

NANO - LECTURE 1




Nano Science and Nanotechnology

Introduction and History

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Nano Science and Nanotechnology

- The term '**nano**' originates from the Greek word for **dwarf** (short person). It is the **billionth (10^{-9})** of a unit.
- Nanoscience primarily deals with synthesis, characterization, exploration, and utilization of nanostructured materials. 
- These materials are characterized by at least one dimension in the nanometer (nm) range.

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- **Nanoscience** is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale.
- **Nanotechnologies** are the design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometre scale.

Bulk versus Nano

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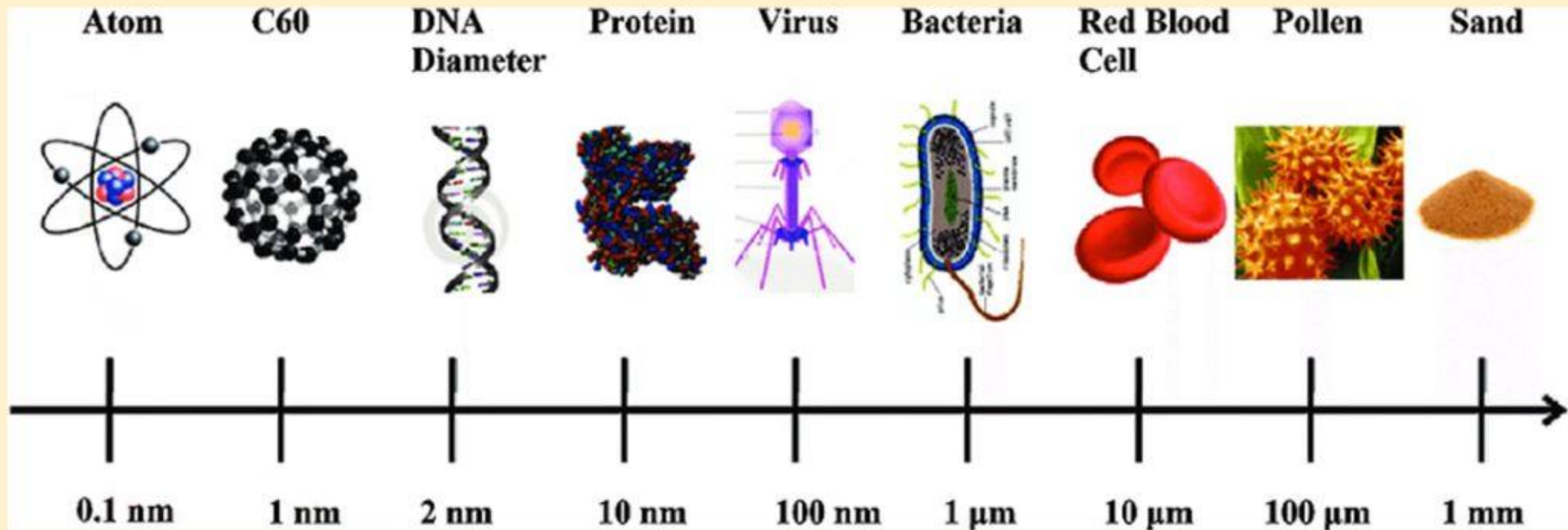
- Bulk Materials (small pieces or objects in our daily life) possess continuous (macroscopic) physical properties
- Also the same properties were found in micro sized (μm) particles (sand, powders of material etc)
- But there is big difference in properties when we go to particle sizes to nanometers(nm), because at these dimensions quantum mechanics principles governs the properties.
- Same material (such as gold or silver) have different properties at nanoscale as compared to their bulk counterpart.

Nanomaterials

- Nanomaterials : **Dimensions less than 100 nanometers (at least nanoscale in one dimension)**
- A sheet of paper is about 100,000 nanometers thick, a human hair is around 80,000-100,000 nanometers wide
- We can compare some dimensions of objects:

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How small is nano?



Atom
0.1 nm



Ball
22 cm



Earth
12756 km

Nanotechnology

Nanometer: $10^{-9} \text{ m} = 10 \times 10^{-10} \text{ m} = 10$ atoms in a line
(one atom, ${}^2\text{He}^4 \sim 10^{-10} \text{ m} \sim 0.1 \text{ nm}$)

1 meter = 10^0 m

1 nanometer = 10^{-9} m

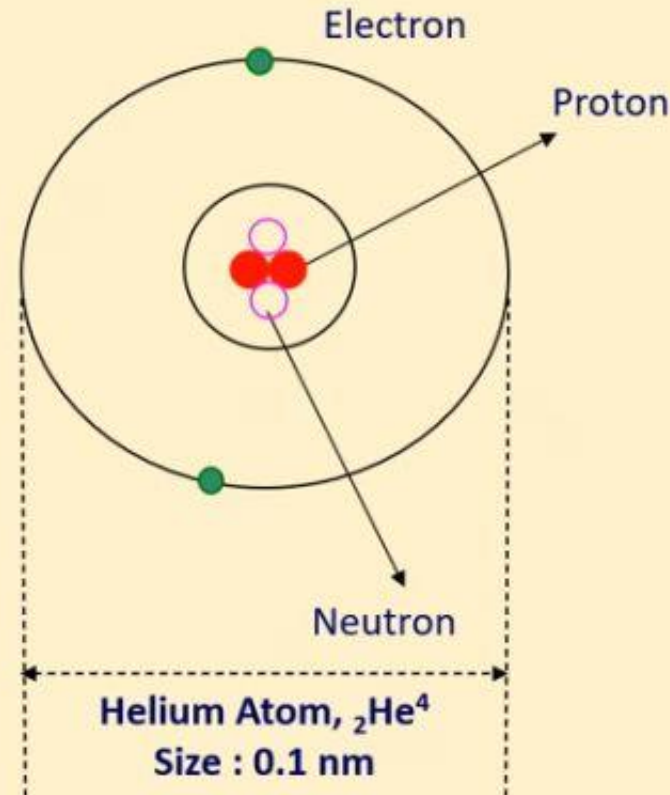
**One nanometer is approximately the length equivalent to:
10 Helium atom
or 5 silicon atoms aligned in a line**

Sub-Nanometer Sizes:

Electron $\sim 1.986 \times 10^{-18} \text{ m}$
 $\sim 2 \times 10^{-9} \text{ nm}$

Proton $\sim 10^{-15} \text{ m} \sim 10^{-6} \text{ nm}$

Neutron $\sim 10^{-6} \text{ nm}$



History: When did nanotechnology start?

Nanotechnology is not a new idea. Nanoparticles have in fact been used by people for thousands of years.

The Egyptians used ink containing nanoparticles of black pigment.

Nanoparticles of lead sulphide were used by the Romans to dye their hair black.



Nanoparticles of gold and silver have also been used since the 10th century to colour ceramics and stained glass.

Examples:

The **stained-glass** windows and **Lycurgus cup** are the examples of Medieval era/Roman era which consist of a few tens parts per million (ppm) of gold and silver nanoparticles in the glass matrix and exhibit unique optical properties.

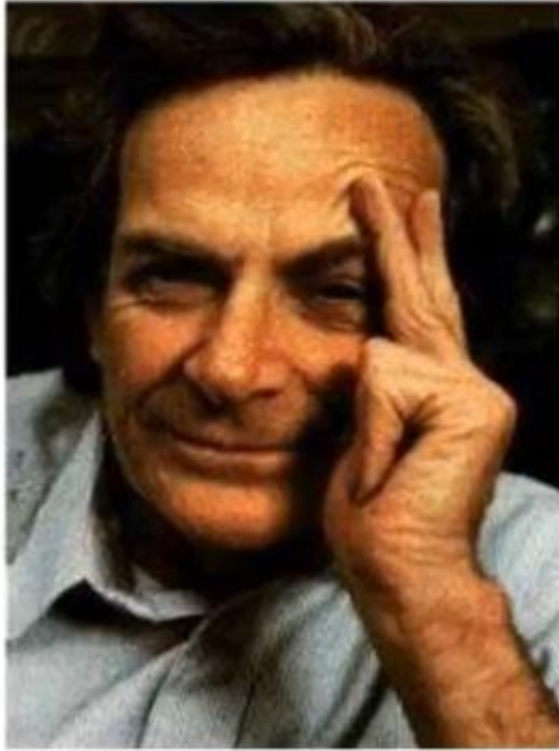
The **Lycurgus Cup** is a 4th-century Roman glass cage cup made of a dichroic glass, which shows a different colour depending on whether or not light is passing through it: red when lit from behind and green when lit from in front.



HISTORY OF NANOTECHNOLOGY

History

- The first ever concept was presented in 1959 by the famous professor of physics **Dr. Richard P. Feynman**.
- Invention of the **scanning tunneling microscope** in 1981 and the discovery of **fullerene**(C₆₀) in 1985 lead to the emergence of **nanotechnology**.
- The term "**Nano-technology**" had been coined by Norio Taniguchi in 1974



**THERE'S PLENTY
OF
ROOM AT THE
BOTTOM**

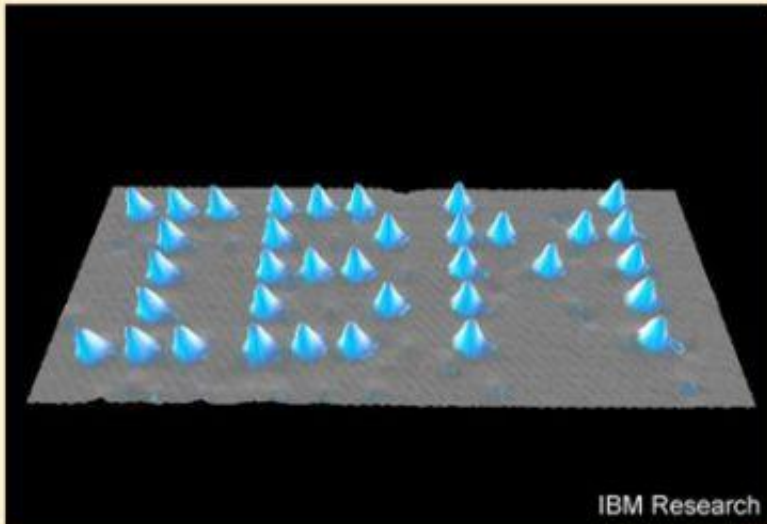
The Japanese scientist called **Norio Taniguchi** of Tokyo University of Science was first to use the term "**nano-technology**" in a 1974 conference,

Development of Nanotechnology

As scientists have steadily made things smaller, they have needed new **equipments** to help them.

In 1981, the **scanning tunnelling microscope (STM)** was invented and allowed scientists to see the nano-world.

Using an STM, it is possible to see individual atoms and even move them around.



In 1989, an STM was used to move 35 xenon atoms onto a tiny piece of nickel.

The atoms spelled the name of the company:
IBM (International Business Machines Corporation).

Are there nanoparticles in nature?

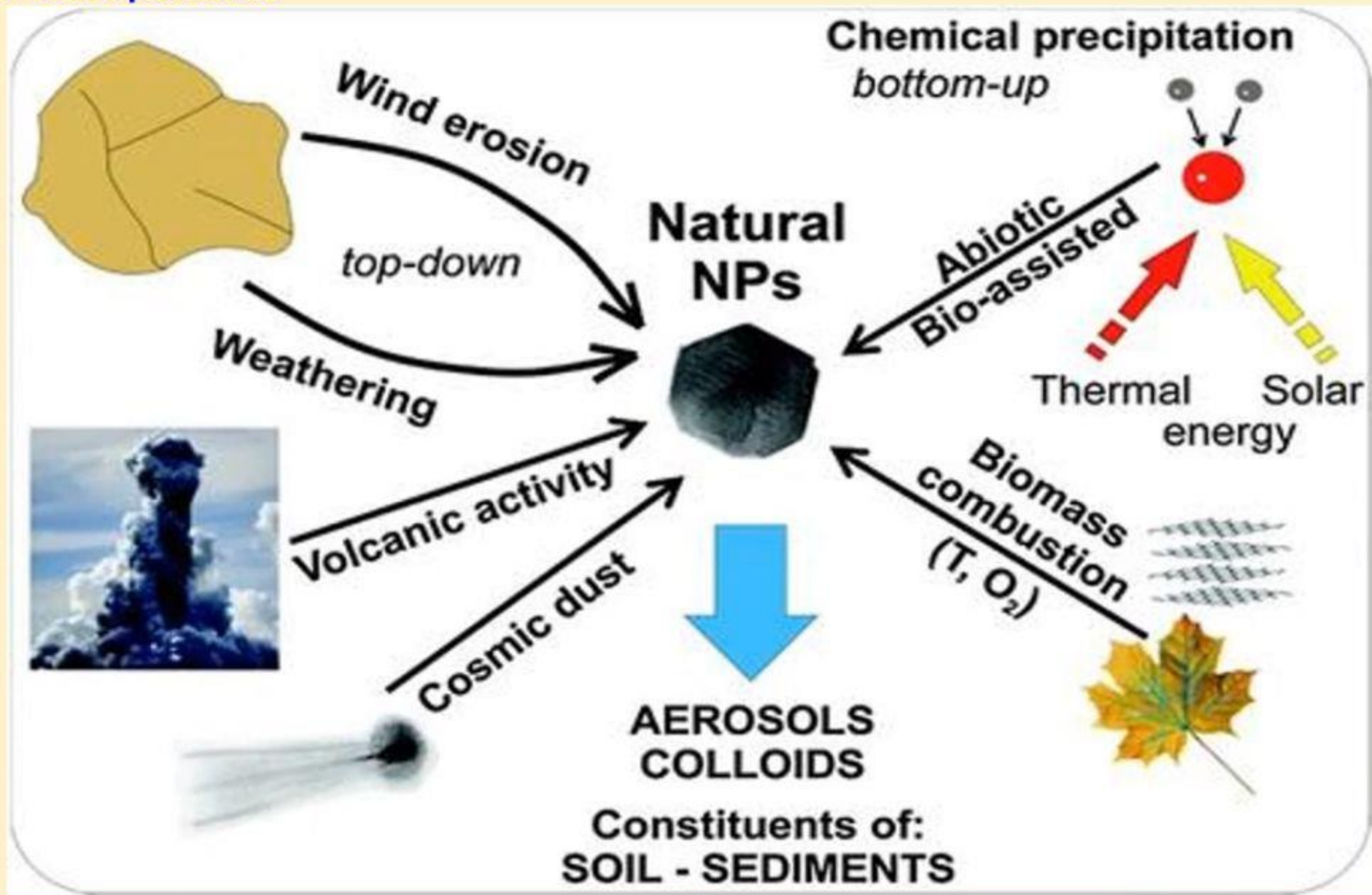
Natural nanoparticles also exist. For example:

- Insects and lizards are able to stick to walls because of the nanostructures on their feet.
- Spiders' webs are made of super-strong nanofibers.
- Butterflies' wings contain shiny reflective nanocrystals.
- Chloroplasts in plant cells are nanofactories that harness the Sun's energy to make glucose.

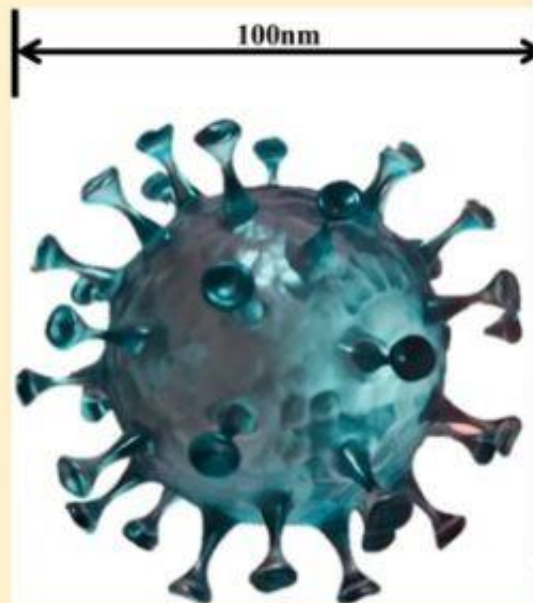


Nanotechnology scientists try to copy natural nanoparticles to make new materials that are useful.

Natural Nanoparticles



Viruses



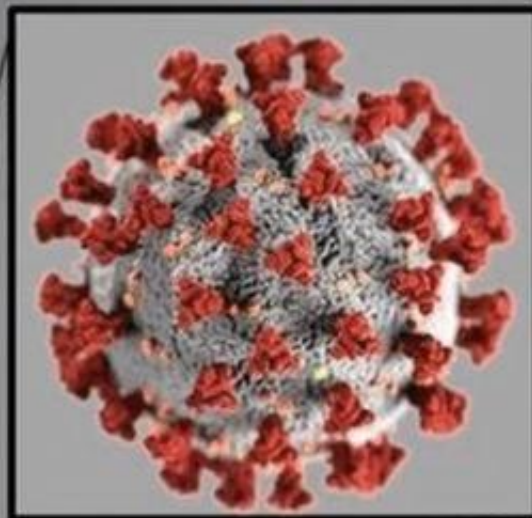
Few hundred nanometre

Respiratory face mask



Particles filtered by mask
 $0.007 \mu\text{m}$

SARS-CoV-2



Coronavirus

$0.06-0.14 \mu\text{m}$

HIV

$0.1 \mu\text{m}$

E. coli

$2 \mu\text{m}$

PM 2.5

$2.5 \mu\text{m}$

Red blood cell

$7 \mu\text{m}$

PM 10

$10 \mu\text{m}$

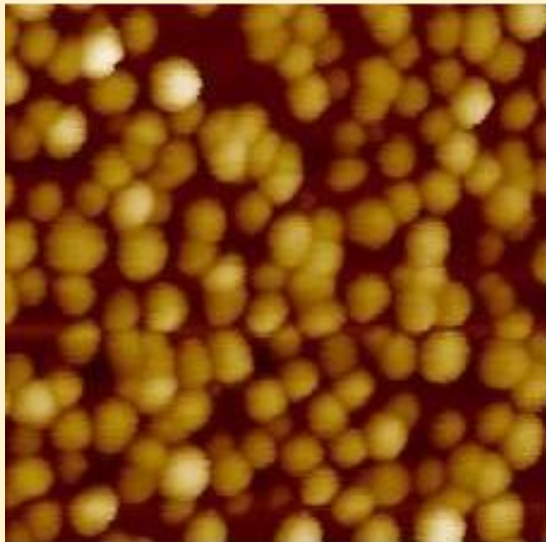
Pore Size of Reverse Osmosis membrane $0.0001 \mu\text{m}$

Pore Size of Nanofiltration membrane $0.001 \mu\text{m}$

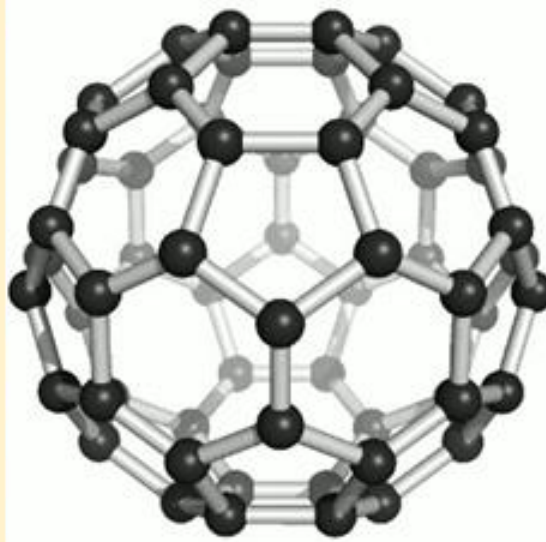
$1 \mu\text{m} = 1 \text{ microns} = 1000 \text{ nm} = 0.001 \text{ mm}$

Examples of Nanomaterials

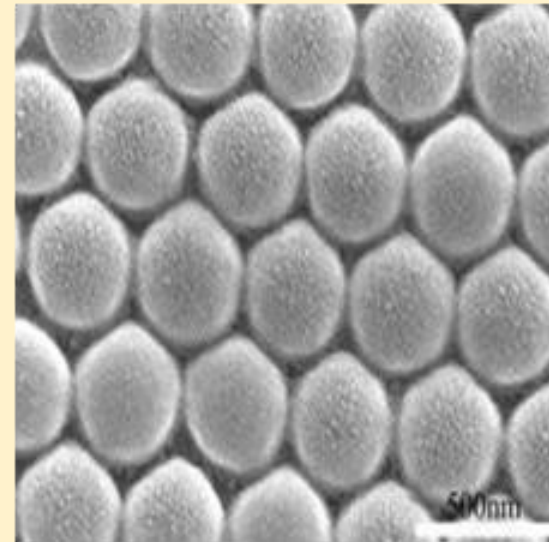
Nanomaterials (gold, carbon, metals, meta oxides and alloys) with variety of morphologies (shapes)



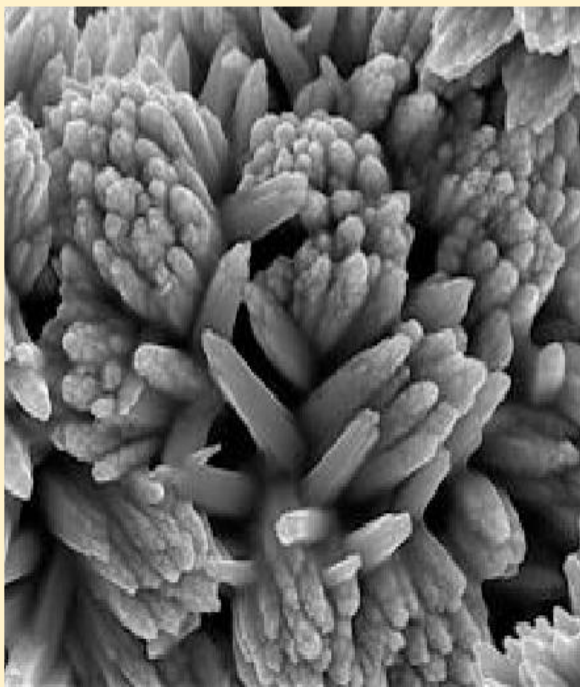
Au nanoparticle



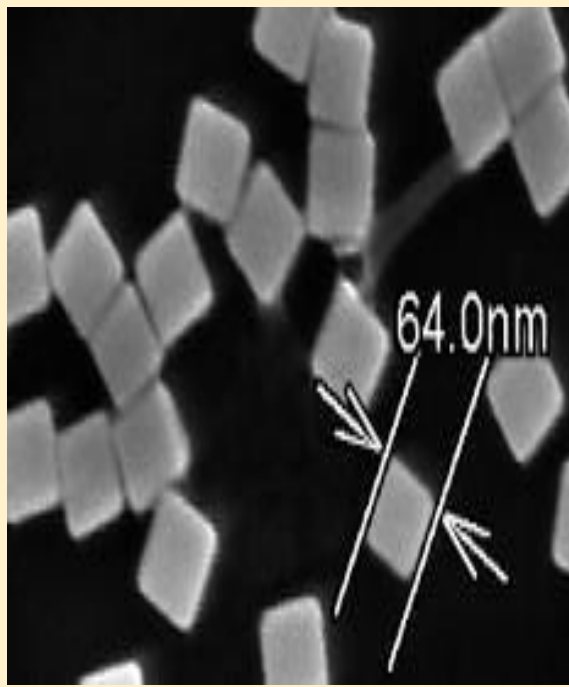
Buckminsterfullerene



FePt nanosphere



Titanium nanoflower



Silver nanocubes



SnO₂ nanoflower

Recent Nanotechnology Trends and start ups (year 2025)

- 1. Carbon Nanomaterials**
- 2. Semiconductor Nanodevices**
- 3. Green Nanotechnology**
- 4. Nanocomposites**
- 5. Nano sensors**
- 6. Nanofilms**
- 7. Nanoencapsulation**
- 8. Energy Nanomaterials**
- 9. Computational Nanotechnology**
- 10. Nanorobotics**

Thanks for Watching