- Nanotechnology deals with the manipulation of matter at the atomic and molecular scale
- The word 'nano' is derived from the Greek word 'Nanos,' which equates to 'dwarf' or something extremely small
- Technically, 1 meter = 1000 mm. while a nanometer (nm) = one billionth of a meter. Thus, all nanoscale structures typically have a dimensional range or length between 1 and 100 nanometers.

Key topic in Science and Technology and relevant for exam

like **static** (fundamental concepts) and **dynamic** (current affairs and applications) aspects of nanotechnology

· **Types of Nanomaterials:**

- **Carbon-based:** Fullerenes, Carbon Nanotubes (CNTs), Graphene (very important, often asked).
- **Metal-based:** Gold nanoparticles, silver nanoparticles, quantum dots.
- **Polymer-based:** Dendrimers, liposomes (especially for drug delivery).
- **Others:** Nanofibers, nanowires, nanocomposites.

· **Key Properties:** how their small size leads to novel optical, electrical, magnetic, and mechanical properties.

Most Crucial Aspect : Applications of Nanotechnology

- Healthcare and Targeted delivery
- Agriculture, Food Preservation
- Environmental Conservation and Remediation, water purification
- Renewable Energy
- Electronics and Information Technology
- Manufacturing and Construction
- Textiles-· Stain-resistant, wrinkle-free, self-cleaning fabrics.
- **Defense Technology:** Lightweight armor, stealth coatings, explosives detection.

Concerns and Challenges :

- Health and Safety Risks (Nanotoxicity)
- Environmental Impact
- Ethical Concerns
- Economic Challenges

Way Forward:

- Increased funding for R&D.
- Robust regulatory framework for safe and ethical use.
- International collaboration.
- Public-private partnerships.
- Public awareness and education.

Legal Aspects :

India does not yet have a single, comprehensive legal act specifically dedicated to nanotechnology
Instead, the regulation of nanotechnology and nanomaterials currently falls under various existing laws and guidelines, depending on the application and sector.

I. Legal Acts (Existing, Applicable to Nanotechnology):

- **Environment Protection Act, 1986:** This is an umbrella legislation for pollution control and prevention of environmental hazards. It could be used to regulate the environmental release and disposal of nanomaterials

- **Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008:** These rules are important for dealing with waste generated from nanotechnology processes or products.
- **Drugs and Cosmetics Act, 1940:** If nanomaterials are used in pharmaceutical products or cosmetics
- **Insecticide Act, 1968:** For nano-insecticides, this act would be relevant. There have been proposed amendments to specifically address nano-insecticides.
- **Food Safety and Standards Act, 2006 & Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011:** If nanomaterials are used in food products, packaging, or additives, these regulations by FSSAI (Food Safety and Standards Authority of India) would be applicable.

II. Nodal Ministry:

The primary **nodal ministry** for the promotion of research and development (R&D) in nanotechnology in India is the:

- **Ministry of Science and Technology**
  - Specifically, the **Department of Science and Technology (DST)** through its **Nano Mission (now National Programme on Nano Science and Technology)**.

While DST is the main driver, other ministries and departments also support nanotechnology R&D in their respective domains, including:

- **Department of Biotechnology (DBT):** For nano-biotechnology, nanomedicine, agriculture.
- **Ministry of Electronics and Information Technology (MeitY):** For nanoelectronics.
- **Council of Scientific & Industrial Research (CSIR):** Through its various labs working on advanced materials and chemicals.
- **Indian Council of Agricultural Research (ICAR):** For nano-agriculture.
- **Indian Council of Medical Research (ICMR):** For nanomedicine and health applications.
- **Department of Atomic Energy (DAE) & Department of Space (DoS) / ISRO:** For specific applications in their fields.

III. Key Institutions and their Locations

- Institute of Nano Science and Technology (INST) Mohali, Punjab
- Indian Institute of Science (IISc): Bengaluru, Karnataka
- Tata Institute of Fundamental Research (TIFR), Mumbai
- National Chemical Laboratory (NCL), Pune
- National Physical Laboratory. Delhi

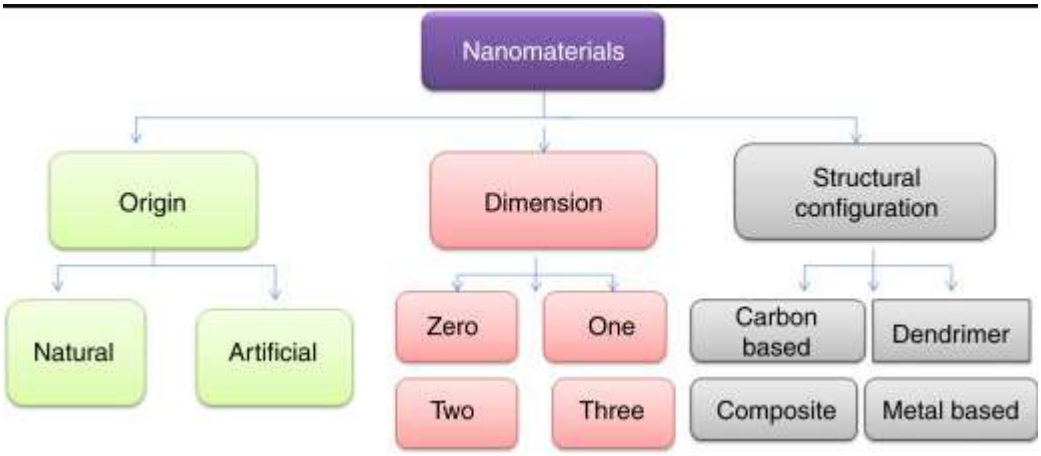
INTRODUCTION

- Nanotechnology involves manipulating of materials at nanoscale, typically between 1 and 100 nanometers.
- One nanometer (nm) is one-billionth or (10^{-9}) of a meter.
- At this incredibly small scale, materials can exhibit unique physical, chemical, and biological properties that are different from their bulk counterparts.

BACKGROUND

- Term Coined by : Norio Taniguchi (1974)
- U.S. physicist Richard Feynman is considered the father of nanotechnology.(1959)
- Prof. C.N.R. Rao is considered as the "Father of Indian Nanotechnology"Prof. C.N.R. Rao is considered as the "Father of Indian Nanotechnology"

CLASSFICATION : BASED ON origin, dimensions, and structural configuration



Natural Nanomaterials: These occur naturally in the environment (e.g., volcanic ash, Dust storms, clay (contain layered silicate minerals with nanoscale dimensions.), Ocean Spray and Also derived from Bacteria, fungi, virus, plants,

Artificial :

- **Carbon nanotubes:** These are cylindrical structures made of carbon atoms
- **Nanowires:** One-dimensional nanostructures
- **Nanosheets:** Two-dimensional nanomaterials
- **Graphene:** A two-dimensional sheet of carbon atoms arranged in a hexagonal lattice
- **Nanoparticles (e.g., gold, silver, titanium dioxide):** These are particles with all three dimensions
- **Fullerenes:** Spherical or cage-like carbon molecules, such as C60
- **Dendrimers:** Artificially synthesized, highly branched polymer molecules with 3 D nanoscale dimensions
- **Liposomes:** Vesicles with a lipid bilayer structure in the nanometer range, used for drug delivery

Feature	Carbon Dots (C-dots)	Carbon Nanotubes (CNTs)	Graphene	Fullerenes (e.g., C60)	Nanowires	Nanosheets
Structure	Tiny spheres (like tiny balls)	Long, hollow tubes	Single thin sheet	Hollow cages (like soccer balls)	Long, thin wires (can be other materials)	Thin sheets (can be other materials)
Carbon Only?	Mostly carbon, can have other atoms	Only carbon	Only carbon	Only carbon	Can be carbon or other materials	Can be carbon or other materials
Dimensions	Very small in all directions (0D)	Long, but very thin (1D)	Very thin, but wide (2D)	Small in all directions (0D)	Long, but very thin (1D)	Thin, but wide (2D)
Key Property	Glow when light shines on them	Very strong & conducts electricity	Very strong & best electricity conductor	Can trap other molecules inside	Can have unique electrical & optical properties	High surface area, can be strong & flexible
Main Uses	Bioimaging, sensors, LEDs	Strong materials, electronics, energy storage	Electronics, strong materials, transparent screens	Drug delivery, antioxidants	Tiny electronics, sensors, energy harvesting	Filters, energy storage, flexible electronics

Classification type	Key description
Inorganic-Based Nanomaterials	– These particles are generally non-toxic, hydrophobic, biocompatible, and highly stable. – **Examples:** Metal and metal oxide nanoparticles – **Applications:** Biomedicine, catalysis, sensors, etc.
Organic-Based Nanomaterials	– These particles are biocompatible, biodegradable, and non-toxic. – **Examples:** Liposomes, layered biopolymers, dendrimers, protein aggregates, lipid bodies, milk emulsions – **Applications:** Drug delivery, cosmetics, food science, etc.
Carbon-Based Nanomaterials	– These particles are known for their low toxicity, high electrical conductivity, flexibility, and optical transparency. – **Examples:** Graphene, fullerenes, carbon nanotubes – **Applications:** Electronics, sensing, drug delivery, composites, coatings, etc.
Composite-Based Nanomaterials	– These particles include materials with enhanced properties such as **flexibility, high strength, electrical conductivity, heat resistance,** and increased barrier properties. – **Examples:** Carbon nanotube-quantum dot hybrids, graphene-polymer composites – **Applications:** Sensors, energy storage, structural reinforcement, etc.

What is Quantum Computing?

Quantum computing is a new paradigm of computing that harnesses the principles of quantum mechanics to perform calculations. Unlike classical computers, which use "bits" that can only be in one of two states (0 or 1) at any given time, quantum computers use **"qubits"** (quantum bits) A qubit can exist in a superposition of both 0 and 1 simultaneously.

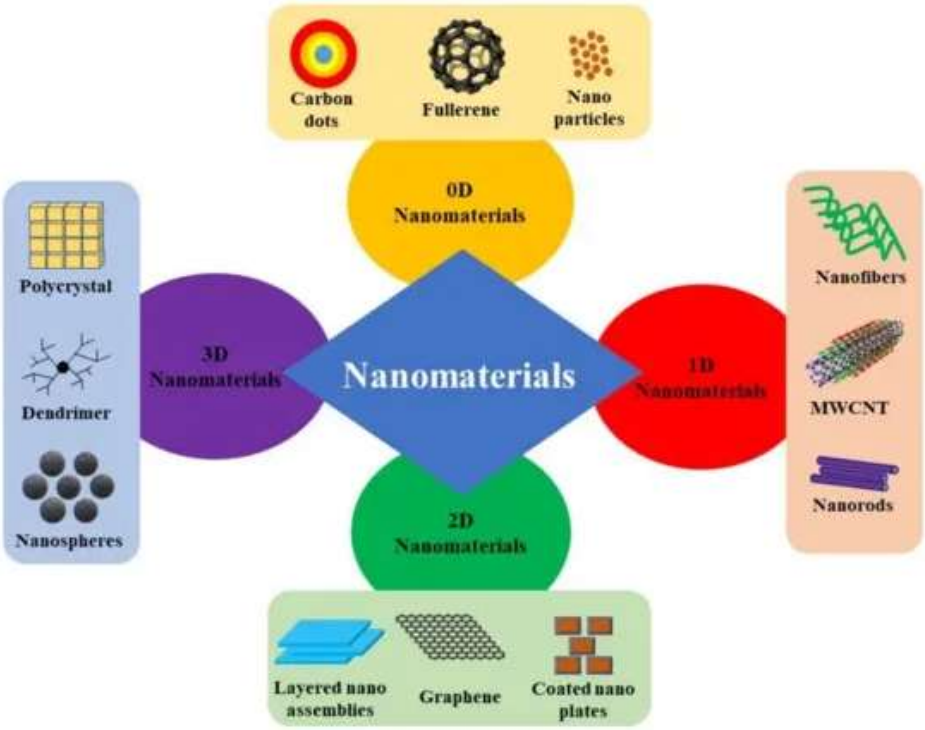
quantum dots are nanoscale semiconductor crystals whose electronic and optical properties are governed by quantum mechanics

Without the ability to precisely engineer matter at the nanoscale, quantum computers as we envision them would not be possible.

NanoMaterials :

They are classified into 2 types : organic consisting of carbon Nano tubes & inorganic Nano material consisting of metals and their oxides.

- **Engineered nanomaterials, as for example, nanospheres, nanotubes, nanowires and** nanosheets, possess a unique combination of physical, chemical, biological, mechanical, electrical and thermal properties.
- examples of Nano particles: Ag+, Copper, zinc and other oxides like titanium dioxide (strong antimicrobial material)



APPLICATIONS OF NANOTECHNOLOGY-

Holds immense potential to address pressing global challenges and foster sustainable development across sectors.

- Health : targeted drug delivery, gene therapy, cancer treatment, and the development of advanced diagnostic toolsfor early disease detection.
- Renewable Energy : Nanoscale materials enhance the efficiency and capacity of batteries, solar cells, and fuel cells, driving innovations in renewable energy
- Electronics: Drives miniaturization, creating faster, smaller, and more energy-efficient devices, including sensors and processors..Ultra HD Tv Screen used Nano scale
- The environmental sector benefits from nanomaterials in water purification, air filtration, and pollution remediation.
- Advanced coatings and lightweight nanomaterials improve performance in transportation and aerospace
- Materials: Produces stronger, lighter, and more durable materials for construction, transportation, and manufacturing.
- Agriculture: Enhances crop productivity through controlled-release fertilizers and pesticides.
- Sustainability: Contributes to eco-friendly solutions by reducing waste, conserving resources, and enabling greener technologies.
- Personal Care Products such as nanoscale titanium dioxide and zinc oxide have been used in sunscreens for years to provide protection from the sun

Q. With reference to the use of nanotechnology in the health sector, which of the following statements is/are correct? (2015)

1. Targeted drug delivery is made possible by nanotechnology.
2. Nanotechnology can largely contribute to gene therapy.

Select the correct answer using the code given below:

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Ans: (c)

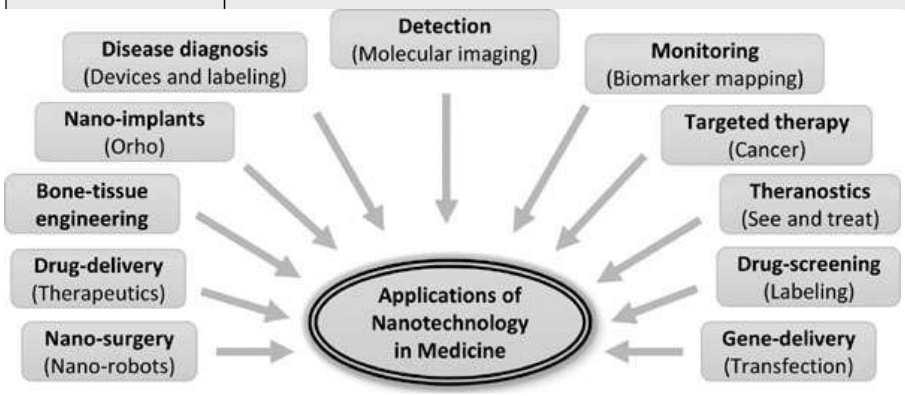
Nanotechnology in health sector can be used for targeted drug delivery as well as it can also help in gene therapy.
Gene therapy is a medical strategy that seeks to treat, cure, or prevent disease by modifying a person's genetic material

Gene therapy uses genes to treat or prevent a disease. It allows the doctors to treat a disorder by inserting a gene into the patient's cells instead of using drugs or surgery. Hence, statements 1 and 2 are correct. Therefore, option (c) is the correct answer.

APPLICATIONS OF NANO TECHNOLOGY

- **Medicine & Healthcare**: Drug delivery, bioimaging, diagnostics, antimicrobial coatings, cancer treatment.
- **Electronics**: Nanoelectronics, sensors, data storage devices, quantum dot displays.
- **Energy**: Solar cells, lithium-ion batteries, fuel additives, hydrogen generation and storage.
- **Automotive**: Fuel cells, lighter and stronger materials, advanced lubricants.
- **Aerospace**: Lighter and stronger composites, structural health monitoring.
- **Defence**: Lightweight soldier armour, surveillance, sensors, nano-coatings for equipment.
- **Environment:** Pollutant degradation, water treatment, nano-filtration, catalytic converters.
- **Agriculture**: Pesticides, fertilisers, pathogen detection, encapsulated agrochemicals.
- **Food & Packaging**: Antimicrobial films, nano-coatings with improved barrier properties, moisture control, and thermal stability.
- **Textiles**: Stain and wrinkle-resistant fabrics, lightweight protective clothing, moisture wicking.
- **Cosmetics**: UV protection in sunscreens, long-lasting colour pigments, anti-ageing creams.
- **Paints & Coatings**: Anti-corrosive coatings, thermal barrier coatings.

Health & Medicine:	• Targeted drug delivery in destroying the cancer cells without harming healthy cells, • Nano sponges (polymer) for absorbing toxins and removing them from bloodstreams. • Gold nano cells for location and elimination of cancer cells. • Antiviral Nano coating on Face mask and PPE kits. • Nano robotics can act as miniature surgeons.
Environment:	• CNTs membrane used for water desalination, nanoscale sensors for identifying water contaminations. • Nano fabric "Paper-towel" used in oil for clean-up applications. • Iron nanoparticles for remediation of contaminated groundwater.
Food and Agriculture:	• Titanium dioxide nanoparticles as antimicrobial agents. • Antibacterial Silver nanoparticles in food packaging to increase shelf-life. • Bio indicators to detect the biomagnification of pesticide and fertilizers.

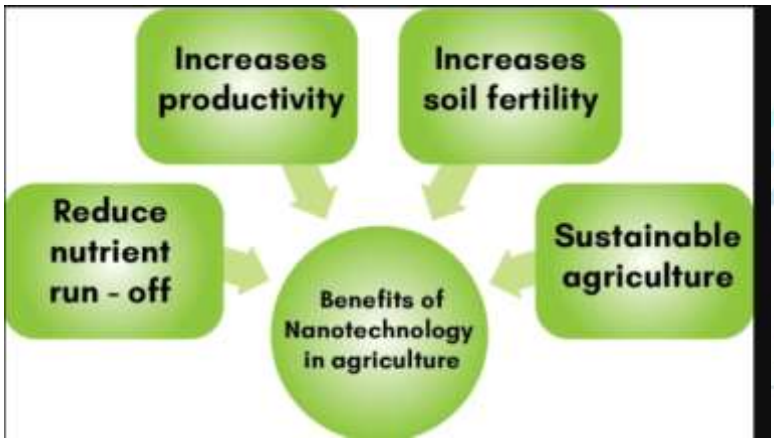


Nanotechnology holds immense potential to revolutionize the health sector in India, offering innovative solutions for diagnosis, treatment, and prevention of diseases. However, its widespread adoption faces several challenges.
positive and negative impacts of nanotechnology in the Indian health sector:

Aspect	Importance (Potential & Applications)	Issues (Challenges & Concerns)
I. Disease Diagnosis	Early & Accurate Detection using nano sensors and quantum dots to treat disorders	High R&D costs for development of sophisticated diagnostic tools
	Point-of-Care Diagnostics: Development of portable, affordable, and rapid diagnostic devices for remote and rural areas.	Need more Technological Infrastructure and Skilled People
	Enhanced Imaging: Nanoparticles as	**Standardization & Regulation:** Absence of clear

	contrast agents for improved resolution and specificity in MRI, CT, and ultrasound	regulatory frameworks and standardized testing protocols for nano-diagnostic products
II. Drug Delivery & Therapeutics	**Targeted Drug Delivery:** Nanocarriers (liposomes, polymeric nanoparticles, dendrimers) can deliver drugs specifically to diseased cells/tissues, minimizing side effects on healthy cells and increasing drug efficacy	**Nanotoxicity & Biocompatibility:** Potential for nanoparticles to accumulate in the body, interfere with immune systems, or cause unforeseen toxic effects (nanotoxicology). Long-term effects are largely unknown.
	Antimicrobial Agents: Nanomaterials like silver nanoparticles to combat antibiotic resistance.	**Ethical Concerns:** Issues related to informed consent, equity of access, and potential misuse of powerful nanotechnology-based therapies.
III. Regenerative Medicine & Tissue Engineering	RM is Medical approach focused on repairing, replacing, or regenerating damaged or diseased cells, tissues, or organs to restore normal function.	Complex Biological Interactions and High cost clinical translations
IV.Other Applications & Initiatives in India	Vaccine Development, wound healing , water purification	Lack of Funding & Infrastructure and Shortage of trained scientists, engineers, and medical professionals **Public Awareness & Acceptance:** Lack of public understanding and potential apprehension regarding nanotechnology in healthcare.

NANOTECHNOLOGY : AGRICULTURE APPLICATIONS



1. Enhanced Nutrient Management and Fertilizers:

- **Nano-fertilizers:** These nano-sized formulations deliver nutrients directly to plant roots or through foliar spray, significantly increasing nutrient use efficiency and improving crop yields This reduces the amount of fertilizer needed, minimizing costs for farmers and lowering environmental pollution due to leaching or runoff.
- **Controlled Release:** Nano-encapsulation allows for the slow and sustained release of nutrients
- **Micronutrient Delivery:** Indian soils often suffer from micronutrient deficiencies. Nanotechnology can effectively deliver essential micronutrients like zinc, iron, copper, and manganese, boosting plant health and productivity

2 Improved Crop Protection:

Nano-pesticides and Herbicides: Nanoscale pesticide formulations enhance solubility, dispersion, and target-specific delivery of active ingredients. This means lower doses are more effective, reducing chemical residue in the environment and food, and minimizing toxicity to non-target organisms.
Ex Nano Silver is known to have strong bactericidal and broad spectrum antimicrobial activities
Nanomagnets: For removal of soil contaminants
Nanoparticles of clay: To improve soil structure, water retention, and nutrient-holding capacity
Disease Detection and Management : Nanobiosenors can quickly and accurately detect plant pathogens (bacteria, viruses) at early stages, enabling timely intervention and preventing widespread crop loss
Stress Tolerance: Nano-coatings of silica nano particles on leaves can shield plants from high temperatures and strong UV radiation, enhancing their resilience to environmental stresses and crop protection
3. Precision Agriculture and Smart Farming:

Nano-sensors: Networks of nanosensors can provide real-time monitoring of soil conditions (moisture, nutrient levels), plant health, and environmental parameters. This data enables precision farming, allowing farmers to apply inputs precisely when and where needed, optimizing resource use.
4. Post-Harvest Management and Food Safety:
Extended Shelf Life: Nano-coatings on fruits and vegetables can restrict oxygen and moisture penetration, delaying ripening and preventing spoilage during storage and transportation, thereby reducing post-harvest losses
· **Food Packaging:** Nanosilver particles incorporated into food containers and packaging films provide antimicrobial protection, preventing contamination and improving food safety.
· **Food Quality and Safety Monitoring:** Nanosensors can detect gases released during food decomposition, identify contaminants, and allergens in food samples within minutes, ensuring food quality and safety.

5. Other Potential Benefits:

- **Water Management:** Nanotechnology can contribute to precision water management by improving water retention in soil and enabling efficient irrigation.
- **Soil Remediation:** Nanomaterials can be used for the bioremediation of polluted environments, addressing issues like heavy metal contamination.
- **Genetic Improvement:** Nanotechnology may play a role in genetic improvement, making crops more resistant to heat and waterlogging.

Nano-fibre arrays: Can deliver genetic material to cells quickly and efficiently.

Single walled carbon nanotubes (SWNTs): Can serve as effective nanotransporters to deliver DNA and small dye molecules into plant cells, thus can be used as small treatment delivery systems in plants.

POTENTIAL HARMFUL EFFECTS OF NANOTECHNOLOGY ON AGRICULTURE

1. Toxicity to Plants (Phytotoxicity):

Toxicity to Non-Target Organisms: Nano-pesticides and nano-fertilizers might harm beneficial insects, soil organisms, and other non-target species.
Reduced Germination and Growth: Some nanoparticles, particularly at higher concentrations or with specific compositions (e.g., silver (AgNPs), zinc oxide (ZnO NPs), copper oxide (CuO NPs)), can inhibit seed germination, root elongation, and overall plant growth.
Impact on Soil Ecosystems: **Disruption of Microbial Communities:** Many nanoparticles, especially those with antimicrobial properties (like AgNPs), can negatively affect beneficial soil microorganisms such as nitrogen-fixing bacteria and mycorrhizal fungi. These microbes are crucial for nutrient cycling, soil fertility, and overall soil health.

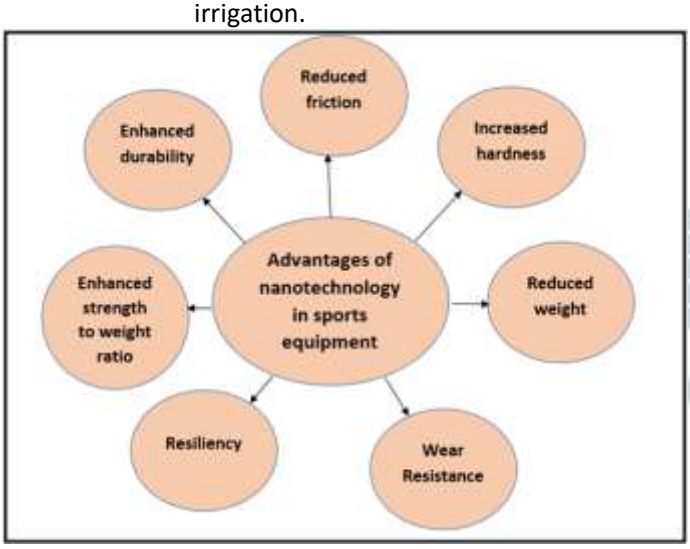
Environmental Contamination: Nanoparticles (NPs) can leach into soil and water, impacting microbial health, soil quality, and aquatic ecosystems. Long-term effects are largely unknown.
Persistence and Mobility: Some nanoparticles are highly stable and can persist in the soil for extended periods, raising concerns about their long-term environmental fate and potential for leaching into groundwater.
Bioaccumulation and Trophic Transfer in the Food Chain: Uptake by Plants and Transfer to Animals:
Human Health Risks: Exposure to nanomaterials through food or direct contact during application (farmers) can pose health concerns like oxidative stress, DNA damage, and organ accumulation
Genotoxicity: Some studies suggest certain nanoparticles might cause DNA damage.
Water Contamination: Runoff from agricultural fields where nanoparticles are used can lead to their accumulation in water bodies, potentially harming aquatic life and disrupting aquatic ecosystems.
· **High Costs & Accessibility:** High research, development, and production costs of nanoproducts may limit adoption, especially for small and marginal Indian farmers.
· **Regulatory Gaps:** Lack of comprehensive and standardized regulatory frameworks for nano-products creates uncertainty regarding safety assessment and approval.
Uncertain Long-Term Effects: The long-term environmental and health impacts of widespread nano-application are still under-researched and require more robust studies.
Nano fertilisers are nutrients that are encapsulated within a nanomaterial in order to enable controlled release, and its subsequent slow diffusion into the soil.
Indian Farmers Fertiliser Cooperative Limited (IFFCO) got the Fertiliser (Control) Order, 1985 (FCO) approval for Nano Zinc and Nano Copper liquids.
FCO is administered by Dept. of Agriculture Cooperation under the Essential Commodities Act, 1955.

Earlier, IFFCO's nano-liquid urea and nano-liquid Di-Ammonia Phosphate (DAP) were also approved under FCO.
Significance of Zinc and copper micronutrients in agriculture:
Zinc: Enzyme functioning in plants, plant growth and development etc.
Copper: Enzymatic activities in plants and chlorophyll and seed production
LIQUID NANO UREA

Developed by **Indian Farmers and Fertiliser Cooperative (IFFCO)**
India will be the first country to start commercial production of Liquid Nano Urea

BENEFITS OF NANO UREA

- As compared to conventional urea, uptake of Nano Urea is more than 80%.
- Required in lesser amounts as compared to the conventional urea fertilisers.
- Cheaper than conventional urea
- Easy to store
- Reduced input costs to farmers
- Easy to apply as Nano urea is directly sprayed on leaves (can be absorbed directly through the leaves' pores)
- Reduced import of conventional urea saving precious foreign exchange
- **Crop protection: Silica** nanoparticles applied on leaves shield the plants from high temperatures and **strong UV radiation**.
- **Nano-coatings on fruits** restrict oxygen and moisture penetration to **delay ripening** and prevent spoilage during storage.
- **Water purification:** Magnetic nanoparticles, carbon nanotubes and nano filters enable rapid decontamination of water from **pesticides, fertilizers, pathogens** etc. which is then safely reused for irrigation.



NANOTECHNOLOGY IN INDIA

Parent Ministry : DST

- Research and Development: The Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) was founded in Bengaluru in 1989
- Department of Science and Technology (DST) initiated the Nano Science and Technology Initiative (NSTI) in 2001
- The Nano Mission was launched in 2007 under the DST emphasizes the need for industry participation through PPP models to facilitate the translation of research into commercial products
- **Council of Scientific and Industrial Research (CSIR):** Various CSIR laboratories are engaged in nanotechnology research and development Ex its New Millennium Indian Technology Leadership Initiative Programme to integrate nanotechnology developments with industrial applications

LEGAL MECHANISMS:

Currently, India **does not have specific, comprehensive legislation solely dedicated to nanotechnology**

- **Guidelines and Best Practices for Safe Handling of Nanomaterials in Research Laboratories and Industries (Department of Science and Technology):** These guidelines, **while not** legally binding regulations, provide a framework for the safe handling and use of nanomaterials in research and industrial settings.
- **Drugs and Cosmetics Act, 1940:** Regulates the import, manufacture, distribution, and sale of drugs and cosmetics, including nanopharmaceuticals and nanomedical devices
- **Food Safety and Standards Act, 2006:** The Food Safety and Standards Authority of India (FSSAI) is considering and developing guidelines for nano-based food products and agri-inputs to ensure safety and quality

- **Environment Protection Act, 1986, and Hazardous Waste (Management, Handling, and Transboundary Movement) Rules, 2008:** These provide a basis for regulating nanotechnology waste and identifying nanomaterials as potentially hazardous substances.
- **Intellectual Property Rights (IPR) Laws:** Existing patent laws are used to protect innovations in nanotechnology.

while there is no specific "Nanotechnology IPR Act" in India, the existing IPR framework, particularly the Patents Act and the Designs Act, are the most relevant for protecting innovations in this field. The Copyright Act and the Semiconductor Integrated Circuits Layout-Design Act may also be applicable in specific contexts. The Trade Marks Act is relevant for branding in the nanotechnology sector.

With reference to carbon Nano-tubes, consider the following statement: (UPSC Prelims 2020)

1. **They can be used as earners of drugs and antigens in the human body.**
2. **They can be made into artificial blood capillaries for an injured port of human body.**
3. **They can be used in biochemical sensors.**
4. **Carbon Nano-tubes are biodegradable.**

Which of the statements given above are correct?

a) **1 and 2 only**
b) **2, 3 and 4 only**
c) **1, 3 and 4 only**
d) **1, 2, 3 and 4**

Answer: (d)

Que : Consider the following statements: (UPSC Prelims 2022)

1. **Other than those made by humans, nanoparticles do not exist in nature.**
2. **Nanoparticles of some metallic oxides are used in the manufacture of some cosmetics.**
3. **Nanoparticles of some commercial products which enter the environment are unsafe for humans.**

Which of the statements given above is/are correct?

a) **1 only**
b) **3 only**
c) **1 and 2 only**
d) **2 and 3 only**

Answer: (d)

Q : There is some concern regarding the nanoparticles of some chemical elements that are used by the industry in the manufacture of various products. Why? (UPSC Prelims 2014)

1. **They can accumulate in the environment, and contaminate water and soil.**
2. **They can enter the food chains.**
3. **They can trigger the production of free radicals.**

Select the correct answer using the code given below.

a) **1 and 2 only**
b) **3 only**
c) **1 and 3 only**
d) **1, 2 and 3**

Answer: (d)

Disadvantages of Nanotechnology

- Health concerns: Nanoparticles, which can enter the human body through inhalation, ingestion, or skin contact, raise concerns about their long-term health effects

- Toxicity: Nanoparticles may induce oxidative stress, inflammation, DNA damage, etc. by interacting with proteins, lipids, and nucleic acids
- Environmental Impact: The production and disposal of nanomaterials may lead to pollution, bioaccumulation, and ecological disruption.
- Ethical Issues: The use of nanotechnology in surveillance, genetic manipulation, or weaponry raises ethical and societal concerns.
- Economic Disparities: High development costs might widen the gap between wealthy and underprivileged nations, creating inequitable access to nanotechnology benefits.

Key Challenges :

- Lack of Private Sector Participation
- Lack of Regulatory Challenges due to the absence of a single authority
- Limited Academic Presence: Few students pursue nanotechnology degrees, and career opportunities are less
- Long-term Effects: Limited research on the long-term impact of nanomaterials leaves uncertainties about their safety and sustainability.
- Lack of Public Awarness and Understanding of Nano Technology which can lead to misconceptions and fears about the safety and potential applications.
- Low Investment
- Limited Funding and resources for R&D of NT. in India which hinder innovation and and commercialization of the Technology based Products and Applications.

IMPORTANT NANOMATERIALS

Notes : Different type of Carbon Allotropes : Charcoal, Graphite, Diamond, Fullerenes and Carbon nanotubes.

Intentionally Made Nano Particles produced through fabrication Process, ex Fullurene, Graphene, Carbon nanotubes, Carbon fibres , Quantum dots , Nano Titanium dioxide

Nano Titanium dioxide : Used in Sun cream and coating on glass acts as self cleaning process or new types of paints

FULLERENE

- Fullerene is a family of carbon allotropes that consists of cage-like or tubular structures
- The most well-known fullerene is buckminsterfullerene (C60), which resembles a soccer ball with 60 carbon atoms forming pentagons and hexagons
- Fullerenes (not typically abundant) are found naturally in soot, volcanic eruptions, interstellar dust clouds and lightning strikes.
- They have unique molecular structure and extraordinary macroscopic properties like High tensile strength, High electrical conductivity than diamond , High ductility ,High Heat Conductivity and relative chemical Inactivity .
- Ex .Cylindrical Fullerene called Carbon Nanotubes (buckytubes)
- Recently They have detected in Outer Space.

APPLICATIONS OF FULLERENE

- Electronics and Energy storage: Can be used in organic photovoltaics (solar cells), organic light-emitting diodes and organic field-effect transistors.
- Medicinal Chemistry: Can act as antioxidants, scavenging free radicals, targeted drug delivery and imaging applications such as magnetic resonance imaging.
- Catalysts: Can act as catalyst supports in fuel cells and environmental remediation.
- Water Purification: Removal of pollutants and contaminants due to their adsorption and catalytic properties.

What is Carbon Nanotubes and Carbon Fibre ?

- are an allotrope of carbon- they are cylindrical hollow fibers,
- Graphene can be rolled up to form CNTs which are cylindrical in shape with diameter in nanoscale

Properties:

- High tensile strength and light-weight
- High electrical and thermal conductivity
- Have large surface area and is chemically stable

APPLICATIONS OF CNT

- Applications in aerospace and automotive engineering.
- Electronic devices, such as transistors, high sensitivity sensors, solar cells, flexible electronics and touchscreens, organic light emitting diodes.

- Used in energy storage (electrodes for Lithium-Ion batteries, capacitors), drug storage and drug delivery.

Carbon fibers are fibers about 5–10 micrometres in diameter and composed mostly of carbon atoms

- carbon fiber are- high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These make them very popular in aerospace, civil engineering, military and sports

Applications of Carbon Nanotubes

- **Medical Applications : Used in as : Antioxidants , Antiviral Agents(inhibit virus or suppress virus like AIDS, Hepatitis C), Prevent Cell toxicity, Drug Delivery and Gene Delivery**
- **Electronic packaging industry:** Solders and heat sinks for thermal management.
- **Automobile industry:** gears, break shoes, piston rings and cylinder liners.
- Used for protective eyewear because they have properties of optical limiting which can be used in protective eyewear and sensors.
- **Used in Solar Cells as excellent acceptors (photovoltaics)**
- **Sports industry:** badminton and tennis rackets and light weight bicycles.
- **Space applications:** structural radiators and high gain antenna boom, Used to build light weight space craft
- **Aerospace industry:** landing gears and aircraft brakes.
- Nano tube electrodes in thermo cells generate electricity from waste heat
- **Cosmetics:** NT can be used in sun screen based cosmetics like using Nano particles of titanium oxides which impart long term stability & also protects from UV rays. and prevent skin damage.
- **TextileIndustry:** Nano fibers make cloth water and stain repellant and wrinkle fee. Nano fibers will be stronger than the strongest natural spider silk fibers.
  It can be used to make strong bullet proof jacket. More Over, fluorescent Nano fibers will also provide different colors to the fabrics.

With reference to carbon Nano-tubes, consider the following statement: (UPSC Prelims 2020)

1. They can be used as earners of drugs and antigens in the human body.
2. They can be made into artificial blood capillaries for an injured port of human body.
3. They can be used in biochemical sensors.
4. Carbon Nano-tubes are biodegradable.

Which of the statements given above are correct?

a) 1 and 2 only
b) 2, 3 and 4 only
c) 1, 3 and 4 only
d) 1, 2, 3 and 4

Answer: (d)

GRAPHENE

- An allotrope of carbon consisting of a single layer of Carbon atoms arranged in a two-dimensional hexagonal lattice.

Applications of Graphene

- Flexible Electronics: Can be used in wearable electronics, flexible displays, electronic textiles, and bendable sensors.
- Energy Storage: Enhance performance and capacity of energy storage systems like supercapacitors and highperformance batteries
- Water purification: Suitable for water filtration and desalination systems
- Bio-sensors: To sense chemical and biological agents, explosives, radiation, and other hazardous substances.
- Aerospace and Defence: Develop lightweight, high-strength armour and ballistic protection. Have potential to absorb and dissipate electromagnetic waves, making it valuable for developing stealth coatings.
- Medical Applications: Biosensing, bioimaging, targeted drug delivery, tissue engineering, phototherapy and cancer treatment. Has antibacterial properti

GRAPHENE BASED BATTERY

- Recently, Scientists have developed a new graphene-based battery material with charging speed five times faster than lithium-ion batteries.
- Graphene form of carbon consists of **planar sheets (2D structure of carbon atoms)** which are one atom thick, with the atoms arranged in a **hexagonal lattice** (honeycomb-shaped lattice).
- Very good conductor of electricity and heat •
- About 200 to 300 times stronger than steel and nearly transparent. and harder than diamond (means good mechanical strength)
- **Applications**: It can be used as/in Paints and coatings, lubricants, oils and functional fluids, capacitors and batteries, thermal management applications, display materials and packaging, solar cells, inks and 3Dprinters' materials and films ,biomedical etc.

- Used in Integrated Circuit for minimise the size and Terahertz speed transistor can be easily maintained with the help of Graphene
- Energy storage devices or super capacitors
- Used as Graphene oxide made Desalination Filters
- Used in Ethanol Distillation
- Used in Solar Cells for energy conversion .

What are Carbon Dots?

- are one of the youngest members of the carbon nanomaterial family.
- They were discovered in 2004
- Tiny, fluorescent nanoparticles made mostly of carbon, usually less than 10 nm in size.
- **Fluorescence:** Emit light when exposed to certain wavelengths
- **Low Toxicity:** Generally considered less harmful than some other nanoparticles

Natural Carbon Dots: Carbon dots can be **naturally extracted** from some carbon-rich materials found in nature. ex honey

Artificial Carbon Dots-used in research and applications are **synthesized artificially** from various carbon sources.

- CDs possess remarkable optical properties
- Moreover, CDs are inexpensive, highly biocompatible, and environment-friendly.
- Play a key role in Pollution sensing because of their high fluorescence emission. They also enable the detection of pollutants with colour change by the colourimetric method
- CDs can also be useful for water treatment as they are promising nano-fillers
- CDs have been produced from water hyacinth waste, which showed green fluorescence under UV light. They were also proven to be fluorescent sensors to detect herbicides causing trouble in aquatic bodies

Precision Farming

- site-specific crop management, is a modern approach to farm management that uses **information and communication technology**
- maximize output (crop yield) while minimizing input (fertilizers, pesticides,etc) through monitoring environment variables and applying targeted action.
- Precision farming makes use of computer GPS and remote sensing devices to measure highly localized environment.
- Nano Tubes has the potential to revolutionize agriculture sector by becoming an integral part of ”Precision Farming
- Nano sensors distributed throughout the field where they can monitor soil condition, crop growth including rapid disease detection.
- **Thus, network Nano sensor in precision farming may help in crop scouting and integration and processing of special data through Geographical Information System (GIS).**

Which of the following is the core principle of precision farming?

a) Applying uniform inputs across the entire field.
b) Minimizing the use of any technology in farming.
c) Managing variability within a field to optimize inputs.
d) Relying solely on traditional farming knowledge.

Solution: c) Managing variability within a field to optimize inputs

Which of the following is a key benefit of adopting precision farming techniques?

a) Increased reliance on manual labor.
b) Higher uniform application of chemicals.
c) Reduced environmental impact through optimized input use.
d) Decreased need for data collection and analysis.

Solution: c) Reduced environmental impact through optimized input use.

N9 Pure SilverTM:

- contains active silver particles that inhibit the growth of odor causing bacteria and micro-organisms
- A very low dosage of N9 Pure Silver has been shown to inhibit bacterial growth and show 99.9% reduction of this growth . Used in Shoes, socks ,textiles
- It remains intact on the treated textile and works to protect it from bacteria and other microbes. This means that there is minimal loss of silver into the environment or onto the skin
- Cosmetics can be preserved and their antimicrobial properties can be enhanced.

Silver nanoparticles have been found to be an effective antiviral which act against many deadly viruses like HIV, Hepatitis B, Herpes simplex virus, Influenza virus, and so on

NEWS: The alcohol free, aqueous, non-inflammable and non-toxic hand sanitizer has been developed from Silver Nanoparticles by a Pune based start-up. It has successfully completed Central Drugs Standards Control Organisation (CDSCO) approved clinical trial for the hand sanitizer and demonstrated high efficiency in killing viruses

Gray goo

- is a hypothetical global catastrophic scenario involving molecular nanotechnology in which out-of-control self-replicating machines consume all biomass on Earth while building many more of themselves
- a scenario that has been called *ecophagy*
- Ecophagy is a term coined by **Robert Freitas** that means the **literal consumption of an ecosystem**
- However, the word "ecophagy" is now applied more generally in reference to any event–nuclear war, the spread of monoculture, massive species extinctions–that might fundamentally alter the planet.

1. The "Gray Goo" scenario is a hypothetical end-of-the-world event involving:

a) A sudden ice age caused by atmospheric changes.
b) A pandemic of a highly virulent and untreatable disease.
c) Self-replicating nanobots consuming all biomass on Earth.
d) A massive asteroid impact leading to global extinction.

Solution: c) Self-replicating nanobots consuming all biomass on Earth

2. The term "Gray Goo" was popularized by:

a) Stephen Hawking in his book on black holes.
b) Bill Joy, co-founder of Sun Microsystems, in an essay on the dangers of emerging technologies.
c) K. Eric Drexler in his book "Engines of Creation."
d) Elon Musk in discussions about the risks of artificial intelligence.

Solution: c) K. Eric Drexler in his book "Engines of Creation."

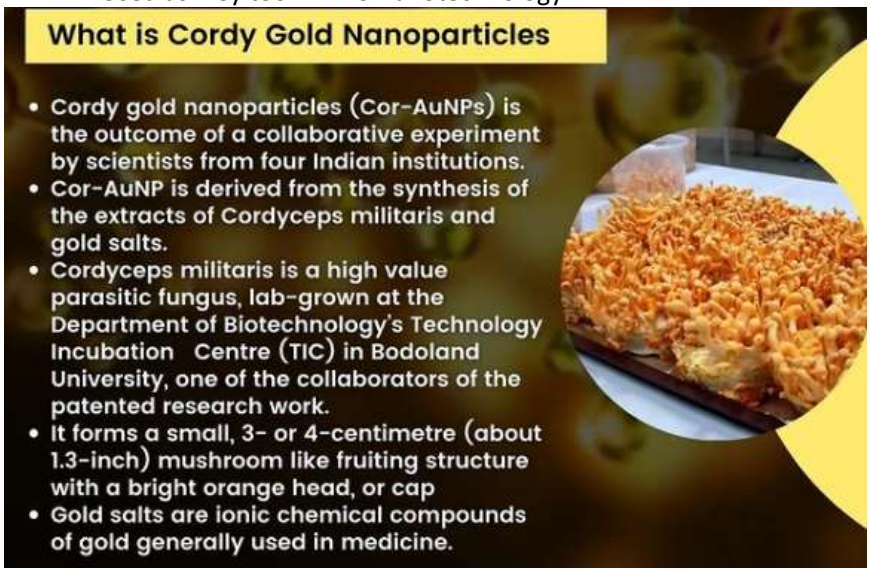
The "Gray Goo" hypothesis is often associated with which field of technology?

a) Biotechnology and genetic engineering.
b) Nuclear physics and weaponry.
c) Molecular nanotechnology and self-replication.
d) Artificial intelligence and robotics.

Solution: c) Molecular nanotechnology and self-replication.

Gold nano- particles : (AuNPs)

- are tiny particles of gold that range in size from 1 to 100 nanometers
- Once dispersed in water, AuNPs are also known as colloidal gold.
- These are also called as 'gold bhasma,'
- These nanoparticles exhibit unique properties due to their small size and large surface area-to-volume ratio
- Used in Biomedical applications and beauty products
- They can arrest the effects of ageing too .
- Used as Key tool in Bio-nanotechnology



Cordy Gold Nanoparticles (Cor-AuNPs) (Gold Mushrooms)

- Recently, scientists from four Indian institutions, including **Bodoland University, have developed Cordy Gold Nanoparticles (Cor-AuNPs),** which can make **drug delivery in the human body** faster and surer.
- They are derived from the synthesis of the extracts of **Cordyceps Mlitaris and Gold Salts**.
- **Cordyceps militaris** is a high value **parasitic fungus,** lab-grown at the **Department of Biotechnology's Technology Incubation Centre (TIC)** in Bodoland University.

- *Cordyceps, a caterpillar fungus found in alpine pastures of the Himalayas*
- Wild Cordyceps mushroom (super mushrooms) are found in the eastern Himalayan belt. because of its tremendous medicinal properties, **adds bioactive components to the synthesis of gold nanoparticles**

With reference to "Gucchi" sometimes mentioned in the news, consider the following statements: (2022)

1. It is a fungus.
2. It grows in some Himalayan forest areas.
3. It is commercially cultivated in the Himalayan foothills of north-eastern India.

Which of the statements given above is/are correct?
(a) 1 only
(b) 3 only
(c) 1 and 2
(d) 2 and 3
Ans: (c)
Exp: It has been **given a GI tag in year 2021**. (Jammu and kashmir region)
Guchhi mushroom is a species of fungus in the family Morchellaceae of the Ascomycota. They are pale yellow in colour. This cannot be cultivated commercially and grown in the foothills in Himachal Pradesh, Uttaranchal, and Jammu and Kashmir. **Hence, option (c) is correct.**

Applications :

- Electronics: Gold nanoparticles are designed for use as conductors from printable inks to electronic chips. Nanoscale gold nanoparticles are being used to connect resistors, conductors, and other elements of an electronic chip.
- Photodynamic Therapy: Near-IR absorbing gold nanoparticles produce heat when excited by light at wavelengths from 700 to 800 nm. This enables these nanoparticles to eradicate targeted tumors.
- Therapeutic Agent Delivery: Therapeutic agents can also be coated onto the surface of gold nanoparticles. The large surface area-to-volume ratio of gold nanoparticles enables their surface to be coated with hundreds of molecules
- Sensors – These are used in a variety of sensors. For example, a colorimetric sensor based on gold nanoparticles can identify if foods are suitable for consumption.
- Diagnostics: These are also used to detect biomarkers in the diagnosis of heart diseases, cancers, and infectious agents.
- They are used for conductors in electronics, targeting tumors in cancer treatment, delivering therapeutic agents, detecting biomarkers, and catalyzing chemical reactions.
- Their unique properties make them versatile tools in various industries.

KEY PROPERTIES :

- These are not – toxic, not phototoxic, not genotoxic, non-irritant and non-sensitizing

Optical properties: Gold nanoparticles exhibit strong absorption and scattering properties, giving them a distinct color depending on their size and shape.

2. Catalytic activity: Gold nanoparticles can act as catalysts for a variety of chemical reactions due to their high surface area.

3. Electrical conductivity: Gold nanoparticles are excellent conductors of electricity, making them useful in electronic applications.

4. Antibacterial properties: Gold nanoparticles have been shown to have antimicrobial properties, making them useful in medical applications.

5. Biocompatibility: Gold nanoparticles are non-toxic to cells and tissues, making them suitable for use in biomedical applications.

6. Surface plasmon resonance: Gold nanoparticles exhibit strong surface plasmon resonance, which can be used for sensing applications.

7. Thermal properties: Gold nanoparticles have high thermal conductivity, making them useful in thermal management applications.

8. Chemical stability: Gold nanoparticles are chemically inert and do not easily react with other substances.

9. Shape control: Gold nanoparticles can be synthesized in a variety of shapes, such as spheres, rods, and triangles, each with unique properties.

10. Surface functionalization: Gold nanoparticles can be functionalized with various molecules to tailor their properties for specific applications.

Project UNNATI

- UNispace Nanosatellite Assembly & Training by ISRO
- Project UNNATI is a capacity-building initiative by the Indian Space Research Organization (ISRO) focused on nanosatellite development
- India announced this program in June 2018
- Objective: Enhance skills of participants from developing nations in nanosatellite building, integration, and testing.
- **ISRO Nano Satellites (INS) Bus System:** ISRO has developed a versatile and modular Nano satellite bus system (INS-1, INS-2 series) designed to carry up to 3 kg of payload with a total satellite mass of 11 kg.

Examples: INS-1A, INS-1B (launched with PSLV-C37 in 2017), INS-1C (launched with PSLV-C40 in 2018)