Nanoparticles: Synthesis & Applications

Subject: Environmental Nanoremediation
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Nano

- A prefix that means very, very, small.

- The word nano is from the Greek word ‘Nanos’ meaning Dwarf. It is a prefix used to describe "one billionth" of something.

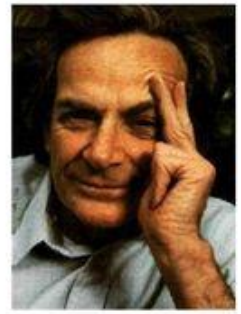
Nano & Technology

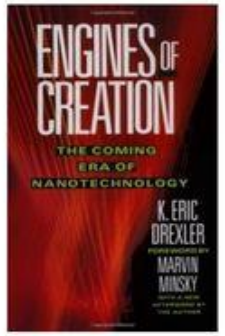
- Nanometer is a unit of length in the metric equal to one billionth of a meter.

- Technology is the making, usage and knowledge of tools, machines and techniques in order to solve the problems or perform a specific function.

History of Nanotechnology

- **~ 2000 Years Ago** – Sulfide nanocrystals used by Greeks and Romans to dye hair
- **~ 1000 Years Ago (Middle Ages)** – Gold nanoparticles of different sizes used to produce different colors in stained glass windows
- **1959** – "There is plenty of room at the bottom" by R. Feynman
- **1974** – "Nanotechnology" - Taniguchi uses the term nanotechnology for the first time
- **1981** – IBM develops Scanning Tunneling Microscope
- **1985** – "Buckyball" - Scientists at Rice University and University of Sussex discover C_{60}
- **1986** – "Engines of Creation" - First book on nanotechnology by K. Eric Drexler. Atomic Force Microscope invented by Binnig, Quate and Gerbe
- **1989** – IBM logo made with individual atoms
- **1991** – Carbon nanotube discovered by S. Iijima
- **1999** – "Nanomedicine" – 1st nanomedicine book by R. Freitas
- **2000** – "National Nanotechnology Initiative" launched



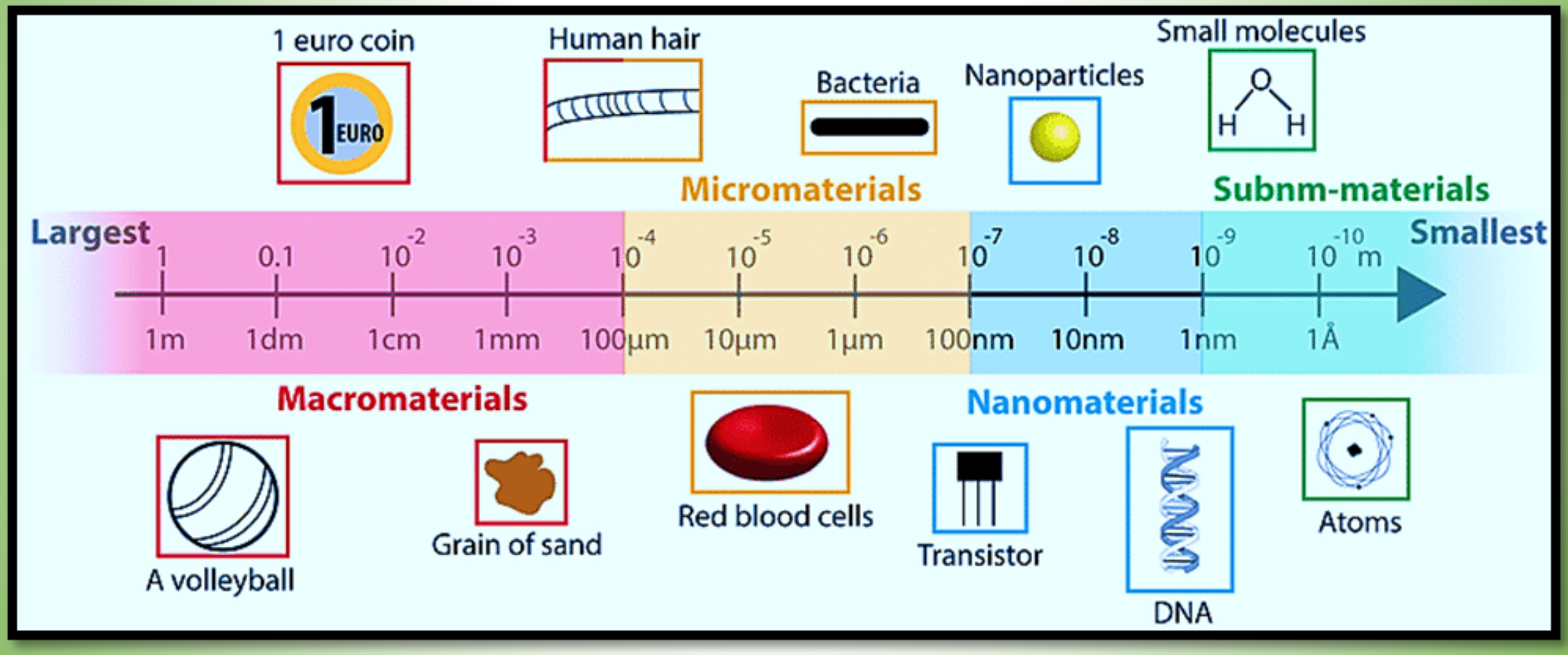


History of Nanotechnology

- Other evidences such as herbal Kajal, Bhasmas etc. are also indicates use of nanotechnology.
- Kajal has been prepared since ancient times by the controlled combustion of coconut oil and collecting soot on silver plate.
- Now it is proved that this synthesized kajal contains nanoparticles of carbon.
- Carbon based nanomaterials have great importance in the field of cosmetics.
- They have antibacterial properties.

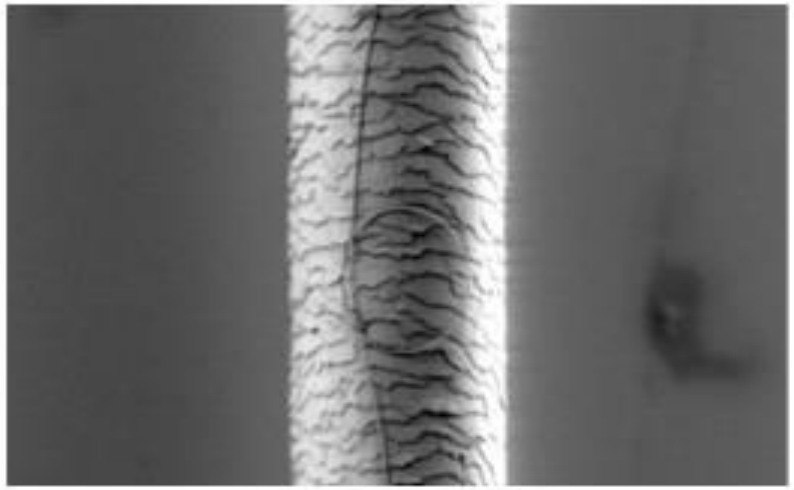
The Herbal Kajal

Scale of dimensions from meter down to nanometer



How small is one nanometer (nm)?

The diameter of a human hair is 100,000 nm



The diameter of DNA is 2 nm


what are other words for nanometer?
micromillimeter, millimicron, nanometre, micromillimetre, nm, metric linear unit
Thesaurus.plus

Nanotechnology

➢Nanotechnology: The art and science of manipulating and rearranging individual atoms and molecules to create useful materials, devices, and systems.

➢Nanotechnology, in simple terms, means the study and exploitation of tiny objects, whose dimensions are just a few molecules and atoms.

➢In strict scientific terms, nanotechnology concerns physical dimensions ranging from 1-100 nm (1 nm = 10^{-9} m).

Nanomaterials

- *Materials with at least one exterior dimension between 1 - 100 nm are referred to as nanomaterials.*
- *Nanomaterials can be made by combustion processes, occur naturally, or can be purposely manufactured through engineering to carry out a specific function. Nanomaterials may differ from their bulk-form counterparts in terms of their physical and chemical characteristics.*
- *Nanomaterials are already being used in our day-to-day lives. Examples range from titanium oxide mineral nanoparticles in our sunscreen and self cleaning surfaces to mobile pigment nanoparticles injected into soldiers' uniforms to improve camouflage to baseball bats made from carbon nanotubes.*
- *Nanomaterials are used in a wide range of sectors, from healthcare and cosmetics to environmental preservation and air purification, since they may be produced in a precise fashion to perform a particular function.*

Classification of Nanomaterials

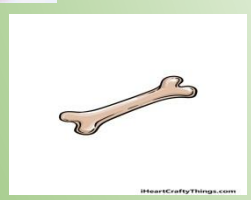
Based on the origin, nanomaterials are classified as natural and artificial.

Natural Nanomaterials

- Minerals (Clay)
- Natural colloids (milk, blood)
- Fog (aerosol type)
- Gelatin (gel type)

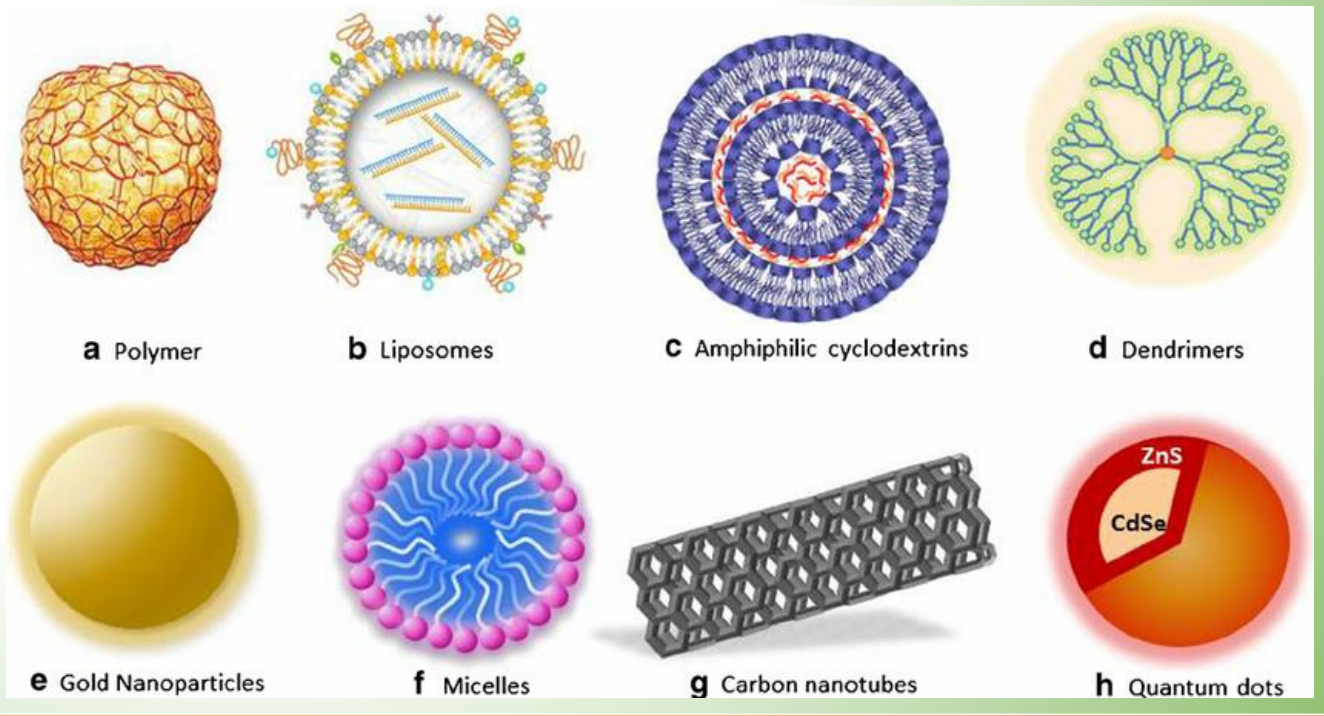






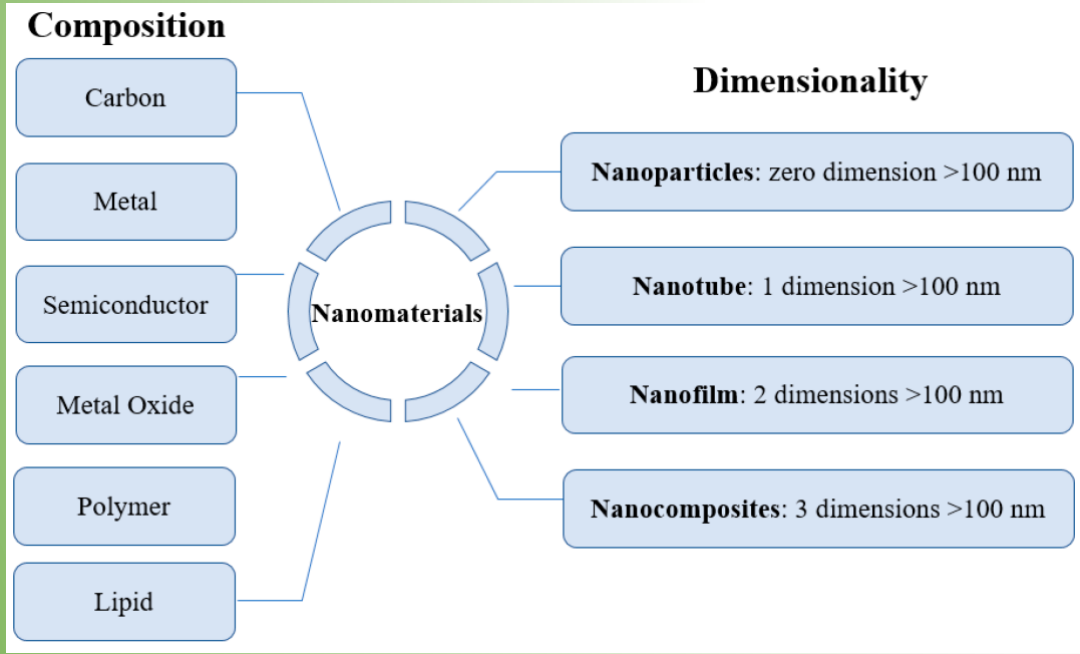
Artificial Nanomaterials

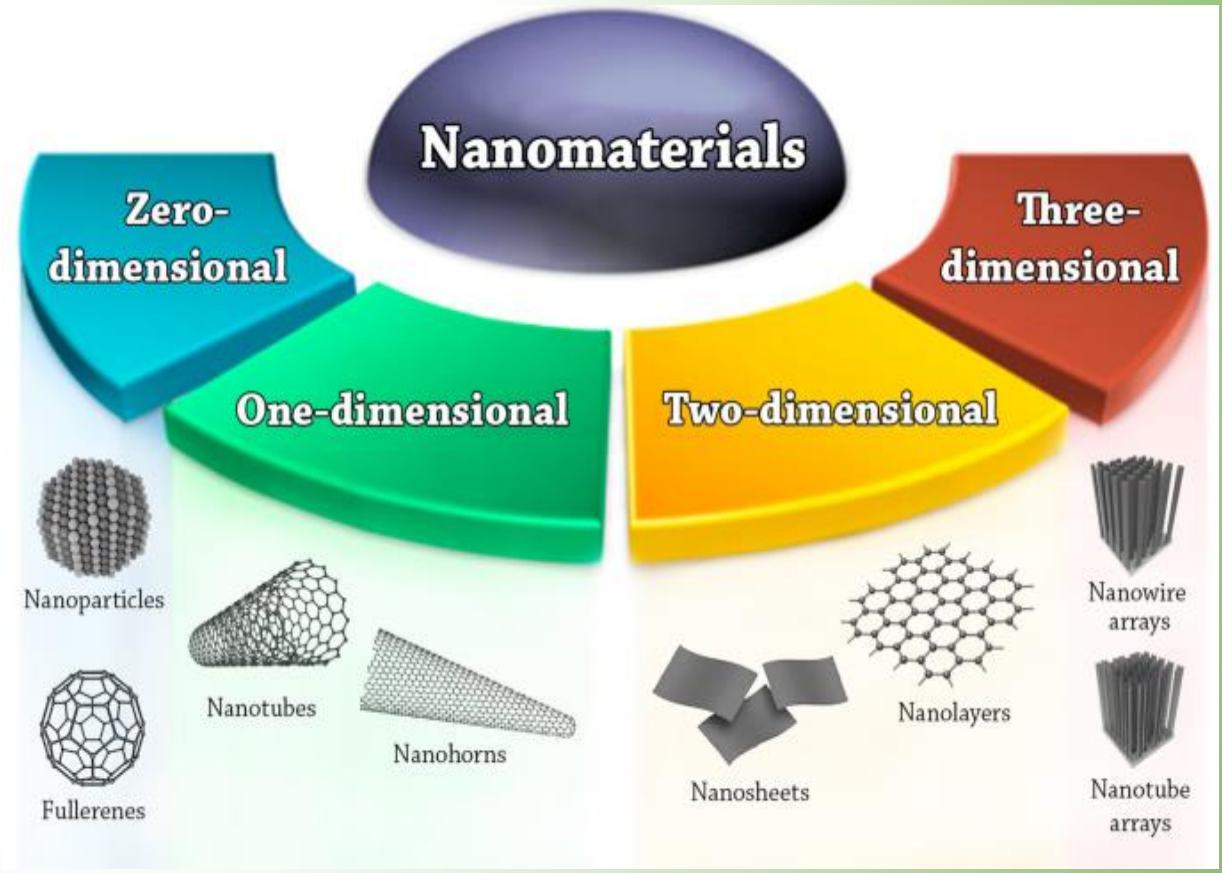
- Carbon Nanotubes
- Semiconductor nanoparticles like quantum dots
- Buckyballs



Based on the dimensions, nanomaterials are classified as:

- *Zero dimensional nanostructures*
- *One dimensional nanostructures*
- *Two dimensional nanostructures*
- *Three dimensional nanostructures*

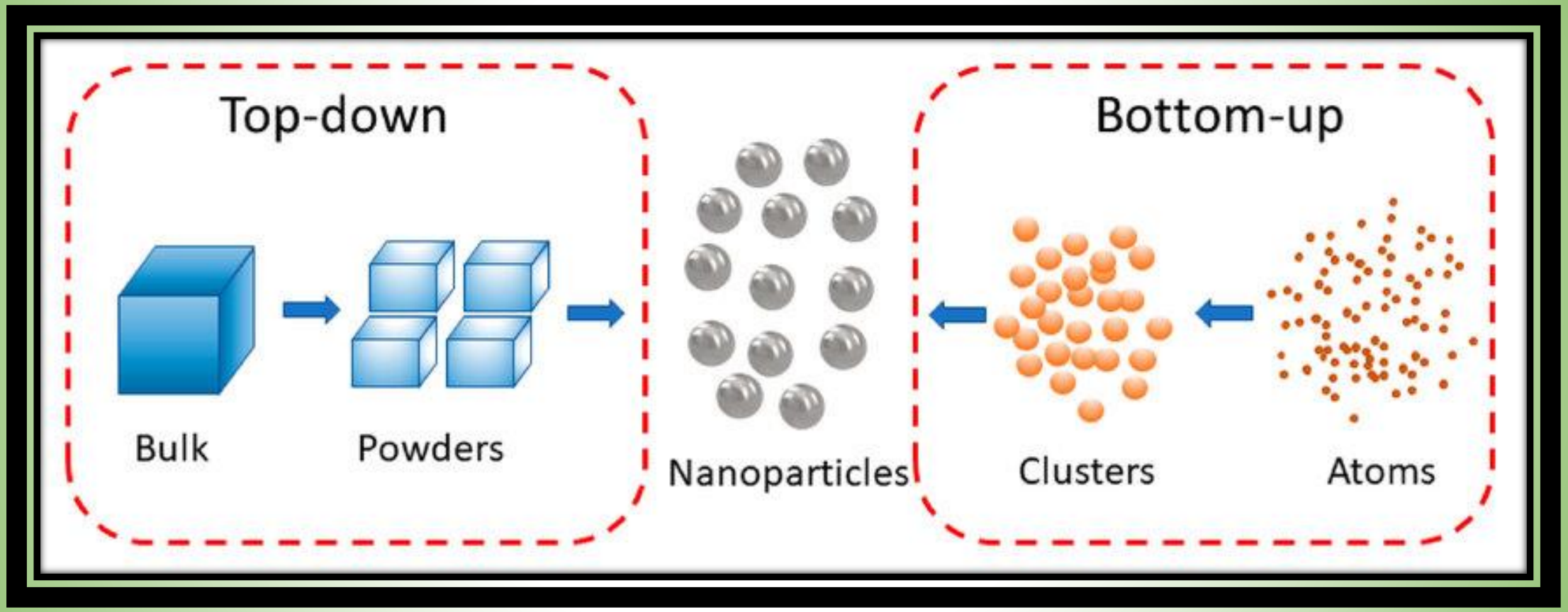




Properties of Nanomaterials

- ✓ *Mechanical Properties*
- ✓ *Thermal Properties*
- ✓ *Melting Point*
- ✓ *Optical Properties*
- ✓ *Magnetic Properties*
- ✓ *Electrical Properties*
- ✓ *Chemical Properties*
- ✓ *Catalytic Properties*

Synthesis of Nanomaterials



Top-down Methods

- Ball Milling
- Lithography
- Gas Condensation
- Severe Plastic deformation

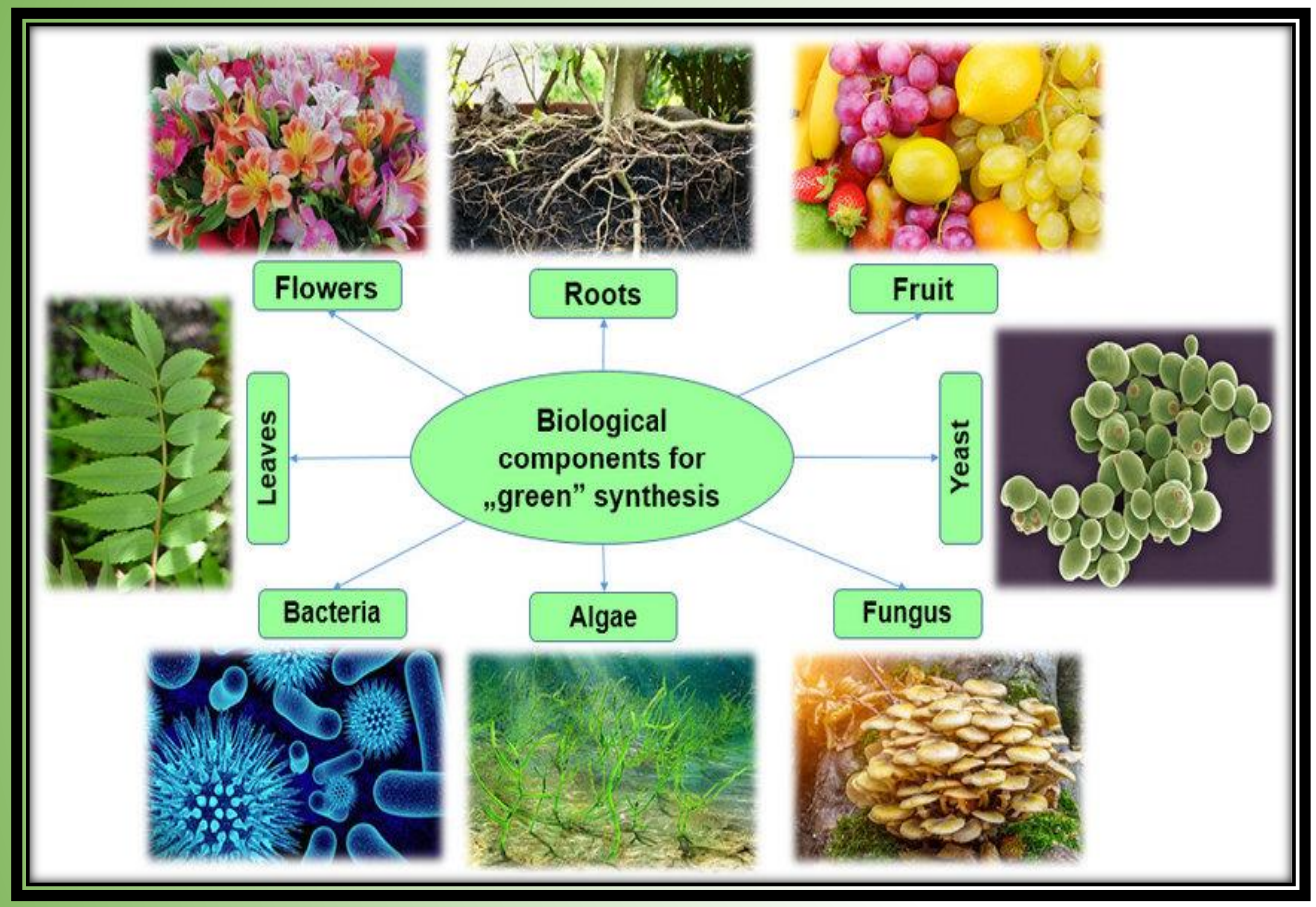
Advantages: *Versatility, miniaturization, precision, reproducibility, batch fabrication capabilities.*

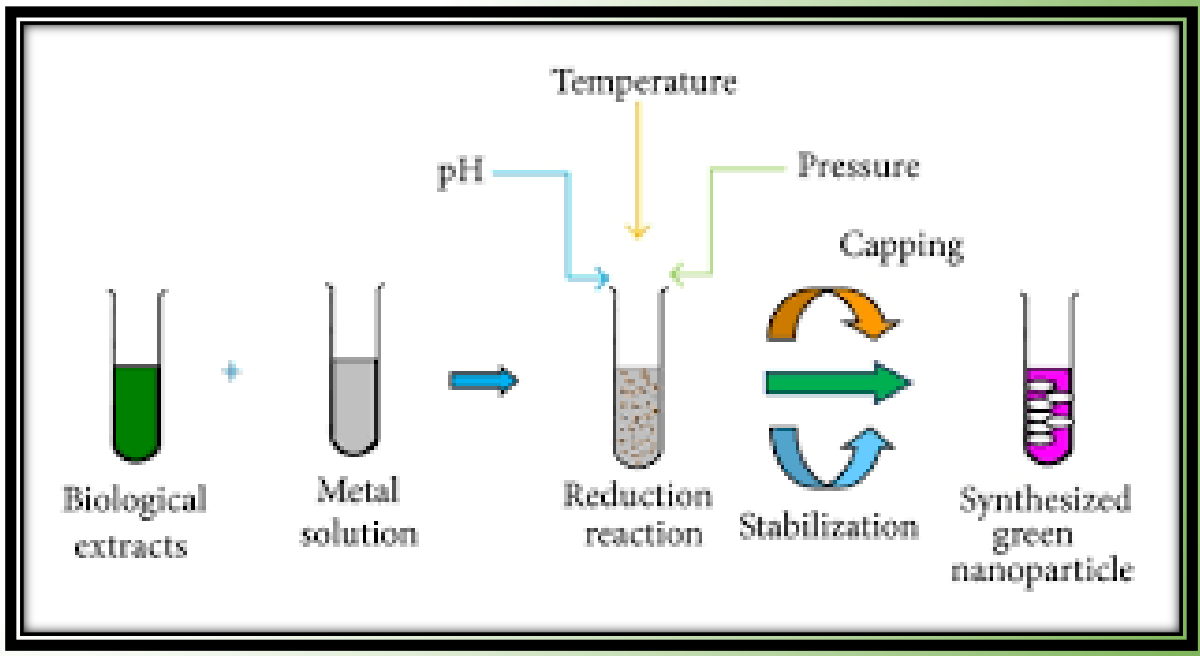
Bottom-up Methods

- Physical Vapor Deposition
- Chemical Vapor Deposition
- Plasma Process
- Sol-gel Process
- Soft Lithography
- Self Assembly

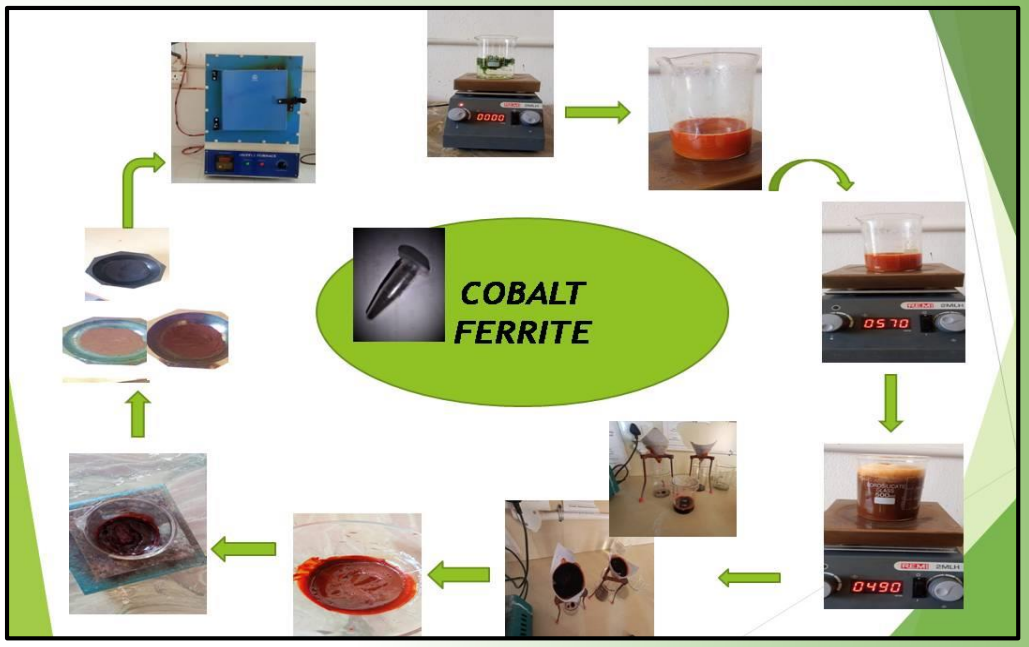
Advantages: *Unique biomolecular control, biomimetic behaviour, create materials with sophisticated properties and unique functionality, enable devices to create automatically through self assembly.*

Synthesis of Nanomaterials Using Natural Sources





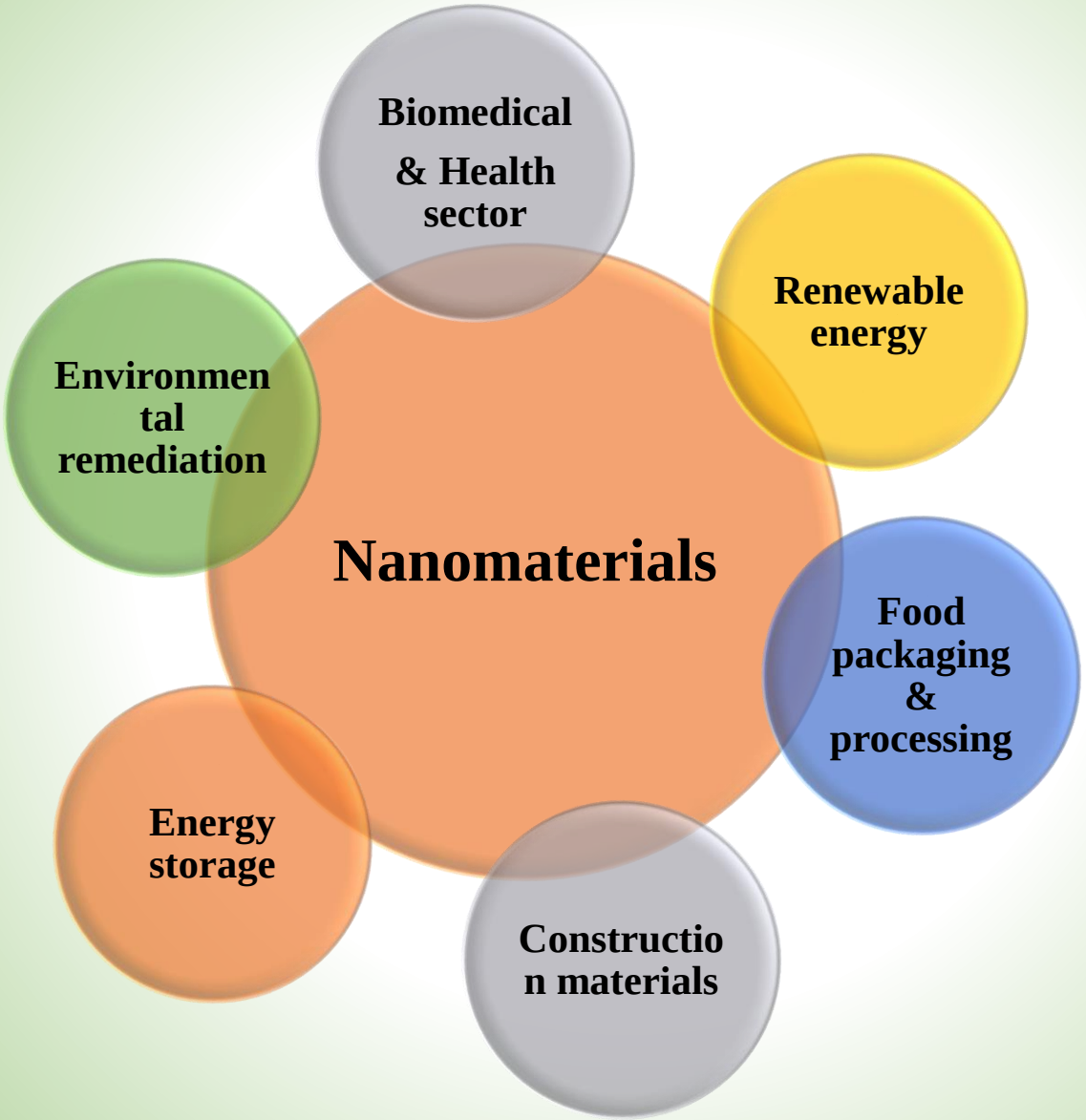
Synthesis of Nanomaterials Using Natural Sources



PREPARATION OF LEAF EXTRACT: The Fresh leaves of *colocasia* was collected and washed thoroughly with distilled water. 20g of leaves was cut and added to 300ml of distilled water. The mixture was boiled for 2hrs until half of it is reduced and the color of aqueous solution became green. The extract was cooled at room temperature and filtered.

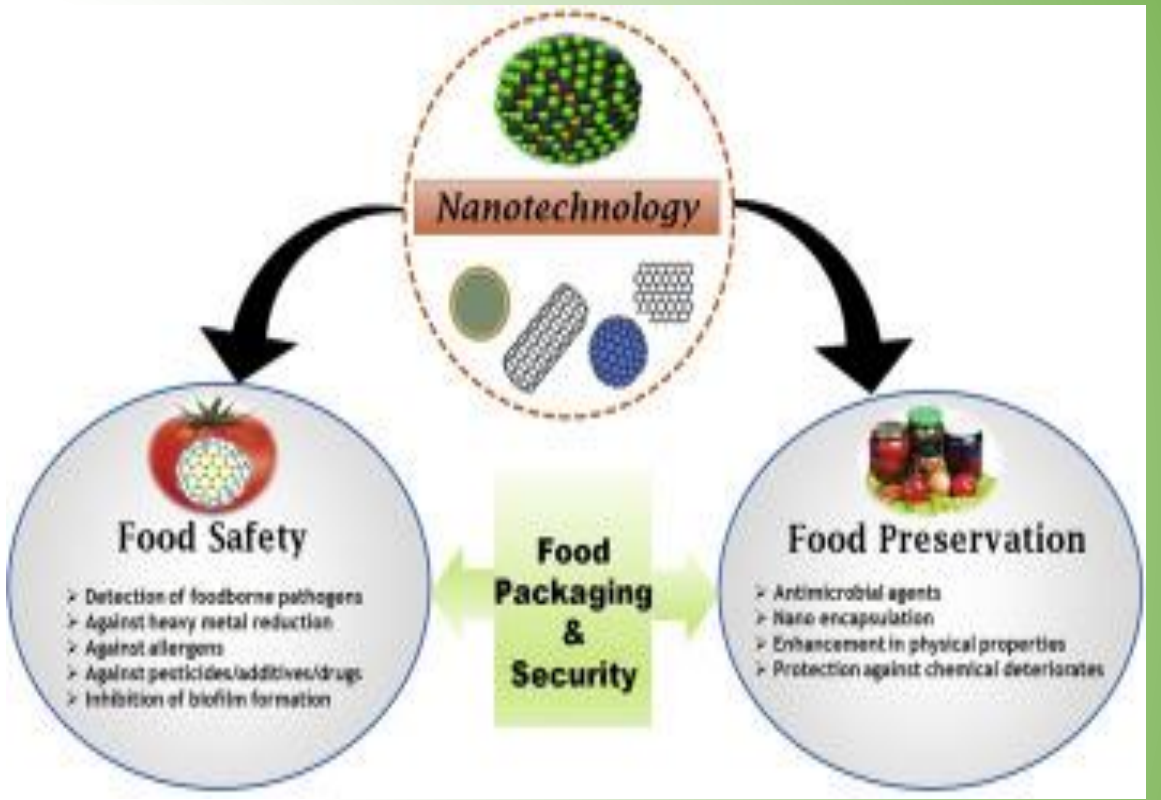
PREPARATION OF COBALT FERRITE NANOPARTICLES: For the preparation of cobalt ferrite nanoparticles from *colocasia* leaf extract, the metal nitrates in the ratio $2Fe^{3+}$:$1Co^{2+}$ were added to the 100ml of aqueous extract of *colocasia esculenta* leaf under continuous stirring. The pH of the mixture was raised by adding (25%) NH_4OH solution. The dark brown precipitates were separated from aqueous solution. The precipitates were filtered and dried over hot plate. The dried powder was annealed at 800^oC for 2hr to improve the degree of crystallization of cobalt ferrite.

Applications of Nanomaterials in Various Fields



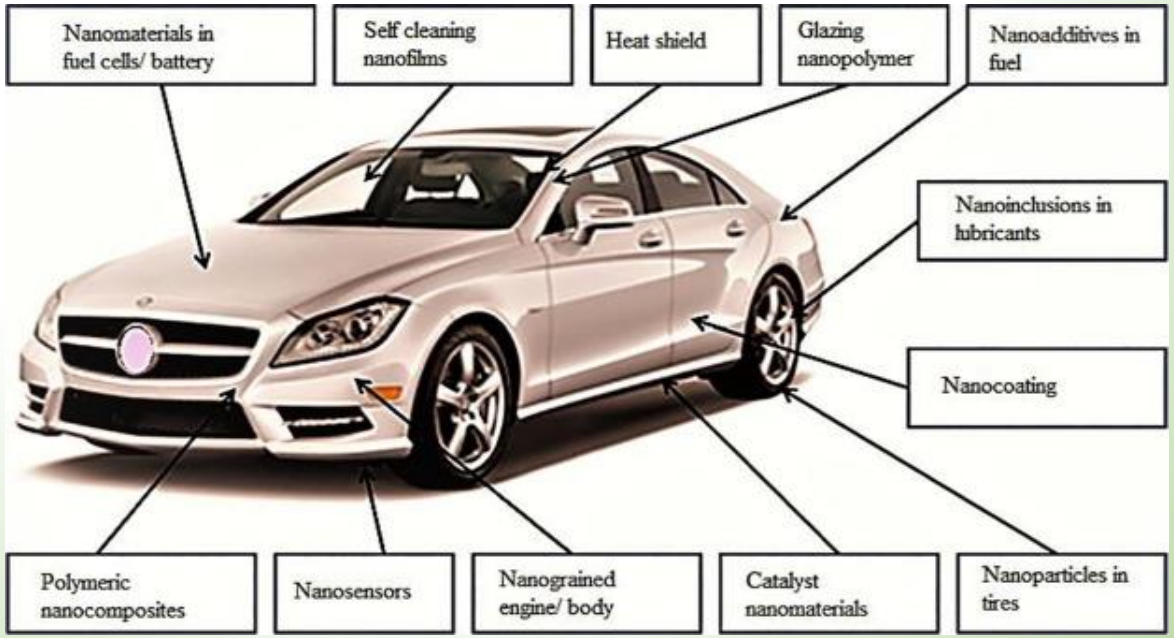
• Food Industry

- Nanoparticles like Silver mixed with polymers are being used to enhance the quality of food packaging material thereby increasing its shelf life.
- Making it last longer and taste better. Furthermore, "***smart packaging***", through which biological changes occurring in the food are detected is also one of the significant applications of Nanotechnology.
- Keeping in mind the assurance of food safety, various applications of nanotechnology are involved in agriculture and agri-business.
- The importance of nanotechnology in food processing can be evaluated by considering its role in the improvement of food products in terms of food texture, food appearance, food taste nutritional value of the food, and food shelf-life.



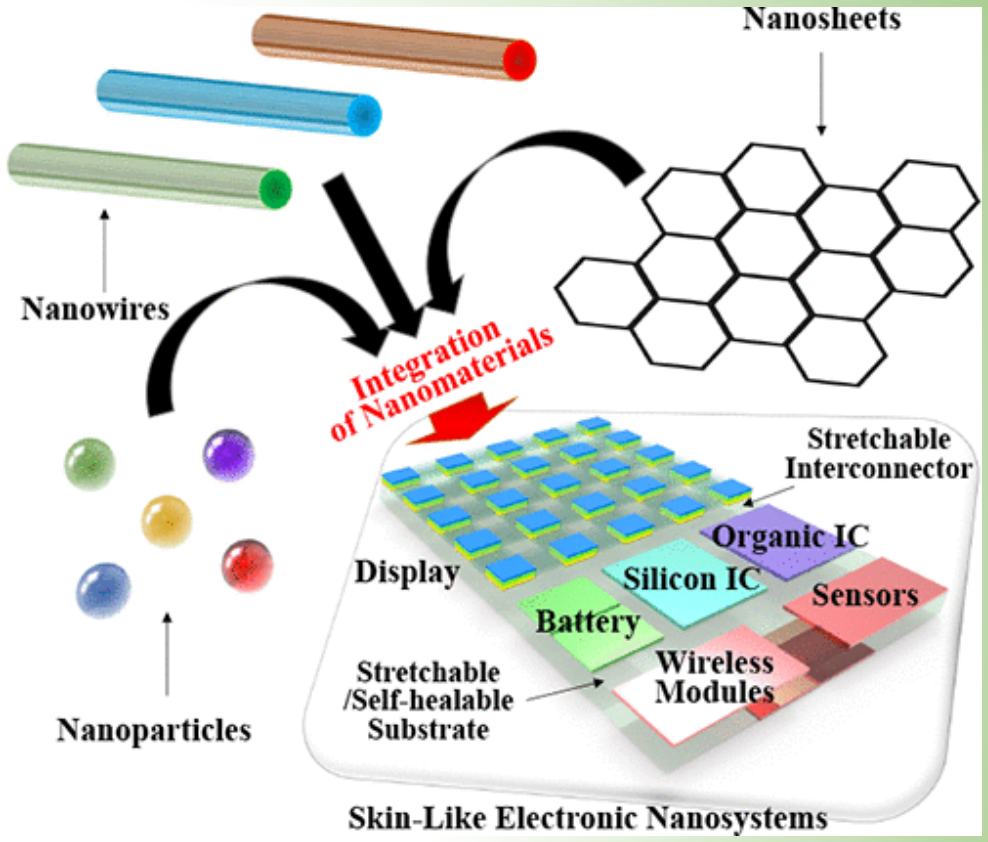
• Automobile Industry

- The automobile industry has seen a paradigm shift in the past decade.
- Every now and then, new four- and two-wheeler models are launched which work on extra-edge technology.
- This is yet another industry where the applications of Nanotechnology are visible.
- Various polymer nanocomposites like Natural Rubber-Organoclay have been used in tyres to make them abrasion-resistant.
- Furthermore, adding nanoparticles like tungsten nanospheres to car fluids has enhanced their mechanical properties.



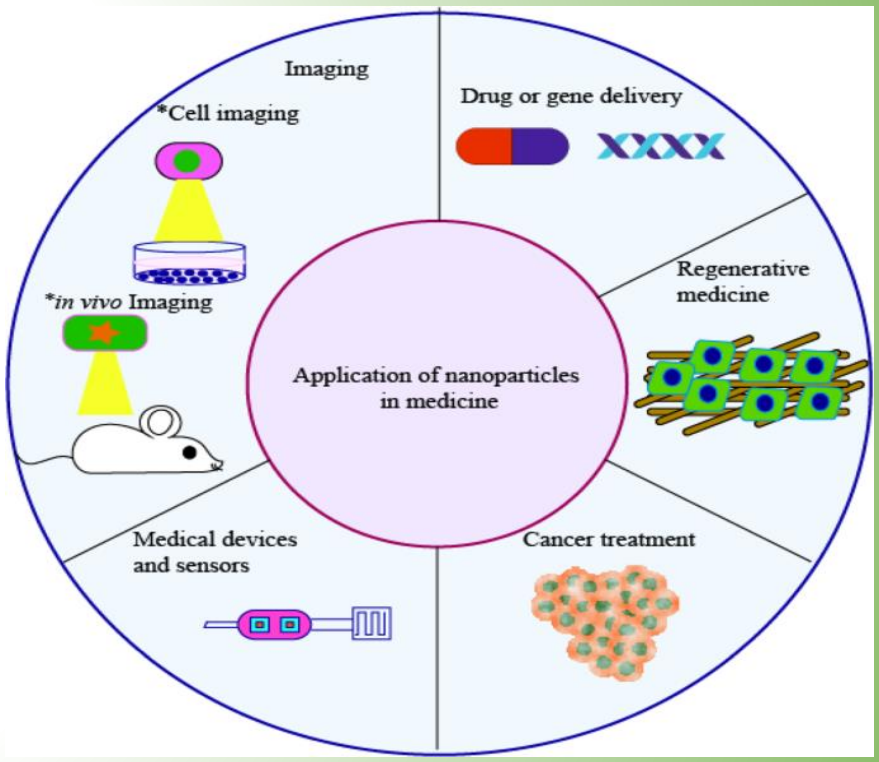
• Electronic Devices

With the advancement in technology, we have shifted from bulky Television sets and mobile phones to sleek TV sets and smartphones. Moreover, with the use of nanomaterials like Graphene, thin, lightweight, better quality TV screens which also consume less power.



• Medicine

- Various treatments and medicines for chronic diseases like cancer, brain tumor, etc have severe side effects on the patients.
- For this, Nanoparticles are being utilized wherein, the drug will be targeted to the infected cells instead of the whole body.
- Apart from this, a wide range of nanomaterials is being used to enhance the efficiency of imaging devices.
- Medicinal applications of nanotechnology are not only restricted to the aforementioned areas but are also seen in gene therapy, wound treatment, etc.



• Improving Air Quality

- ❑ Deteriorating air quality has become a global issue and for this, nanomaterials are being used extensively.
- ❑ On one hand, membranes coated with nanomaterials like Graphene Oxide are being used to separate pollutants from the air.
- ❑ While on the other, research is being conducted to improve the efficiency of catalysts which can help in minimizing the effect of air pollutants from industrial plants, cars, air conditioners, etc.
- ❑ Such catalysts, which are made up of nanoparticles provides a large surface area for the chemicals to react.

• Enhancing Water Quality

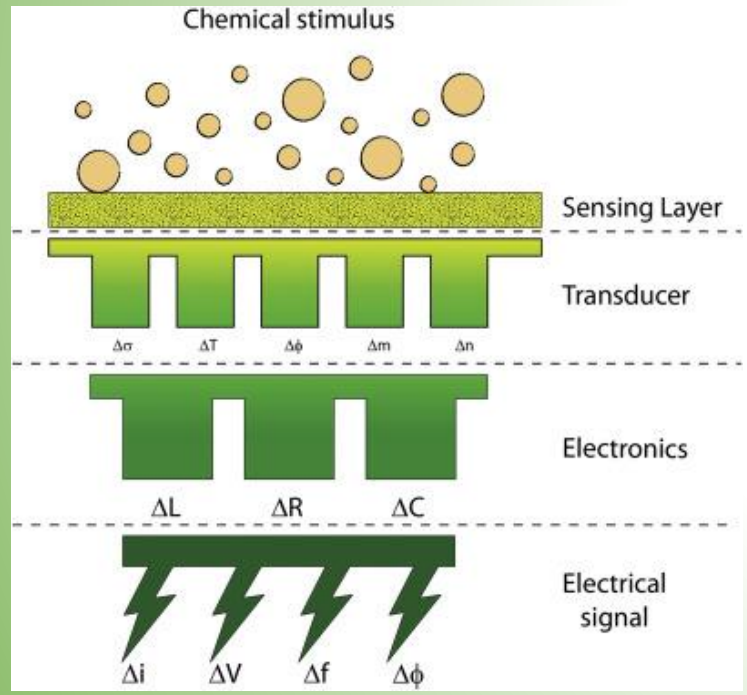
This is one of the best applications of Nanotechnology where unique nanoparticles are used on filtration membranes to improve the quality of water by removing chemical and industrial waste such as TCE from the river and groundwater. Using Nanotechnology for purification of water is highly effective and comparatively cheaper.

• Space Science

Another domain where the applications of Nanotechnology is visible is Space Science and Research. Apart from making the outer structure of satellites durable and lightweight using materials like CNT, research is also being done on how to send spacecraft with lesser fuel.

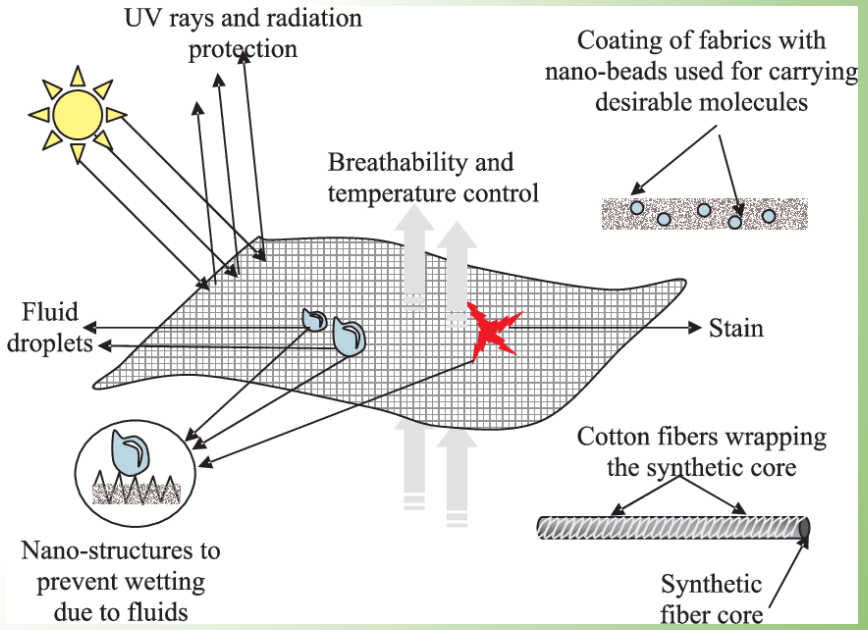
• Chemical Sensors

Using nanomaterials like Zinc Oxide nanowires, Carbon nanotubes as well as palladium nanoparticles, various sensors have been designed which can easily detect even the smallest amounts of hazardous chemicals. This has been made possible as the electrical properties of these materials enhance at the nano-level.

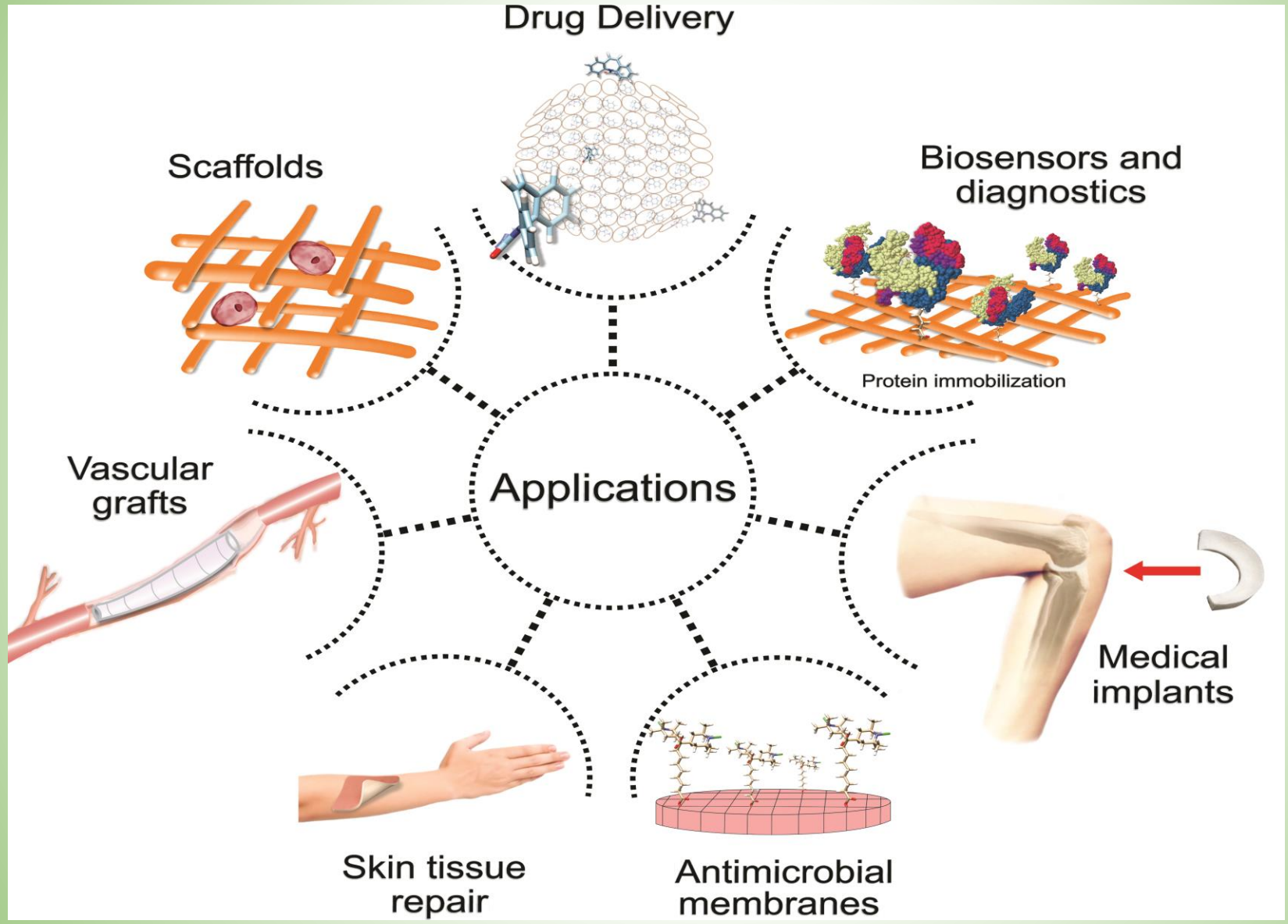


•Textiles and Fabrics

To make a piece of cloth wearable, wrinkle and odor-free across seasons, specialized fabrics with nano-sized Silver and Titanium particles are being used. This has led to the production of lightweight, thin and breathable fabrics. The other applications of Nanotechnology in this industry include making fabrics stain-resistant and improving durability.



Applications of Nanobiotechnology



Nanomedicines: Targeted Drug Delivery

- **Is a method of delivering medication to a patient in a manner that increases the concentration of the medication in some parts of the body relative to others.**

Goal :

- **to prolong, localize, target and have a protected drug interaction with the diseased tissue.**

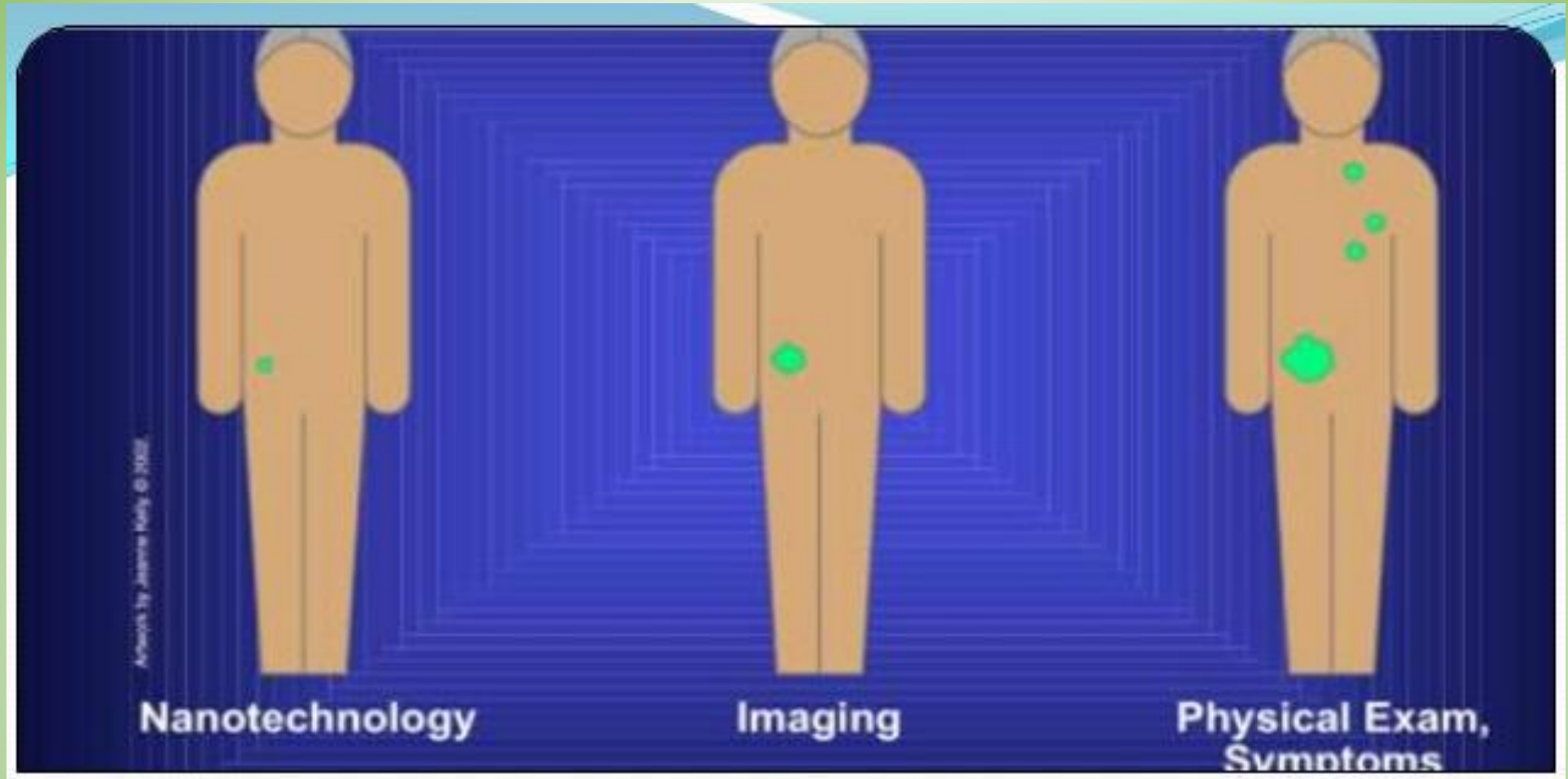
Traditional v/s Targeted Drug Delivery

In *traditional drug delivery systems* such as oral ingestion or intravascular injection, the medication is distributed throughout the body through the systemic blood circulation.

For most therapeutic agents, only a small portion of the medication reaches the organ to be affected.

Targeted drug delivery seeks to concentrate the medication in the tissues of interest while reducing the relative concentration of the medication in the remaining tissues.

Targeted delivery is believed to improve efficacy while reducing side-effects.



Nanodevices can improve cancer detection

- Detection of cancer at early stages is a critical step in improving cancer treatment. Currently, detection and diagnosis of cancer usually depend on changes in cells and tissues that are detected by a doctor's physical touch or imaging expertise.

Advantages of Nanotechnology Treatment

- Nanoscale devices have the potential to radically change cancer therapy for the better and to dramatically increase the number of highly effective therapeutic agents.

- Nanotechnology may also be useful for developing ways to eradicate cancer cells without harming healthy, neighboring cells.

Antimicrobial Nanoparticles

- Despite numerous existing potent antibiotics and other antimicrobial means, bacterial infections are still a major cause of morbidity and mortality.
- Moreover, the need to develop additional bactericidal means has significantly increased due to the growing concern regarding multidrugresistant bacterial strains and biofilm associated infections.
- Consequently, attention has been especially devoted to new and emerging nanoparticle-based materials in the field of antimicrobial chemotherapy.

Silver Nanoparticles

- Of the metal nanoparticles, silver nanoparticles have been widely used as an effective antimicrobial agent against bacteria, fungi, and viruses .
- Ag and its compounds have long been used for the disinfection of medical devices and water purification.
- In medicine, Ag compounds are commonly applied to treat burns, wounds, and a variety of infectious diseases .
- Although the Ag nanoparticle mechanism of action is still not clear, small diameter Ag nanoparticles have a superior antimicrobial effect to those of a larger diameter.

Titanium Oxide

- Titanium dioxide (TiO_2) is another metal oxide that has been extensively studied for its antimicrobial activities .
- TiO_2 has long been known for its ability to kill both Gram-positive and Gram-negative bacteria .
- More recent reports have shown its efficiency against various viral species and parasites.
- TiO_2 is effective against many bacteria including spores of Bacillus , which is the most resistant organism known.
- As with other NM, combinations of Ti or TiO_2 with other NM such as Ag were found to have a synergistic effect and to enhance their activity.

Zinc Oxide

- Zinc oxide (ZnO) NM are of relatively low cost and effective in size dependency against a wide range of bacteria .

- These include pathogens such as *Klebsiella pneumonia* , *Listeria monocytogenes*, *Salmonella enteritidis* , *Streptococcus mutans*, *Lactobacillus and E. coli with low toxicity to* human cells.

- Furthermore, treatment using zinc was approved by the FDA and nowadays Zn is available as a food additive.

Iron Oxide and Gold

- Fe_3O_4 nanoparticles and gold (Au) represent an additional class of antimicrobial materials used in health care .
- Microbiological assays have proved that surfaces modified using Fe_3O_4 nanoparticles demonstrate antiadherent properties and significantly reduce both Gram-negative and Gram-positive bacterial colonization .
- Au nanoparticles and nanorods have been reported to be bactericidal when photothermally functionalized.

AND MANY MORE……

Conclusion

Nano materials have increased surface area and nano scale effects, hence used as a promising tool for the advancement of drug and gene delivery, biomedical imaging and diagnostic biosensors.

There is a very bright future to nano technology, by its merging with other technologies and the subsequent emergence of complex and innovative hybrid technologies.

Thank You