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ROLE OF NANOTECHNOLOGY IN PHARMA INDUSTRIES – REVIEW

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ABSTRACT

The development of drug formulations based on nanoparticles has opened up opportunities to address and treat challenging diseases successfully. Advantage and efficacy of nanoparticles stem from their sub-microscopic size, which can range from 100 to 500 nm. The surface features, composition, size and morphology of nanoparticles might be modified to create intelligent systems with stealth capabilities that can incorporate medicinal and imaging materials. These devices also have the capability of delivering medicines to specific locations and controlled release therapy. Through targeted and sustained medicinal products distribution, medication-related toxicity is decreased and patient compliance with less frequent dosing is increased. Nanotechnology playing a pivotal role in drug discovery research and showed promise in treating AIDS, Cancer, and many other diseases, as well as in enhancing the testing through nano-diagnostics. This review will primarily focus on the desirable features of efficient drug delivery systems based on nanomaterials, and the nano enabled tools also the nanomedicines where these systems have shown promise. Curiosity in creating semi-synthetically accessible lead compounds that mirror the chemistry of their counterparts is a current theme in medication development based on natural products.

KEYWORDS: **N**anomaterials, Nano-diagnostics, Nano-enabled tools, Nanomedicines.

INTRODUCTION: After decades worth of study across science and engineering fields, the core concepts of nanotechnology become evident.[1] Based to the theory of renowned physicist Richard Feynman (1959), "there is enough of space on the beneath," which most experts believe presaged the development of nanotechnology, indicates that it should be able to construct machines small enough to produce products with the level of microscopic precision.[2] Nanoparticles acquire special, distinct properties and capabilities at this smallest size scale which are very different to those observed at the macroscopic level.[3] Researchers can work with the nanoparticles because of their nanoscopic size, superficial modification, enhanced dispersibility, and versatility which opens up a lot of new research possibilities.[4] The unique properties of nanoparticles which enables that unanticipated interaction with the complicated biological processes and operates at the tiny size of biomolecules.[5] The early difficulties of low throughput, faulty data, and other problems are now starting to be resolved by technological advancements.[6] Innovative solutions are provided by the revolutionary format of nanotechnology, which allows researchers to store, screen molecular, and tissue libraries with less sample volume while also improving data quality and analytical capability.[7] Nowadays, nanotechnology serves a key role in medication discovery and development by enhancing diagnostic techniques, creating better compilations of medication, and creating the network of transportation of bioactive molecules for the treatment of diseases.[8] The pharmaceutical sector has recently become stronger by incorporating nanotechnology principles, **Fig. 1:** illustrates the different sorts of nanomaterials and **Fig. 2:** highlights the applications of nanotechnology.[9,10]

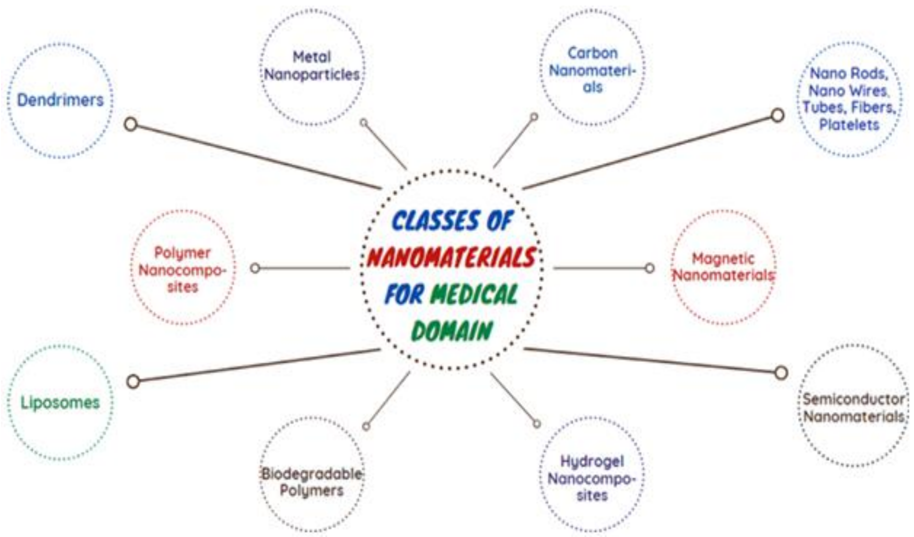

Fig. 1: Types of Nanomaterials.[11]

Nanomaterials and Nano enabled tools: Nanotechnology is primarily employed in the pharma industry for developing sophisticated medication distribution systems which allow for targeted lead molecule transport to fixed sites in the body, enhance drug solubility, and minimize side effects by precisely regulating the release of active pharmaceutical ingredients (APIs).[12] This results in an increased efficacy and lower dosage requirements, especially when treating complex diseases like cancer and neurodegenerative disorders.[13] The emergence of nanomaterials aims to satisfy the demand for increased sensitivity in high throughput screening and key application of nanomaterials in health science are.

i. Targeted drug delivery: Medications can be precisely delivering their intended destination in the human body with the help of surface modified nanoparticles which target certain cell types or tissues and reducing off-target side effects.

ii. Enhanced bioavailability: Bio-active molecules which are poorly soluble can be encapsulated by nanoparticles, which can boost the drug's solubility and absorption in the body and improve the therapeutic outcomes.

iii. Controlled release: Drug release can be modulated over time by modifying the nanoparticle's features, enabling longer-lasting therapeutic benefits with less dosages.

iv. Imaging and Diagnostics: The delivery of drug and progress of disease curing can be tracked in real time by designing the nanoparticles with characteristics which render them visible using imaging process for instance fluorescence or magnetic resonance imaging (MRI).

Ultrafine particles (bars, dots, dendrimers or colloids) offer molecular markers that are extremely durable, conveniently assorted and similar in size to the molecular components of interest.[14] Since nanoparticles and proteins have an identical size range, nanomaterials are capable of being utilized for bio-docketing or marking.[15] Nevertheless, a biological or molecular coating or a layer functioning as a bioinorganic interface must be affixed to the nanoparticle in order for it to engage with a target.[16] Devices and gadget used for measuring and working with minuscule scale structures are known as nano-empowered tools. Some examples of nanotools include software, lithography systems, systems for manipulation and manufacture, probes, and microscopes. **Table 1** describes the properties of different types of nano-enabled tools.[17]

Table 1: Different types of Ultrafine micro devices.

Sub-microscopic tools	Ultrafine particles/ materials	Nano-enabled drugs
Atomic force microscopy	Quantum dots	Examples include: Abraxane Rena Zorb Antimicrobial emulsions Antioxidants and Fullerenes
Nano-mass spectroscopy	Shells	
Dip-pen nanolithography	Bars	
Nano-arrays	Dendrimers	

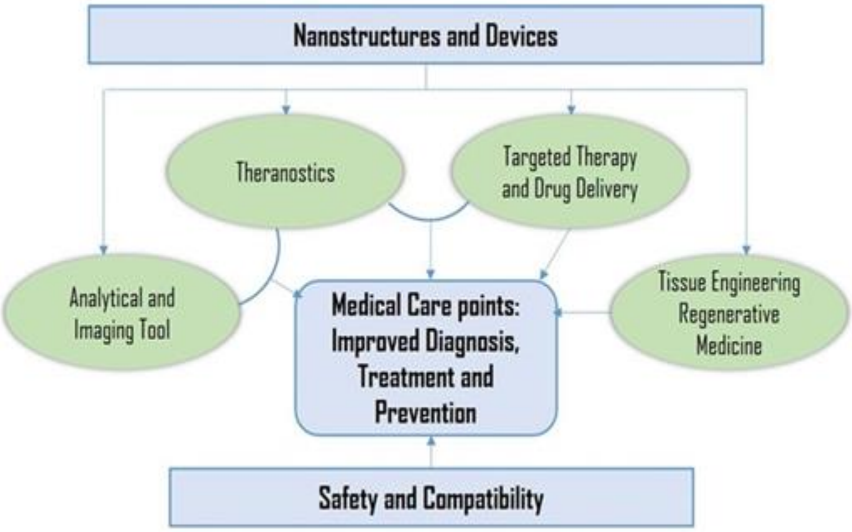

Fig. 2: Application of Nanostructures.[18]

Due to the unique characteristics, they possess at the nanoscale, which enable them for targeted delivery and improved functionality.[19] Devices rendered feasible by nanotechnology are utilized in numerous fields, notably medical field (drug transport, diagnostics, treatment of tumours), electronics (smaller, faster components), agriculture (improved fertilizers and pesticides), energy storage (increased efficiency), environmental remediation (political detection and removal), and food packaging (increased shelf life and safety). The following are the essential variables to consider while utilizing nanotechnology in pharmaceuticals.[20]

- **Toxicity and safety:** Thorough evaluation of the potential toxicity and long-term effects of nanoparticles is crucial before clinical application.
- **Regulatory aspects:** Nanomedicines are subject to stringent regulatory guidelines to ensure safety and efficacy.
- **Manufacturing challenges:** It can be difficult to scale up the manufacturing of nanoparticles with identical dimensions and attributes.

Relevance of Nanoparticles: The application of ultrafine particles in the new medication research are, it will recognize the protein on the target surface, which aids in recognition and verification. Through assay automation, speed, and dependability, nanoscale materials will improve the administration process of lead active molecules. The primary issues associated with employing ultrafine particles for drug delivery are, in-vivo unpredictability, inadequate systemic intake, limited dissolution, and insufficient bioavailability are. Issues with the tonic's efficiency, target-specific transport, and the risk of adverse drug reactions. Thus, adopting innovative drug transport methods to target specific body parts with treatments might be a way to address these urgent issues. Thereby, the creation of improved medicine and drug formulations, targeting, and highly effective controlled drug release and delivery depend heavily on nanotechnology. It has been shown that nanotechnology may bridge the gap between the physical and biological sciences by employing nanostructures and nanophases in a range of scientific fields. The global pharmaceutical industry and healthcare system are expected to be significantly impacted by pharmaceutical submicron medicine artifacts.[21] Since 1995–2021, the Food and Drug Administration (FDA) and the European Medicines Agency (EMA) have approved over seventy {70} ultrafine bioactive leads. Every year, the recently approved nanomedicines of previously approved drugs are evaluated to see if they work better than their traditional counterparts. **Table 2** revealed the list of commercial nanomedicines available for cancer therapy.[22]

Table 2: Ultrafine medicines for the cancer therapy.

Curative drugs	**Composition**	**Applications** (for the treatment)
Genexol-PM	mPEG-PLA micelle loaded with paclitaxel	Metastatic breast cancer
Doxil/Caelyx	Liposomal doxorubicin	Kaposi's sarcoma, Ovarian, breast cancer, multiple myeloma
Onivyde	Liposomal irinotecan	Pancreatic cancer
Myocet	Liposomal doxorubicin	Metastatic breast cancer (combination therapy)
Cynviloq	Paclitaxel-loaded poly(ethylene glycol)-b-poly(D,L-lactic acid) block copolymers	Non-small cell lung cancer and metastatic breast cancer

The substantial market demand and the quick expansion of research and development (R&D) show how important ultrafine technology is in the field of medication delivery. Instead of demonstrating increased efficacy, the majority of licensed nanomedicines already on the market have demonstrated minimal morbid and adverse effects.[23] RenaZorb is a patented "growth-in-film" nanotechnology-based inorganic active medicinal component (API) based on lanthanum that has been demonstrated to enable phosphate management in renal dialysis patients.[24] The FDA approved medication Abraxane may be used to treat metastatic breast cancers. It may be made without using a solvent through the combination of bioactive lead molecule Paclitaxel with albumin, a naturally occurring protein, to create ultra-micron particles that are 1/100th of the size of a red blood cell. The internationally commercialized nanomedicines are shown in **Table 3** and may be categorized as either nanoparticles of the following inorganic, dendrimer-based, polymer-based, lipid-based, protein-based, or nanocrystals.[25]

Table 3: Ultrafine particles - categories, features and strengths.

Categories of Ultrafine components	Brand name and Organization	Date of approval and Active constituents	Used as/for
Ultra scale crystals	Rapamune, Wyeth Pharma Inc.	FDA (2015), sirolimus (rapamycin)	Lung disease
	Ivemend, Merck & Co. Inc.	FDA, EMA (2008), (Injection) fosaprepitant dimeglumine	Antiemetic drug
	Emend®, Merck & Co. Inc.	FDA (2003), aprepitant	Antiemetic drug
Lipid-based Nanoparticles	Onpattro®, Alnylam	FDA & EMA(2018), patisiran	Genetic disease
	Curosurf®, Chiesi	FDA (1999), poractantalfa	(RDS) Respiratory Distress Syndrome
	Pfizer-Bio N Tech Vaccine, Pfizer Pharmaceuticals	FDA(2020), mRNA Vaccine	COVID-19 infection
Polymer-based Nanoparticles	Somavert®, Pfizer Pharma Ltd.	EMA (2002) & FDA (2003), analog of human growth hormone	Acromegaly
	PegIntron®, Merk & Co. Inc.	EMA (2000) & FDA (2001), alphainterferon (INF) molecule	Hepatitis C
	Copaxone®/FOGA, Teva Pharmaceutical Industries Ltd.	FDA (1996) & EMA (2016), glatirameracetate	Multiple Sclerosis (MS)
Inorganic Nanoparticles	Feridex®/Endorem®, AMAG Pharma Industries Ltd.	FDA (1996), SPION-dex	Imaging agent
	Hensify®, Nanobiotix	EMA(2019), Hafnium-oxide (HfO_2) nanoparticles	Squamous cell carcinoma
	Ferinject®, Vifor Pharma Ltd.	FDA & EMA(2013), Iron Carboxy Maltose Colloid	Anaemia (Iron deficiency)

Without a doubt, the enormous advancements in the domains of individual hygiene, nutrition and personal care products, and healthcare have fuelled the expansion of the worldwide nanotechnology business. AgNPs and other nanoparticles have substantially enhanced nourishment conservation in the dietary field, improving longevity and profitability.[26]

Nanotechnology research - National status: In India, nanotechnology research has become a vibrant and quickly developing sector that is advancing medication delivery systems, diagnostics, and illness management.[27] The potential for point-of-care diagnostics and tailored treatment is enormous when nanotechnology is integrated with the robots, artificial intelligence, and 3D printing. India has a solid scientific infrastructure, cooperative projects, and government backing, which would enable it to significantly impact the field of nanomedicine worldwide. Patients and healthcare systems throughout the world will eventually profit from the expansion of nanomedicine research in India, which will be further fuelled by sustained funding, multidisciplinary partnerships, and smart policy frameworks.[28]

Although India's nanomedicine research has advanced significantly over the last ten years, there are still a number of obstacles to overcome. The development of nanoscience and technology is hampered by a lack of qualified researchers, the high expense of equipment which is used in nanotechnology, and regulatory barriers. Nonetheless, measures for skill development, policy changes, and capacity building are being used to address these issues. In conclusion, the initiatives of several academic groups are enabling the area of nanomedicine in India to see substantial growth and development. By facilitating targeted medication delivery, enhanced diagnostics, and novel therapeutic techniques, the research being out by these teams has the potential to completely transform the healthcare industry.[29] Undoubtedly, more research in this area will result in discoveries that significantly alter medical procedures and patient results. The hunt for efficient drug discovery techniques and methods is an ongoing struggle in the highly competitive drug discovery field.[30,31] The medication manufacturing firms need toward identify, evolve and demonstrate the novel therapies for a range of illnesses in order to overcome growing regulatory barriers, economic stress, and other challenges.[32]

DISCUSSION

Nowadays, almost all pharmaceutical companies find new medications using the same technological procedures, which consist of cloning and expressing human receptors and enzymes in formats that are suitable for high throughput, automated screening, and combinatorial chemistries. In light of the genome and proteome rebellion, the medicinal product progress sector now has access to a vast quantity of information on the molecular elements of life, including a greater number of suitable lead candidates and targets than at any time prior. Biotechnology and pharmaceutical firms have spent billions of dollars on cutting-edge technologies that can speed up the drug discovery and development operations throughout the years in an effort to increase productivity and maintain market position.

Applications involve clinical trials, administration, marketing, sale-up, and target selection and validation.

It is evident that technology influence the drug discovery process into a new direction where new lead molecules can be rapidly synthesized even for the difficult targets. Automation and robotics-based techniques have significantly boosted the outputs in chemical synthesis and screening, but they have only just started to make a difference. Lead active molecule investigation has already undergone an upsurge due to the advent of microarrays and Lab-On-a-Chip (LOC) technology. These cutting-edge technologies produce valuable information quickly, reducing the amount of guessing required to choose targets, leads, and medication candidates. Furthermore, by operating at levels far lower than traditional micro-arrays, even more innovative technologies, including nanotechnology, are poised to significantly simplify the drug discovery process through assay automation, speed, and reliability. Cross-disciplinary researchers have the chance to create multifunctional submicron particles that can target, diagnose, and cure illnesses like cancer thanks to this quickly expanding discipline. Ultrafine technology's primary goal in the field of drug research and development is to enhance illness therapy by creating better drug formulations, improved drug delivery systems, and enhanced diagnostic techniques. The distinctive physical and chemical characteristics of substances at the sub-micro scale are drawing a growing amount of interest from researchers in an effort to discover inventive uses that will enhance human health.

CONCLUSION

At present the main goals of nanoscale particles in healthcare industry will be focused on the safe transportation of medication and finding of bioactive lead molecules for the treatment of diseases. Despite nanotechnology's enormous advantages, it faces undoubtedly yet numerous obstacles to be conquered. The incorporation of nanoscale strategies in the development of new medication has begun to provide significant advances in our knowledge of working principles of biological systems, while it will also result in the new, novel types of micro- and nanofabricated gadgets and systems with the greater percentage of efficacy. Due to its outstanding advantages over conventional therapies, the combination of nanotechnology with photo radiation therapy has grown into an increasingly popular choice for the number of clinical diseases. In new evolution of this therapy where organic dyes are being substituted with the ultrafine particles including quantum dots, liposomes, or polymeric micelles which having both excellent photo-stability and multiplexing characteristics also perfectly binds with the photosensitizers, which enables improved tumour targeting and regulated the release of active molecules in photochemical treatment. In the marking of biological molecules, as well as to distinguish between various biochemicals, ultrafine bars can be used which are made of alternating layers of reflective metals that may be optically scanned like an actual bar codes. These techniques outperform the conventional tagging, facilitate the creation of a large number of labels, enhance the success rate of photodynamic therapy, and have infinite possibilities.

In the current context the life science industry community start using the micromachining as a technique for miniaturizing interdisciplinary devices. Ultrafine technology offers some special prospects, despite the fact that many of the concepts explored in nanomedicine may appear to be from science fiction. Nanotechnology has enormous potential for enhancing health and extending life since it will soon make it possible to monitor, diagnose, and treat numerous diseases in a less intrusive manner. Although customized healthcare combines enhanced illness prevention and evaluations, the use of nanoscale medicine may be the next major advancement in disease therapy.

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