INTRODUCTION TO NANOTECHNOLOGY

Lec.1

What is nanotechnology ?

- **"Nano" – From the Greek word "dwarf",**

and means 10-9, or one-billionth of a meter.

1 nm = 1/1000 µm = 1/1000000 mm= 1/1000000000 m.

Nanoscale: having one or more dimensions of the order of 100 nm or less.

Nanoparticle: particle with two or more dimensions at the nanoscale.

A bulk material: should have constant physical properties regardless of its size, but at the nano-scale this is often not the case.

Abbreviations and Size

meter	m	1	$1X10^{0}$
decimeter	dm	1/10	$1X10^{-1}$
centimeter	cm	1/100	$1X10^{-2}$
millimeter	mm	1/1000	$1X10^{-3}$
micrometer	μm	1/1000000	$1X10^{-6}$
nanometer	nm	1/1000000000	$1X10^{-9}$
angstrom	Å	1/10000000000	$1X10^{-10}$

- **Nanoscience - refers to the world as it works on the atomic or molecular scale, from one to several hundred nanometers, its pertain to the synthesis, characterization, exploration, and utilization of nanostructured materials, which are characterized by at least one dimension in the nanometer range.**

- **Nanobiotechnology-"the branch of engineering that deals with things smaller than 100 nanometers (especially with the handling of individual molecules)"**

- Green nanotechnology: It refers to the use of the products of nanotechnology to enhance sustainability.

- **Agglomerate:** Collection of weakly bound particles or mixtures of the two where the resulting external surface area is similar to the sum of the surface areas of the individual components.

The forces holding an agglomerate together are weak forces, for example van der Waals forces, or simple physical entanglement.

- **Aggregate:** Particle comprising strongly bonded or fused particles where the resulting external surface area may be significantly smaller than the sum of calculated surface areas of the individual components.

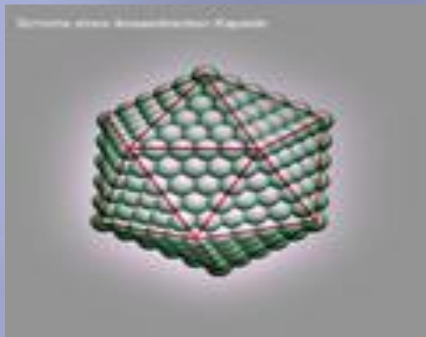
The forces holding an aggregate together are strong forces, for example covalent bonds.

- **Nanotechnology** is Field of science whose theme is the control and manipulation of matter on an atomic and molecular scale to create novel structures, devices and systems .

- Its about creating and using these devices and systems that have novel and better properties and functions because of their small sizes.

Natural Nanomaterials

- Nanoscale materials are found in nature. For instance, hemoglobin, the oxygen-transporting protein found in red blood cells, is 5.5 nanometers in diameter.
- Naturally occuring nanomaterials exist all around us, such as in smoke from fire, volcanic ash, and sea spray, etc.
- The structure viruses (capsid), the wax crystals covering a lotus leaf, spider-mite silk, the "spatulae" on the bottom of gecko feet, some butterfly wing scales, and even our own bone matrix are all natural organic nanomaterials.

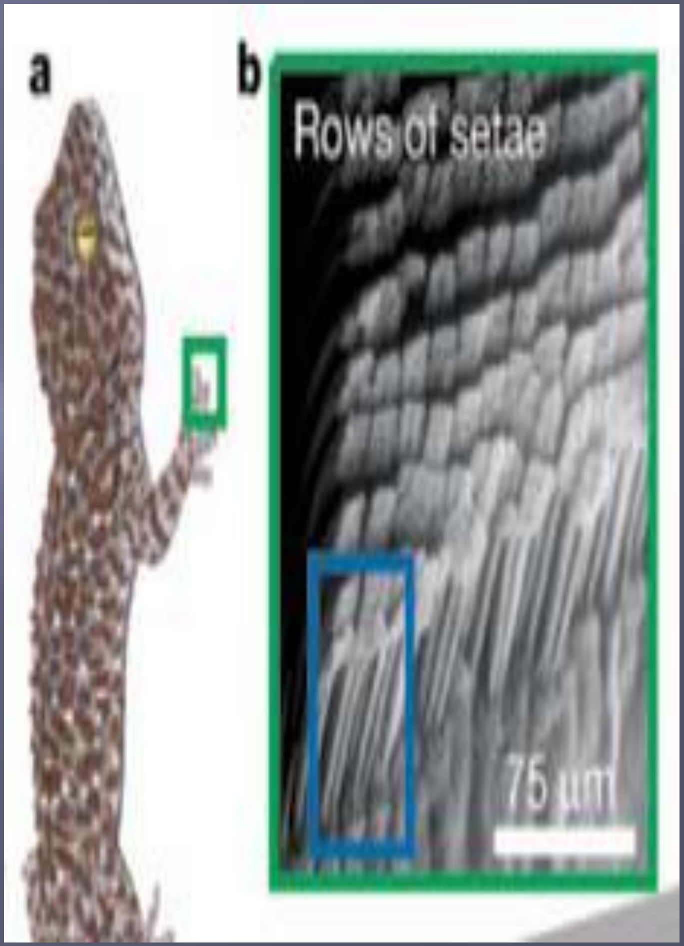


Viral capsid

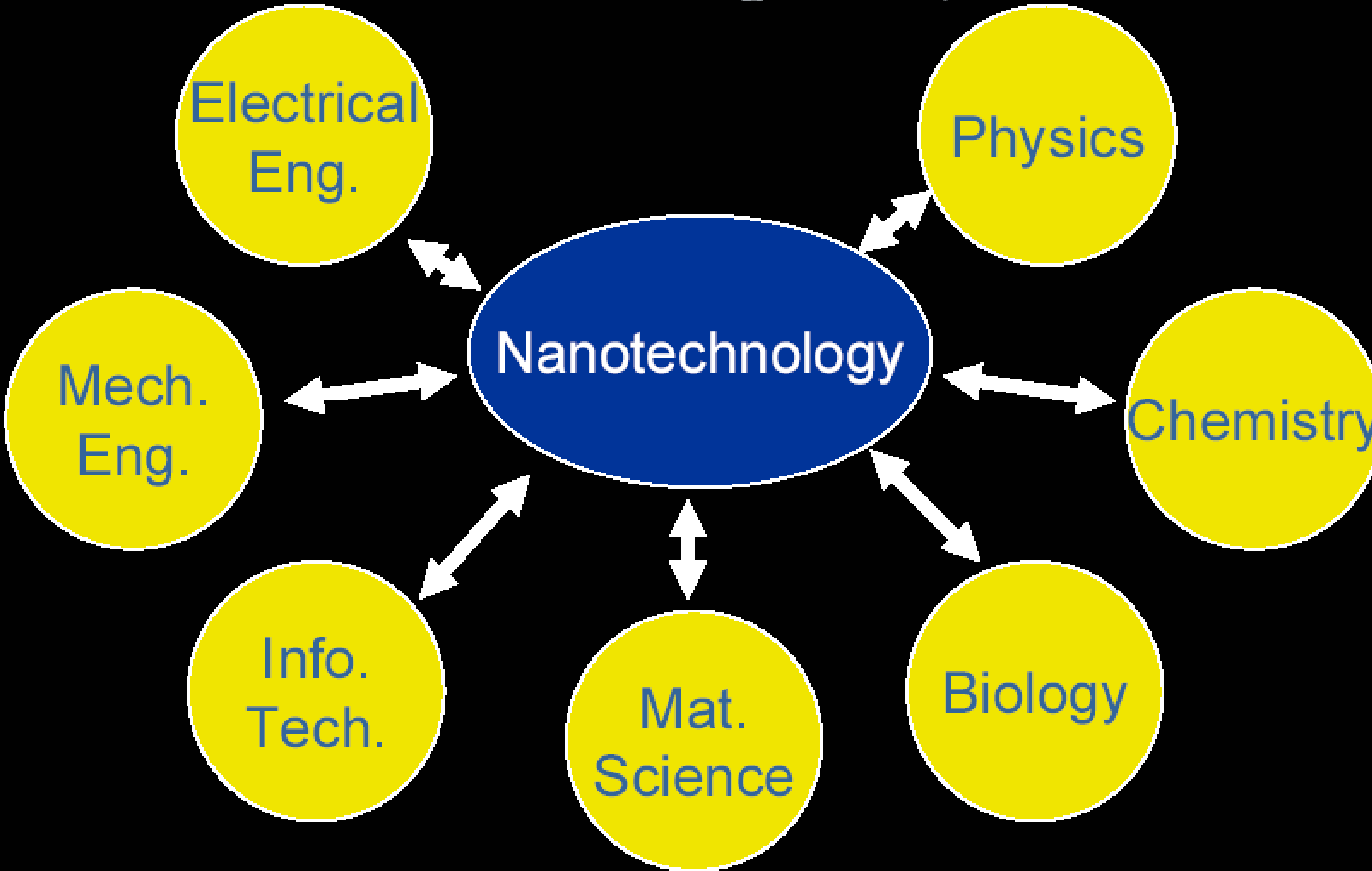
Lotus effect", hydrophobic effect with self-cleaning ability

Close-up of the underside of a gecko's foot as it walks on a glass wall.

- Studies of adhesive force under both hydrophobic and hydrophilic conditions indicate the gecko’s ability to stick to and climb smooth surfaces is due to (relatively weak) van der Waals intermolecular interactions.
- Nanofabricated, synthetic setae show similar adhesive forces.


a
b
Rows of setae
75 μm

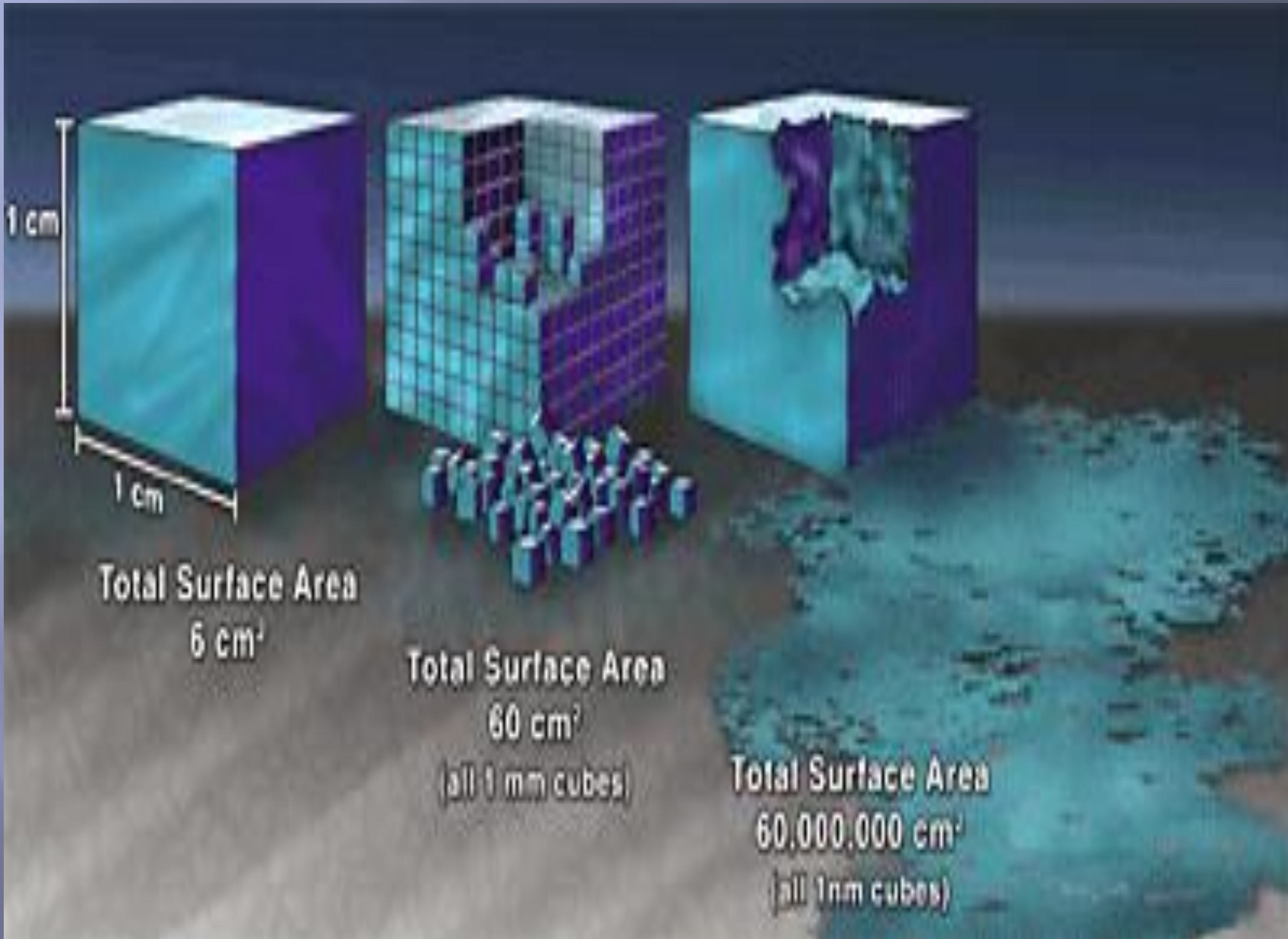
Nanotechnology is multidisciplinary:



Why might properties of materials/structures be different at the nanoscale?

- Two of the reasons:

1. Ratio of surface area-to-volume of structure increases (most atoms are at or near the surface, which make them more weakly bonded and more reactive).
2. Quantum mechanical effects are important (size of structure is on same scale as the wavelengths of electrons, and resulting in changes in electronic and optical properties)


1 cm
1 cm
Total Surface Area
6 cm²
Total Surface Area
60 cm²
(all 1 mm cubes)
Total Surface Area
60,000,000 cm²
(all 1nm cubes)

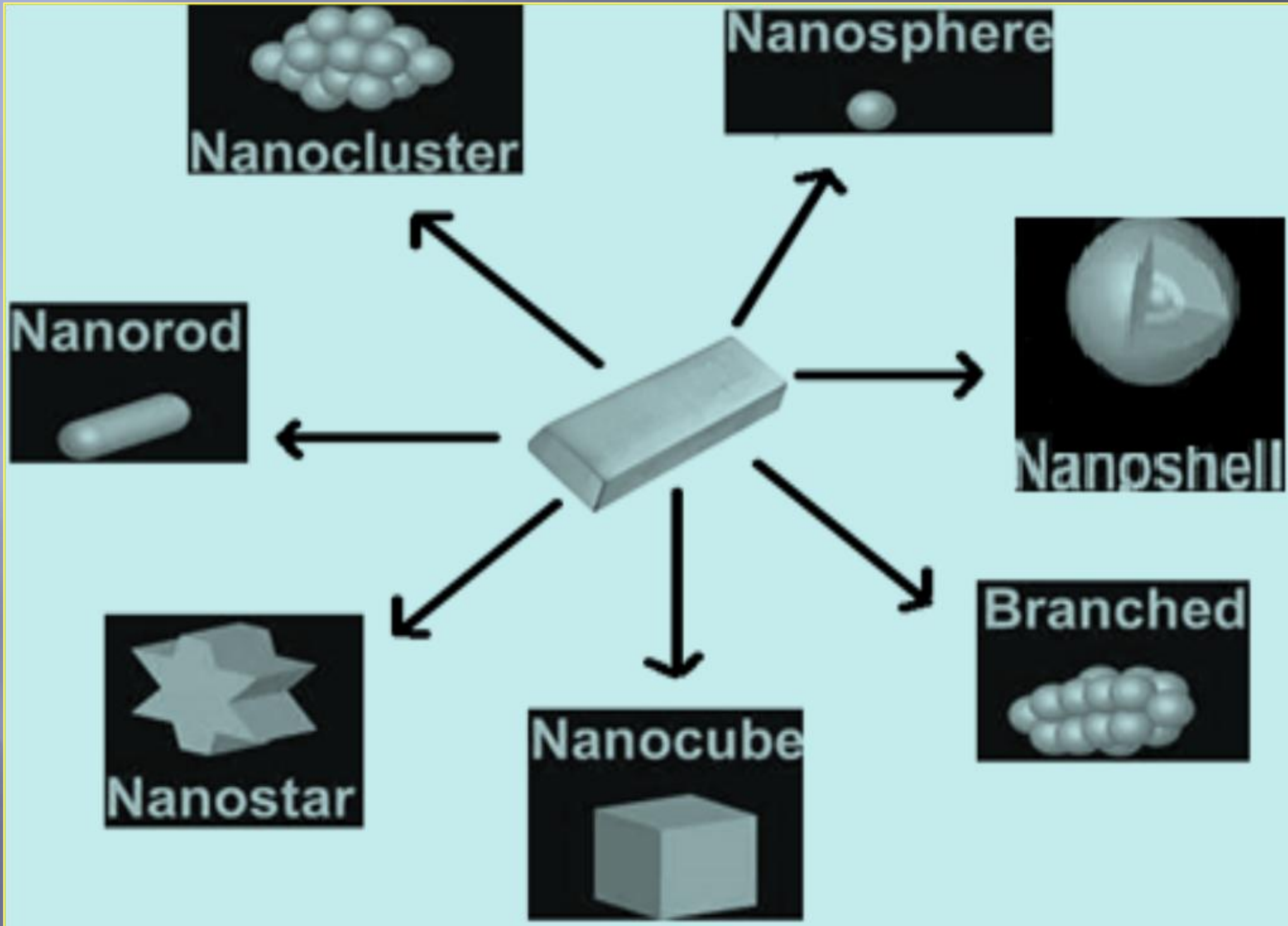
Gold as a nanoparticle

- Properties of gold nanoparticles are different from its bulk form because bulk gold is yellow solid and it is inert in nature, while gold nanoparticles are wine red solution and are reported to be anti-oxidant.

- Inter particle interactions and assembly of gold nanoparticles networks play key role in the determination of properties of these nanoparticles.

- Gold nanoparticles exhibit various sizes ranging from 1 nm to 8 µm and they also exhibit different shapes such as spherical, octahedral, irregular shape, tetrahedral, nanotriangles, nanoprisms, hexagonal platelets and nanorods .

- gold is an inert element, meaning it does not react with many chemicals, whereas at the nanoscale.


Nanocluster
Nanosphere
Nanorod
Nanoshell
Nanostar
Nanocube
Branched

Why is Small Good?

- Faster
- Lighter
- Can get into small spaces
- Cheaper
- More energy efficient
- Different properties for very small structures
-High packing density
-Potential to bring higher speed to information processing
-The small energetic differences between the various possible nanostructures configurations.

Vision of Nanotechnology in 1959

The Principles of Physics, as far as I can see, do not speak against the possibility of Maneuvering things atom by atom. It is not an Attempt to violate any laws; it is something, in Principle, that can be done; but in practice, it Has not been done because we are too big"

Richard Feynman

K. Eric Drexler – 1981

Development of the ability to design protein molecules will open a path to the fabrication of devices to complex atomic specifications

Commercialization Timeline

1995-2004
Nanotech creates new tools & instruments

2002-2007
Nanotech materials enter production

2005-2015
Nano-biotech 'personalizes' medicine

ELECTRONICS

- Hard disk drives
- Semiconductors

MATERIALS

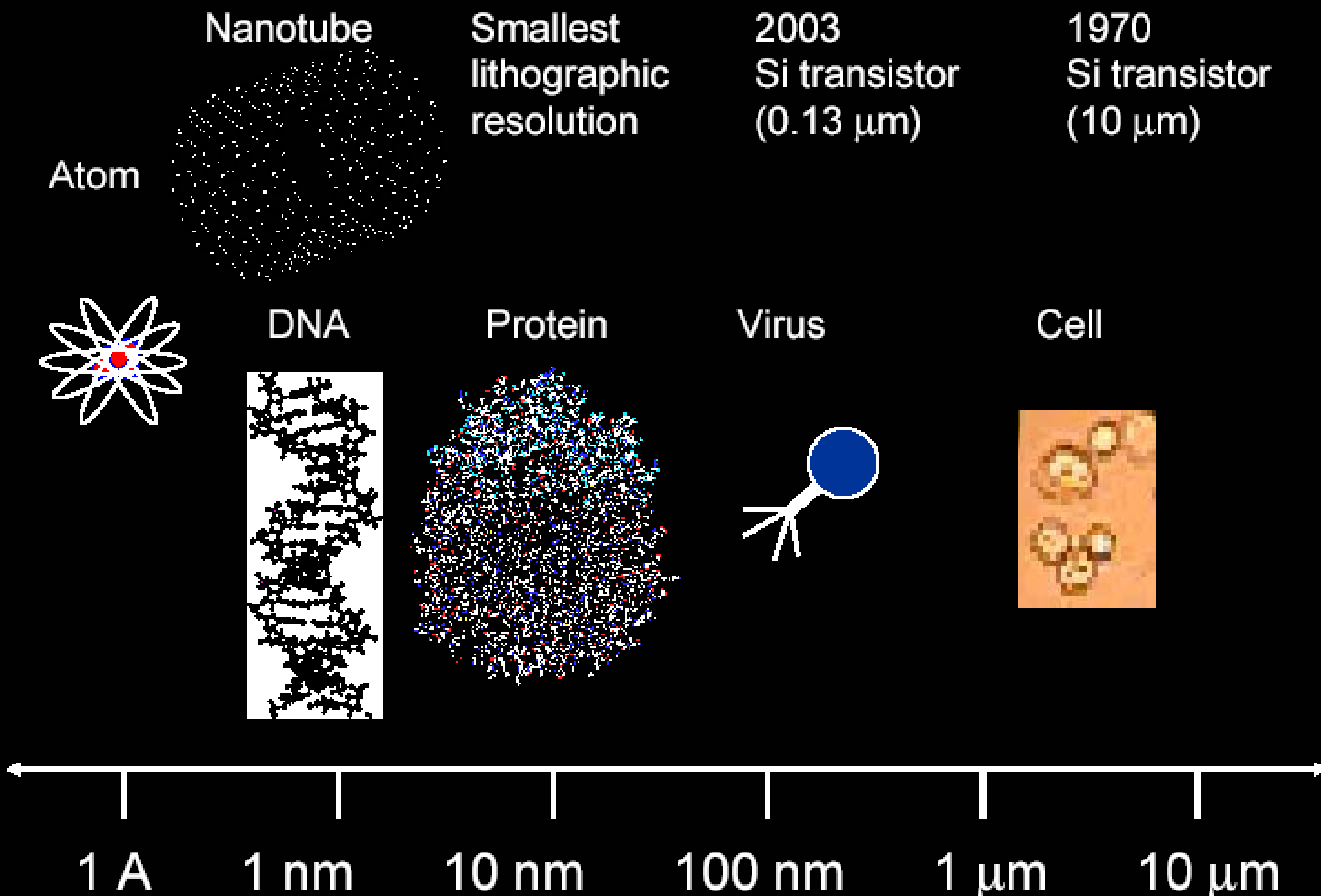
- Automotive
- Aerospace
- Defense
- Opto-electronics

BIOTECH

- Diagnostics
- Pharmaceuticals

Source: Forrester Research

Length scales



Nano structures generations

First Generation: passive nanostructures in coatings, nanoparticles, bulk materials (nanostructured metals, polymers, ceramics): **~ 2001 –**

Second Generation: active nanostructures such as transistors, amplifiers, actuators, adaptive structures: **~ 2005 –**

Third Generation: 3D nanosystems with heterogeneous nanocomponents and various assembling techniques **~ 2010 –**

Fourth Generation: molecular nanosystems with heterogeneous molecules, based on biomimetics and new design **~ 2020 (?)**

Risks of nanomaterial

- Health Risks
  - Ultrafine particles can catalyze chemical reactions in the body.
  - Carbon nanotubes can cause infections of lungs
  - They could easily cross the blood-brain barrier, a membrane that protects the brain from harmful chemicals in the bloodstream.
- Environmental Risks

  Air pollution