Journal of Carcinogenesis
Covering Genesis to Therapeutics

Journal of Carcinogenesis, ISSN: 1477-3163

2026; Vol 25: Issue 1, https://carcinogenesis.com/

Innovation of Nano-Technology in Cancer Treatment- A Systematic Overview

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ABSTRACT:

Cancer is one of the leading causes of mortality which is the result of unhealthy practices in daily lifestyle. Although extensive techniques are in use for diagnosis as well as treatment with intention of reduction in death rate, chronic pain, and improvement in the life of valiant. Cancer therapy with nanotechnology proves to be an effective solution .Nanotechnology along with the diverse conventional therapeutic techniques imparts eminent outcomes. Nanomaterials are increasingly used as drug carriers for cancer therapy. Nanomaterials also appeal to researchers in the areas of cancer diagnosis and biomarker discovery. Among the newly developed nanomedicine and nanodevices such as quantum dots, nanowires, nanotubes, nanocantilevers, and nanopores, nanoshells and nanoparticlesare the most promising applications for various cancer treatments. This article aims at giving a present status of nanotechnology in cancer therapy and the prospects of nanomaterials as drug carriers for future clinical applications.

Keywords: Cancer, Nanomaterials, Nanowires, Nanotubes, Nanopores, Nanoshells

How to Cite: Mr. Jaivin Jaisingh. J, Mr. Simon Samuvel, Mrs. Abisha Kamal. D, Mrs. Sheetal Singh, Ms. Aarzoo, Ms. Juhi Singh, (2026) Innovation of Nano-Technology in Cancer Treatment- A Systematic Overview, *Journal of Carcinogenesis*, *Vol.25, No.1*, 89-104

INTRODUCTION

The term “nanotechnology” is a concept that has only emerged in the last decade with the prefix “nano”cited from the Greek word “nanos”, indicating that something is dwarf-sized. Therefore, the term “nanotechnology” refers to a technology that uses very small particles invisible to the naked eye. Before the century, although the term nanotechnology had not yet been globally defined, the applications of nanotechnology were already used in the industrial field. Nowadays nanotechnology are used in cancer treatment. Nanotechnology is manipulating matter at the atomic/molecular level (1-100 nano meters) to create materials and devices with novel properties, impacting electronics, medicine, and materials science by controlling atoms to build things stronger, lighter, or with unique functions, like smart fabrics, better displays (quantum dots), and targeted drug delivery systems. Nanotechnology revolutionizes cancer treatment by using nanoparticles for targeted drug delivery, significantly improving efficacy and reducing side effects by concentrating therapy at tumors. There are different methods and approaches for using nanoparticles in nanomedicine[1]. Both inorganic and organic nanomaterials have been investigated in clinical experiments for treatment of cancer.

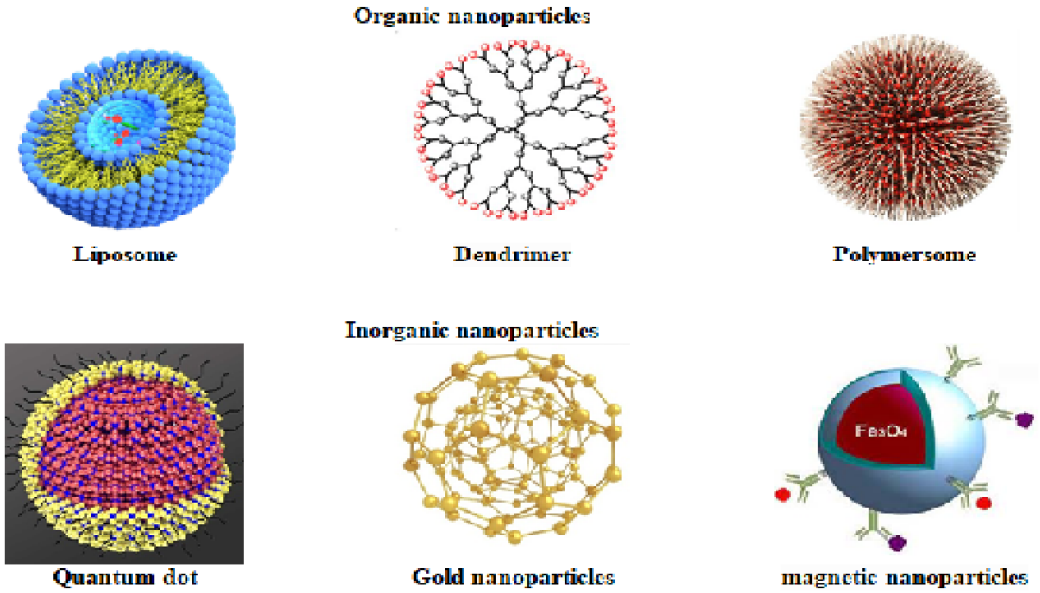
NANOPARTICLE

Nanoparticle are particles between 1 and 100 nanometers (nm) in size with a surrounding interfacial layer. The interfacial layer is an integral part of nanoscale matter, fundamentally affecting all of its properties. The inter facial layer typically consists of ions, inorganic and organic molecules. Organic molecules coating inorganic nanoparticles are known as stabilizers, capping and surface ligands, or passivating agents. Nanoparticles embrace a wide spectrum of applications sparking another industrial revolution.

The nanoparticles are of different shape, size and structure. It be spherical, cylindrical, tubular, conical, hollow core, spiral, flat, etc. or irregular and differ from 1 nm to 100 nm in size. The surface can be a uniform or irregular with surface variations. Some nanoparticles are crystalline or amorphous with single or multi crystal solids either loose or agglomerated. Numerous synthesis methods are either being developed or improved to enhance the properties and reduce the production costs. Some methods are modified to achieve process specific nanoparticles to increase their optical, mechanical, physical and chemical properties. A vast development in the instrumentation has led to an improved nanoparticle characterization and subsequent application [2,3].

CLASSIFICATION OF NANOPARTICLES

The nanoparticles are generally classified into the organic, inorganic and carbon based.



Organic Nanoparticles

Dendrimers, micelles, liposome's and ferritin, etc. are commonly knows the organic nanoparticles or polymers. These nanoparticles are biodegradable, non- toxic, and some particles such as micelles and liposome's has a hollow core, also known as nanocapsules and are sensitive to thermal and electromagnetic radiation such as heat and light. These unique characteristics make them an ideal choice for drug delivery. The organic nanoparticles are most widely used in the biomedical field for example drug delivery system as they are efficient and also can be injected on specific parts of the body that is also known as targeted drug delivery.

Inorganic Nanoparticles

Inorganic nanoparticles are particles that are not made up of carbon. Metal and metal oxide based nanoparticles are generally categorized as inorganic nanoparticles.

Metal based

Nanoparticles that are synthesized from metals to nanometric sizes either by destructive or constructive methods are metal based nanoparticles. Almost all the metals can be synthesized into their nanoparticles.[9]The commonly used metals for nanoparticle synthesis are aluminium (Al), cadmium (Cd), cobalt (Co),copper (Cu), gold (Au), iron (Fe), lead (Pb), silver(Ag) and zinc (Zn). The nanoparticles have distinctive properties such sizes as low as 10 to 100nm, surface characteristics like high surface area to volume ratio, pore size, surface charge and surface charge density, crystalline and amorphous structures, shapes like spherical and cylindrical and colour, reactivity and sensitivity to environmental factors such as air, moisture, heat and sunlight etc.

Metal oxides based

The metal oxide based nanoparticles are synthesized to modify the properties of their respective metal based nanoparticles, for example nanoparticles of iron(Fe) instantly oxidises to iron oxide (Fe_2O_3) in the presence of oxygen at room temperature that increases its reactivity compared to iron nanoparticles. Metal oxide nanoparticles are synthesized mainly due to their increased reactivity and efficiency. The commonly synthesized are Aluminium oxide (Al_2O_3), Cerium oxide (CeO_2), Iron oxide (Fe_2O_3), Magnetite (Fe_3O_4), Silicon dioxide (SiO_2), Titanium oxide (TiO_2), Zinc oxide (ZnO). These nanoparticles have possessed exceptional properties when compared to their metal counterparts.

Carbon based

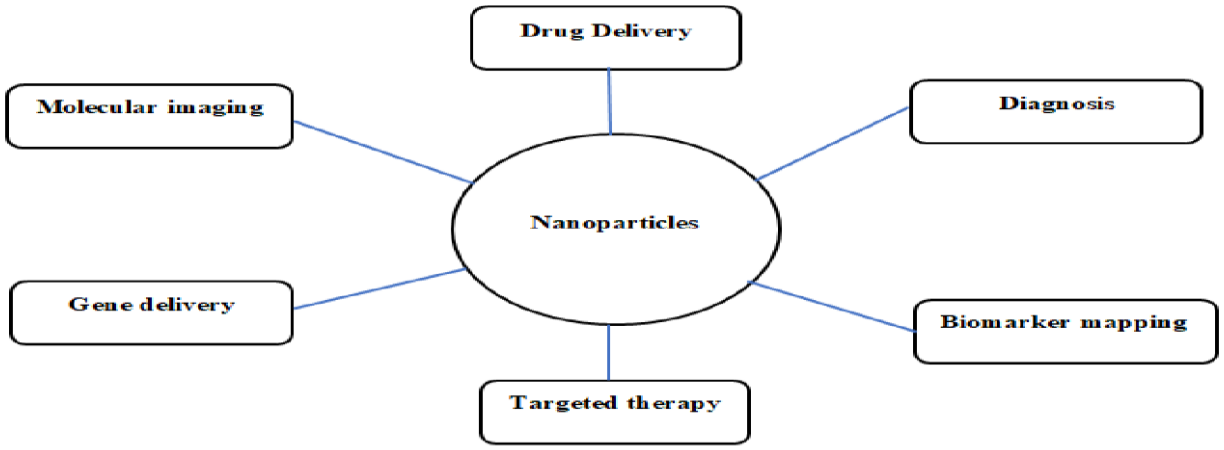
The nanoparticles made completely of carbon are knows as carbon based. They can be classified into fullerenes, graphene, carbon nano tubes(CNT),carbon nano fibers and carbon black and sometimes activated carbon in nano size.

1. **Fullerenes:** Fullerenes (C60) is a carbon molecule that is spherical in shape and made up of carbon atoms held together by sp hybridization. About 28 to1500carbonatoms forms the spherical structure with diameters up to 8.2 nm for a single layer and 4 to 36 nm for multi-layered fullerenes.
2. **Graphene:** Graphene is an allotrope of carbon. Graphene is a hexagonal network of honeycomb lattice made up of carbon atoms in a two dimensional planar surface. Generally the thickness of the graphene sheet is around 1 nm.
3. **Carbon Nano Tubes (CNT):** Carbon NanoTubes (CNT), a graphene nanofoil with a honeycomb lattice of carbon atoms is wound into hollow cylinders to form nanotubes of diametersas low as 0.7 nm for a single layered and 100 nm for multi-layered CNT and length varying from a few micrometres to several millimetres. The ends can either be hollow or closed by a half fullerene molecule.
4. **Carbon Nano fiber:** The same grapheme nano foils are used to produce carbon nanofiber as CNT but wound into a cone or cup shape instead of aregular cylindrical tubes.

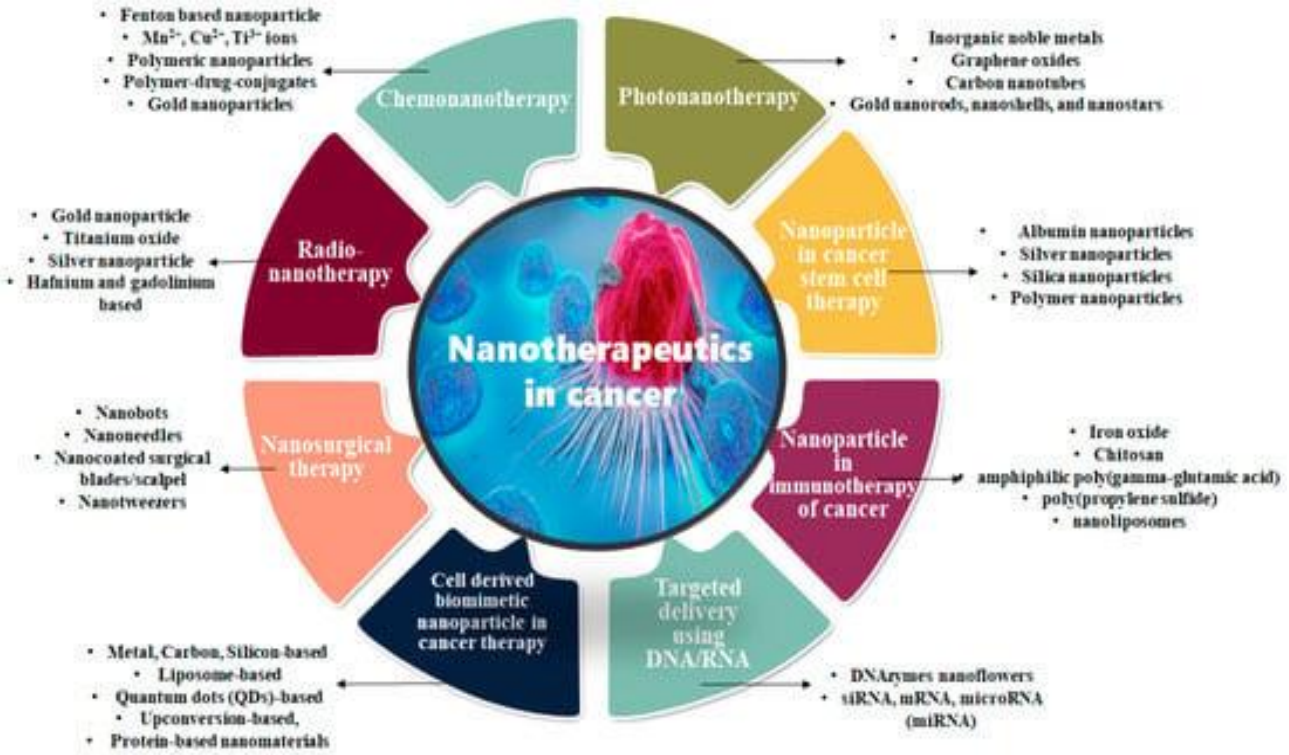
Carbon black: An amorphous material made up of carbon, generally spherical in shape with diameters from 20 to 70 nm. The interaction between the particles are so high that they bound in aggregates and around 500nm agglomerates are formed.

USING NANO TECHNOLOGY IN CANCER

An American physicist introduced nanotechnology[4] in



APPLICATION OF NANOTECHNOLOGY



APPLICATIONS OF NANO-TECHNOLOGY[5]

The applications of nano technology in commercial products, although most applications are limited to the bulk use of passive nanomaterials. Examples include:

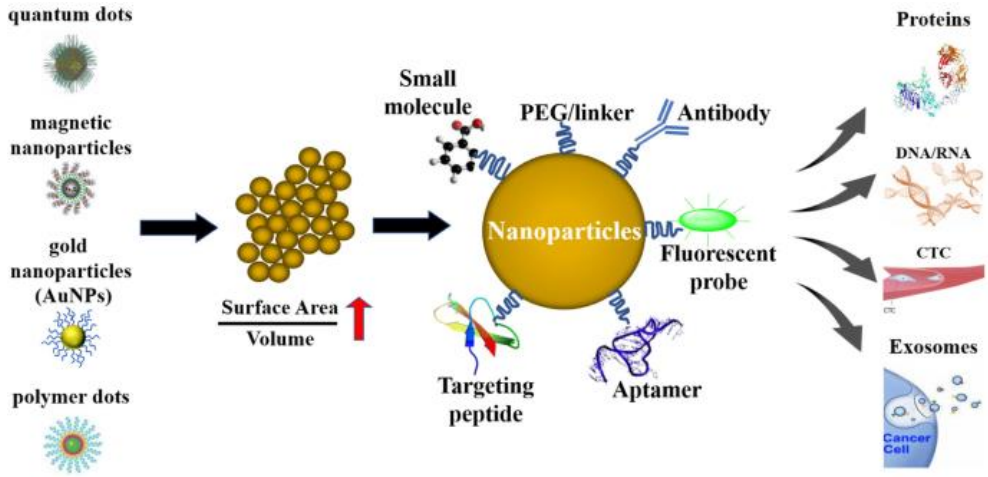
1. Titanium dioxide and zinc oxide nano particles in sunscreen, cosmetics and some food products
2. Silver nano particles in food packaging, clothing, disinfectants and household appliances.
3. Silver Nano-carbon nano tubes for stain-resistant textiles; and cerium oxide as a fuel catalyst.

Nanotechnology is being used in developing countries to help treat disease and prevent health issues. The umbrella term for this kind of nanotechnology is Nanomedicine.

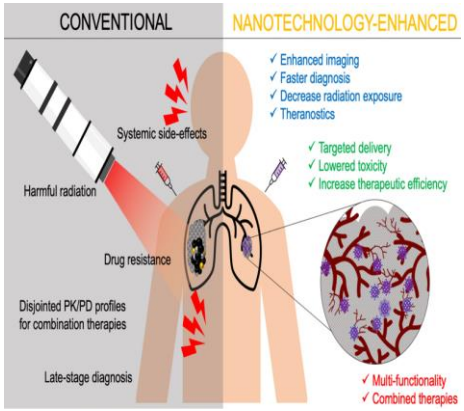
1. Nanotechnology is also being applied to or developed for application to a variety of industrial and purification processes. Purification and environment clean up applications include the desalination of water, water filtration, waste water treatment, ground water treatment, and other nanoremediation.
2. In industry, applications may include construction materials, military goods, and nano-machining of nano-wires, nano-rods, few layers of graphene, etc.

Also, recently a new field arisen from the root of Nanotechnology is called Nanobiotechnology. Nanobiotechnology is the biology-based, application-oriented frontier area of research in the hybrid discipline of Nano science and biotechnology with an equivalent contribution.

Nanotechnology-based cancer Detection & diagnosis



Nanotechnology offers revolutionary ways to diagnose cancer earlier and more accurately by using tiny particles (nanoparticles) to detect cancer biomarkers, circulating tumor cells (CTCs), and genetic changes with high sensitivity, improving imaging contrast (MRI, PET), and enabling early screening through nanosensors and nanobots that target specific cancer markers, promising less invasive, more precise detection than traditional methods. These nanomaterials, like quantum dots, gold nanoparticles, carbon nanotubes, and liposomes, enhance detection by binding to cancer signals, signaling their presence through optical, magnetic, or electrical changes, leading to earlier intervention and better outcomes



Nanotechnology Aids Cancer Diagnosis**:**

- **Biomarker Detection:** Nanoparticles capture scarce cancer-related proteins, circulating tumor DNA (ctDNA), and exosomes in blood, significantly boosting detection sensitivity.
- **Enhanced Imaging:** Nanoparticles (e.g., gold, iron oxide) act as superior contrast agents in MRI, PET, and ultrasound, providing clearer, higher-resolution images of tumors.
- **Nanosensors:** Nanocantilevers and other nanosensors detect specific cancer molecules by bending or changing frequency upon binding, revealing malignant cells early.
- **Targeting Specific Cells:** Nanoparticles can be coated with antibodies or peptides to actively bind to cancer cell surfaces, isolating them for detection.
- **Early Screening:** Nanobots and other nanodevices can identify genetic mutations or specific cancer signatures, allowing for detection long before symptoms appear.

Types of Nanomaterials Used:

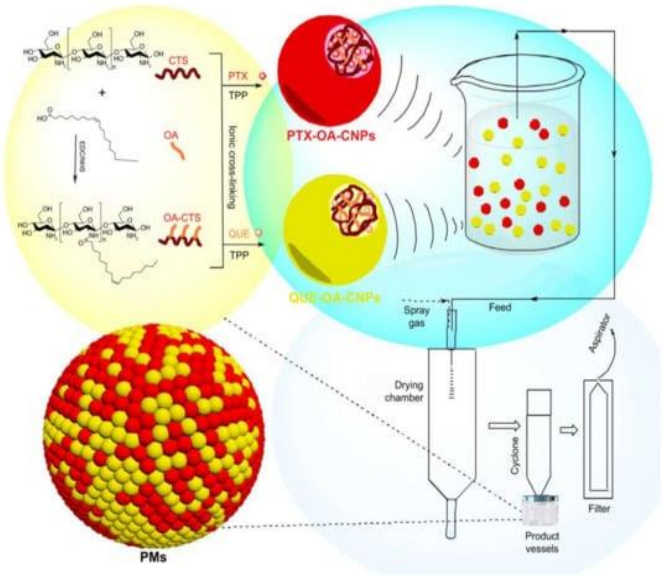
- **Gold Nanoparticles (AuNPs):** Used for sensing, imaging, and drug delivery.
- **Carbon Nanotubes (CNTs):** Offer high conductivity and strength for imaging and detecting cancer.
- **Quantum Dots (QDs):** Provide bright, stable fluorescence for bioimaging.
- **Liposomes & Polymeric Micelles:** Deliver drugs and contrast agents, improving biodistribution.

Benefits & Future:

- **Early Detection:** Critical for improving survival rates, especially for hard-to-detect cancers.
- **Precision:** Offers highly specific detection of cancerous cells and biomarkers.
- **Reduced Side Effects:** Potential for combined diagnosis and therapy (theranostics) with less systemic harm.

NANOTECHNOLOGY IN CANCER THERAPY

Nanomaterials are increasingly used as drug carriers for cancer therapy. Nanomaterials also appeal to researchers in the areas of cancer diagnosis and biomarker discovery. Several antitumor nano-drugs are currently being tested in preclinical and clinical trials and show promise in therapeutic and other settings. We review the development of nanomaterial drug carriers, including liposomes, polymer nanoparticles, dendritic polymers, and nanomicelles, for the diagnosis and treatment of various cancers.



1. Chemonanotherapy

Nano chemotherapy uses tiny nanoparticles to deliver cancer drugs directly to tumors, improving effectiveness and drastically cutting side effects by sparing healthy cells, using mechanisms like passive targeting (EPR effect) or active targeting with special ligands, and offering controlled release, potentially combining with immunotherapy for better outcomes. This approach addresses traditional chemo's non-specificity, leading to reduced toxicity and better patient tolerance, with approved nanomedicines like liposomal doxorubicin already in use.

Drug Encapsulation: Chemotherapy drugs are loaded inside nanoparticles (liposomes, polymers, etc.) or attached to their surface.

Targeted Delivery:

- **Passive Targeting (EPR Effect):** Nanoparticles (around 100-200 nm) leak out of leaky tumor blood vessels and get trapped in the tumor tissue.
- **Active Targeting:** Nanoparticles are coated with molecules (ligands) that specifically bind to receptors on cancer cells, ensuring they "stick" to the tumor.
- **Controlled Release:** Drugs are released at the tumor site, often triggered by internal (pH, enzymes) or external (heat, ultrasound) stimuli, maximizing local concentration.

Types of Nanocarriers

- Liposomes (e.g., Doxil)
- Polymeric nanoparticles/micelles
- Albumin-bound nanoparticles (e.g., Abraxane)

- Inorganic nanoparticles (e.g., Gold NPs, Quantum Dots)

- **Advantages**
- **Reduced Side Effects:** Less drug reaches healthy, fast-dividing cells (like hair, bone marrow), minimizing toxicity.
- **Improved Efficacy:** Higher drug concentrations in tumors.
- **Overcoming Challenges:** Can improve solubility and delivery of poorly soluble drugs like Paclitaxel.
- **Combination Therapies:** Synergizes with immunotherapy and radiation.

2 .Photo nanotherapy:

Photo nanotherapy uses nanoparticles to deliver light-activated agents for treatments like cancer, primarily through **Photothermal Therapy (PTT)** (using light to generate heat to kill cells) or **Photodynamic Therapy (PDT)** (using light to create reactive oxygen species to destroy cells). These nanosystems improve drug delivery, target specificity, and can even trigger powerful anti-tumor immune responses, making them a powerful tool in modern medicine, especially for oncology.

How it Works (Key Mechanisms)

Photothermal Therapy (PTT): Nanoparticles absorb light (often near-infrared, NIR, for deeper tissue penetration) and convert it into heat, raising the temperature in the tumor to selectively destroy cancer cells (hyperthermia).

- **Photodynamic Therapy (PDT):** Nanoparticles deliver photosensitizers that, when activated by light, produce cytotoxic reactive oxygen species (ROS) to kill targeted cells.
- **Nanocarrier Function:** Nanoparticles act as smart carriers, improving drug solubility, targeting tumors, and enabling controlled release of therapies, enhancing overall efficacy and reducing side effects.

Advantages

- **Targeted Delivery:** Nanoparticles accumulate in tumors, concentrating the treatment where it's needed.

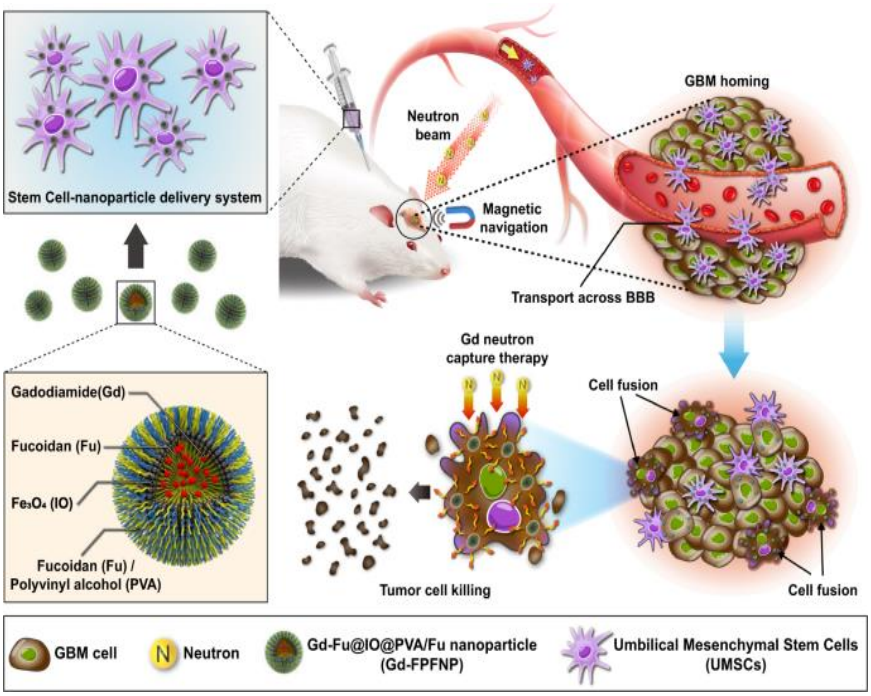
- **Minimally Invasive:** Offers a less invasive approach compared to traditional treatments like surgery or chemotherapy.
- **Synergistic Effects:** Can combine phototherapy with chemotherapy or immunotherapy for enhanced results, creating a "vaccine-like" immune response.
- **Imaging & Therapy (Theranostics):** Some nanoparticles can also be used for diagnostic imaging (like MRI or optical imaging).

Applications

- Primarily used in oncology for various cancers (breast, liver, melanoma, etc.).
- Used for deeper tissue treatments due to NIR light penetration

3. **Nanoparticles Work with Stem Cells in Cancer Therapy:**

Nan particles (NPs) enhance stem cell therapy for cancer by acting as smart carriers, loading drugs or genes, and targeting cancer stem cells (CSCs) that cause relapse, using features like surface coatings (e.g., hyaluronic acid for CSC targeting) or stimuli-responsiveness (pH/heat) for precise release, while also enabling real-time tracking via imaging to monitor stem cell migration and treatment efficacy, offering improved delivery, reduced side effects, and overcoming drug resistance for more effective cancer treatment.



Targeted Drug/Gene Delivery: NPs are attached to or loaded into mesenchymal stem cells (MSCs) and guided to tumors, increasing drug concentration at the site and reducing healthy tissue damage.

Targeting Cancer Stem Cells (CSCs): Specific NP surface modifications, like hyaluronic acid (HA) coating, target CSCs (e.g., CD44-positive cells), delivering therapies to these resilient cells that traditional treatments miss.

- **Overcoming Drug Resistance:** NPs can deliver drugs directly into the nucleus of CSCs or combine treatments (like chemotherapy + thermotherapy) to overcome their resistance mechanisms.

- **Imaging & Tracking:** Fluorescent or magnetic NPs allow non-invasive tracking of stem cell movement and accumulation in tumors, providing crucial feedback for treatment.
- **Stimuli-Responsive Release:** "Smart" NPs release payloads in response to tumor microenvironment cues (low pH, high temperature), enhancing precision.
- **Bio-Inspired Carriers:** Exosomes, natural nanoparticles from stem cells, can be engineered to deliver therapeutic loads, acting as "natural drug carriers".

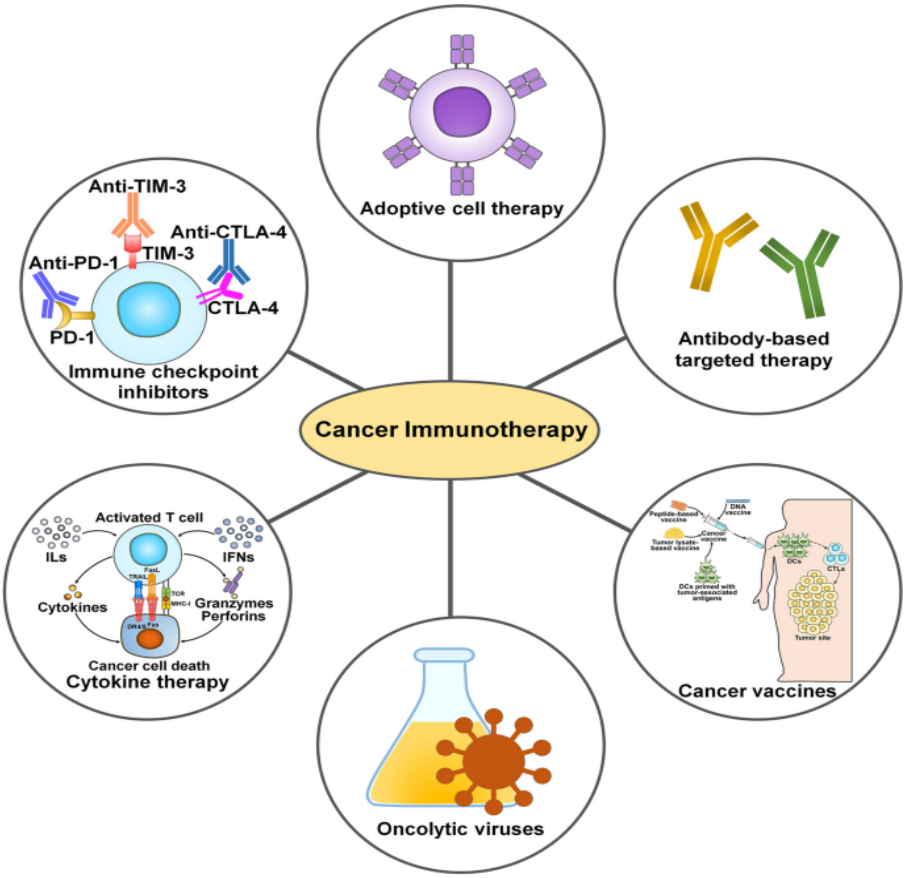
Types of Nanoparticles Used:

- Gold, silver, silica, diamond nanoparticles.
- Liposomes, polymeric nanoparticles (PLGA, chitosan), polymeric nanogels.
- DNA-based nanomaterials (origami, tetrahedrons).

Benefits & Future:

- **Enhanced Efficacy:** Synergistic effects, better drug accumulation, and targeting CSCs.
- **Reduced Toxicity:** Lower systemic toxicity compared to conventional chemotherapy.
- **Monitoring:** Real-time monitoring of treatment progress.
- **Future Directions:** Focus on biosafety, long-term stability, and scalable production for clinical translation.

4. Nanoparticles in immunotherapy for cancer treatment Nanoparticles are revolutionizing cancer immunotherapy by acting as smart carriers to deliver cancer vaccines, immune activators, and checkpoint inhibitors directly to tumors or immune cells, enhancing anti-cancer responses while reducing side effects. Their nanoscale size allows passive targeting via the leaky tumor vasculature (EPR effect) and enables specific targeting by surface functionalization, improving antigen delivery to antigen-presenting cells (APCs) for stronger immune activation and overcoming tumor resistance. Types include polymeric, lipid, and metallic NPs, with innovations like cell membrane-coated NPs mimicking natural cells to improve delivery and reverse immunosuppression in the tumor microenvironment (TME).

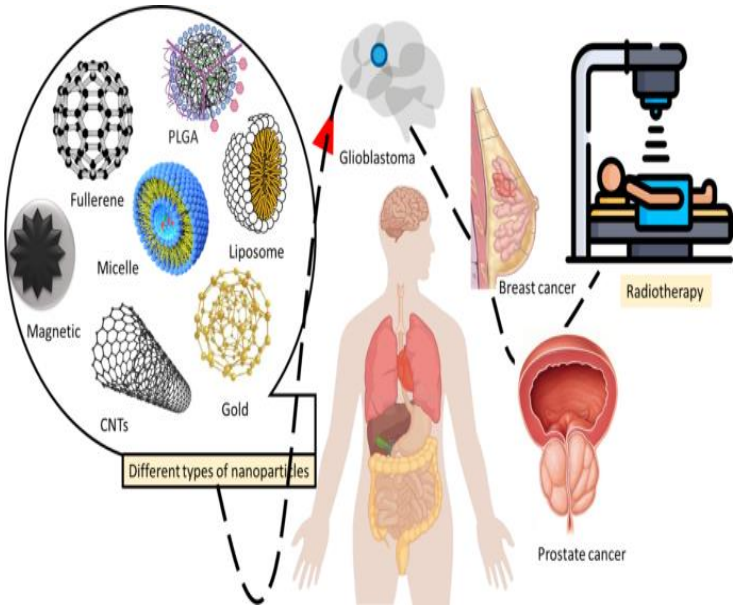


Key Roles of Nanoparticles in Immunotherapy:

- **Enhanced Antigen Delivery:** NPs encapsulate tumor-associated antigens (TAAs) and adjuvants, facilitating uptake by dendritic cells (DCs) for better presentation and stronger T-cell responses.
- **Targeted Delivery:** They can be designed to passively accumulate in tumors (EPR effect) or actively target cancer cells/immune cells with specific ligands.
- **Modulating the Tumor Microenvironment (TME):** Nanoparticles can reprogram immunosuppressive cells (like MDSCs) or deliver agents to reverse the TME, turning it from immune-suppressive to immune-activating.
- **Combination Therapies:** NPs enable the simultaneous delivery of immunotherapies with chemotherapy, photothermal therapy (PTT), or photodynamic therapy (PDT) for synergistic effects.
- **Improved Vaccine Efficacy:** They offer sustained release, controlled presentation of antigens, and can eliminate the need for repeated dosing, similar to priming-boosting strategies.

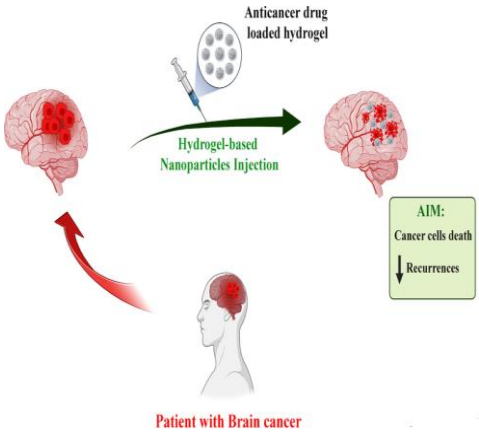
5. Nanoparticles in radiotherapy for cancer treatment

Nanoparticles (NPs) revolutionize radiotherapy by acting as **radiosensitizers**, dramatically boosting radiation's cancer-killing power while protecting healthy tissues, primarily through enhancing X-ray absorption (especially high-Z metals like gold) and generating toxic reactive oxygen species (ROS). They also offer precise tumor targeting via the EPR effect and functionalization, deliver other drugs (chemo, immuno) simultaneously, overcome treatment resistance, and can even be combined with phototherapy or hyperthermia for synergistic attacks, leading to better outcomes and fewer side effects.



Key Mechanisms & Advantages

- **Enhanced Radiation Absorption:** High atomic number NPs (Gold, Platinum) concentrate radiation energy in tumors, causing more DNA damage via Auger electrons and radical formation.
- **Targeted Delivery:** NPs accumulate in tumors (Enhanced Permeation & Retention, EPR effect) and can be coated with antibodies for active targeting, increasing cancer cell exposure and reducing systemic toxicity.
- **ROS Generation:** NPs amplify radiation-induced production of reactive oxygen species, which directly damage cancer cell DNA and organelles.



- **Overcoming Resistance:** They help overcome radioresistance and drug resistance (chemo/immuno) by disrupting cell repair mechanisms and altering the tumor microenvironment (TME).
- **Combination Therapies:** NPs act as versatile carriers, delivering drugs, photosensitizers, or heat (hyperthermia), creating multi-pronged attacks (chemo-radio, immuno-radio).

6. Nanoparticles in immunotherapy for cancer treatment

Nanoparticles are revolutionizing neurosurgery for cancer by overcoming the blood-brain barrier (BBB) to deliver drugs directly to brain tumors, enhancing imaging for better surgical guidance, and enabling new therapies like mechanical destruction (using magnetic forces) or photothermal therapy. They offer targeted delivery (active/passive), improved drug stability, and reduced systemic toxicity, improving outcomes for aggressive cancers like glioblastoma by combining diagnosis and treatment, though challenges in pharmacology remain[6,7,8].

Applications in Neurosurgery for Cancer:

1. **Targeted Drug Delivery (Therapeutics):**

- **BBB Penetration:** Nanoparticles (e.g., polymeric, gold) are engineered to cross the BBB, delivering chemotherapy drugs (like doxorubicin) or genes directly to tumors, increasing concentration and reducing side effects.
- **Active Targeting:** Functionalized with antibodies (e.g., anti-EGFR) or ligands (e.g., folic acid) to bind specifically to cancer cells, ensuring precision.
- **Mechanical Force:** Magnetic nanoparticles (MNPs) spun by magnetic fields can physically disrupt cancer cell membranes, inducing programmed cell death (apoptosis).

Enhanced Imaging & Diagnosis:

- **MRI Contrast:** Gadolinium-based NPs improve contrast for better visualization of tumor margins during surgery.
- **Optical Imaging:** Fluorescent nanoparticles (like quantum dots) aid in identifying cancerous tissue for complete resection (removal).
- **Multimodal Probes:** Designed for combined imaging (MRI, PET, SPECT) for comprehensive tumor characterization.

Novel Therapies:

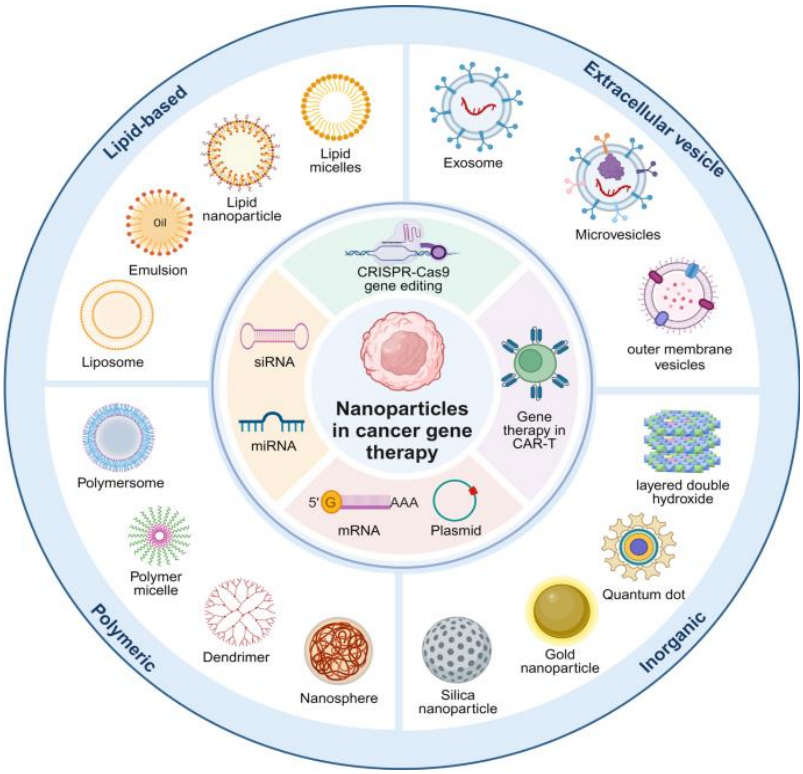
- **Photodynamic/Photothermal Therapy:** Nanomaterials absorb light/energy to generate heat or reactive oxygen species, destroying tumors locally.
- **Gene/Immunotherapy:** Nanoparticles can deliver therapeutic genes or stimulate immune responses against cancer.

How They Work (Mechanisms):

- **Enhanced Permeability and Retention (EPR Effect):** Tumor blood vessels are leaky, allowing nanosized particles to accumulate passively in the tumor site.

- **Active Targeting:** Specific molecules on the NP surface target receptors overexpressed on cancer cells.

7. Nanoparticles in targeted delivery using DNA/RNA for cancer treatment Nanoparticles (NPs) are revolutionizing cancer therapy by acting as targeted delivery vehicles for DNA/RNA, protecting these fragile molecules from degradation and delivering them specifically to cancer cells, minimizing harm to healthy tissue, and enabling gene therapies like mRNA vaccines or siRNA-based silencing to fight tumors. Common NP types include lipids (LNPs), polymers, and inorganic materials, modified with targeting ligands (like antibodies) for precision, achieving targeted gene editing, immunotherapy (like *in vivo* CAR-T), or delivering tumor suppressor DNA, with significant ongoing clinical translation for blood cancers and solid tumors.



How Nanoparticles Deliver DNA/RNA for Cancer Therapy

Protection & Stability: NPs encapsulate DNA (like plasmids) or RNA (like siRNA, mRNA) to shield them from enzymes (nucleases) in the bloodstream, ensuring they reach the tumor site intact.

Targeting: NPs are surface-modified with ligands (antibodies, aptamers) that recognize specific markers on cancer cells, allowing for precise delivery and uptake, often via endocytosis.

Release: Once inside, NPs release their nucleic acid payload, triggering therapeutic effects, such as silencing cancer-promoting genes (siRNA) or instructing cells to produce anti-cancer proteins (mRNA).

Types of Nanoparticles Used

- **Lipid-Based NPs (LNPs)**: Highly effective for RNA delivery (like mRNA vaccines), encapsulating the cargo within a lipid bilayer for stability and cell entry.
- **Polymeric NPs**: Made from biocompatible polymers, offering good loading capacity and controlled release.
- **Inorganic NPs**: Gold or iron oxide NPs can serve as carriers and offer theranostic (therapy + diagnostics) potential, allowing imaging of delivery.

Applications in Cancer Treatment

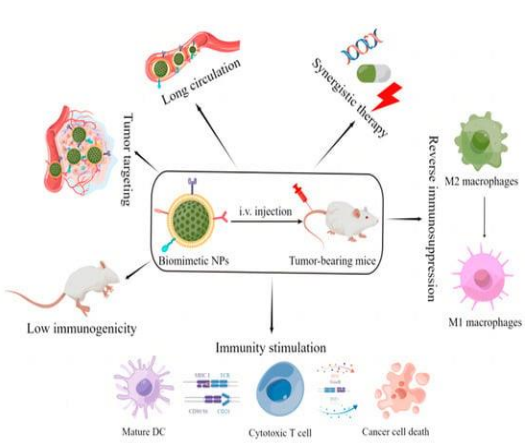
- **Gene Silencing**: siRNA-loaded NPs can silence oncogenes (e.g., KRAS) crucial for cancer growth.
- **Immunotherapy**: Delivering mRNA to generate *in vivo* CAR-T cells or carrying immune-stimulating nucleic acids.
- **Gene Replacement**: Delivering DNA encoding tumor suppressor genes to kill cancer cells.

Benefits

- **Reduced Toxicity**: Precise targeting minimizes damage to healthy cells.
- **Overcoming Barriers**: NPs can help navigate biological barriers, including tumor microenvironments.
- **Versatility**: Can carry various nucleic acids (DNA, mRNA, siRNA, miRNA) for diverse therapeutic strategies.

8. Nanoparticles in Cell derived biomimetic for cancer treatment[9]

Cell-derived biomimetic nanoparticles (NPs) are engineered nanocarriers that use natural cell membranes (like red blood, cancer, or platelet cells) to camouflage a therapeutic core, creating "stealth" nanobots for targeted cancer therapy. These hybrid NPs mimic natural cells, evading the immune system (RES), increasing circulation time, and targeting tumors via homotypic binding (cancer cell membrane coating) or specific surface proteins, delivering drugs or genes precisely to kill cancer cells while minimizing side effects, and even enhancing immunotherapy.



How They Work

Core-Shell Structure: A core nanoparticle (e.g., PLGA, magnetic NPs) carries therapeutic agents, coated with a cell membrane shell.

Immune Evasion: The cell membrane acts as a "self" signal, preventing rapid clearance by the immune system (RES).

Targeting:

Homotypic Targeting: Using cancer cell membranes (CCM) allows NPs to specifically recognize and bind to other cancer cells.

- **Active Targeting:** Adding targeting ligands to membranes (like RBCs or WBCs) guides them to tumor sites.
- **Enhanced Delivery:** They combine the targeting/biocompatibility of cells with the drug-loading capacity of synthetic NPs for better drug delivery and therapeutic efficacy.

Types of Cell Membranes Used

- **Red Blood Cells (RBCs):** Provide long circulation and biocompatibility.
- **Cancer Cells (CCMs):** Enable homotypic targeting to tumors.
- **Platelets (PLTs):** Offer prolonged circulation and cancer targeting.
- **White Blood Cells (WBCs) (Neutrophils):** Enhance immune escape and targeting.

Applications in Cancer

- **Targeted Chemotherapy:** Delivering drugs like Doxorubicin directly to tumors.
- **Cancer Immunotherapy:** Repolarizing immunosuppressive macrophages (M2 to M1) and triggering anti-tumor immunity.
- **Theranostics:** Combining diagnosis and therapy.
- **Diagnosis:** Isolating circulating tumor cells (CTCs) for early detection.

Nano medicine: Future Applications

Future application of nanomedicine may involve the elimination of bacterial infections in a patient within minutes, instead of using treatment with antibiotics over a period of weeks. In future, by the application of nanomedicine, we may have the ability to perform surgery at the cellular level, removing individual diseased cells and even repairing defective portions of individual cells. It may contribute significantly for lengthening of the human lifespan by repairing cellular level conditions that cause the body to age.

REFERENCES

1. Boer J, Lim JK, Chen X, Plebanski M, Mohamud R. A perspective review on the role of nanomedicine in the modulation of TNF-TNFR2 axis in breast cancer immunotherapy. J Oncol. 2019;2019:13.
2. Mody V, Siwale R, Singh A, Mody HR. Introduction to metallic nanoparticles. J Pharm Bioallied Sci. 2010;2:282-9.
3. Farokhzad OC, Langer R. Impact of nanotechnology on drug delivery. ACS Nano. 2009;3:16-20.
4. Ferrari M. Cancer nanotechnology: opportunities and challenges. Nat Rev Cancer. 2005;5(3):161-71.
5. Riggio C, Pagni E, Raffa V, Cuschieri A. Nano-oncology: clinical application for cancer therapy and future perspectives. J Nanomater. 2011;2011:164506.
6. Custódio C, Santo V, Oliveira M, Gomes M, Reis R, Mano J. Functionalized microparticles producing scaffolds in combination with cells. Adv Funct Mater. 2014;24(10):1391-400.
7. Lima A, Puga A, Mano J, Concheiro A, Alvarez-Lorenzo C. Free and copolymerized γ-cyclodextrins regulate the performance of dexamethasone-loaded dextran microspheres for bone regeneration. J Mater Chem B. 2014;2(30):4943-56.
8. Simón-Yarza T, Formiga F, Tamayo E, Pelacho B, Prosper F, Blanco-Prieto MJ. PEGylated-PLGA microparticles containing VEGF for long-term drug delivery. Int J Pharm. 2013;440(1):13-8.
9. Green MR, Manikhas GM, Orlov S, Afanasyev B, Makhson AM, Bhar P, et al. Abraxane, a novel Cremophor-free, albumin-bound particle form of paclitaxel for the treatment of advanced non-small-cell lung cancer. Ann Oncol. 2006;17:1263-8.