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A comprehensive review on Nanotechnology

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Abstract
Contrary to its name, nanotechnology has completely transformed several sectors worldwide. The cutting-edge discipline of nanotechnology is devoted to working with matter at the molecular and atomic size, usually less than 100 nanometres. Because of the accuracy of the nanoscale, it makes it possible to design, create, and implement systems with improved properties. Materials, electronics, energy, and healthcare have all been profoundly altered by the development of nanotechnology. Commercialisation is hampered by regulatory issues and health worries, which call for teamwork and aggressive risk management. The significance of nanoparticles (NPs) in technological advancements is due to their adaptable characteristics and enhanced performance over their parent material. The recent research on bio-systems at the nano-scale and the nanotechnology has created one of the most dynamic science and technology domains at the confluence of physical sciences, molecular engineering, biology, biotechnology, and medicine. This review article presents the most outstanding contributions in the field of nanotechnology as drug delivery system and its applications, its future prospectives.

Keywords: Nanotechnology, health care, agriculture, food industry, nanoparticles

Introduction

Globally, nanotechnology has gradually but significantly dominated a variety of industries. Particularly in the industrialised world, where nano-scale markets have quickly taken over in the last ten years, this rapid pace of technological innovation is evident. Since nanotechnology is now a general-purpose technology, it is not a novel idea. Active and passive nanoassemblies, general nanosystems, and small-scale molecular nanosystems are the four generations of nanomaterials that have surfaced and are employed in transdisciplinary scientific domains.

Nanotechnology evolved as the achievement of science in the 21st century. The synthesis, management, and application of those materials with a size smaller than 100 nm fall under the interdisciplinary umbrella of this field. Nanoparticles (NPs) have significant applications in different sectors such as the environment, agriculture, food, biotechnology, biomedical, medicines, etc. like; for treatment of waste water, environment monitoring, as a functional food additive, and as an antimicrobial agent. Cutting-edge properties of NPs such as; nature, biocompatibility, anti-inflammatory and antibacterial activity, effective drug delivery, bioactivity, bioavailability, tumor targeting, and bio-absorption have led to a growth in the biotechnological, and applied microbiological applications of NPs.

To take advantage of the enormous potential of this new science, millions and billions of dollars and euros are being invested globally on nanotechnology, particularly in the developed worlds of China, America, and Europe. But because they cannot even keep up with the industrial advancements of the past ten years, emerging countries continue to lag behind. The primary reason for this lag is that these nations are still struggling economically and require some time to advance in the field of nanotechnology. Nonetheless, it is important to highlight that the scientific community in both the developed and developing worlds concur that nanotechnology will be the next technological advancement. In the upcoming years, this will make additional industrial upgrading and investment in the field of nanotechnology essential [1-6].

History of nanotechnology

The term “nanotechnology” was first used in 1974 by Japanese scientist Professor Norio Taniguchi at an international symposium on industrial production held in Tokyo. Taniguchi coined the phrase to refer to the nanoscale ion beam milling and semiconductor manipulation method. He defined nanotechnology technically by stating that it involves the processing processes of dissociation, merging, and material deformation. The “golden era” of nanotechnology began in 1981 when Gerd Binning and Heinrich Rohrer invented the Scanning Tunneling Microscope (STM), which made it possible to identify individual atoms (“Scanning the past,” 2013). The discovery of Buckminsterfullerene C60 (buckyballs) by Robert Curl, Richard Smalley, and Harry Kroto further accelerated this age. One of the main contributors to the advancement of nanotechnology concepts was Eric Drexler of Massachusetts Institute of Technology (MIT). Drexler gave nanotechnology a commercial definition in his 1986 book “Engines of Creation: The Coming Era of Nanotechnology,” where he defined it as engineering on the billionth of a meter scale. To increase public understanding of nanotechnology concepts and ramifications, Drexler established the Foresight Institute after the book’s publication. Throughout the late 1980s and early 1990s, significant discoveries and inventions further propelled nanotechnology’s development. These advancements led to

Significant improvements in nanotechnology research, design, and publication output, shaping its trajectory for future growth and innovation [7-10].

Pharmaceutical nanotechnology-based systems
Pharmaceutical nanotechnology consisting of two basic types, which are nano-materials and nanodevices, which play a key role in pharmaceutical nanotechnology and other fields.

Nanomaterials
These are made from biomaterials; these are used in orthopedic or dental implants or as scaffolds for tissue engineered products. Their surface can be modified or coatings can be done which enhances biocompatibility with the living cells. These are further classified into two types nanocrystalline and nanostructure materials.

Nanocrystalline
These are readily manufactured and can substitute the less performing bulk material. These materials are directly used in drug encapsulation, bone replacement, prostheses, and implants.

Nanostructured materials
These are processed forms of nanomaterials with special shapes and functions. These include quantum dots, dendrimers, fullerenes, and carbon nanotubes.

Nanodevices
These are the small devices in the nano scale. These include nano and micro electromechanical systems (NEMS/MEMS), micro fluidics, and micro assays. These also include biosensors and detectors, which are used in diagnosis [3, 11-14].

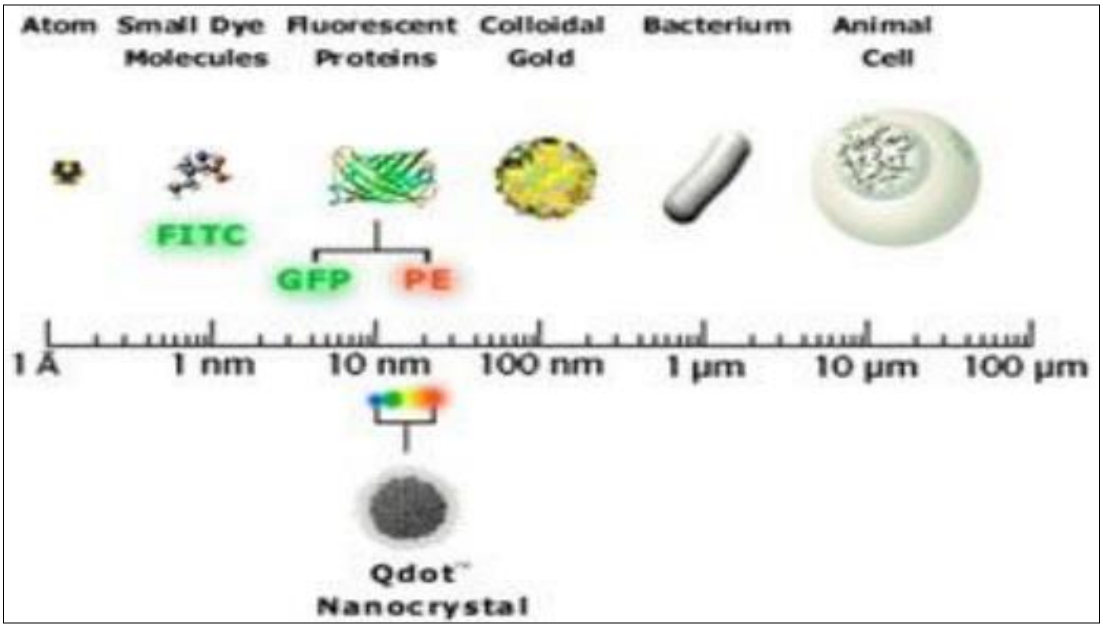

Fig 1: Representing the nano-particles with their approximate sizes

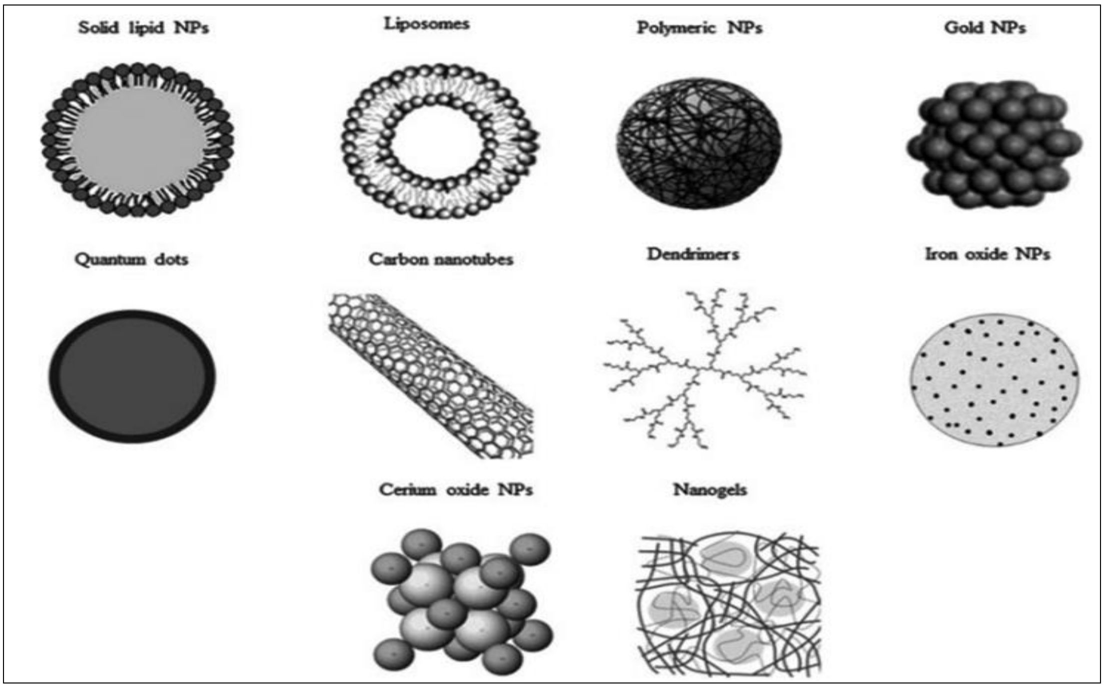

Fig 2: Different types of nanoparticles

Nanotechnology and food industry

The applications of nanotechnology in the food industry are immense and include food manufacturing, packaging, safety measures, drug delivery to specific sites, smart diets, and other modern preservatives, as summarized in Figure 1. Nanomaterials such as polymer/clay nanocomposites are used in packing materials due to their high barrier properties against environmental impacts. Similarly, nanoparticle mixtures are used as antimicrobial agents to protect stored food products against rapid microbial decay, especially in canned products. Similarly, several nanosensor and nano-assembly-based assays are used for microbial detection processes in food storage and manufacturing industries [14, 15].

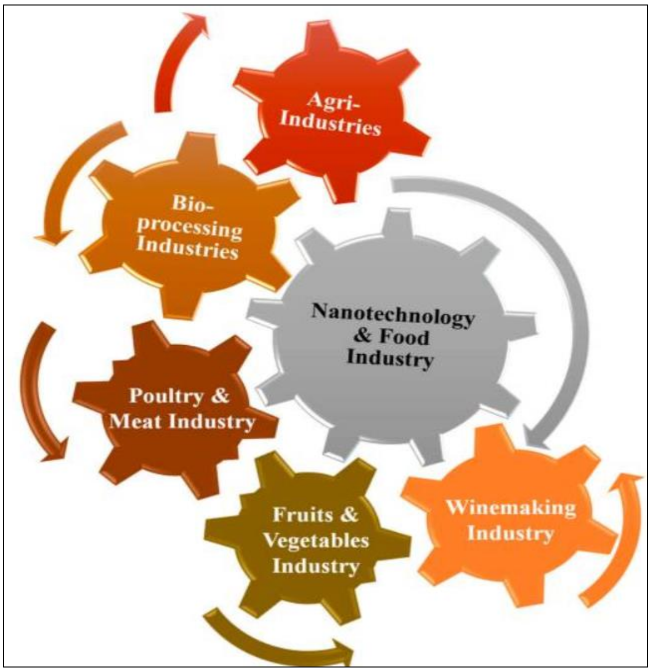

Fig 3: Nanotechnology applications in food and interconnected industries

Fig 4: Nanotechnology applications in medical industry. Nanotechnology has a broad range of applications in various diagnostics and treatments using nanorobotics and drug delivery systems

Nanotechnology, healthcare, and medical industry

The genesis of nanomedicine simply cannot be ignored when we talk about the large fields of biological sciences, biotechnology, and medicine. Nanotechnology is already making its way beyond the imagination in the broader vision of nanobiotechnology. The quality of human life is continuously improved by the successful applications of nanotechnology in medicine, and resultantly, the entire new field of nanomedicine has come to the surface, which has allowed scientists to create upgraded versions of diagnostics, treatment, screening, sequencing, disease prevention, and proactive actions for healthcare. These practices may also involve drug manufacturing, designing, conjugation, and efficient delivery options with advances in nano-based genomics, tissue engineering, and gene therapy. With this, it could be predicted that soon, nanomedicine will be the foremost research interest for the coming generation of biologists to study the useful impacts and risks that might be associated with them [1, 16-18].

In various medical procedures, scientists are exploring the potential benefits of nanotechnology. In the field of medical tools, various robotic characters have been applied which have their origins in nano-scale computers, such as diagnostic surfaces, sensor technologies, and sample purification kits. Similarly, some modifications are being accepted in diagnostics with the development of devices that are capable of working, responding, and modifying within the human body with the sole purpose of early diagnosis and treatment. Regenerative medicine has led to nanomanufacturing applications in addition to cell therapy and tissue engineering. Similarly, some latest technologies in the form of 'lab-on-a-chip', as elaborated upon earlier, are being introduced with large implications in different fields such as nanomedicine, diagnostics, dentistry, and cosmetics industries. Some updated nanotechnology applications in genomics and proteomics fields have developed molecular insights into antimicrobial diseases. Moreover, medicine, programming, nanoengineering, and biotechnology are being merged to create applications such as surgical nanorobotics, nanobioelectrics, and drug delivery methods. All of these together help scientists and clinicians to better understand the pathophysiology of diseases and to bring about better treatment solutions in the future.

After thorough and careful analyses, a wide range of industries-in which nanotechnology is producing remarkable applications-have been studied, reviewed, and selected to be made part of this review. It should be notified that multiple subcategories of industrial links may be discussed under one heading to elaborate upon the wide-scale applications of nanotechnology in different industries. A graphical abstract at the beginning of this article indicates the different industries in which nanotechnology is imparting remarkable implications, details of which are briefly discussed under different headings in the next session [19-22].

Future perspectives

There are numerous potentials uses for metal nanoparticles in a variety of industries, such as electronics, energy storage, catalysis, and medicine. But there are also a number of obstacles to overcome and possible paths forward for the creation and application of metal nanoparticles. The synthesis and processing of metal nanoparticles with exact control over size and form is a significant problem. High temperatures and harsh chemical conditions are used in several metal NP synthesis techniques, which might make them difficult to scale up for large-scale manufacturing. Furthermore, metal nanoparticles' properties and possible uses can be greatly impacted by their size and form, thus it is critical to synthesise NPs with exact control over size and shape.

The effects of metal nanoparticles on the environment present another difficulty. In addition to potentially harming aquatic life, certain metal nanoparticles (NPs), like silver, may also have additional effects on the ecosystem. More studies on the effects of metal nanoparticles on the Environment are required, as is the creation of greener synthesis and processing techniques. One interesting avenue for future research is the application of metal nanoparticles (NPs) for environmental protection, energy conversion, and storage. Metal nanoparticles, for instance, might be utilised to create more effective solar cells or enhance battery performance. Metal nanoparticles may also be employed in catalysis to increase the effectiveness of chemical reactions. Additionally, studies on metal nanoparticles in medicine, including drug delivery, are still being conducted [23-27].

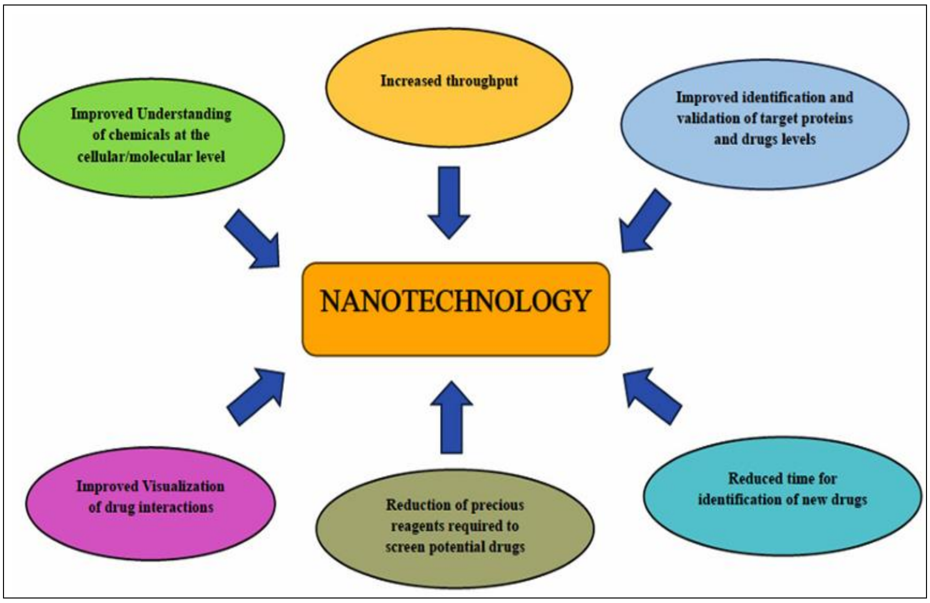

Fig 5: Role of nanotechnology in drug delivery

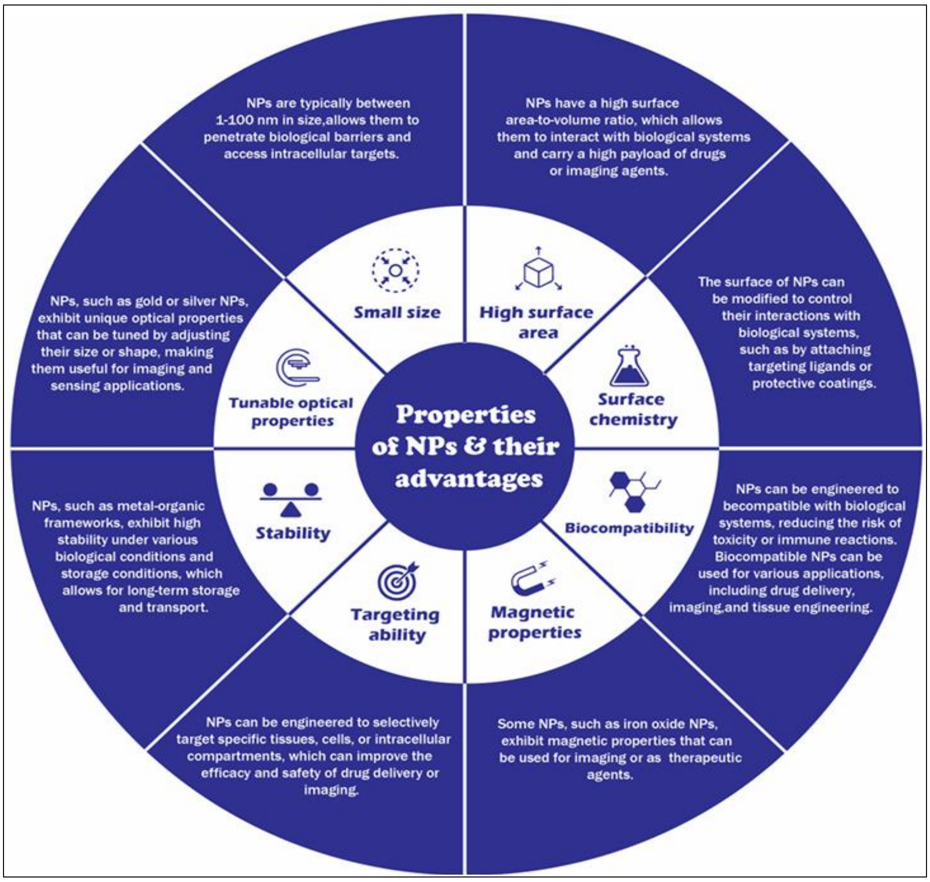

Fig 6: Properties of nanoparticles and their advantages

Conclusion

Pharmaceutical nanotechnology has become a field with great promise for delivering bioactives and diagnostics in both space and time, as well as for producing intelligent materials for tissue engineering. Through its nano-engineered technologies, it provides new tools, opportunities, and breadth that are anticipated to have a significant impact on many aspects of disease, diagnostics, prognosis, and therapy. In areas where more traditional and established technologies may be reaching their limits, pharmaceutical nanotechnology offers chances to develop new technologies and enhance materials and medical equipment. By offering new patentable technology in response to income loss from off-patent medications, it gives industry new hope. Because pharmaceutical nanotechnology provides new tools for studying cells and distinguishing between normal and aberrant cells, it has a significant impact on attempts to prevent disease. It might provide information about the molecular causes of illness.

In the fields of materials science and mechanical science, highly promising and affordable nanotechnologies are being introduced. This paper provides a thorough overview of these technologies. Researchers and experts from a variety of disciplines will find this overview useful in further exploring the ways that nanotechnology is being applied in their specific fields of interest. Although nanotechnology has many uses, the hazards associated with unrestricted use are still unknown and subtle. In order to identify more solutions in the field of nanotoxicology, more work must be connected and carefully determined. In order to investigate choices and effectively utilise nanotechnology in field trials, it is also advised that researchers, technicians, and industrialists collaborate at the field and educational levels. In order for us to be aware of this enormous technology, more advancements need be developed and thoroughly evaluated at the nanoscale for a future world. Because of the amazing ways that nanotechnology is being used in industry, it is highly likely that it will soon be integrated into every industry. However, we must take preventative steps to educate ourselves about the potential health risks to living creatures as well as environmental and pollution issues that could result from the improper application of nanotechnology. This is significant since sustainability is a factor that is being taken into account more and more globally. Therefore, it is possible to ensure that nanotechnology will have a profitable future by combining it with sustainability.

Conflicts of interest

None declared.

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