Nanotechnology In Medicine

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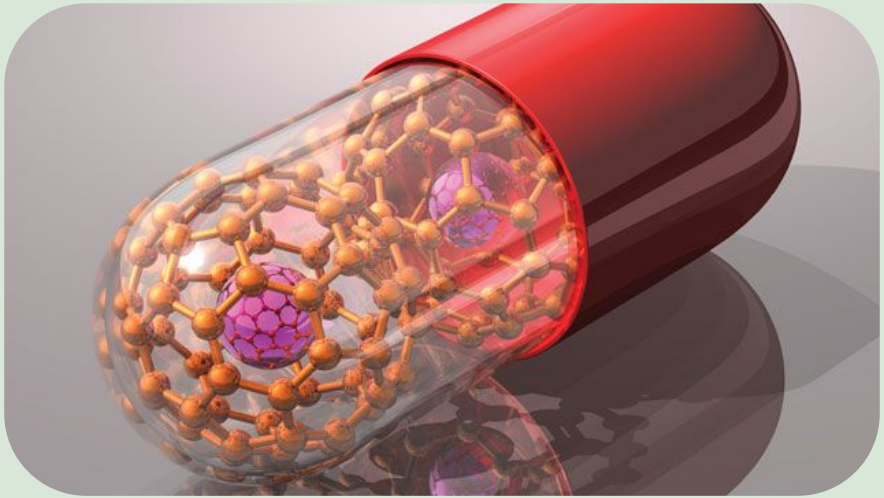
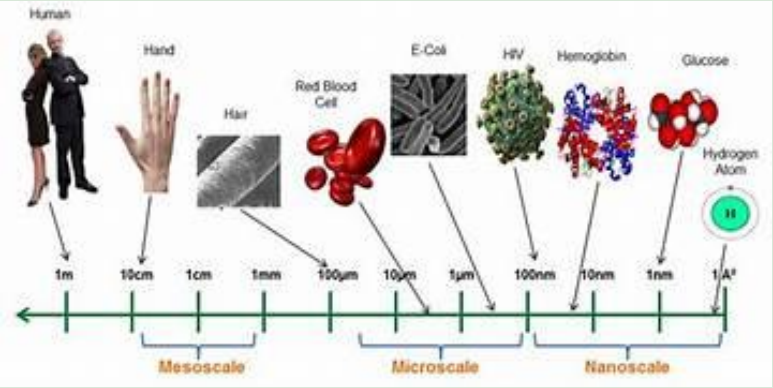
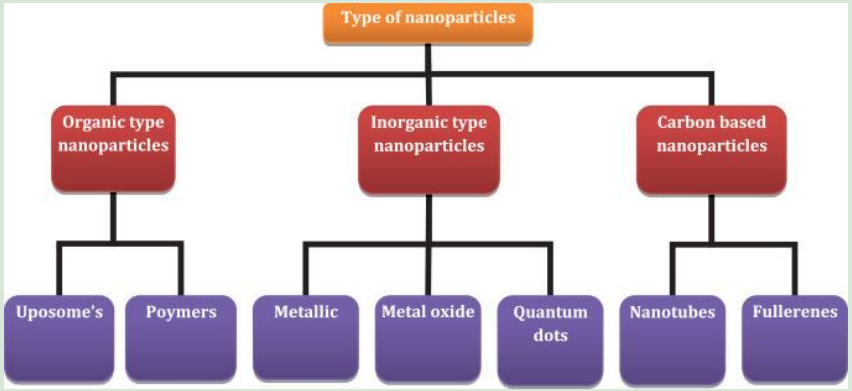


Introduction To Nanotechnology





Nanotechnology involves manipulating matter at the nanoscale (1–100 nanometers) to create materials with unique properties. The term “nano” refers to one billionth of a meter. Since the scale is incredibly small, the materials can exhibit different physical, chemical, and biological properties. Nanotechnology is used in many fields, especially in medicine.

Importance

Physical Properties: Changes in melting points, magnetic properties, and optical behaviors

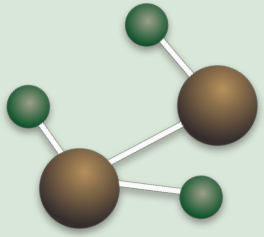
Chemical Properties: Increased chemical reactivity due to higher surface area to volume ratio.

Biological Properties: Improved interactions with biological systems, enabling targeted drug delivery and advanced imaging techniques.

Drug Delivery: Nanoparticles can be designed to deliver drugs directly to specific cells, minimizing side effects and improving efficacy.

Imaging: Enhanced imaging techniques using nanoparticles allow for earlier and more accurate diagnosis of diseases.

Therapies: Innovative treatments, such as photothermal therapy for cancer, utilize the unique properties of nanoparticles.



History and Origins Of Nanotechnology

Historical Milestones:

Richard Feynman 1959 Lecture

- Richard Feynman was an American physicist who was the founding father of nanotechnology, having introducing the concept at 1959.
- He discussed the potential manipulating individual atoms and molecules and inspired many scientists from working at a nanoscale.

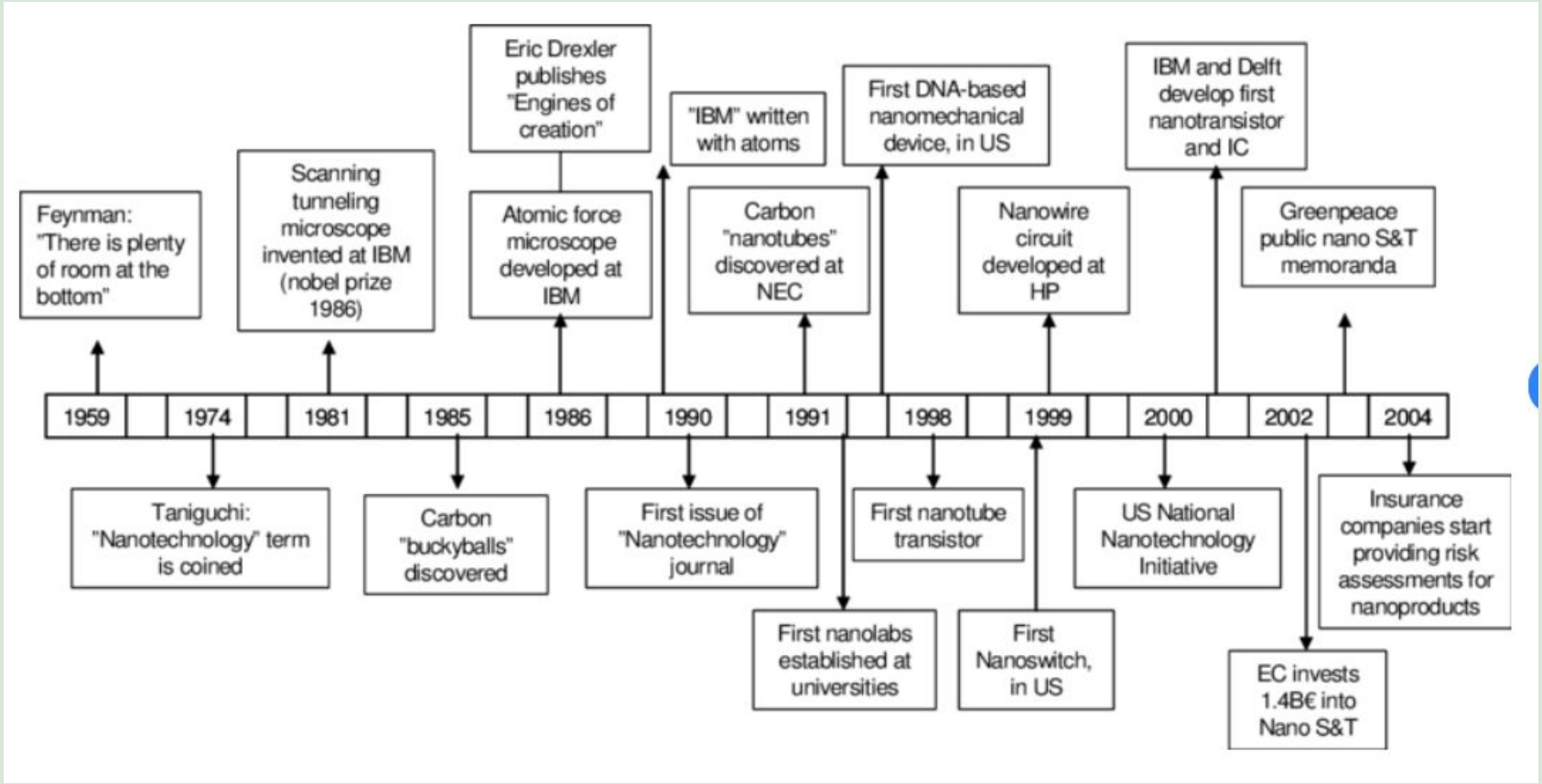
Development of the Scanning Tunneling Microscope (STM) in the 1980s:

- Gerd Binnig and Heinrich Rohrer invented the scanning tunneling microscope at IBM Zurich in 1981, which allowed scientists to visualize and manipulate individual atoms for the first time.
- STM provided them to manipulate the nanoscale and advanced the field.

Eric Drexler

- Greatly popularized nanotechnology through his books “Engines Of Creation: The Coming Era Of Nanotechnology in 1986.
- He primarily focused on the potential of molecular manufacturing and self-replicating nanosystems.

Milestone Timeline



Nanoparticles

Metallic Nanoparticles:

Properties

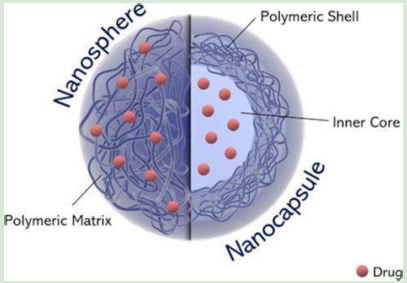
- Metallic nanoparticles have a high surface area to volume ratio, which enhances their reactivity and interaction with biological systems.
- Due to their small size and high reactivity, it’s applied for many medical applications.

Applications

- Metallic nanoparticles like gold and silver are used to deliver drugs directly to targeted cells and aid in improving efficacy.
- Nanoparticles are also used in imaging techniques like MRI and CT scans and provide detailed images.
- Gold nanoparticles are used in cancer therapy and imaging, whereas silver nanoparticles are used with antimicrobial properties.

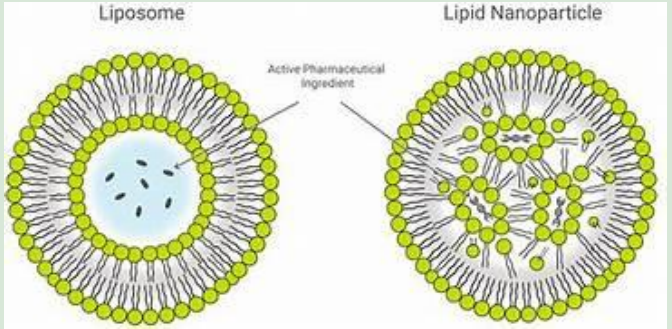
Polymeric Nanoparticles

- They are made from biodegradable materials, thereby making then safe to use in the body.
- Can be programmed to release payload over a controlled period and improve therapeutic treatments,
- Polymeric Nanoparticles are used to deliver genetic material to specific cells.



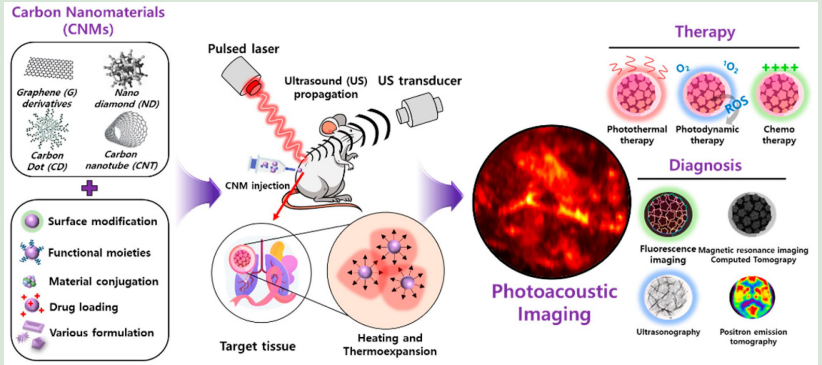
Lipid-Based Nanoparticles

- They are made from natural/synthetic lipids and are non-toxic.
- Have the ability to carry a wide range of therapeutic agents.
- Lipid nanoparticles are crucial in delivering mRNA vaccines, as seen with the COVID-19 vaccines.



Carbon-Based Nanoparticles

- They have enhanced electrical and thermal conductivity.
- Are known for mechanical strength and flexibility.
- Carbon nanoparticle are especially used to deliver drugs to cells and tissues.
- Are used in scaffolds for tissue engineering due to their strength and flexibility.
- Used in cancer treatment and when exposed to tumor cells and near-infrared light, it generates heat and destroys cancer cells without harming healthy tissue.



Synthesis and Characterization Of Nanoparticles

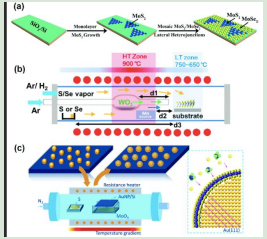
Methods Of Synthesis:

Chemical Vapor Deposition (CVD)

- Process where gaseous reactants are used to produce a solid material on a substrate.
- Involves deposition of a material from a vapor onto a surface to create high-performance solid materials.

Steps

1. Precursor gases are introduced into a reaction chamber.
2. The gases decompose on the heated substrate surface.
3. Solid material forms a thin film on the substrate.

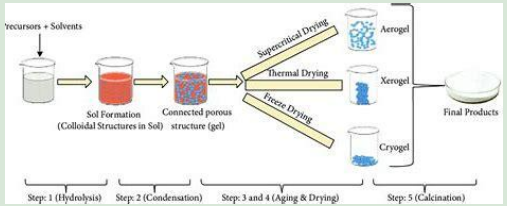


Sol-Gel Process

- A wet-chemical technique used to fabricate materials, starting from a chemical solution that acts as a precursor for polymers.

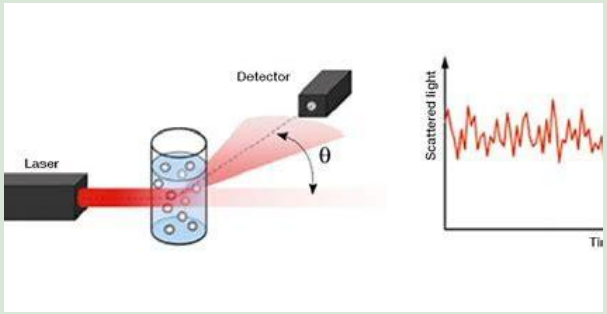
Steps

1. Hydrolysis and polycondensation reactions of precursors.
2. Formation of a sol, a colloidal suspension of particles.
3. 3.Gelation of the sol to form a network structure.
4. Drying and thermal treatment to produce the final material.



Dynamic Light Scattering (DLS)

- Technique used to determine the size distribution profile of small particles.
- Used by measuring the scattering of light caused by particles undergoing motion.
- It provides info on size distribution, stability, and aggregation state of nanoparticles in a solution.

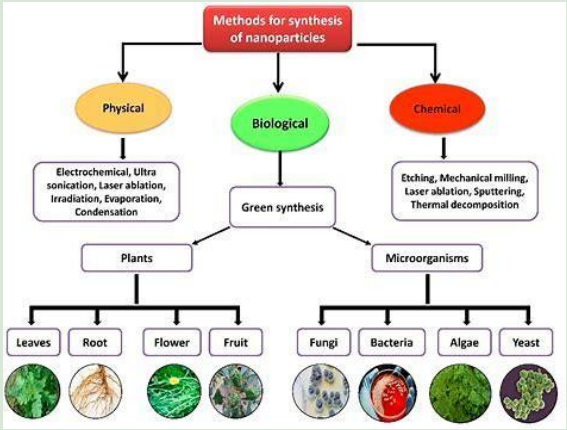


Biological Methods

- Usage of microorganisms, plant extracts, and enzymes to synthesize nanoparticles.

Steps

1. Biological units produce nanoparticles as part of metabolic process.
2. Extraction and purification of the nanoparticles.



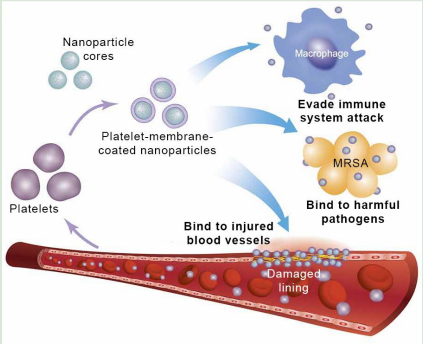
Drug Delivery Systems

Targeted Drug Delivery

- Nanoparticles can be programmed to deliver drugs to impaired cells.
- This can be accomplished by attaching antibodies to the surface of the nanoparticles and can bind to receptors on the targeted cells like cancer cells.
- During targeted cancer therapies, nanoparticles are targeted to carry chemotherapy drugs and release them directly within the affected cells, thereby excluding the healthy cells.

Controlled Release

- Process in which nanoparticles can release drugs over a controlled period, essentially improving treatment.
- They can be engineered to release their payload to targeted physiological conditions like temperature or enzymatic activity.
- Providing a steady dosage the drug can improve patient's cohesion to the treatment regimen.



Imaging and Diagnostics

Nanotechnology in Medical Imaging

- Enhances MRI, CT, and other imaging techniques.
- Iron oxide nanoparticles in CT scans have unique optical and magnetic properties that improve the contrast between different tissues, allowing for precise imaging.

Molecular Imaging

- Nanotechnology provides imaging at the molecular level and aid in early disease detection.
- Can be functionalized with antibodies that bind to molecular targets in association with diseases.
- Doing this allows visualization of cellular processes and early detection of pathological changes.

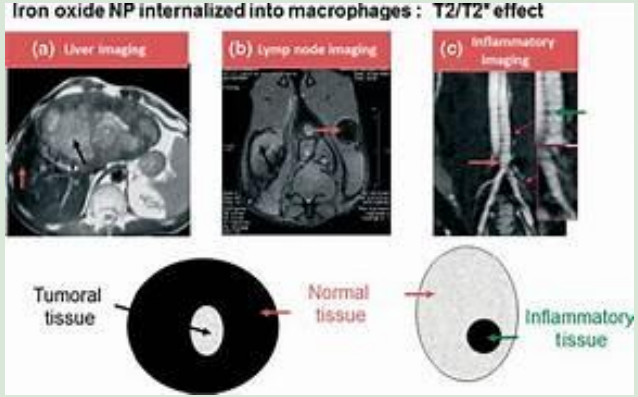
Diagnostics

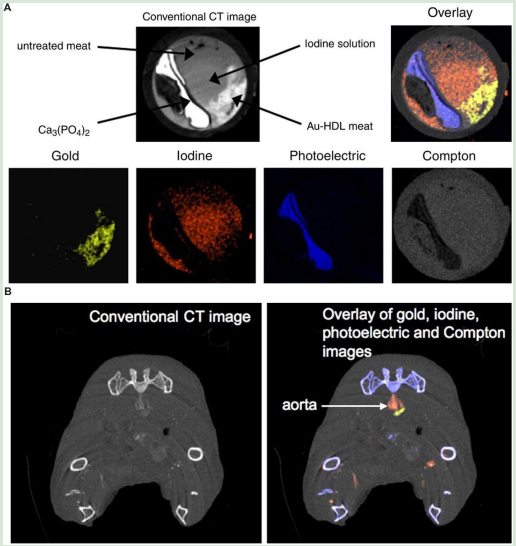
- Nanoparticles improve the sensitivity and specificity of biosensors for detecting biomarkers.
- They can be used to amplify the signal in biosensors, enhancing their ability to detect low concentrations of biomarkers.
- It increases the sensitivity and the diagnostic tests to display accurate results.

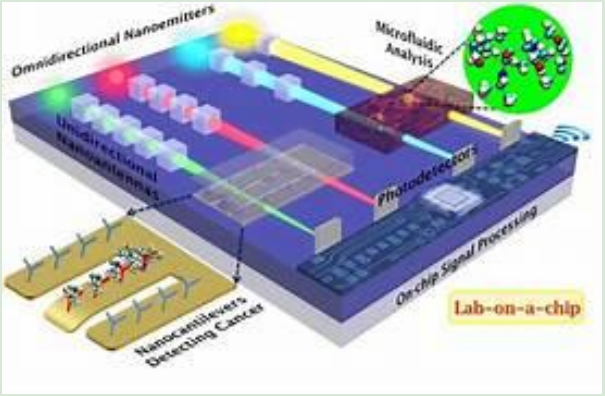
Lab-on-a-Chip Devices

- These devices integrate nanoscale materials and channels to manipulate small volumes of fluids, allowing for the rapid and simultaneous analysis of multiple samples.
- They are cost-effective and provides quick diagnostic results.

Imaging and Diagnostics Visuals



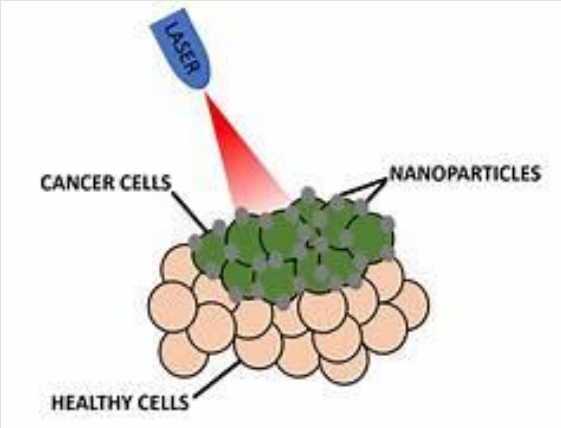




Cancer Treatment

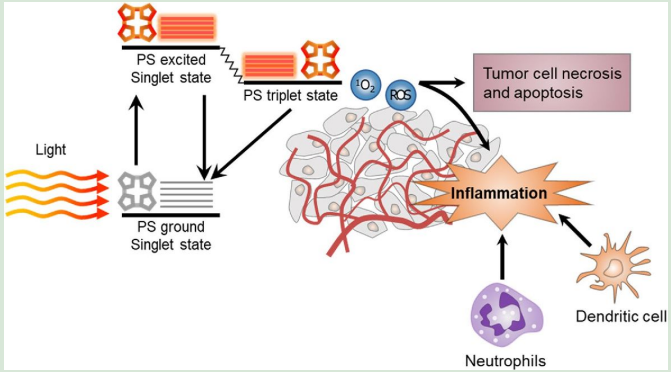
Photothermal Therapy

- Process in which nanoparticles convert light into heat or reactive oxygen species to kill cancer cells.
- Gold nanoshells absorb near-infrared light and convert it into heat, destroying cancer cells.



Photodynamic Therapy

- Nanoparticles deliver photosensitizing agents that produce reactive oxygen species.
- When exposed to specific wavelengths of light, it destroys cancer cells.
- Used in treating skin cancers and other accessible tumors.



Summary and Implications

To conclude, nanotechnology is a growing field that is revolutionizing medicine with its diverse implications in drug delivery, imaging, diagnostics, and cancer treatment. From targeted therapies advanced imaging techniques that enable early disease detection, nanotechnology offers promising solutions to some of the most challenging medical problems. As more research and development continues to advance, there will be more innovative treatments and diagnostic tools that can improve patient outcome.

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