



## Novel Applications of Nanomaterials and Nanotechnology in Medical Sciences-A Review

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### ABSTRACT

Nanotechnology is a Scientific Technology, to manufacture the tools, materials and devices at atomic and molecular levels, including the synthesis of very minute sized particles called nanomaterials or nanomaterials. Nanomaterials are the nano-crystalline particles which owing the grain size with very minute ranges of about  $10^{-9}$ m. Nanomaterials have noticeable fascinating and valuable characteristics which can be implied for most of sciences and technologies today. Due to very sharp unique, beneficial, chemical and mechanical properties of nanomaterials, these are being used for broad form of scientific programs like next era laptop electronic chips, Kinetic Power Penetrators etc. Innovations in nanotechnology promise to modernize the drug synthesis, drug supply, and therapeutic diagnostics. By learning how substances behave contrarily at the specific cellular or unit level, researchers are beginning to expose the massive medical prospective of nanoscale tools. Though much of this work is still in its early stages, scientists and researchers are creating novel tools and developing new methods for crucial research areas of drug synthesis, drug carriers, targeting technologies, toxicity reduction, and materials optimization. By additionally inquire about in nanotechnology, it can be valuable for each part of human life. Solution, regenerative drug, undifferentiated organism research and nutraceuticals are among the main parts that will be changed by nanotechnology developments.

**KEY WORDS:** *Nanotechnology; Nanomaterials; Nano-devices; nano-crystalline particles; nanoscale tools*

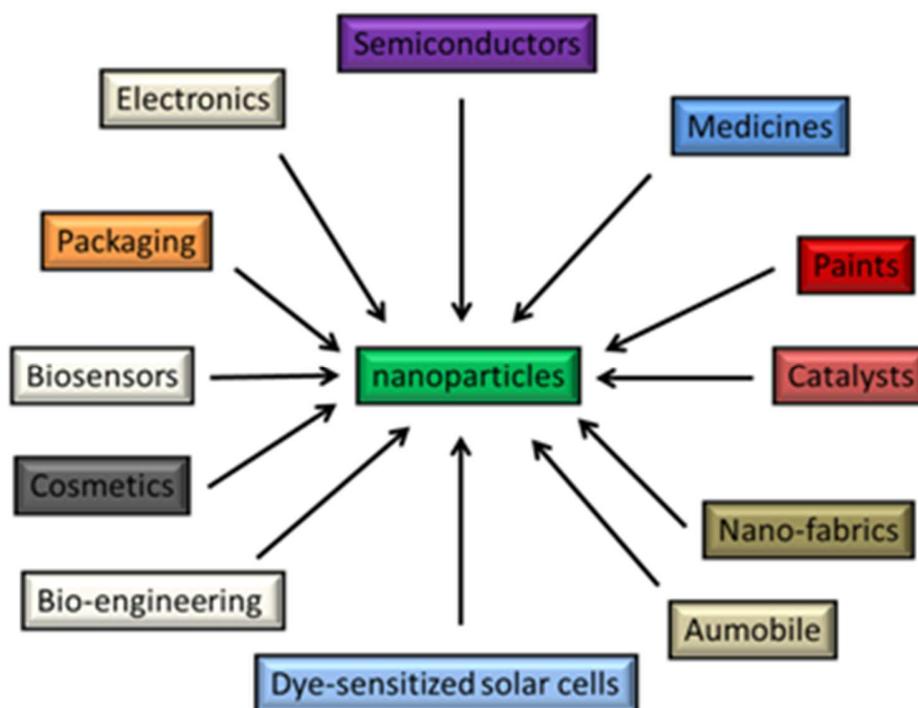
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### 1. INTRODUCTION

The products of the chemical industry are used to produce objects that vary enormously in their size from say the iron girders for bridge building to silicon chips in microprocessors[1]. However, techniques are now available which make it possible to manipulate materials on the atomic or molecular scale to produce objects which are no more than a few nanometres in diameter. A nanometre is  $1 \times 10^{-9}$ metres (a billionth of a metre). This is more than a 1000 times smaller than a silicon chip. The processes used to make and manipulate such materials are known as nanotechnology and the materials or objects themselves are called nanomaterials[2].

Nanotechnology is the manufacturing of tools and nano-devices by controlling the matter at the atomic level[3]. It also said that Nanotechnology is a Scientific Technology, dominated by advances in Elementary Chemistry, Physics and medical Researches[4], where the occurrences on very small levels (atomic along with molecular levels) are implied to offer the materials or tools and structures that accomplish the tasks which are impossible to perform using the tools in their Typical Macroscopic System[5]. The Advancement in Technology and Instrumentation, along with its related scientific fields, such as Chemistry, Physics and medical fields, is making the research studies developed and aggressive on nanotechnology[6]. Nanotechnology deals with the study of particles in the size of range of 0.1-100 nm; conversely[7], it is besides essential that these particles must show diverse properties; magnetism, optical effects, chemical reactivity, electrical conductance, and physical strength[8].

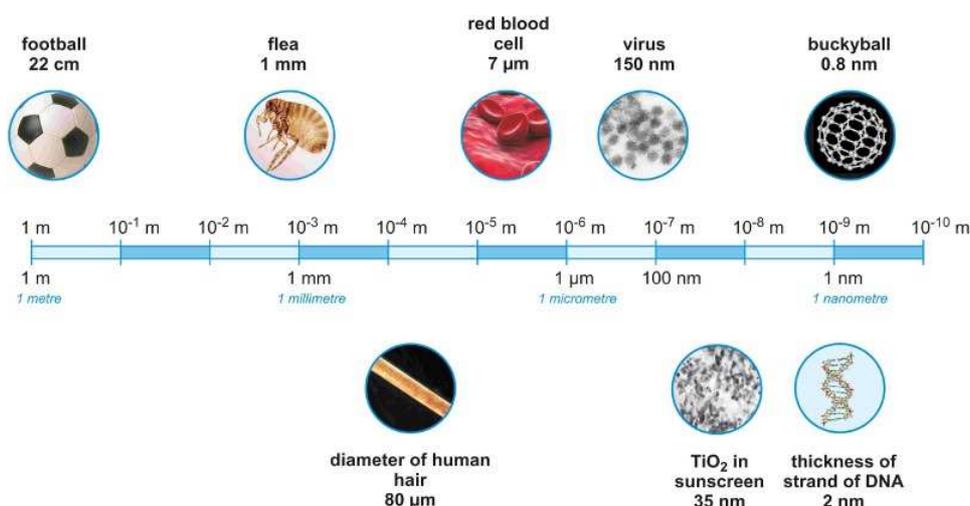
Nanotechnology focuses on material at sizes in the nanometer scale length (0.1-100 nm), and thus can be applied for a wide range of uses and applications, and the formation of several types of nanomaterials and nano-devices[9]. Materials or objects (Fig.2) that need to be measured in nanometers have always existed but the techniques for manipulating materials on this scale have only been developed during the last twenty years or so[10].



**Fig.1: Applications of Nanomaterials**

Nanomaterials are the nano-crystalline particles which owing the grain size with very minute ranges of about  $10^{-9}$ m. Nanomaterials have noticeable fascinating and valuable characteristics[11] which can be implied for most of sciences and technologies today. The small dimensions of nanomaterials also lead to the chance of them developing intimate mixtures with other materials with the assessment to improving the characteristics of the material[12]. In medical treatments, they can be tailored to provide opportunities to target some medications more precisely[13]. Due to very sharp unique, beneficial, chemical and mechanical properties of nanomaterials, these are being used for broad form of scientific programs (Fig.1) like next era laptop electronic chips[14], Kinetic Power Penetrators etc. These are being popularly used as excellent insulating stuff[15]. These are used extremely in High Definition TVs, Low Cost Flat-Panel Displays, Very Hard and Tough Cutting Tool, and High Power Magnets[16]. These are also used to eliminate the environmental pollution, to make the High Range weapons, Long-term satellites, medical appliances[17], Ductile, Machinable Ceramics, enormous Electrochromic display devices[18].

Innovations in nanotechnology promise to modernize the drug synthesis, drug supply, and therapeutic diagnostics. By learning how substances behave contrarily at the specific cellular or unit level, researchers are beginning to expose the massive medical prospective of nanoscale tools. Though much of this work is still in its early stages, scientists and researchers are creating novel tools and developing new methods for crucial research areas of drug synthesis, drug carriers, targeting technologies, toxicity reduction, and materials optimization[19-20].



**Fig.2: A scale to show the relative dimensions of various objects**

## 2. Medicinal use of Nano Materials

Nano medicine is a comparatively novel field of science and technology. By interrelating with biotic particles at nano scale, nanotechnology develops the scope of research and applications[21]. Collaborations of nano devices with biotic particles can be assumed mutually in the extracellular media and within the human bio-cells[22]. Process at nano scale permits utilization of physical characteristics, unlike from those perceived at micro scale such as the volume to surface ratio.

Two practices of nano medicine that have previously been experienced in mice and are pending for human trials; practice of gold nano shells to aid the analyze and cure the cancer, and the practice of liposome as serum adjuvants and as automobiles for drug transportation. Also, drug detoxification is additional application for nano medicine which has been tested effectively in mice. Medical tools can make use of smaller devices are less intrusive and can probably be embedded inside of body, and their biological response times are much smaller. As compared to typical drug delivery, nano devices are faster and additional complex[23].

## 3. Nanotechnology in health and medicine

Nanotechnology will have amassive impression in the healthcare and particular care industries, because of the enormously small extents of nanomaterials and their flexibility[24]. The chemical reaction kinetics, the location of influence, and duration of a therapy all are altered by particle size. Effective drug delivery is being verified already. Biological micro-electro-mechanical devices injected and fixed within patient's body to deliver the drugs[25] or transport new cells to injured tissues

In the field of biomedical imaging, the application of nanomaterials (Fig.3) as image enhancers is being advanced[26]and most developed.

Even today various disease like cancer, Alzheimer's disease, Parkinson's disease, diabetes, multiple sclerosis and cardiovascular diseases, also different kinds of serious provocative or infective diseases, for example; HIV and AIDS[27], create a broad range of severe and complex disorders which are creating a most problematic situation for the humans. Nano medicine is an application of nanotechnology which works in the field of health and medicine. Nano-medicine makes use of nano materials, and nano electronic biosensors [28]. In the future, nano medicine will benefit molecular nanotechnology. The medical field of nano medicine application has many predictable welfares and is hypothetically appreciated for all human competitions[29].

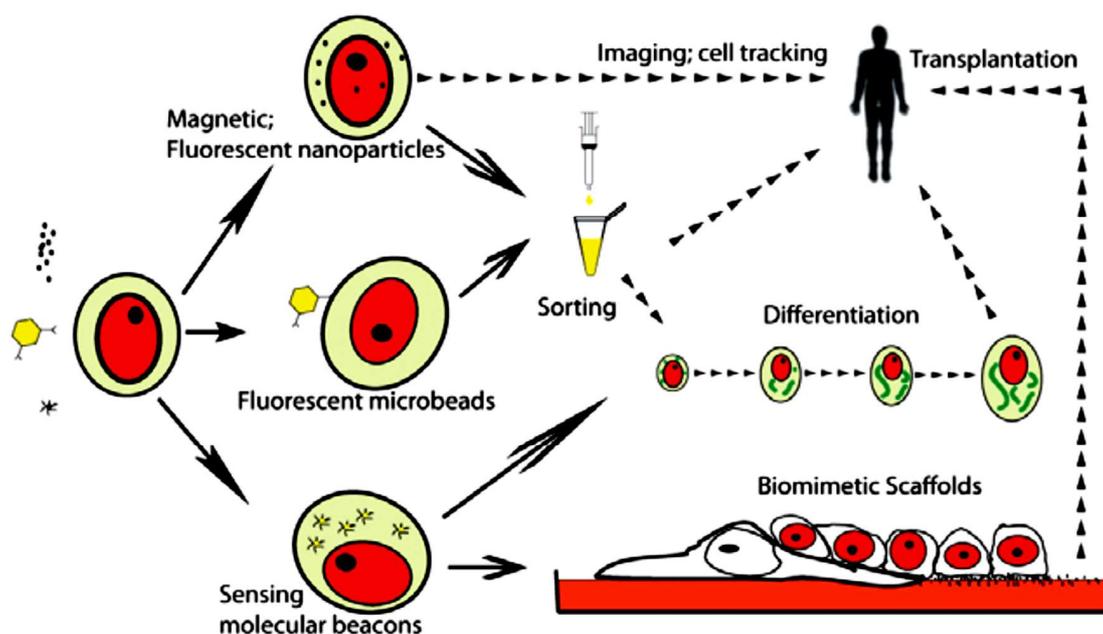
With the help of nano medicine, early detection and prevention, improved diagnosis, proper treatment and follow-up of diseases are possible. Certain nano scale particles are used as tags and labels, biological can be performed quickly, the testing has become more sensitive and more flexible. Gene sequencing has become more efficient with the invention of nano devices like gold nanomaterials, these gold particles when tagged with short segments of DNA[30] can be used for detection of genetic sequence in a sample.

With the help of nanotechnology, damaged tissue can be reproduced or repaired. These so called artificially stimulated cells are used in tissue engineering, which might revolutionize the transplantation of organs or artificial implants.

Advanced biosensors with novel features can be developed with the help of Carbon nano tubes[31]. These biosensors can be used for astrobiology and can throw light on study origins of life. This technology is also being used to develop sensors for cancer diagnostics. Though Carbon Nano Tube (CNT) is inert, it can be functionalized at the tip with a probe molecule[32]. Their study uses AFM as an experimental platform.

- i. Probe molecule to serve as signature of leukemia cells identified.
- ii. Current flow due to hybridization will be through CNT electrode to an IC chip.
- iii. Prototype biosensors catheter development.

Nanotechnology has made excellent contribution in the field of stem cell research. For example, magnetic nanomaterials have been successfully used to isolate and group stem cells. Quantum dots have been used for molecular imaging and tracing of stem cells, for delivery of gene or drugs into stem cells, nano materials such as carbon nano tubes, fluorescent CNTs and fluorescent MNPs have been used. Unique nanostructures were designed for controllable regulation of proliferation and differentiation of stem cells is done by designed unique nano structures[34]. All these advances speed up the development of stem cells toward the application in regenerative medicine. The recent applications of nanotechnology in stem cell research promises to open new avenues in regenerative medicine. Nanotechnology can be a valuable tool to track and image stem cells, to drive their differentiation into specific cell lineage and ultimately to understand their biology. This will hopefully lead to stem cell-based therapeutics for the prevention, diagnosis and treatment of human diseases[35]. Nano devices can be used in stem cell research in tracking and imaging them. It has its applications for basic science as well as translational medicine. Stem cells can be modulated by mixing of nano carriers with biological molecules. Nano devices can be used for intracellular access and also for intelligent delivery and sensing of biomolecules[36]. These technologies have a great impact in stem cell microenvironment and tissue engineering studies and have a great potential for biomedical applications.



**Fig.3: Nanotechnology applications in stem cell biology and medicine.**

#### 4. Drug Delivery

In nanotechnology nanomaterials are used for site specific drug delivery. In this technique the required drug dose is used and side-effects are lowered significantly as the active agent is deposited in the morbid region only. This highly selective approach can reduce costs and pain to the patients. Thus variety of nanomaterials such as dendrimers, and nano porous materials find application. Micelles obtained from block co-polymers, are used for drug encapsulation. They transport small drug molecules to the desired location. Similarly, nano electromechanical systems are utilized for the active release of drugs[37]. Iron nanomaterials or gold shells are finding important application in the cancer treatment.

A focused on prescription diminishes the medication utilization and treatment costs, influencing the treatment of patients to savvy. Nano prescriptions utilized for medicate conveyance, are comprised of nano scale particles or atoms which can enhance sedate bioavailability. For expanding bioavailability both at particular places in the body and over some stretch of time, atomic focusing on is finished by nano built gadgets, for example, nano robots[38]. The atoms are focused on and conveying of medications is finished with cell accuracy. In vivo imaging is another range where Nano apparatuses and devises are being produced for in vivo imaging.

Utilizing nano molecule pictures, for example, in ultrasound and MRI, nanomaterials are utilized as complexity. The nano built materials are being produced for successfully regarding sicknesses and illnesses, for example, growth[39]. With the headway of nanotechnology, self-gathered biocompatible nano gadgets can be made which will identify the harmful cells and consequently assess the sickness, will cure and get ready reports.

The pharmacological and remedial properties of medications can be enhanced by legitimate outlining of medication conveyance frameworks, by utilization of lipid and polymer based nanomaterials. The quality of medication conveyance frameworks is their capacity to adjust the pharmacokinetics and bio distribution of the medication[40]. Nanomaterials are intended to stay away from the body's resistance systems can be utilized to enhance medicate conveyance. New, complex medication conveyance components are being produced, which can get tranquilizes through cell layers and into cell cytoplasm, subsequently expanding productivity. Activated reaction is one path for sedate particles to be utilized all the more proficiently[41]. Medications that are put in the body can enact just on accepting a specific flag. A medication with poor solvency will be supplanted by a medication conveyance framework, having enhanced dissolvability because of essence of both hydrophilic and hydrophobic situations. Tissue harm by medication can be forestalled with tranquilize conveyance, by managed sedate discharge. With medicate conveyance frameworks bigger freedom of medication from body can be decreased by changing the pharmacokinetics of the medication[42]. Potential nano medications will work by particular and surely knew components; one of the significant effects of nanotechnology and nanoscience will be in driving advancement of totally new medications with more valuable conduct and less reactions.

Thus nanomaterials are promising tools for the advancement of drug delivery, as diagnostic sensors and bio imaging[43]. The bio-distribution of these nanomaterials is still imperfect due to the complex host's reactions to nano- and micro sized materials and the difficulty in targeting specific organs in the body. Efforts are made to optimize and better understand the potential and limitations of nano particulate systems.

In the excretory framework, investigation of mice dendrimers is epitomized for tranquilize conveyance of emphatically charged gold nanomaterials, which were found to enter the kidneys while contrarily charged gold nanomaterials stayed in the critical organs like spleen and liver. The positive surface charge of the nanoparticle diminishes the rate of opsonization of nanomaterials in the liver, along these lines influencing the excretory pathway. Because of little size of 5 nm, nanomaterials can get put away in the fringe tissues, and in this manner can get gathered in the body after some time. In this way nanomaterials can be utilized effectively and productively to target and dispersion, additionally research should be possible on nano danger so its restorative uses can be expanded and moved forward.

Silver nanomaterials provide powerful antiseptic properties and are used, for example, in baby food cartons to prevent cross-contamination[44] and in fabric dressings(Fig.4).



Fig.4: Silver Nanoparticle based antibacterial plaster

### 5. The applications of nanomaterials in drug delivery

Nano technology based drug delivery is based upon three facts: i) efficient encapsulation of the drugs, ii) successful delivery of said drugs to the targeted region of the body, and iii) successful release of that drug there.

Abraxane, is egg whites bound paclitaxel, a nano molecule utilized for treatment of bosom disease and non-little cell lung growth[45]. Nanomaterials are utilized to convey the medication with upgraded viability for treatment for head and neck tumor, in mice demonstrate contemplate, which was done at from Rice University and University of Texas MD Anderson Cancer Center[46]. The announced treatment utilizes Cremophor EL which permits the hydrophobic paclitaxel to be conveyed intravenously. At the point when the poisonous Cremophor is supplanted with carbon nanomaterials its reactions decreased and medicate focusing on was quite enhanced and needs a lower measurements of the lethal paclitaxel.

Nano molecule fasten was utilized to convey the medication doxorubicin to bosom growth cells in a mice learn at Case Western Reserve University. The researchers arranged a 100 nm long nano molecule chain by artificially connecting three attractive, press oxide nano circles, to one doxorubicin stacked liposome[47]. After infiltration of the nano chains inside the tumor attractive nanomaterials were made to vibrate by producing, radiofrequency field which brought about the burst of the liposome, in this way scattering the medication in its free shape all through the tumor. Tumor development was ended more successfully by nanotechnology than the standard treatment with doxorubicin and is less hurtful to sound cells as less dosages of doxorubicin[48] were utilized.

Polyethylene glycol (PEG) nanomaterials conveying payload of anti-microbials[49] at its center were utilized to target bacterial disease all the more exactly inside the body, as announced by researchers of MIT. The nano conveyance of particles, containing a sub-layer of pH touchy chains of the amino corrosive histidine, is utilized to annihilate microorganisms that have created protection from anti-microbials on account of the focused on high dosage and delayed arrival of the medication[50]. Nanotechnology can be productively used to treat different irresistible infections.

'Mini cell' nano particle are used in early phase clinical trial for drug delivery for treatment of patients with advanced and untreatable cancer. The mini cells are built from the membranes of mutant bacteria and were loaded with paclitaxel and coated with cetuximab, antibodies and used for treatment of a variety of cancers. The tumor cells engulf the mini cells. Once inside the tumor, the anti-cancer drug destroys the tumor cells. The larger size of minicells plays a better profile in side effects.

The minicell drug delivery system uses lower dose of drug and has less side-effects can be used to treat a number of different cancers with different anti-cancer drugs.

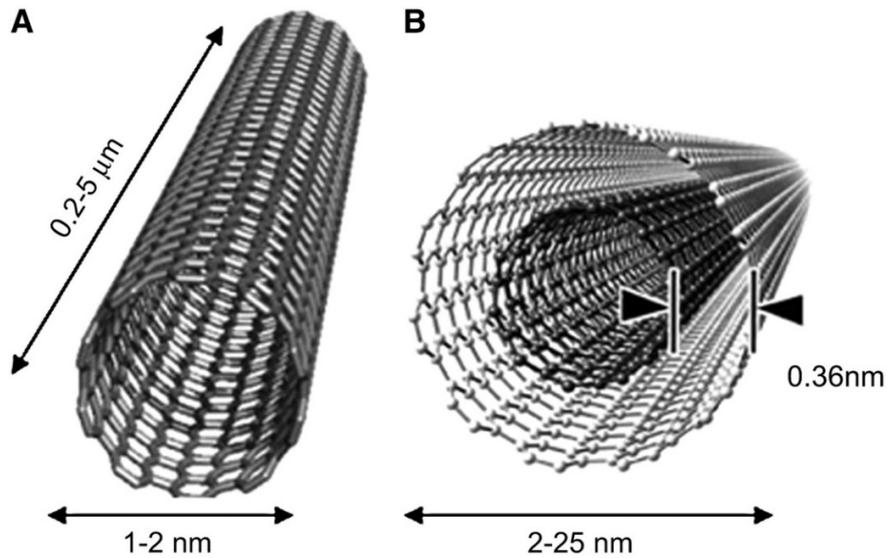
Nano sponges are important tools in drug delivery, due to their small size and porous nature they can bind poorly-soluble drugs within their matrix and improve their bioavailability. They can be made to carry drugs to specific sites, thus help to prevent drug and protein degradation and can prolong drug release in a controlled manner[51].

### 6. Pharmaceutical nanotechnology

Pharmaceutical nanotechnology is isolated in two fundamental sorts of nano apparatuses viz. nano materials and nano gadgets. These materials can be sub characterized into nano crystalline and nano organized materials. Nano structure comprises of nano particles, dendrimers, micelles, medicate conjugates, metallic nano particles[52] and so on.

### 7. Carbon nano tubes (fig)

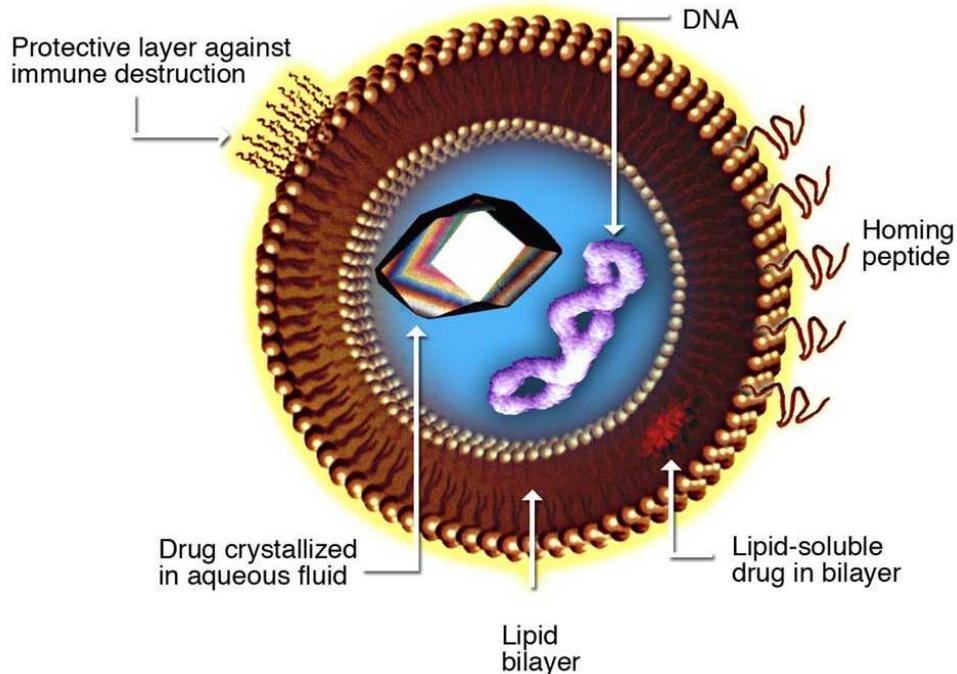
These are little macromolecules that are one of a kind for their size (Fig.5), shape, and have exceptional physical properties. Nano tubes have some exceptional favorable circumstances[53] over other medication conveyance and symptomatic frameworks because of their one of a kind physical properties.



**Fig.5: Carbon Nano Tube**

### 8. Liposomes

Liposomes are composite structures made of phospholipids and may contain little measures of different particles. Despite the fact that liposomes can shift in measure from low micrometer range to many micrometers, unilamellar liposomes, as envisioned here, are normally in the lower estimate run with different focusing on ligands joined to their surface taking into consideration their surface-connection and aggregation in neurotic zones for treatment of malady. These have been widely investigated and most created nano bearers for novel and focused on tranquilize conveyance because of their little size, these are 50-200 nm in estimate[53]. At the point when dry phospholipids are hydrated, shut vesicles are shaped (Fig.6). Liposomes are biocompatible, adaptable and have great ensnarement proficiency. It discovers application as long circulatory and in aloof and dynamic conveyance of quality, protein and peptide.



**Fig.6: Liposome**

### 9. Dendrimers

Dendrimers (Fig.7) are hyper stretched, tree-like structures. It contains three distinct areas: center moiety, stretching units, and firmly pressed surface. It has globular structure and encases inward holes. Its size is under 10 nm. These are utilized for long circulatory, controlled conveyance of bioactive material, directed conveyance of bioactive particles to macrophages[55] and liver focused on conveyance.

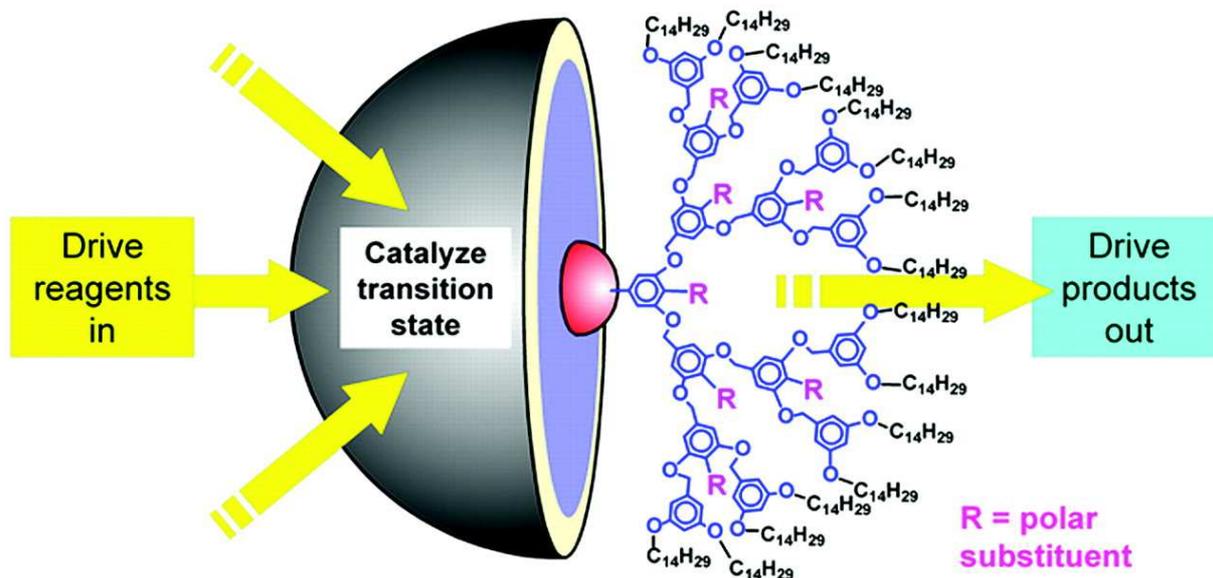


Fig.7: Dendrimers in drug delivery

### 10. Metallic nano particles

Metallic nano particles have used in drug delivery, especially in treatment of cancer and also in biosensors. Amongst various metals, silver and gold nano particles are of prime importance for biomedical use.

### 11. Proteins and Peptide Delivery

Protein and peptides are macromolecules and are called biopharmaceuticals. These have been identified for treatment of various diseases and disorders as they exert multiple biological actions in human body. Nano materials like nano particles and dendrimers are called as nano biopharmaceuticals, are used for targeted and/or controlled delivery.

### 12. Cancer Treatment

Nano shells of 120 nm distance across, covered with gold were utilized to execute disease tumors in mice by Prof. Jennifer at Rice University. These nano shells are focused to attach to carcinogenic cells by conjugating antibodies or peptides to the nano shell surface. Range of the tumor[56] is illuminated with an infrared laser, which warms the gold adequately and murders the disease cells. The applications of various nano systems in cancer therapy are summarized as:

- **Carbon nano tubes**, 0.5–3 nm in diameter and 20–1000 nm length, are used for detection of DNA mutation and for detection of disease protein biomarker.
- **Dendrimers**, less than 10 nm in size are useful for controlled release drug delivery, and as image contrast agents.
- **Nano crystals**, of 2-9.5 nm size cause improved formulation for poorly-soluble drugs, labeling of breast cancer marker Her2 surface of cancer cells.
- **Nano particles** are of 10-1000 nm size and are used in MRI and ultrasound image contrast agents and for targeted drug delivery, as permeation enhancers and as reporters of apoptosis, angiogenesis.
- **Nano shells** find application in tumor-specific imaging, deep tissue thermal ablation.
- **Nano wires** are useful for disease protein biomarker detection, DNA mutation detection and for gene expression detection.
- **Quantum dots**, 2-9.5 nm in size, can help in optical detection of genes and proteins in animal models and cell assays, tumor and lymph node visualization.

### **13. Tuberculosis treatment**

Tuberculosis (TB) is the savage irresistible infection. The long length of the treatment and the pill weight can hamper quiet way of life and result in the advancement of multi-drug resistant (MDR) strains. Tuberculosis in youngsters constitutes a noteworthy issue. There is business non accessibility of the principal line tranquilizers in pediatric shape. Novel anti-infection agents can be intended to conquer medicate protection, cut off the term of the treatment course and to lessen sedate associations with antiretroviral treatments[57]. A nanotechnology is a standout amongst the most encouraging methodologies for the advancement of more compelling and consistent drugs. The headways in nano based medication conveyance frameworks for exemplification and arrival of hostile to TB medications can prompt advancement of a more viable and reasonable TB pharmacotherapy.

### **14. Alzheimer's disease**

Around the world, more than 35 million individuals are influenced by Alzheimer's ailment (AD), which is the most widely recognized shape dementia. Nano innovation finds huge applications in neurology. These methodologies depend on the, early AD determination and treatment is made conceivable by planning and designing of a plenty of nanoparticle substances with high specificity for mind slim endothelial cells[58]. Nano particles (NPs) have high liking for the flowing amyloid- $\beta$  ( $A\beta$ ) structures and in this manner may initiate "sink impact" and enhance the AD condition. In vitro diagnostics for AD has progressed because of ultrasensitive NP-based bio-standardized tags and safe sensors, and in addition examining burrowing microscopy methods equipped for distinguishing  $A\beta$ 1-40 and  $A\beta$ 1-42.

### **15. Other Applications**

Nano particles were found useful in delivering the myelin antigens, which induce immune tolerance in a mouse model with relapsing multiple sclerosis. In this technique, biodegradable polystyrene micro particles coated with the myelin sheath peptides will reset the mouse's immune system and thus prevent the recurrence of disease and reduce the symptoms as the protective myelin sheath forms coating on the nerve fibers of the central nervous system. This method of treatment can potentially be used in treatment of various other autoimmune[59] diseases.

### **16. Conclusion**

Nano materials have expanded surface region and nano scale impacts, subsequently utilized as a promising instrument for the headway of medication and quality conveyance, biomedical imaging and symptomatic biosensors. Nano materials have one of a kind physicochemical and natural properties when contrasted with their bigger partners. The properties of nano materials can incredibly impact their associations with bio particles and cells, because of their impossible to miss estimate, shape, concoction piece, surface structure, charge, dissolvability and agglomeration. For instance, nano particles can be utilized to create excellent pictures of tumor destinations; single walled carbon nanotubes, have been utilized as high-productivity conveyance transporters for biomolecules into cells. There is a brilliant future to nano innovation, by its converging with different advancements and the consequent rise of mind boggling and inventive half and half advances.

Science based advancements are interlaced with nanotechnology. Nanotechnology is now used to control hereditary material, and nano materials are as of now being constructed utilizing organic segments. Advancements in nanotechnology guarantee to modernize the medication blend, sedate supply, and remedial diagnostics. By figuring out how substances carry on conversely at the particular cell or unit level, specialists are starting to uncover the gigantic medicinal forthcoming of nanoscale instruments. In spite of the fact that quite a bit of this work is still in its beginning times, researchers and analysts are making novel devices and growing new strategies for urgent research zones of medication combination, sedate bearers, focusing on advances, lethality diminishment, and materials streamlining.

The capacity of nanotechnology to design matter at the littlest scale is upsetting territories, for example, data innovation intellectual science and biotechnology and is prompting new and interlinking these and different fields. By additionally inquire about in nanotechnology, it can be valuable for each part of human life. Solution, regenerative drug, undifferentiated organism research and nutraceuticals are among the main parts that will be changed by nanotechnology developments.

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