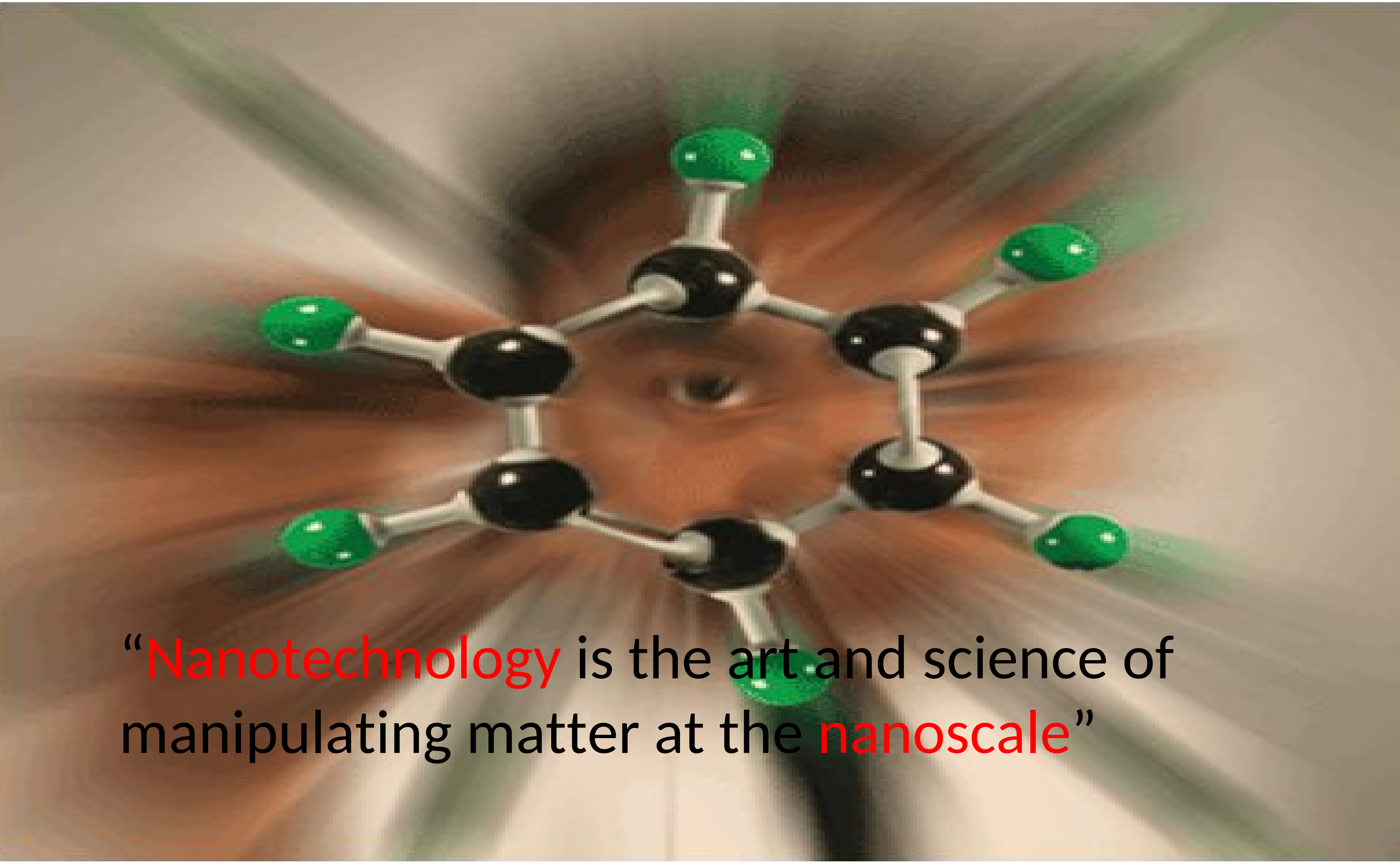
UNIT-I
INTRODUCTION TO NANO SCIENCE AND TECHNOLOGY

What is Nanotechnology?



"Nanotechnology is the art and science of manipulating matter at the nanoscale"

In recent years, nanoscience and technology is emerging as one of the most important and exciting areas of interest in all the fields of science and technology.

Nanoscience deals with the study of properties of material at nanoscale where properties differ significantly than those at larger scale.

The applications of nanoscience emerged as nanotechnology.

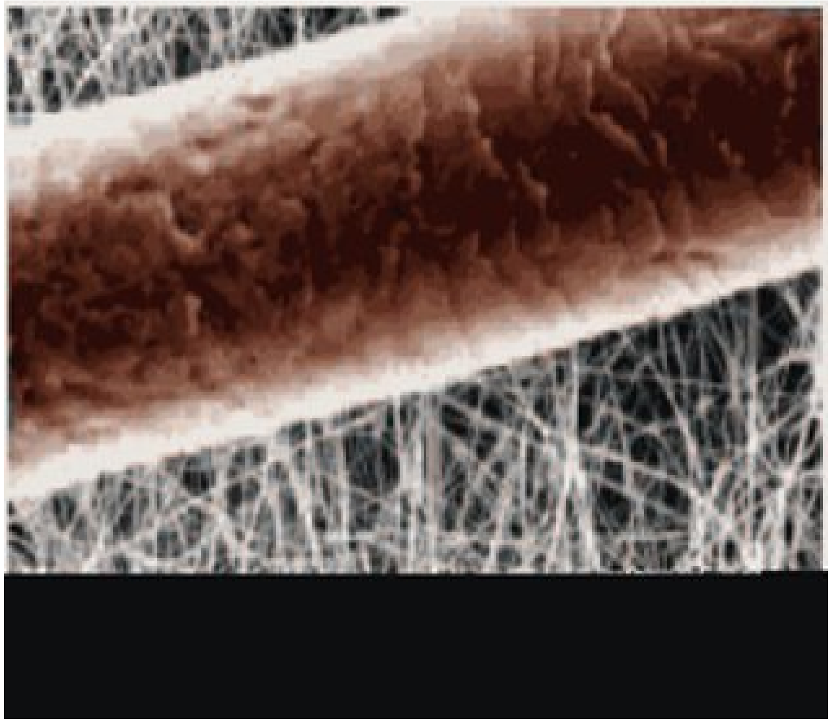
Nanotechnology deals with the design, characteristics, production and applications of nanostructures, nanodevices and nanosystems

Application Of Nanotechnology

How Small Is Nanoscale

How Small Is Nanoscale?

A nanometer is…
– one billionth of a meter



DNA Sample: Approx. 2 nm

Human Hair: Approx. $1x10^5$ nm

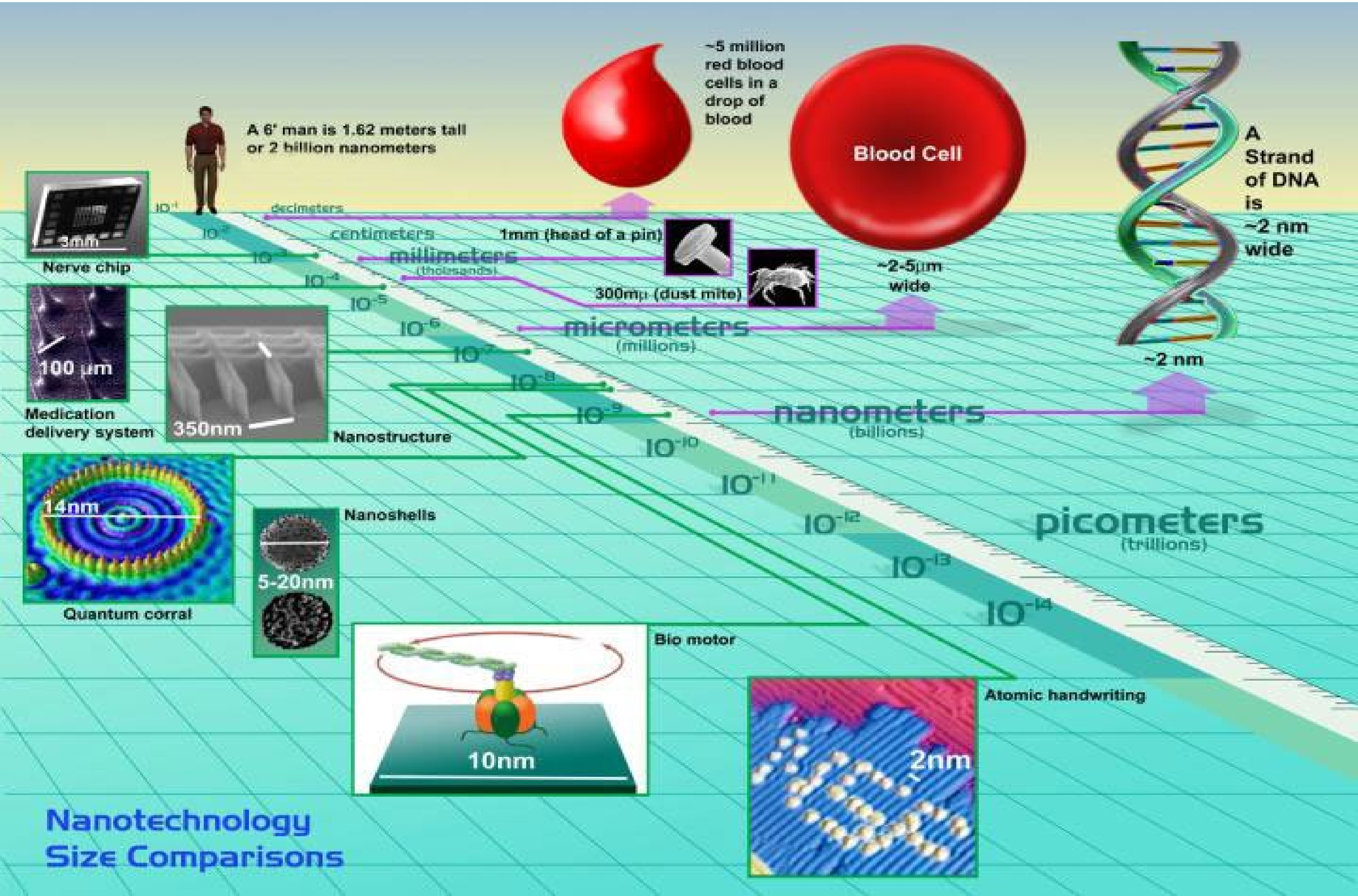
- Nano means 10^{-9} . A nanometre is billionth of a meter (1nm = 10^{-9} m).

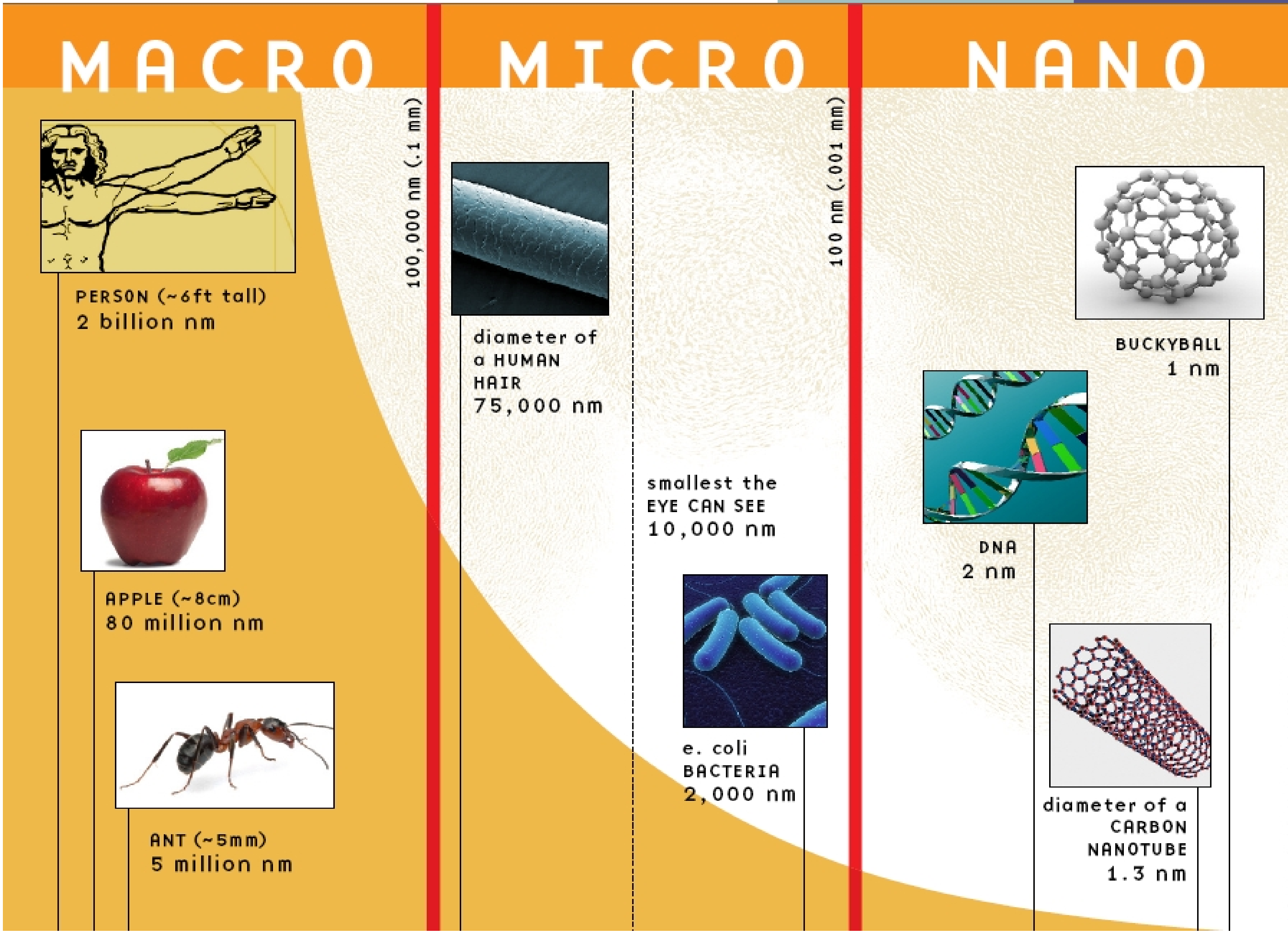
- Size of the atoms can vary from 0.1 to 0.5 nm depending upon the type of element.

- A red blood cell is 7000 nm in diameter and a water molecule is almost 0.3 nm across.

- The size of a virus is 100nm.

How Small Is Nanoscale





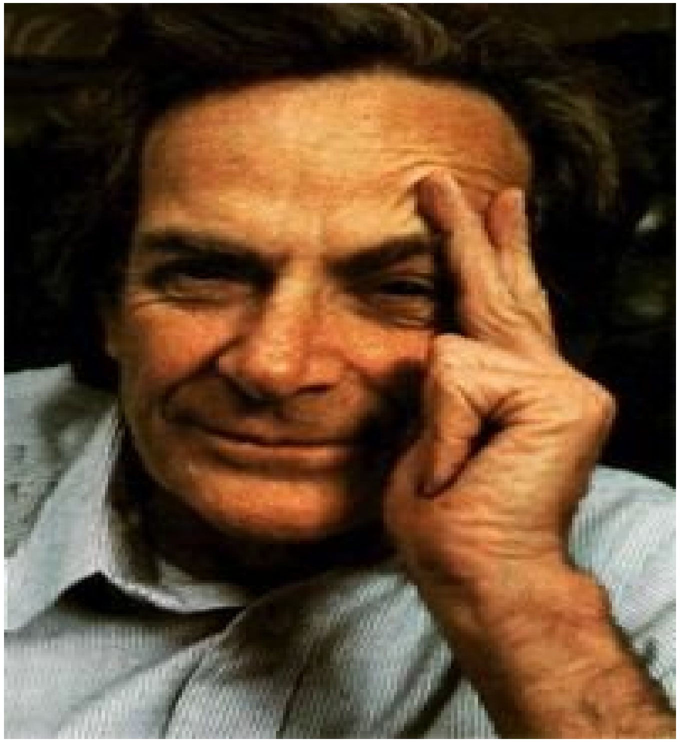
MACRO
MICRO
NANO
100,000 nm (.1 mm)
100 nm (.001 mm)
PERSON (~6ft tall)
2 billion nm
APPLE (~8cm)
80 million nm
ANT (~5mm)
5 million nm
diameter of a HUMAN HAIR
75,000 nm
smallest the EYE CAN SEE
10,000 nm
e. coli BACTERIA
2,000 nm
BUCKYBALL
1 nm
DNA
2 nm
diameter of a CARBON NANOTUBE
1.3 nm

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 Lycurgus Cup was "perhaps made in Alexandria" or Rome in about 290-325 AD, and measures 16.5 x 13.2 cm made of a dichroic glass, which shows a different colour depending on how light is passing through it; red when light from behind and green when light from in front.

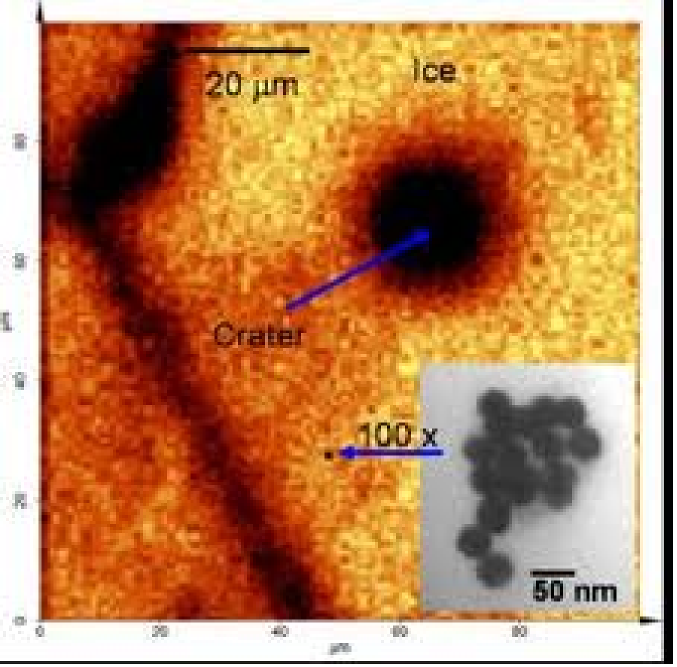
The particles are only about 70 nanometers .

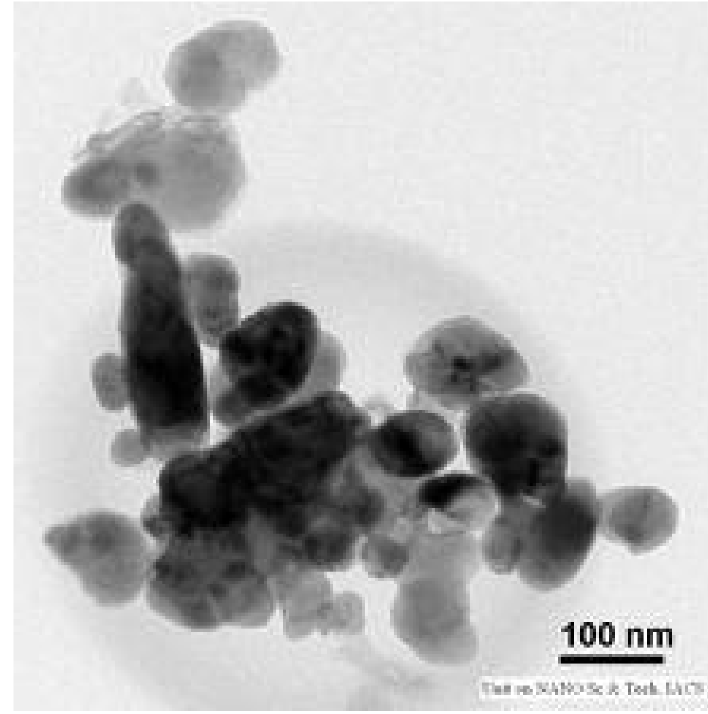
Lycurgus Cup

Damacus sword- An Ancient Product of Nanotechnology

Recently German Scientists found
the presence
of CNTs in these swords

What Is Nanomaterials





What are Nanomaterials?

Nanomaterials are^{-9} materials possessing grain sizes on the order of a billionth of a meter (100 nM)

Nanomaterial research literally exploded in mid -1980's

All materials are composed of grains, which in turn comprises many atoms.

The visibility of these grains depends on their size. Conventional materials have grains varying in size ranging from 1 to 100 nm, is known as Nanomaterials.

When the grain size of an material is reduced to nanoscale, then it exhibit different properties than the same material in bulk form.

1. **Copper is Opaque (when in BULK) becomes transparent when in NANO form**
2. **Gold (in BULK form) as Solid becomes Liquid when reduced to NANO form**

BASIC PRINCIPLES OF NANOMATERIALS

Two principal factors cause the properties of nanomaterials to differ significantly from other materials

1. Increase in Surface Area to Volume Ratio

Due to increase in the surface area, more number of atoms will appear at the surface compared to those inside.

For example:

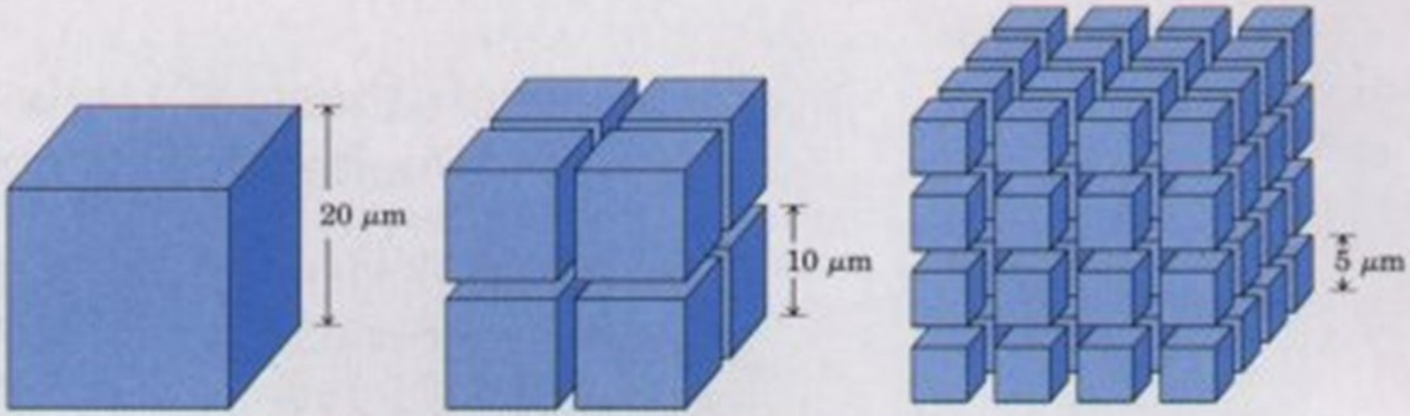
Size-30 nm-> 5% of its atoms on its surface

Size-10 nm->20% of its atoms on its surface

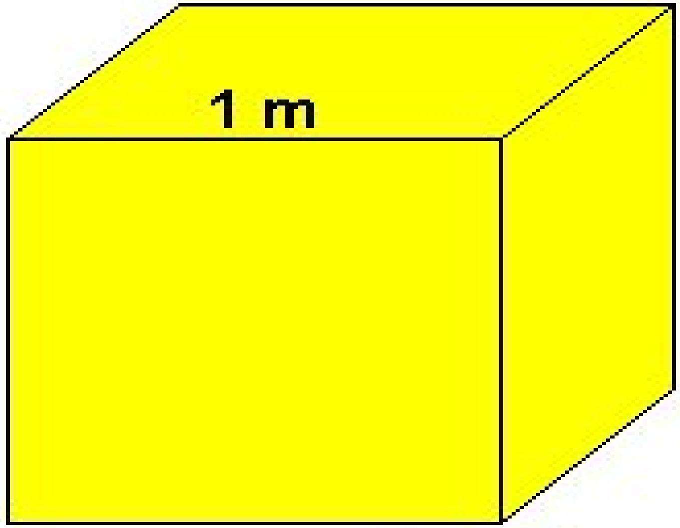
Size-3 nm-> 50% of its atoms on its surface

This makes nanomaterials more chemical reactive. This affects the properties of nanomaterials.

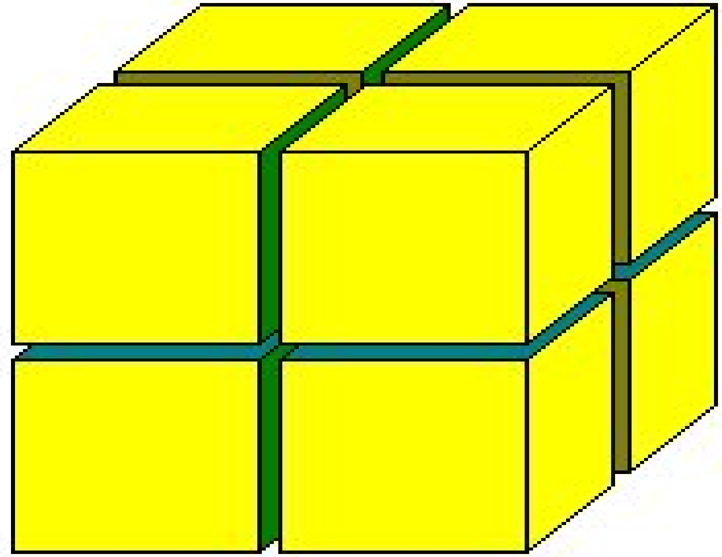
Increase in Surface Area to Volume Ratio



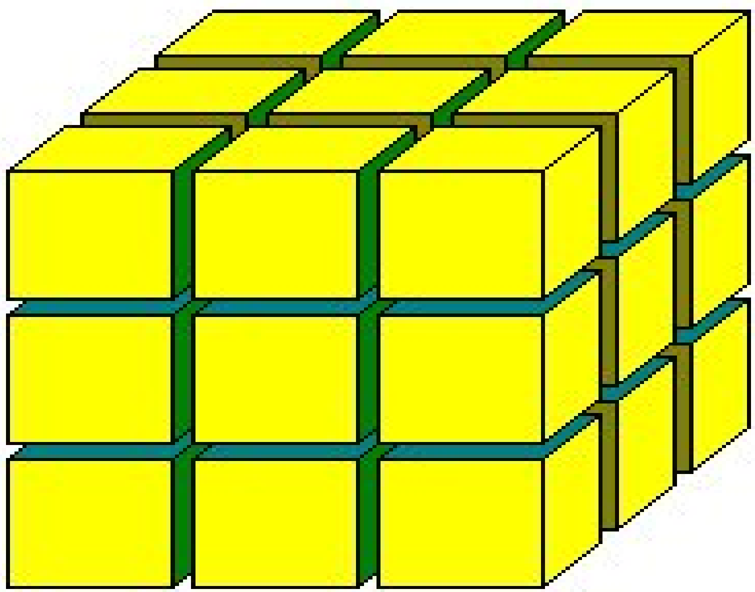
Number of cubes, n	1	8	64
Length of a side, l (μm)	20	10	5
Total surface area, $l^2 \times 6n$ (μm^2)	2,400	4,800	9,600
Total volume, $l^3 \times n$ (μm^3)	8,000	8,000	8,000
Surface area: volume ratio, $\frac{6}{l}$	0.3	0.6	1.2



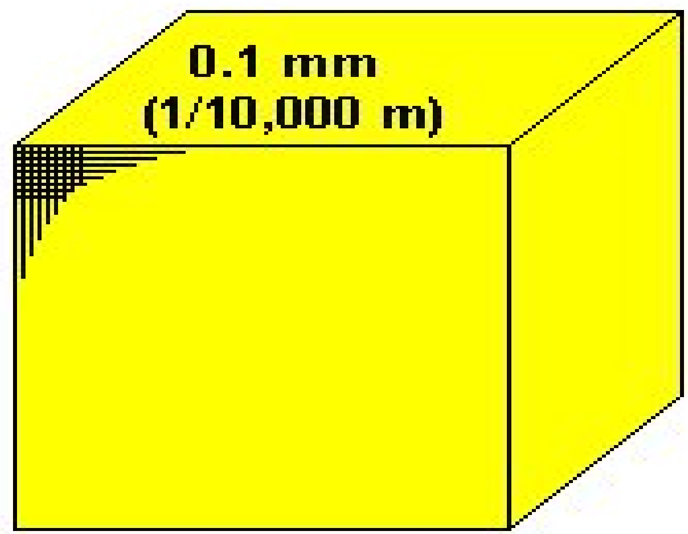
Area = $6 \times 1m^2 = 6\ m^2$



Area = $6 \times (1/2m)^2 \times 8 = 12\ m^2$



Area = $6 \times (1/3m)^2 \times 27 = 18\ m^2$



Area = $6 \times (1/10{,}000m)^2 \times 10^8 =$
$10^4\ m^2$ = 2.5 acres

Quantum Confinement

The properties of materials can be studied based on their energy level. When atoms are isolated, their energy levels are discrete. For materials consisting of a large number of atoms, the energy level split and form bands.

Nanomaterials are intermediate to the above cases. As a result, the energy levels change. When the materials size is reduced to nanoscale, energy levels of electrons change.

This effect is called Quantum Confinement. This affects the optical, electrical and magnetic properties of nanomaterials.

Classification of Nanomaterials

Nanomaterials are those which have structured components with atleast one dimension less than 100nm.

1-D Nanomaterials:

- **One dimension in nanoscale (Other two dimensions are extended) Thin films, Surface Coatings**

2-D Nanomaterials:

- **Two dimensions in nanoscale (Other one dimension is extended)**
  Nanowires, Nanotubes

3-D Nanomaterials:

- **Three dimensions in nanoscale**
  Nanoparticles, Precipitates, Colloids
  Quantum dots (tiny particles of semiconductor material)
  Nanocrystalline materials

Zero-Dimensional(0D) Nanomaterials

- ✓ All dimensions are lessthan100 nm.
- ✓ No dimension, including length, width, or height exceeds nanoscale.
- ✓ Discrete and confined particles(point-like).
- ✓ Examples: Quantum Dots (CdSe,PbS,InP)–tunable photoluminescence, fullerenes,metal and metal oxide nanoparticles–Ag,Au,TiO_2NPs.

❖Key Features include quantum confinement, which results in size-dependent optical and electronic properties.

❖Applications: Used in bioimaging, solar cells, drug delivery, energy storage applications etc.

One – Dimensional (1-D) Nanomaterials:

They are materials whose length > 100nm,but diameter or width<100 nm.
Carbon nanotubes (CNTs) , Nanowires, Nanorods.

KeyFeatures:

- ✓ High aspect ratio
- ✓ Efficient charge transport used in transistors,s ensors,supercapacitors

Two-Dimensional(2D)Nanomaterials

- ✓ They are materials whose Thickness < 100 nm,length and width >100nm.
- ✓ They characterized by sheet-like structures with layered atomic arrangements.

- ✓ **Examples**

✓Graphene: one-atom-thick carbon sheet
✓Nanoclays, nanosheets

KeyFeatures:

- ➢Large surface area-to-volume ratio
- ➢Excellent mechanical, electronic ,and optical properties
- ➢Used in flexible electronics ,energy storage, catalysis

Three-Dimensional(3D)Nanomaterials

They are characterized by external dimensions >100nm,but made of nanoscale buildin blocks

Examples

✓Nanocomposites, Nanoporous materials, Dendrimers,Aerogels, foams with nanoscal porosity

KeyFeatures:

- ➢Enhanced mechanical ,thermal, catalytic properties.
- ➢Used in coatings, structural materials,gas storage.