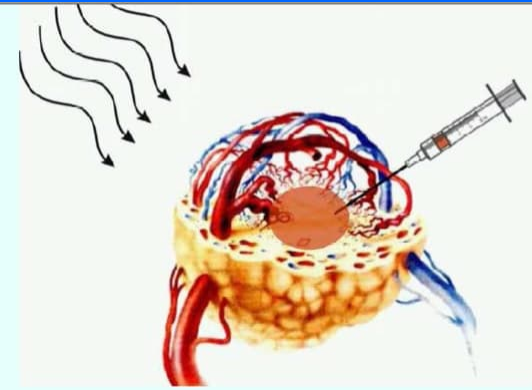
Nature Nanotechnology 2 (2007), 467

Detection

Pregnancy test based on Au colloids surface plasmon absorption of Au Nps

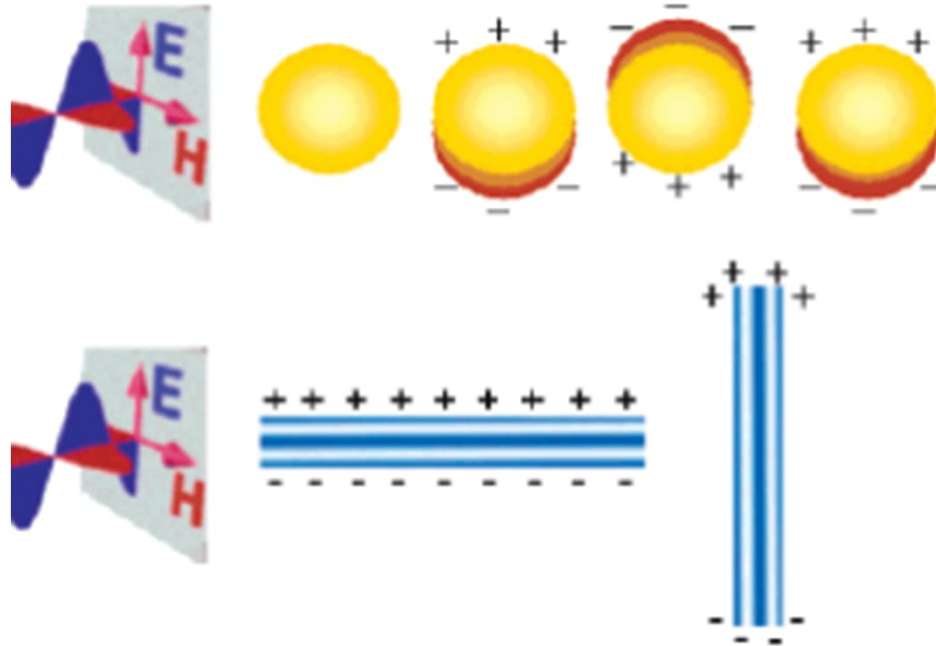


Nano-Therapeutics: Hyperthermia

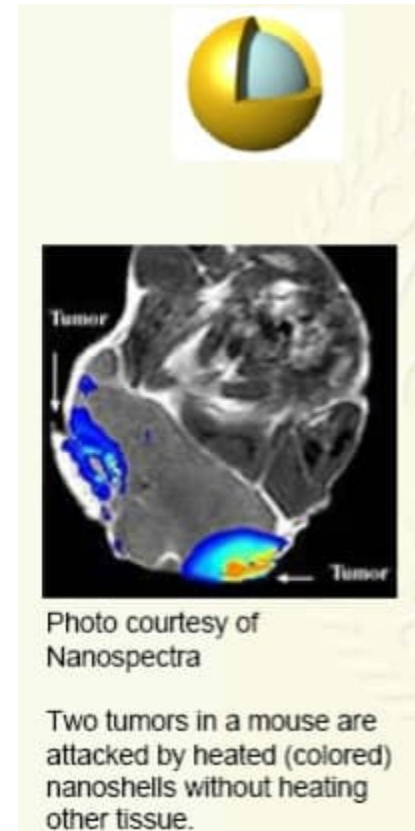


injectable magnetic implants

interaction of an electromagnetic radiation
with metal nanostructures



plasmonics



Electron microscope image of a complex mechanical clutch, part of one of today's advanced micromechanical systems. The gears shown are just 50 microns in diameter. Source: Sandia National Laboratories.

