

PHYSICAL AND CHEMICAL NATURE OF NANOPARTICLES

Lec.2

Non-engineered and engineered NPs.

Nanoparticles are of two types:

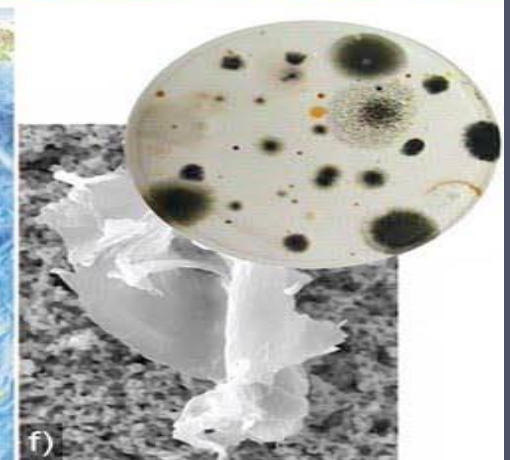
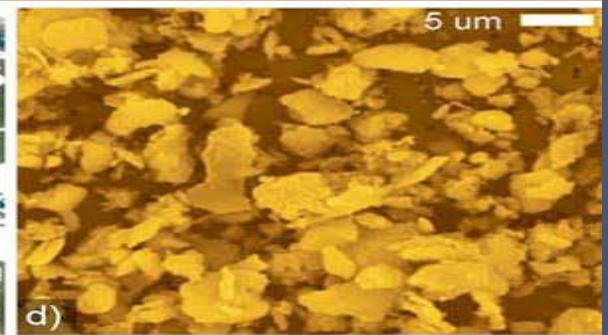
Non-engineered NPs present in the environment are derived from natural events such as terrestrial dust storms, erosion, volcanic eruption, and forest fires.

Terrestrial dust storms

- ▣ Dust storms appear to be the largest single source of environmental nanoparticles.
- ▣ Approximately 50% of troposphere atmospheric aerosol particles are minerals originating from the deserts.
- ▣ The **size of particles** produced during a dust storm varies from **100 nm** to several microns.

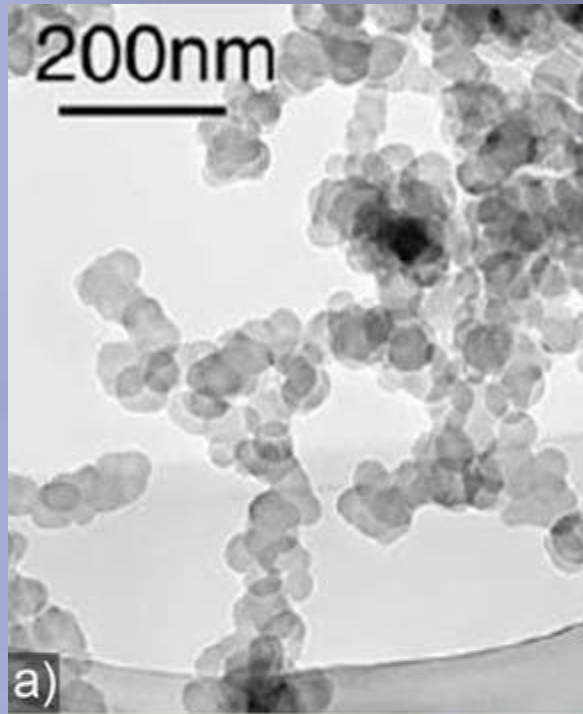
Extraterrestrial dust

- ▣ Nanoparticles **exist widely in extraterrestrial space.**
- ▣ Examples of dust collected from space, from the **moon**, and on **Mars**.
- ▣ The extraterrestrial dust poses major environmental problems for astronauts as well as for equipment.



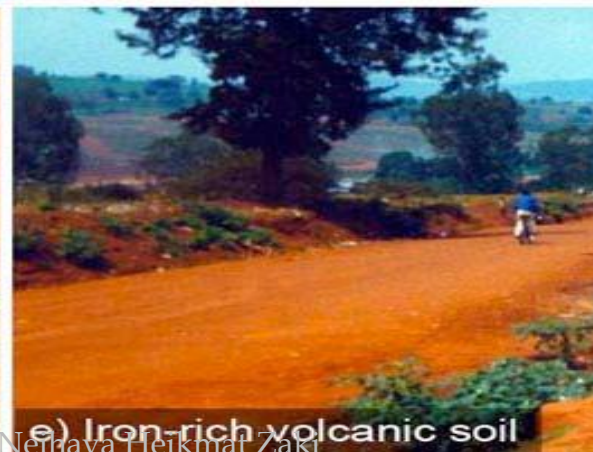
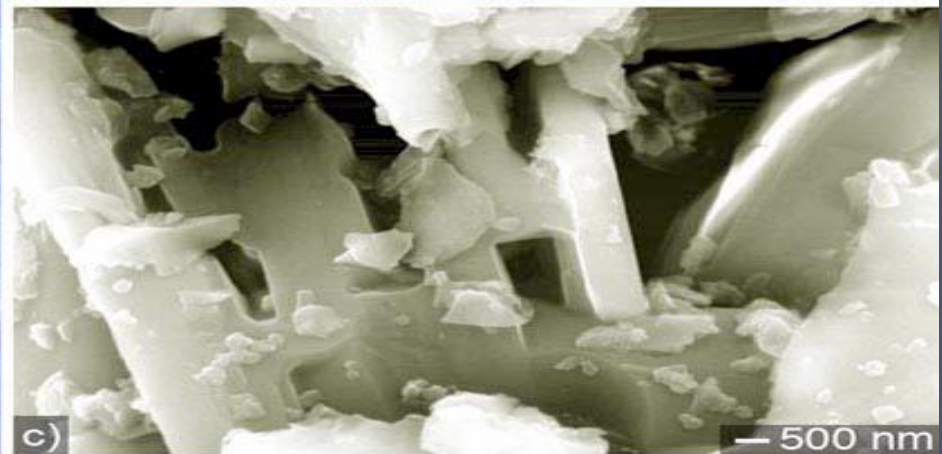
Forest fires

- ▣ Forest fires and grass fires are primarily caused by **lightning strikes** or by **human activity**.
- ▣ Major fires can spread **ash and smoke** over thousands of square miles and lead to an increase of particulate matter (including **nanoparticles**) exceeding ambient air quality standards.



Volcanoes

- ▣ When a volcano erupts, ash and gases containing particulate matter ranging from the nanoscale to microns, are propelled high into the atmosphere, sometimes reaching heights over 18000 meters.
- ▣ a single volcanic eruption can eject up to 30 million tons of ash.

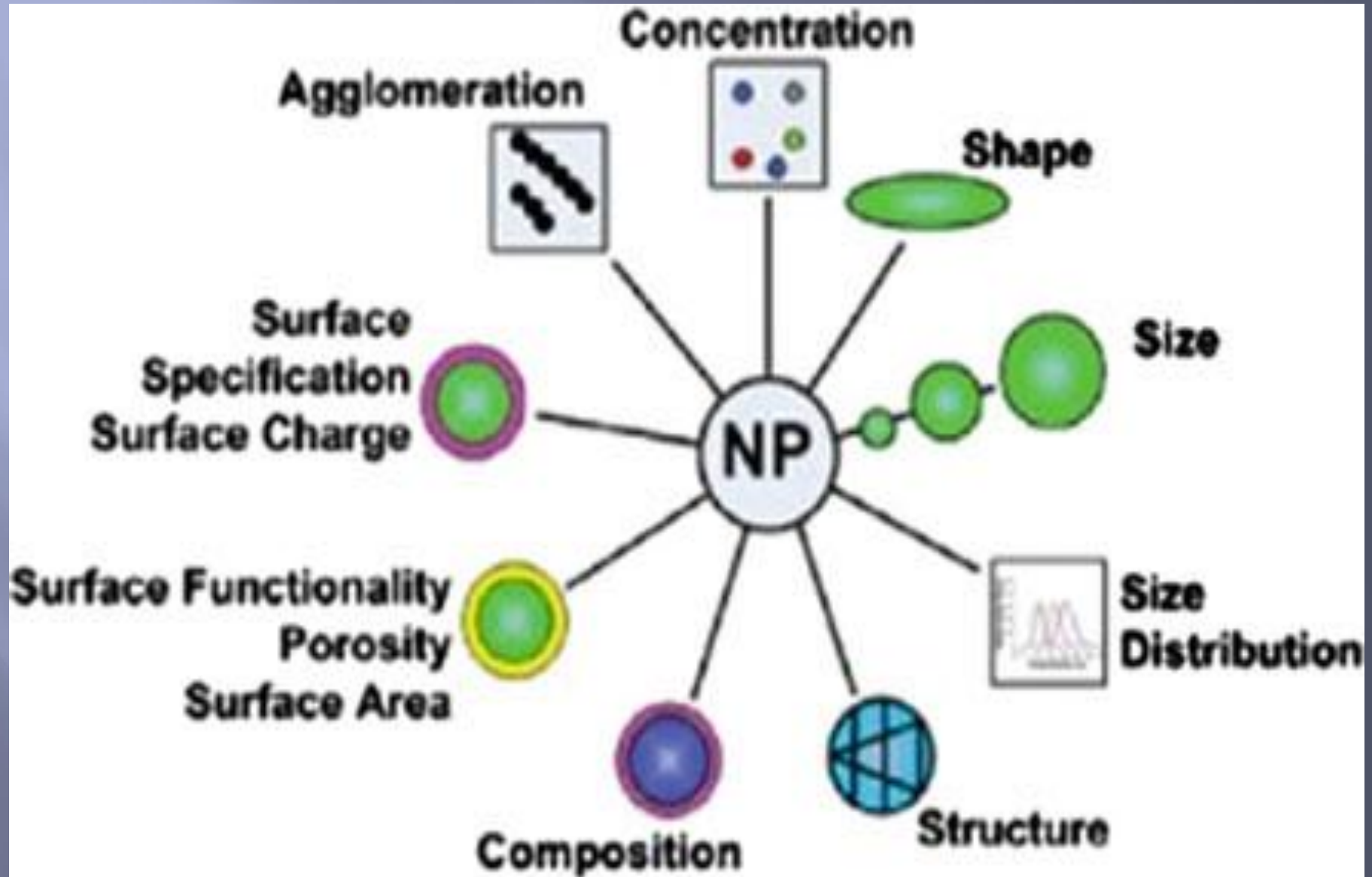


Engineered NPs (ENPs)

are intentionally produced by man using many different materials, such as

- ▣ metals (including Au, Ag, Zn, Ni, Fe, and Cu)
- ▣ metal oxides (TiO_2 , Fe_2O_4 , SiO_2 , CeO_2 , and Al_2O_3)
- ▣ nonmetals (silica and quantum dots)
- ▣ carbon (graphene and fullerene)
- ▣ Polymers (alginate, chitosan, hydroxyethylcellulose, polyhydroxyalkanoates, and poly-E-caprolactone)
- ▣ and lipids (soybean lecithin and stearic acid)

Physical and chemical properties



Physical Properties of Nanoparticles

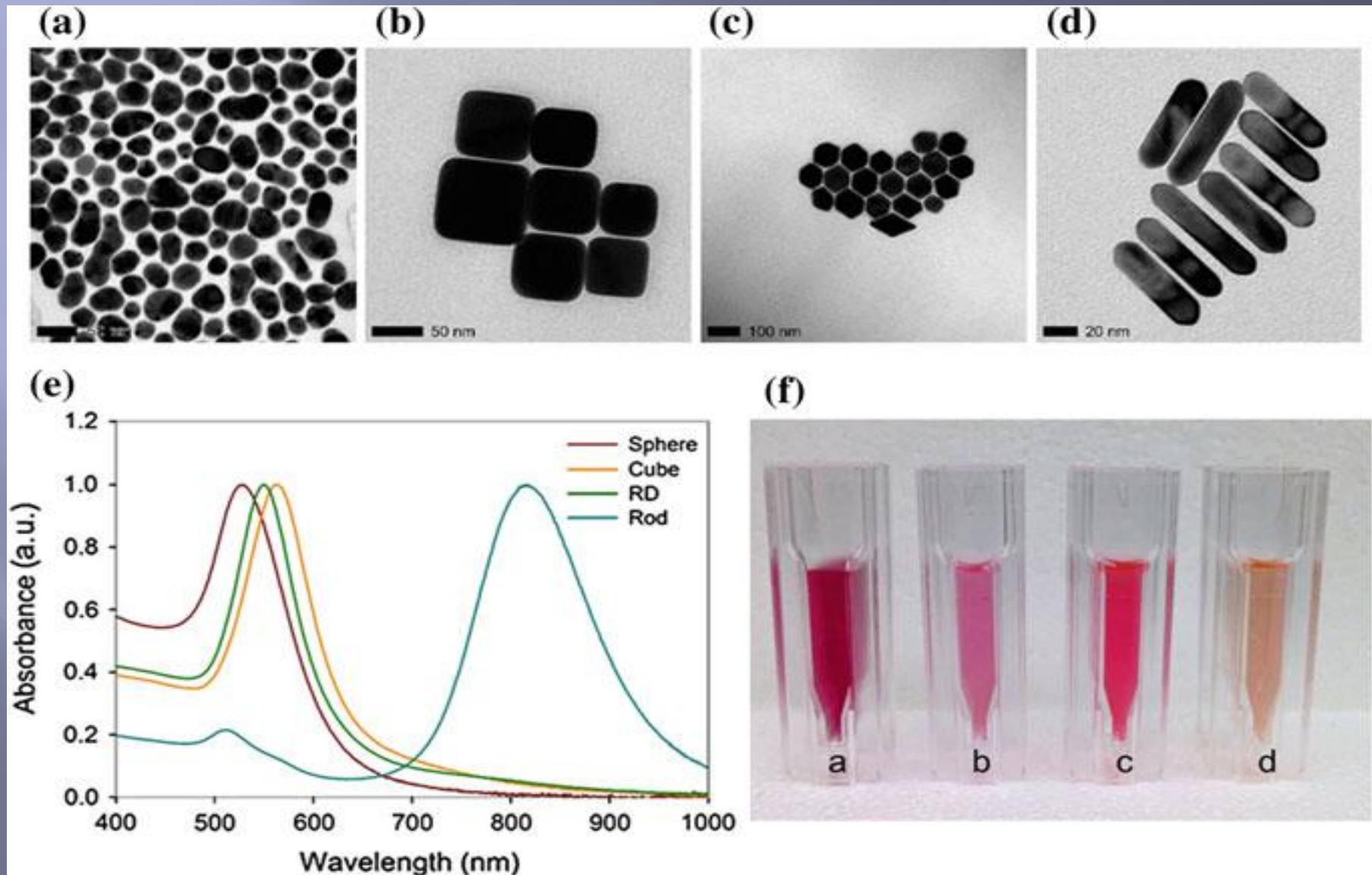
- ▣ Physical properties of NPs include shape, size, specific surface area, agglomeration/aggregation, state of size distribution, surface morphology/topography, and structure including crystallinity, defect structure, and solubility.
- ▣ The size, shape, surface area, and size distribution of NPs are important deciding factors controlling their uptake by organisms.

Size and Shape

- ▣ The size and shape can be identified as the most important parameter to define the nanomaterial in general.
- ▣ NPs **below 20–30 nm** in size are characterized by an **excess of energy** at the surface and are **thermodynamically** unstable because of the **interfacial tension**, acting as a driving force, which leads to a spontaneous **reduction of the surface area**.

- ▣ The **design of NPs** has gained a lot of attention, resulting in particles with various shapes such as **spheres, rods, tubed, fibers, and disks**, etc.
- ▣ and more extraordinary geometries such as **worms, squares, urchins, and ellipsoids**.
- ▣ The **optical properties** of NPs also depend on its size and shape.

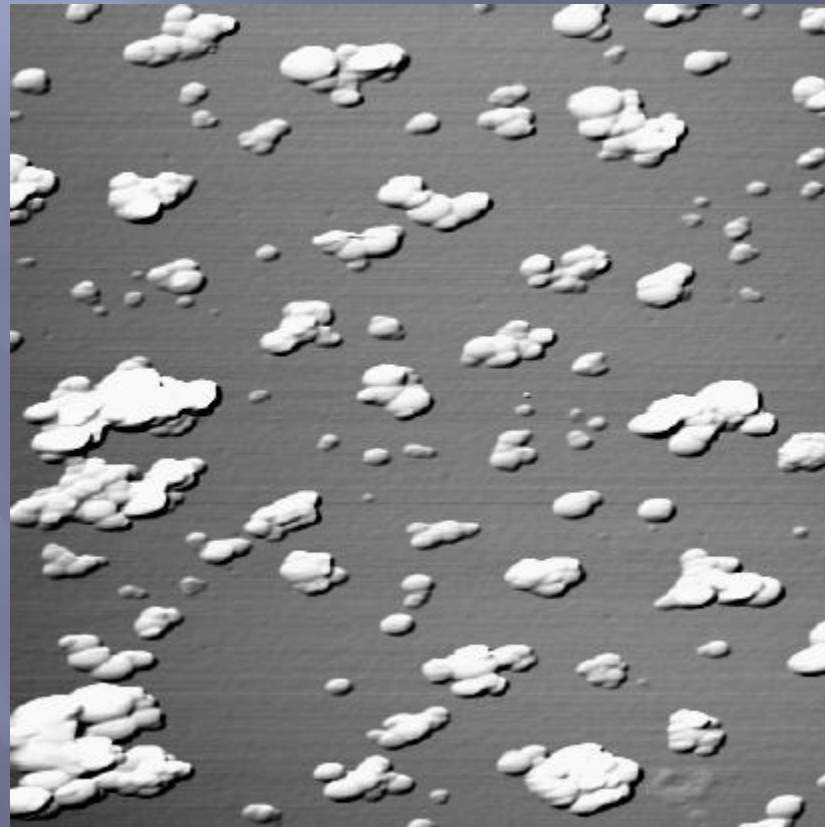
Difference in the optical properties of gold NPs for different shapes



Surface and Size Distribution of Nanoparticles

- ▣ The surface morphology and surface area of NPs can be analyzed using scanning electron microscope (SEM).
- ▣ To get a higher resolution of approximately 0.2 nm, atomic force microscopy (AFM) can be used. It provides real topographical images of sample surfaces.
- ▣ The attachment of NPs to cell membrane seems to be most affected by the surface charge of the NPs.

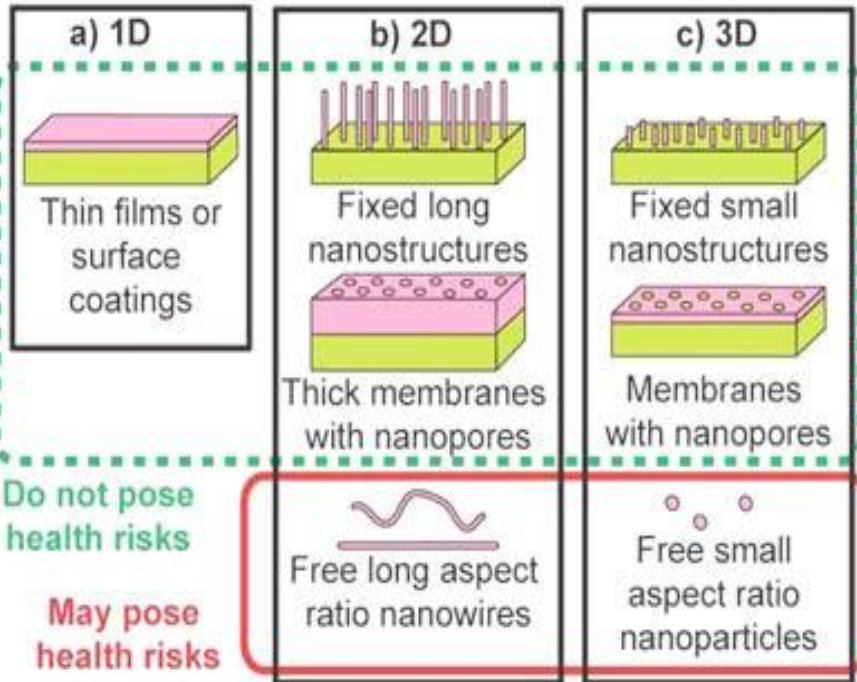
Al₂O₃ nanoparticles deposited on Silicon.



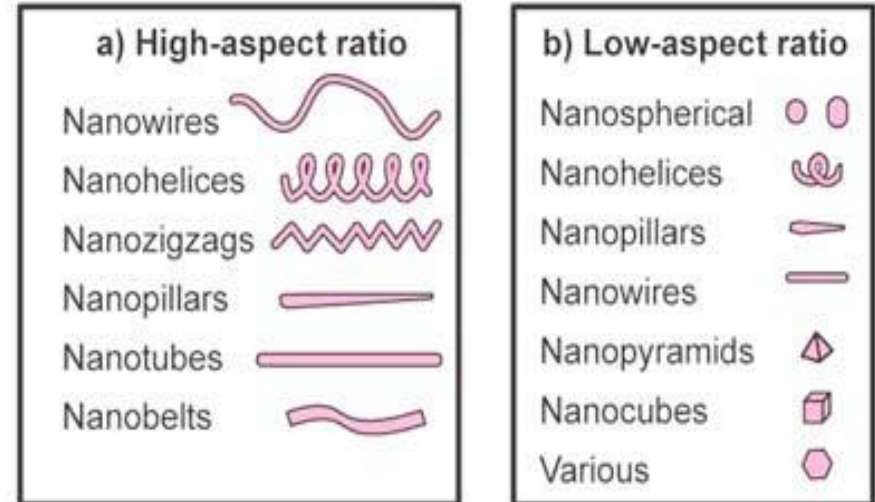
- ▣ NPs of the different parameters such as dispersion, surface properties, agglomeration and de-agglomeration can be controlled using :
- ▣ ultrasonication, ionic strength and pH of aqueous solutions, physiological buffers, and cell culture media.

- ▣ Structural and Species Specifics of Nanoparticles Determinations of purity of NPs are important in biological application.
- ▣ X-ray diffraction (XRD) is the most essential tool used to characterize crystal structures.

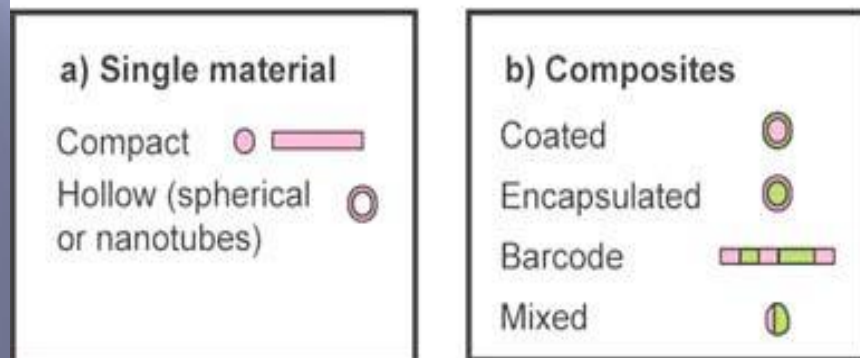
1) Dimensionality



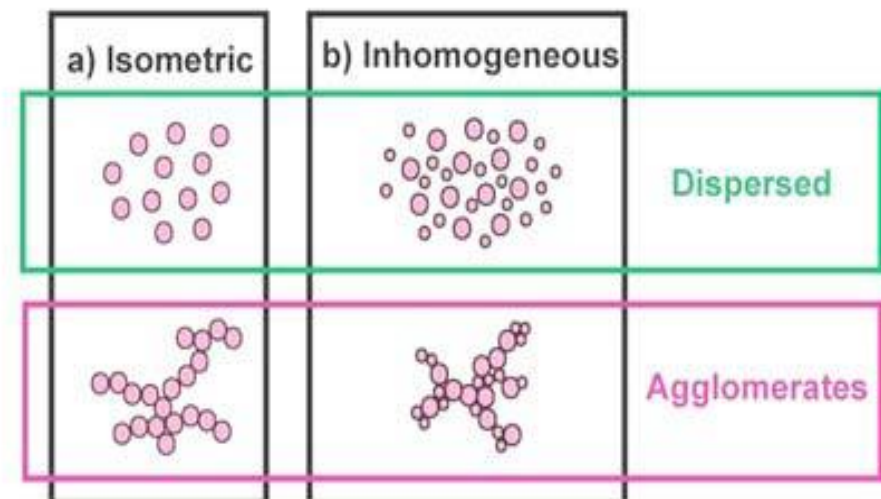
2) Morphology



3) Composition



4) Uniformity & agglomeration state



Chemical Properties of Nanoparticles

- ▣ Chemical properties include the **elemental composition** of nanomaterials and its **surface chemistry** such as **zeta potential** and **photocatalytic** properties.
- ▣ The chemical properties of a material are determined by the **type of motion of its electrons**.

Metallic Nanoparticles

- ▣ Compared with other nanostructures, metallic NPs have been proven to be the **most flexible nanostructures** owing to the synthetic control of their size, shape, composition, structure, assembly, and encapsulation, as well as the resulting tunability of their **optical properties**.
- ▣ Compared with other metallic nanostructures, **colloidal gold and silver NPs** are especially promising in nanobiotechnology because of their **simple and fast preparation and bioconjugation**.

- ▣ The **electromagnetic field** enhancement near the metal surface and the dependence on the **size, shape**, and local **dielectric properties** of NPs.
- ▣ Such nanoparticles work as platform materials for **biomolecular ultrasensitive detection**, **hyperthermal treatment for cancer cell**, **protein labeling**, and **targeted delivery of therapeutic agents** within the cells.

Metal Oxide Nanoparticles

- ▣ Metal oxide NPs can exhibit unique chemical properties due to their **limited size** and a **high density of corner or edge surface sites**.
- ▣ The properties such as structural characteristics, cell parameters, and effect of size, are related to the electronic properties of the oxide, and **structural and electronic properties** obviously drive **the chemical properties** of the solid.
- ▣ Metal oxide particles serve many functions in the various field of plant technology and others.

- ▣ Magnetic NPs exhibit a wide variety of attributions, which make them highly promising connection with biological system and bioapplications usually exists or can be prepared in the form of either single domain or superparamagnetic magnetite (Fe_2O_3) or greigite (Fe_3S_4).
- ▣ Due to their favorable beneficial effects, magnetic NPs approved for clinical use by Food and Drug Administration.

Quantum Dots

- ▣ Quantum dot - semiconductor crystals with a diameter of a few nanometers, having many properties.
- ▣ Structurally quantum dots (QDs) consist of a variety of metal complexes such as semiconductors, metals, and magnetic transition metals.
- ▣ The bioactivity of QDs can be improved by suitable surface coating with biocompatible material and/or modification with desired functional groups.

- ▣ Depending on their size, it fluoresces with different colors.
- ▣ To make them biologically compatible/active, newly synthesized QDs are functionalized or given secondary coatings, which improves water solubility.

Carbon Nanoparticles

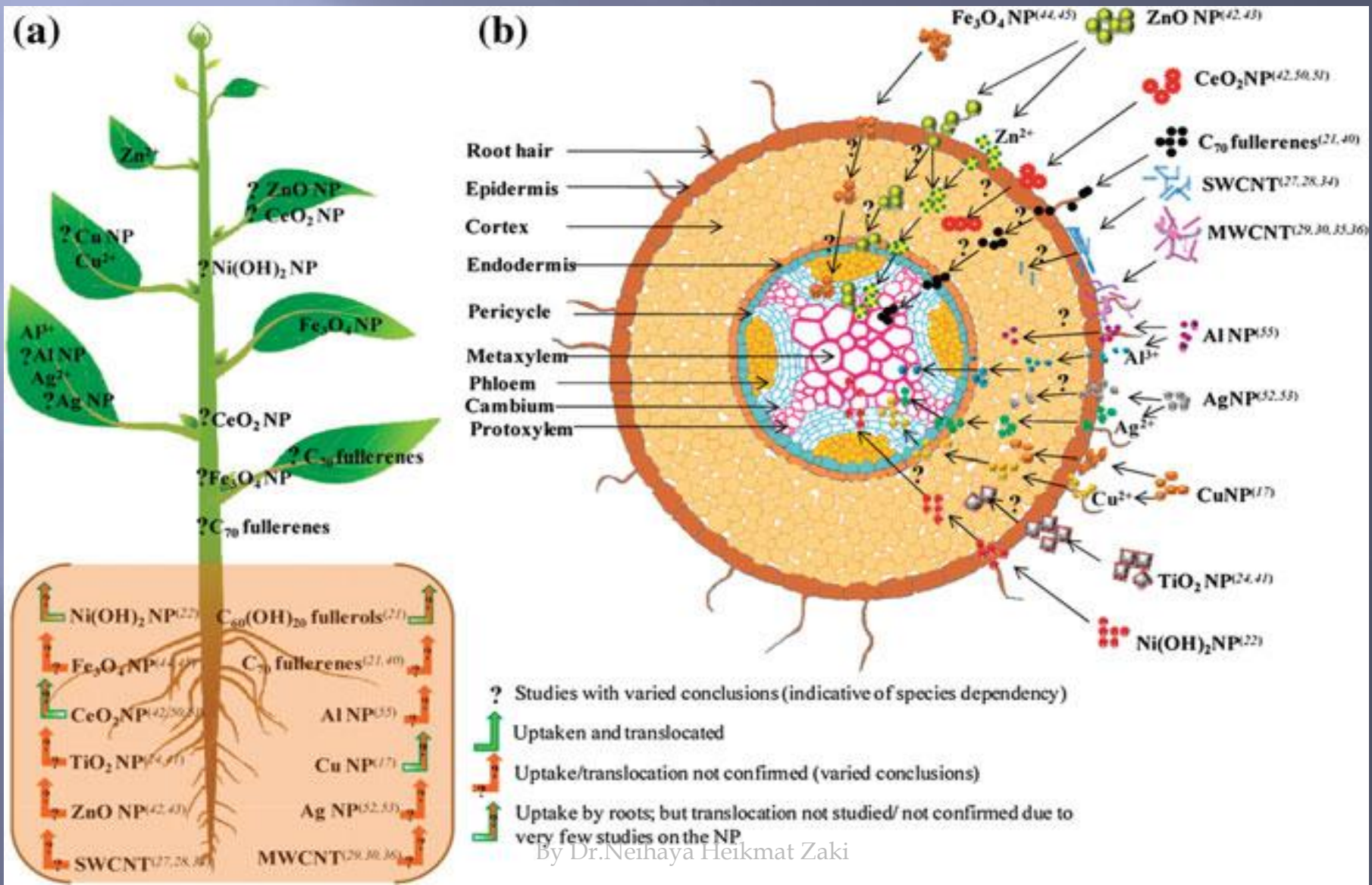
- ▣ Carbon nanotubes (CNTs) represent the **more evident example**.
- ▣ About decade after discovery, the knowledge available increased the interest in **biological and biomedical applications** of carbon nanotubes.

Polymeric Nanoparticles

- ▣ The term polymer nanoparticle is given for **any type of polymer NPs** but specifically for **nanospheres and nanocapsules**.
- ▣ These are obtained from **synthetic polymers**, such as polycaprolactone , polyacrylamide , and polyacrylate
- ▣ or **natural polymers**, albumin, DNA and chitosan, gelatin, and poly (L-lactide) (PLA).

- ▣ The various polymer NPs had been used to improve the **pharmacokinetics and pharmacodynamics** properties of various drugs,
- ▣ for example, **chitosan polymer** used as a carrier of **plant extract**.

Selective uptake, translocation, and biotransformation pathway of different NPs in plant organs



Merits and Demerits of Nanoparticles

- ▣ Due to **instability** of the NPs, retaining the **size and shape of NPs** is highly challenging.
- ▣ As the kinetics associated with NPs is rapid and is **highly reactive**, they **inherently interact with impurities**.
- ▣ In addition, **encapsulation of NPs** becomes necessary when they are **synthesized in a solution**.
- ▣ Synthesis of **pure NPs** becomes highly **difficult**. Hence, retaining high purity in NPs can become a challenge hard to overcome.

- ▣ It is noticeable that **most experimental studies** with NPs have been carried out with **aggregates/agglomerates of NPs**.
- ▣ This has significantly repercussions on the **biokinetics** of the material.