# Nanotechnology

## Applications in Agriculture & Food Science

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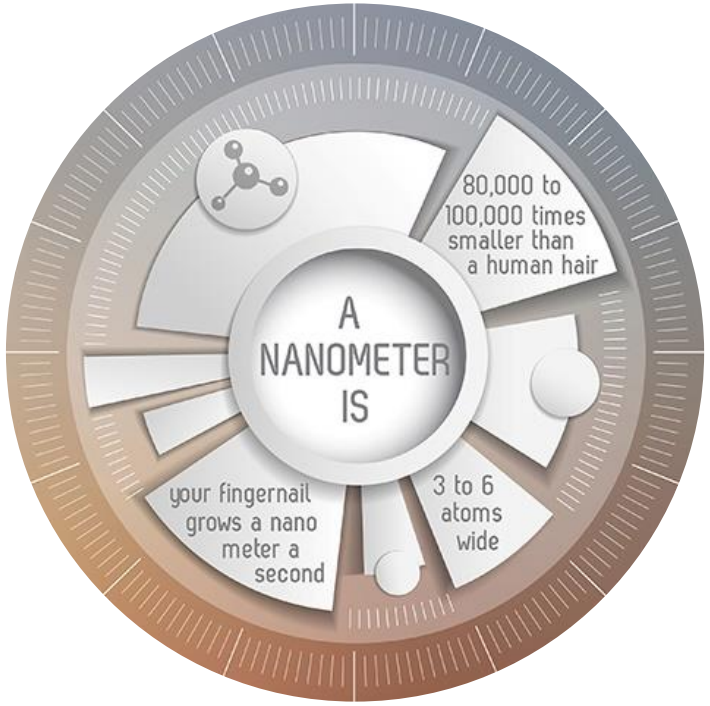
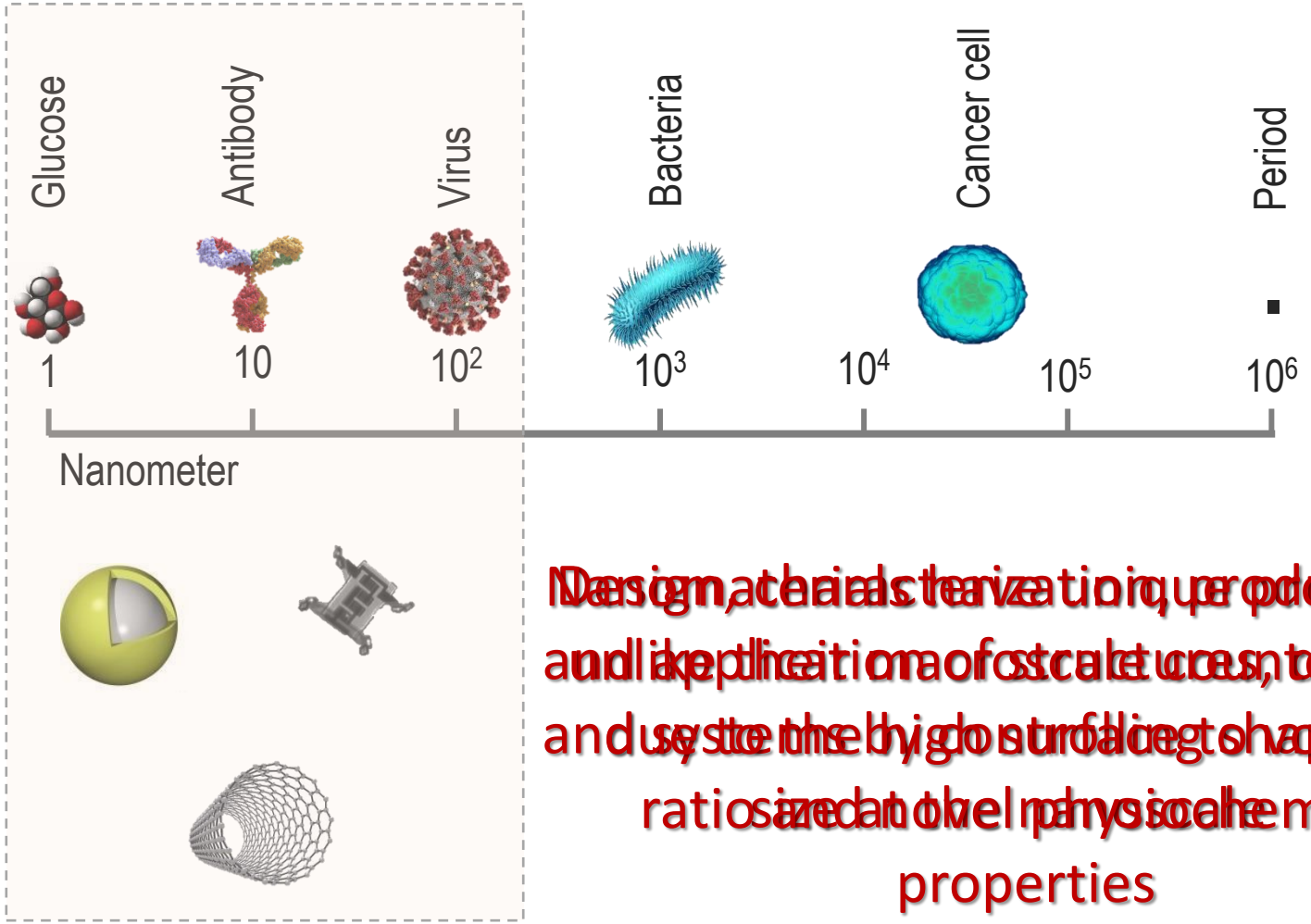
# What is Nanotechnology?



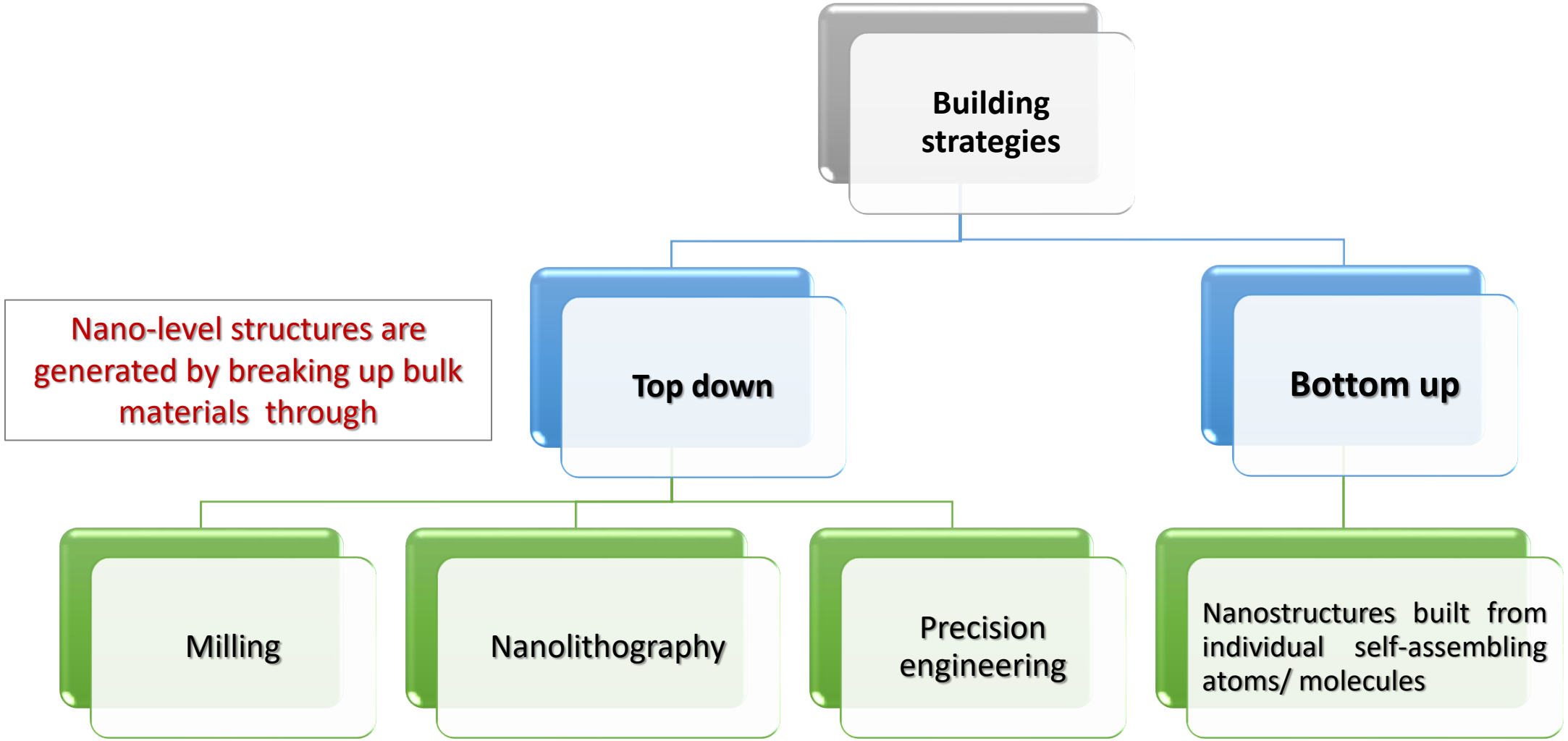




Size range for Nanotechnology

Design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale

Novel and improved physical, chemical and biological properties, phenomena and processes due to their nanometer scale dimensions

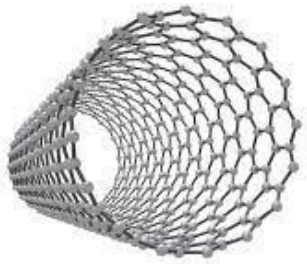
# Building strategies in Nanotechnology



# Multifield Applications of Nanotechnology

- Studying the intra- and inter-molecular interactions
- Improve the complexity and functionality of biological materials
- Elucidation of the mechanisms of catalysis and enzymatic reactions
- Cellular transport
- DNA replication and transcription
- Unknotting and unwinding, and protein folding and unfolding
- Nanotechnology in areas such as food safety and biosecurity

# Nanostructures & their Applications

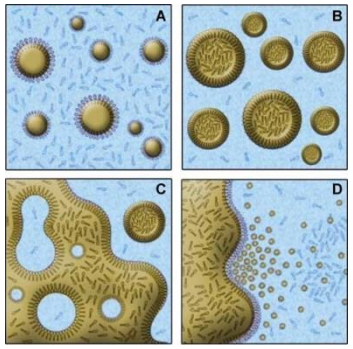


**Nanotubes**

Made by 'winding' single sheets of graphite with honeycomb structures into very long, thin tubes with a stable, strong, and flexible structure.

**Applications**

- Used as part of sensors for molecular recognition of enzymes, antibodies, various proteins and DNA
- For the membrane separation of biomolecules, such as proteins




**Nanoemulsions**

Emulsions with nanometer-size droplet diameters, produced using high pressure valve homogenizers or microfluidizers.

**Applications**

- Effective delivery of target compounds
- Development of single delivery systems containing multiple functional components / Active ingredients

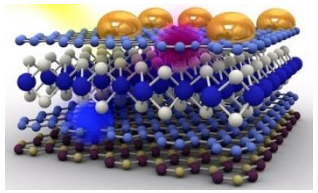
# Nanostructures & their Applications

**Biopolymeric nanoparticles**

Self-association or aggregation of single biopolymers produced using food biopolymers such as proteins or polysaccharides.

**Applications**

- Encapsulate functional ingredients
- Starch nanoparticles used in mixing and emulsification

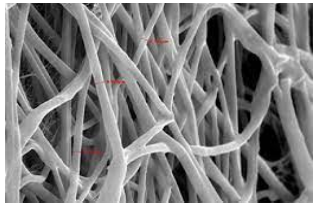


**Nano-composites**

Made from nanoscale structures with unique morphology, & increased modulus, strength & good barrier properties produced by biomineralization.

**Applications**

- Useful for food-packaging applications



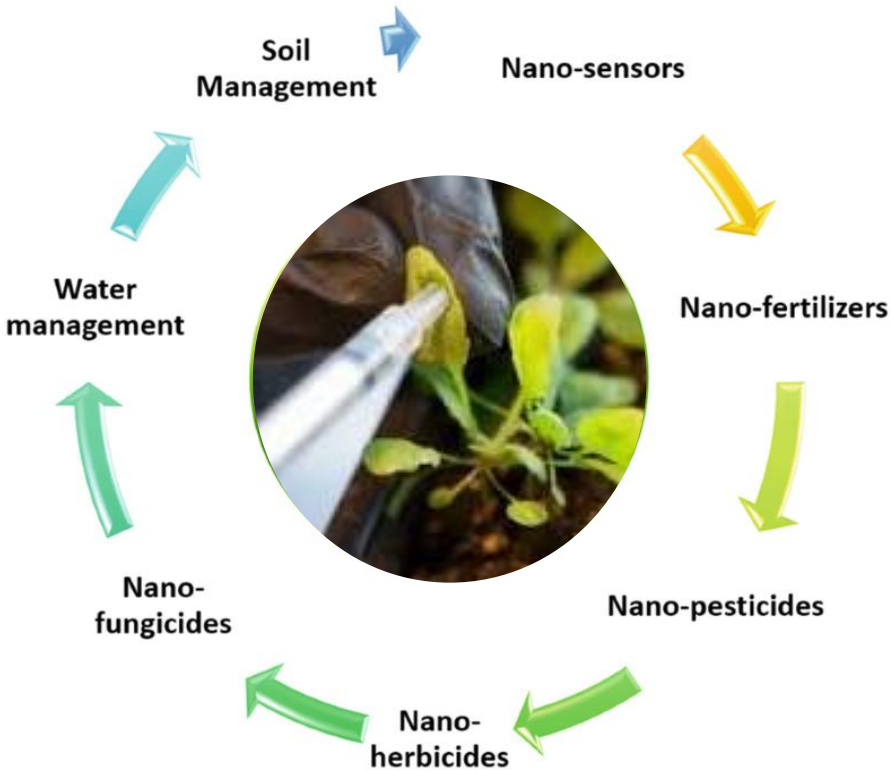
**Nanofibers**

Polymeric strands of sub-micrometer diameters produced by interfacial polymerization & electrospinning.

**Applications**

- Food-packaging materials
- Fabrication of nanostructured scaffolding for bacterial cultures

# Nanotechnology Applications in Agriculture



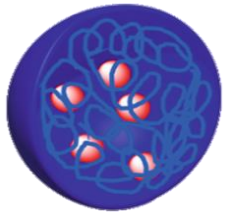

Nazir et al., 2020

1. Nanoformulations of agrochemicals
2. Nanosensors/nanobiosensors in crop protection
3. Nanodevices for the genetic manipulation
4. Plant disease diagnostics
5. Postharvest management
6. Animal health, animal breeding

# Nano-agrochemicals

## Nanopesticides

- **Microencapsulated Nanospheres**



  - Enhanced dispersion of hydrophobic pesticides in aqueous media
  - Enhanced penetration in the plant compared to classical suspension

  e.g. Polycaprolactone and poly(lactic) acid nanospheres are used for encapsulation of insecticide.

- **Controlled Release Formulations**

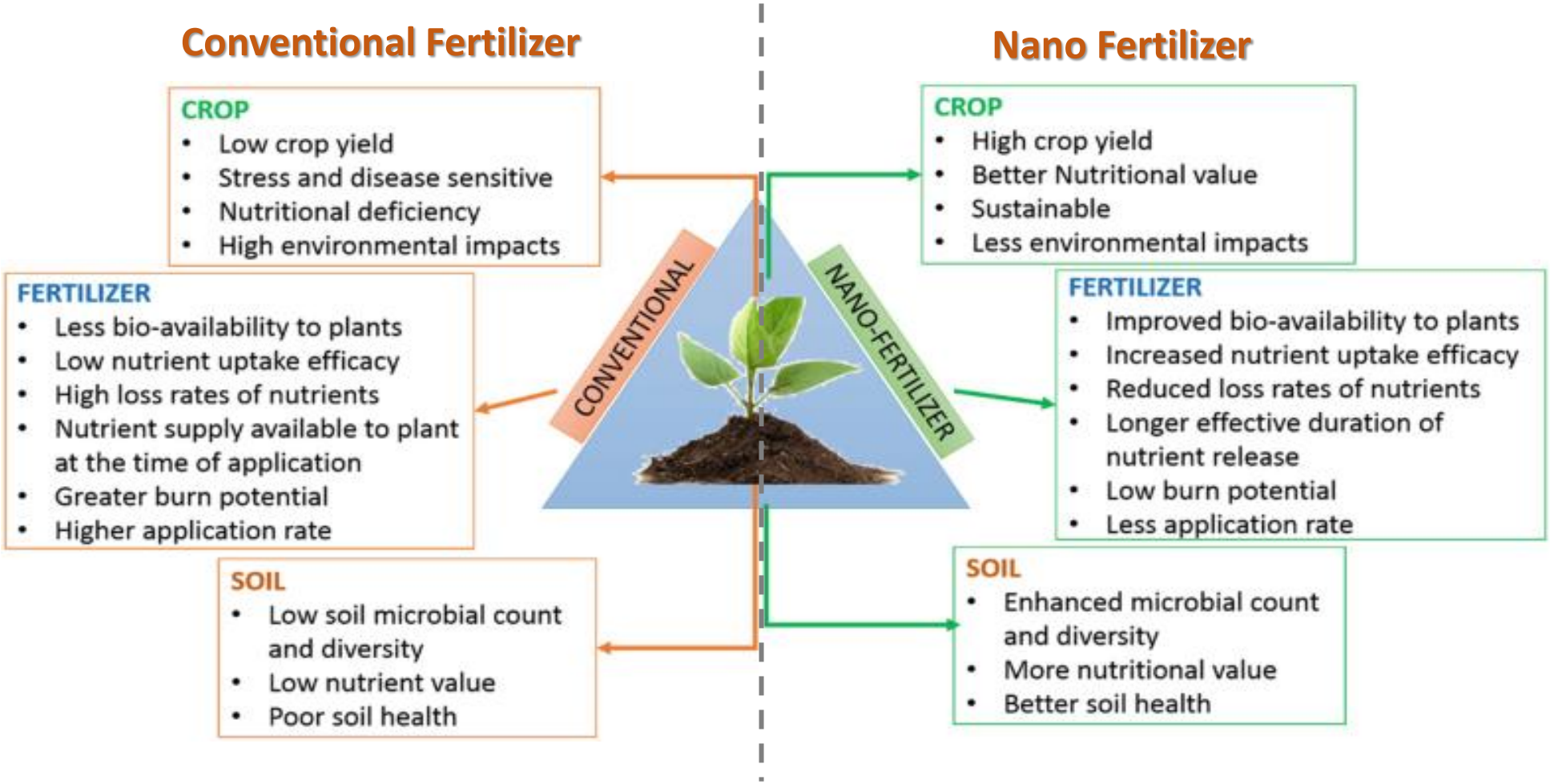
  - Slow chemical release under controlled situations, reducing application dosage and improving efficiency
  - Active compounds release by mechanisms of dissolution, biodegradation, diffusion, and osmotic pressure
  - Absence of residues at the time of harvesting

- **Nanoparticles**

  - Nanomaterials includes polymeric nanoparticles, iron oxide nanoparticles, gold nanoparticles, and silver ions
  - Control delivery of pesticide and achieve greater effects with lower chemical dose
  - Smaller size of nanoparticles and emulsions used make them more potent

# Nano-agrochemicals

## Nano-fertilizers

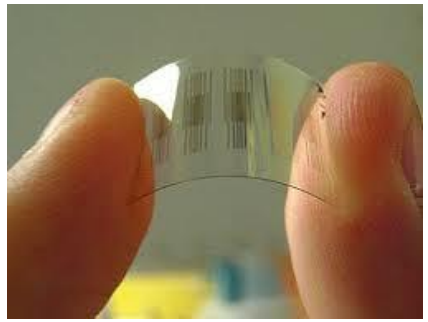


# Nano-sensors in Agriculture

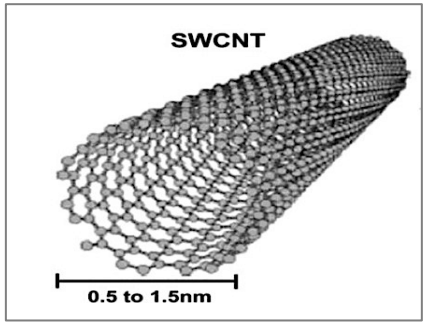
## Applications

- Soil quality
- Disease management
- Contaminants detection
- DNA detection
- Proteins detection
- Precision farming

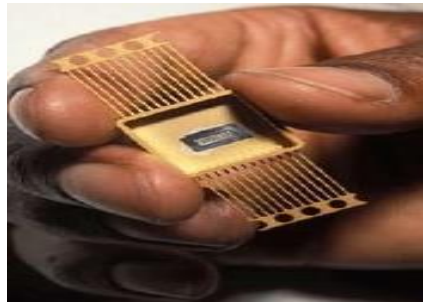
## Types of Sensors



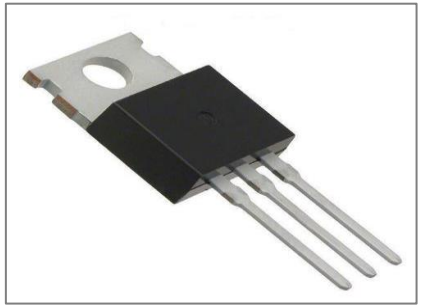
Nano-barcodes




Single-walled carbon nanotube (SWCNT) hybrid sensor



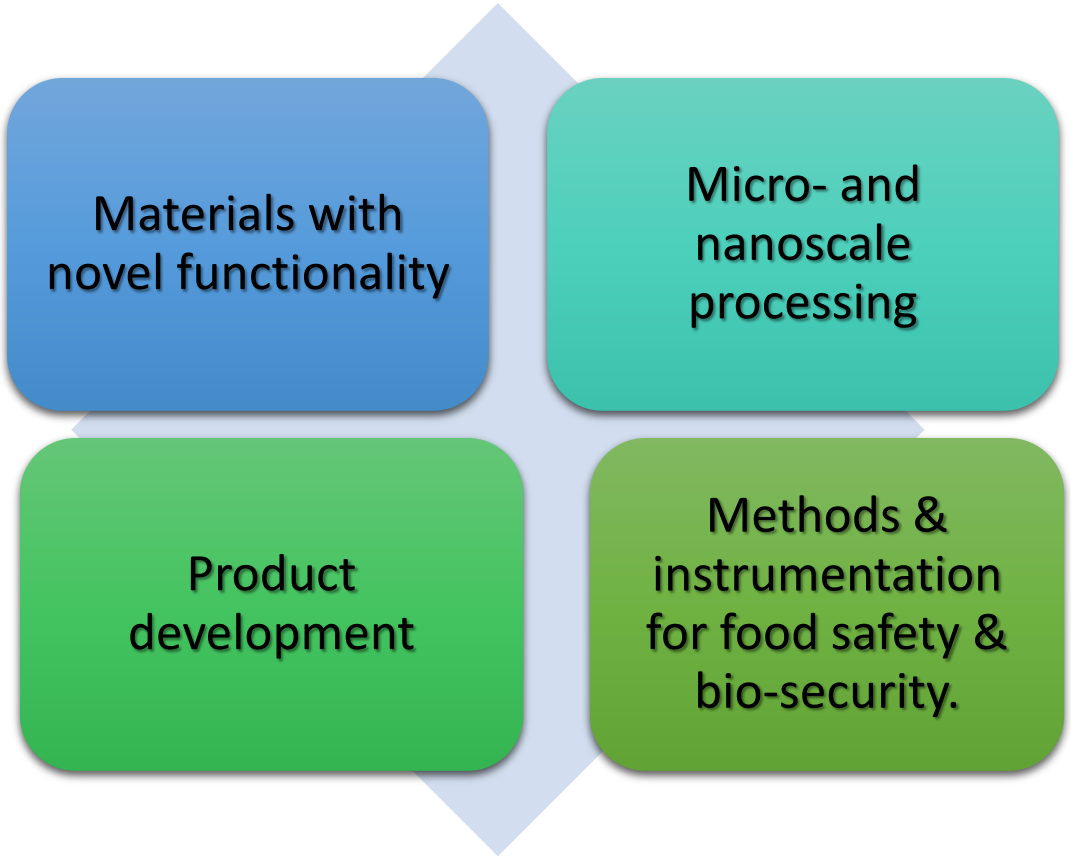
Nanostructure-based gas sensor arrays



Field-effect transistors based on nanotubes, nanowires

# Nanotechnology in Food Science: Target Areas

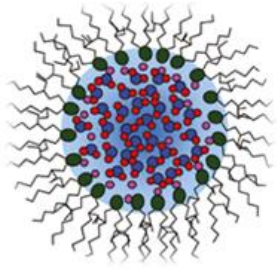
**Four major target areas in food science and technology are expected to be significantly enhanced by nanotechnology**



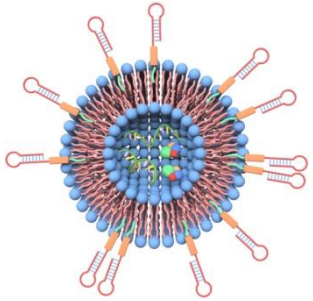
# Nanotechnology Applications: Food Processing

## Nano-delivery Systems

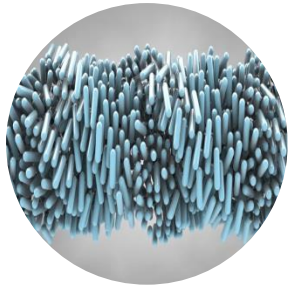
- Nanotechnology in form of encapsulation, emulsions, biopolymer matrices, simple solutions, and association colloids offers efficient delivery systems.
- Facilitates development of novel systems, to deliver functional ingredients.
- Facilitates precise control of properties & functionality at the molecular level.
- Controls delivery of any bioactive compound to various sites within the body.
- Encapsulating delivery systems improves bioavailability and preservation of the active food components.



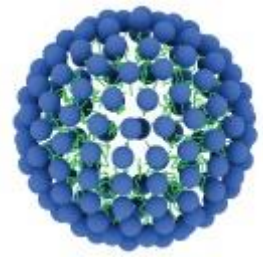
Reverse micelles



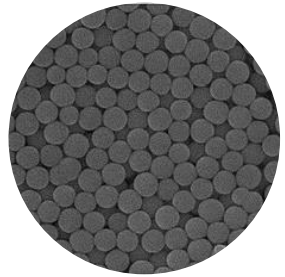
Vesicles



Liquid crystals



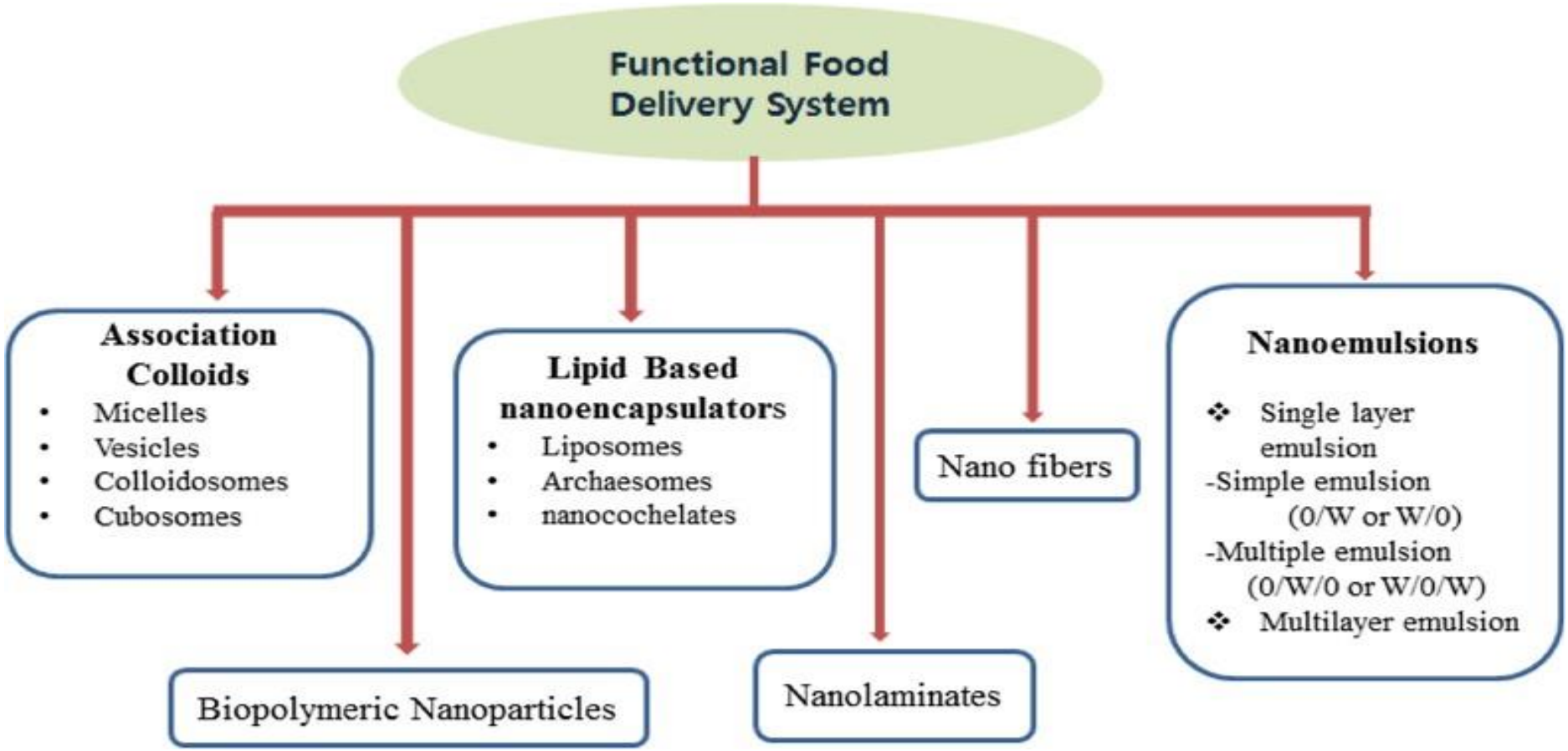
Surfactant micelles



Nano-sized association colloids

# Nanotechnology Applications: Food Processing

## Nano-delivery Systems



# Nanotechnology Applications: Food Processing

## Nano-delivery Systems

# Nanotechnology Applications: Food Processing

## Enhance Texture, Taste, and Appearance of Food

Nanoencapsulation techniques improve the flavor release and retention to deliver culinary balance

- Nanoencapsulation stabilized highly reactive and unstable plant pigment anthocyanins.
- Encapsulation of cyanidin-3-O-glucoside (C3G) molecules within soybean seed H-2 subunit ferritin (rH-2) improved thermal stability and photostability.
- Encapsulation enhanced the solubility, thermal and UV radiation stability of ferritin trapped rutin.
- Metallic oxides such as titanium dioxide and silicon dioxide ($SiO_2$) used as color or flow agents in food items.
- $SiO_2$ nanomaterials are used as carriers of fragrances or flavors in food products.

# Nanotechnology Applications: Food Processing

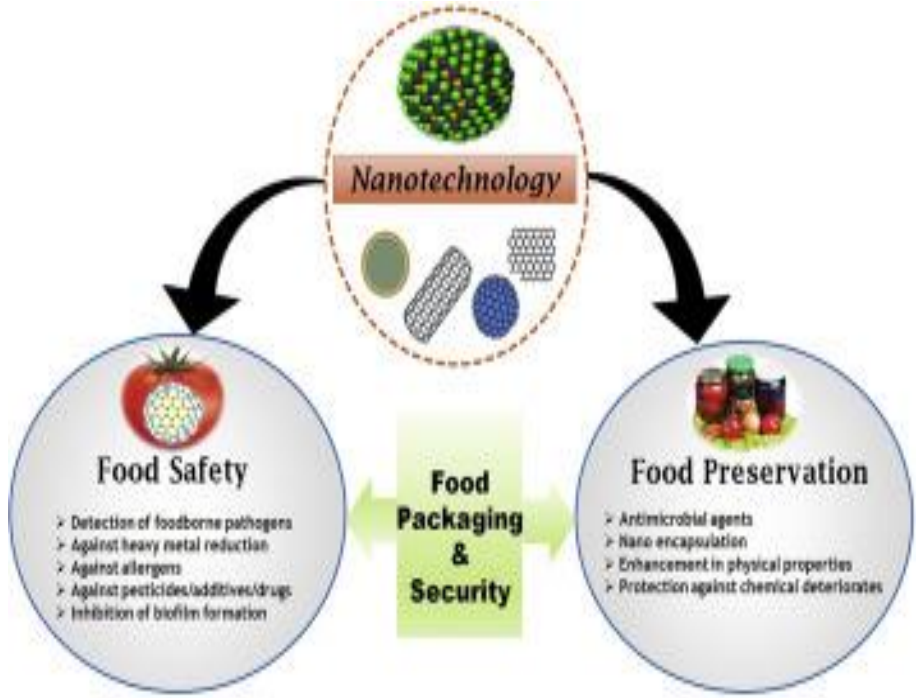
## Enhanced Nutritional Value

| Nano-technique | Characteristic feature | Examples |
|---|---|---|
| Edible coatings | Preserve the quality of fresh foods during extended storage. | Gelatin-based edible coatings containing cellulose nanocrystal |
| Hydrogels | Protects bio-actives from extreme environments, and deliver them in response to environmental stimuli. | Protein hydrogels |
| Polymeric micelles | Solubilize water-insoluble compounds in the hydrophobic interior, high solubility, low toxicity. | [poly(ethylene glycol)block-poly(caprolactone)] Polymeric micelles |
| Liposomes | Delivery vehicles for hydrophobic molecules as well as hydrophilic molecules. | Cationic lipid incorporated liposomes modified with an acid-labile polymer |
| Inorganic Nano particles | Good encapsulation capability and controlled functionalization. | Mesoporous silica nanoparticles |

# Nanotechnology Applications: Quality Control

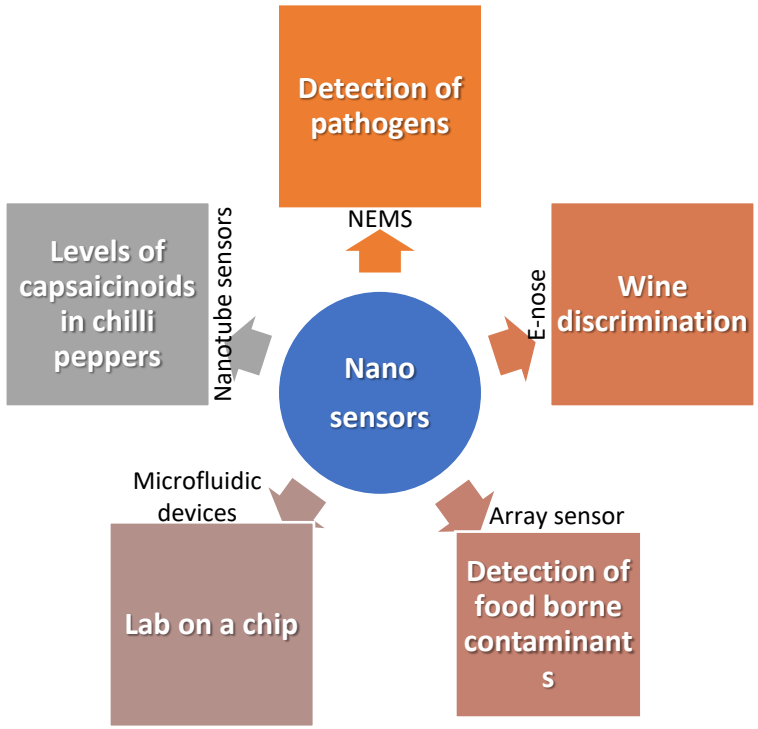
## Microbial contamination

- Microbial safety problems are related to contamination by spore adhesion.
- Quantification of spore adhesiveness by analyzing molecular mechanics.
- Determining adhesion of lactic acid bacteria to the intestinal epithelium.
- The design of materials that are resistant to bacterial adhesion.
- ‘Self-cleaning’ materials with antimicrobial compounds for killing contaminant.
- Nanoemulsions disrupting the membrane of pathogens.



# Nanotechnology Applications: Quality Control

## Detection & Biosensors




Novel solutions required for development of fast, reliable, and highly sensitive biosensors for the detection of biological agents.

Production of triangular prismatic shaped nanoparticles that can detect biological threats e.g anthrax, smallpox, and tuberculosis & genetic and pathogenic diseases .

Chip-based sensing for rapid detection of biological pathogens & early warning systems for exposure to air- and water-borne bacteria, viruses, and other antigens.

A research on reducing the infection capability of human food borne pathogens (*Campylobacter jejuni, C. coli, Salmonella enteritidis, and E. coli*) where Synthetic adhesin-specific nanoparticles bind to target bacteria, inhibiting them & infecting.

# Nanotechnology Applications: Quality Control

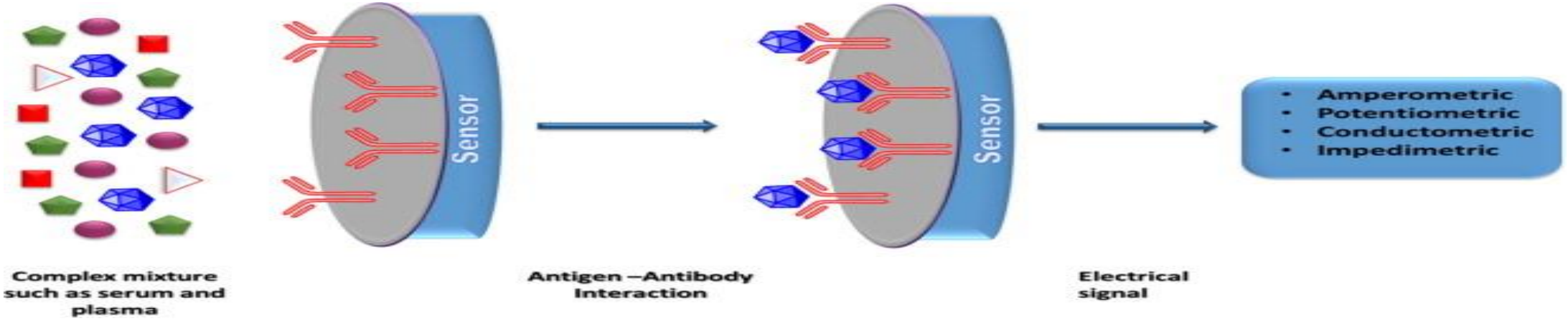
## Mechanism of Nanosensors

### Immunosensors

Specific antibodies, antigens, or protein molecules are immobilized on thin nanofilms or sensor chips which emit signals on detection of target molecules.

**Example**

Dimethylsiloxane microfluidic immunosensor with specific antibody immobilized on an alumina nanoporous membrane helps in rapid detection of *E. coli O157:H7* & *S. aureus*

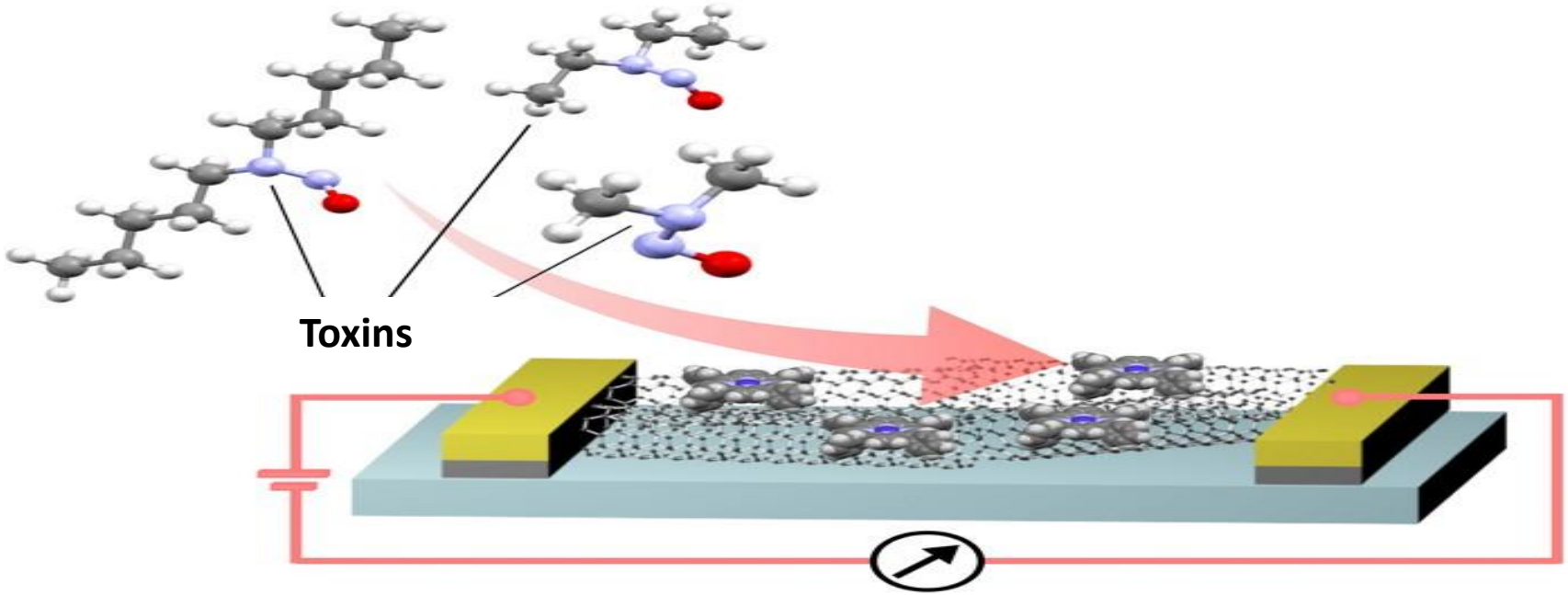


# Nanotechnology Applications: Quality Control

## Mechanism of Nanosensors

**Carbon nanotubes**

Microorganism or toxins antibodies or degraded products of food get attached to nanotubes causes a detectable change in conductivity when bound to waterborne toxins.



# Nanotechnology Applications: Quality Control

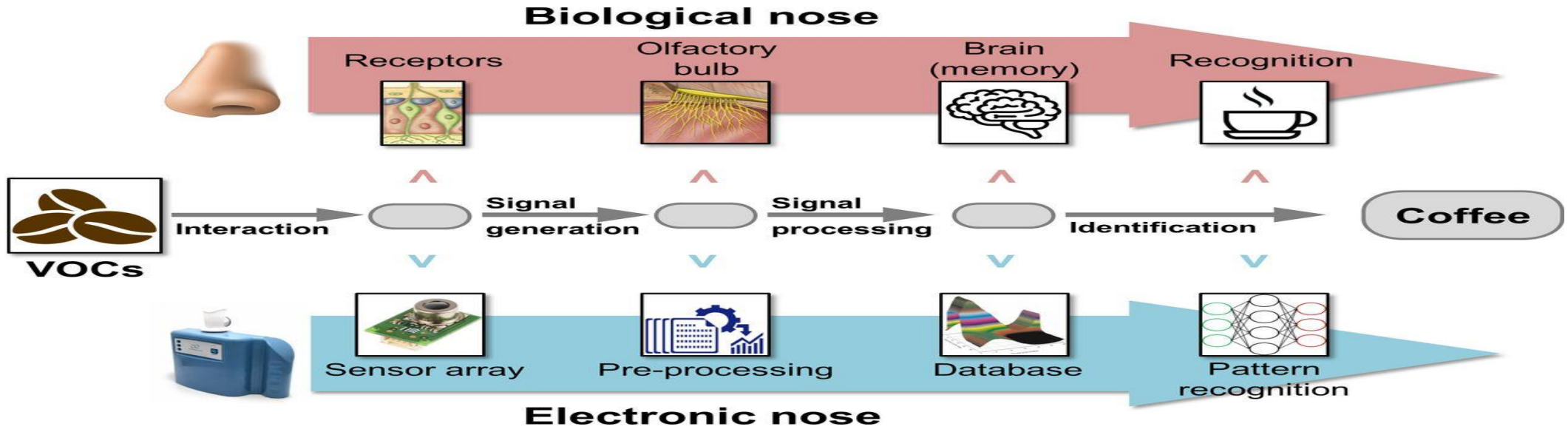
## Mechanism of Nanosensors

**E-nose / E-tongue**

Array of nanosensors monitor the food condition by giving signals on aroma or gases released by food items.

**Example**

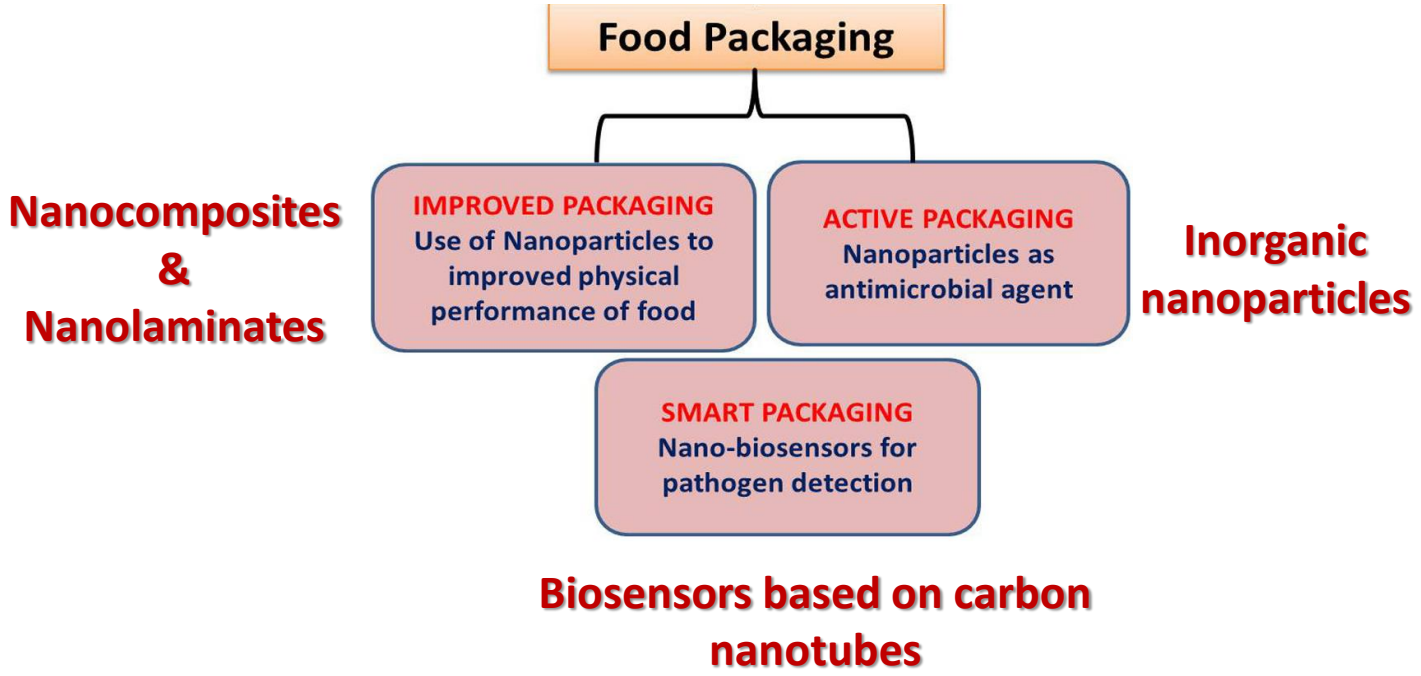
Quartz crystal microbalance (QCM)-based electric nose can detect the interaction between various odorants and chemicals.



# Nanotechnology Applications: Food Packaging

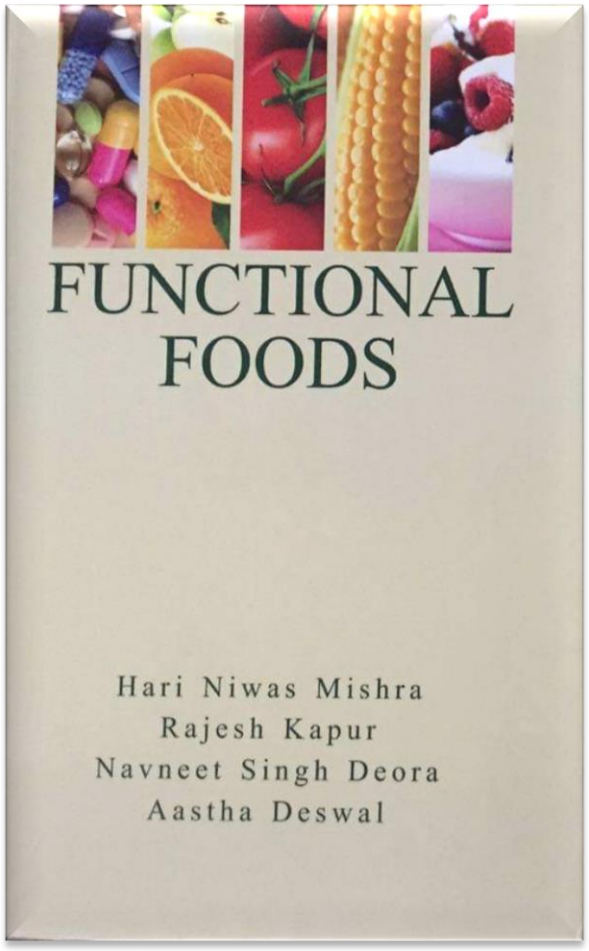
Nano-based “smart” and “active” food packaging provides

- Better packaging material with improved mechanical strength
- Improves barrier properties
- Antimicrobial films
- Nanosensing for pathogen detection
- Alerting consumers to the safety status of food



# Nanotechnology : Challenges & Risks

- Prospect of commercializing ‘nano’ applications in food sector
- Cost-effectiveness in  near future
- Significant changes in current food regulations & legislation
- Concerns for workers health and safety
- Potential harmful effects to environments
- **Limited data on potential human health risks**
  - ✓ Oxidative damage & inflammation of GI
  - ✓ Acute toxicity
  - ✓ Carcinogenicity
  - ✓ Lessions of liver and kidney



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