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Review on Health Sciences Applications of Nanotechnology

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Abstract
Nanotechnology is a relatively new field of study, but it is widely predicted to produce both technical solutions and commercially viable products in a wide range of fields. Nanotechnology's advancements indicate an ever more significant impact on human life. It refers to a collection of technologies that are being used in a wide range of existing industries, including electronics, materials, the environment, metrology, robotics, healthcare, information technology, pharmaceutics, agriculture, and transportation. These technologies primarily overlap in three areas: nanoelectronics, nanomaterials, and nanobiotechnology. In the eyes of many, nanotechnology is a relatively new science that has the potential to revolutionise the economy and enhance people's lives. There are a variety of ways that nanotechnology can be used in the life sciences; this overview outlines some of the more notable examples. This review focuses on the different types of nanomaterials used in the biological sciences like liposomes, dendrimers, carbon nanotubes, metal nanoparticles, and quantum dots. The impact of nanotechnology in the medical domain and its application are also discussed in brief.

1. Introduction

Nanotechnology uses matter at the scale of nanometer size, which is at the order of one-billionth of a meter. It is the study and use of tiny things and is applied in all the branches of research such as material science, physics, chemistry, biology, and engineering. An important aspect of nanotechnology is that it allows scientists and engineers to fine-tune the size and shape of components and systems at the atomic scale **[1, 2]**. The Greek word for "dwarf" is the origin of the term "Nano." The prefix "nano" denotes 10^{-9}, or one billionth of a metre, in science and technology. Nanomaterials are produced using "Top-down", "Bottom-up," and the "Hybrid" approaches. The "Top-down" strategy involves starting with a bulk material and working your way down to the desired nanostructures. An example of the Top-down approach is Integrated circuits. In the "Bottom-up" technique, the nanomaterials are assembled atom by atom or molecule by molecule. Examples of the bottom-up approach are quantum dots and nanotubes. The hybrid techniques include combining both the "top-down" and "bottom-up" approaches **[3]**.

The manipulation of matter at atomic scale was first proposed by Richard Feynman, the famous physicist in a lecture titled "there is plenty of room at the bottom", given at California Institute of Technology. In his presentation, he visualized how atoms and molecules may be controlled and manipulated at a microscopic scale **[4]**. Norio Taniguchi, a professor at Tokyo Science University, created the word "nanotechnology" in 1974 to describe the processing of materials at nanometer level. Nanotechnology has been around for a long time. In the British Museum's Lycurgus glass cup, nanoparticles of gold and silver make it seem green in natural light and red when light shines through it **[5]**.

Nanotechnology made major strides in the 1980s thanks to two innovations that made it possible to see and manipulate individual atoms and molecules. The development of Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM) in 1981 and 1985 respectively made it possible to visualise, measure, and manipulate individual atoms and molecules **[6, 7]**. This accelerated the advancement of nanotechnology, which has the capacity to fundamentally alter our current reality.

It is a promising discipline of science capable of overcoming problems and issues that engineering and medical sciences have struggled to tackle. Nanoscience and technology combine to study and deal with materials on a nanoscale, allowing us to work with, control, and build new tools, materials, and structures at the molecular level by rearranging their atom sequence into useful structures with nanoscale sizes **[8]**. Nanotechnology is an area of science that encompasses a wide range of disciplines, including life sciences, materials science, and information technology. It includes the development, production, characterization, and use of nanoscale materials and technologies in at least one dimension **[8]**. Nanotechnology has transformed the world of medicine, with nanoparticles ranging in size from 1 to 100 nm being manufactured and employed for diagnosis, treatments, and as biomedical research instruments **[9]**.

2. Classification of Nano materials

The Nano scale is a measurement of dimension just above the scale of an atom, where the characteristics of a matter are defined. Nanomaterials have been divided into different categories based on their dimensions. Nanoparticles, dendrimers, micelles, drug conjugates, metallic nanoparticles, and other nanostructure components are used to create nanostructures.

The size range of carbon nanotubes is 50 nm to 10,000 nm, and they have remarkable physical, mechanical, and chemical properties due to their rolled, seamless cylindrical structure. Carbon nanotubes have been utilized for delivery of drugs and diagnostics **[10]**. Due to the liposome's small size, it has been extensively exploited in the development of Nano-carriers for new targeted drug delivery and is the most developed Nano-carrier. When dried phospholipids are moistened, closed vesicles develop. Liposomes are biocompatible, adaptable, and have efficient encapsulation. It’s used in gene, protein, and peptide delivery, both passively and actively. Liposomes, which are employed in drug delivery, have a specific structure **[11]**. Dendrimers resemble trees because of their branches. The core, the branching units, and the densely packed surface make up the dendrimers three major parts. It’s spherical in shape and features internal chambers. It has a diameter of less than 10 nm. The size, shape, and physical characteristics of dendrimers make these more popular. Because of their unique physical features, nano tubes have numerous benefits over traditional medication delivery and diagnostic methods **[12]**. Figure 1 shows the various types of nanomaterials used in the medical field.

Nanoparticles have been made from inorganic metals such as iron, silica, silver, and gold. These metallic nanoparticles have been employed in the administration of drugs, particularly in the treatment of cancer, as well as the development of biosensors. A wide range of medical applications benefit greatly from silver and gold nanoparticles **[13]**. Inorganic elements such as silicon are used to make "artificial atoms" called quantum dots, which have a diameter ranging from 1 to 100 nm. Quantum dots are characterized by light emission of various wavelengths that aid in the imaging of biological material. Biological molecules are imaged using naturally fluorescent compounds such as organic dyes, with each type of molecule in a sample attached with a distinct dye. However, as the dyes emit light at a wide range of wavelengths, their spectra overlap, and only about three different dyes can be utilized at the same time. Because a light source with a single wavelength may excite a huge number of dots of varying sizes, full-color imaging is achievable with QDs. By activating the dots with light, biologists hope to use quantum dots in living cells to aid in the mending of damaged brain connections or the delivery of medications **[14]**.

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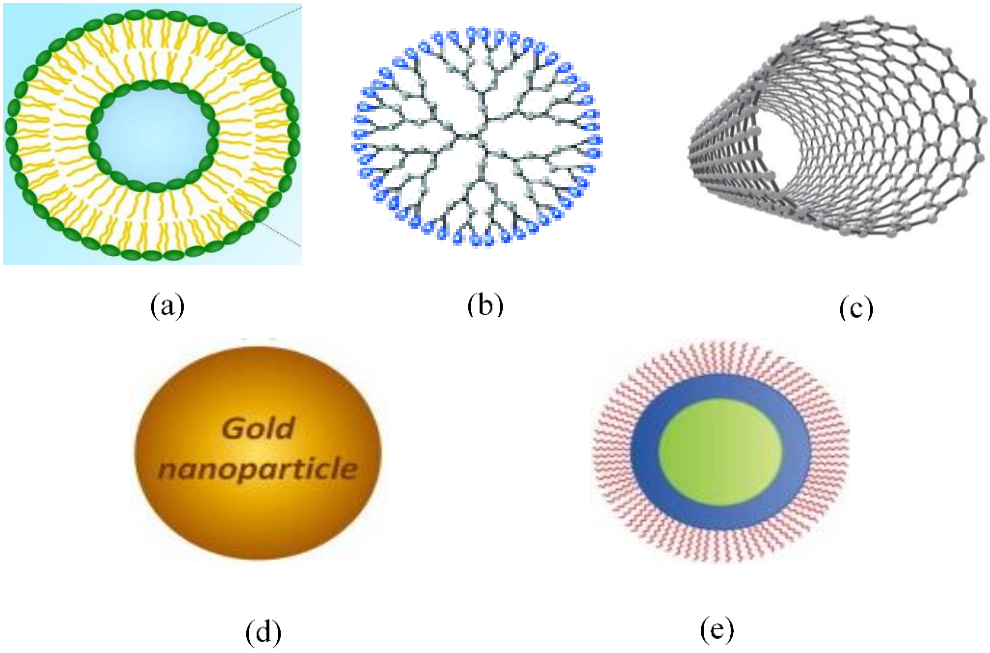

Figure 1. Different types of nanomaterials (a) Liposomes, (b) Dendrimers, (c) Carbon nanotubes, (d) Gold nanoparticles, (e) Quantum Dots.

Impact on medical domain

Nanotechnology is an emerging technology that is expected to provide technological solutions and economically viable goods in a range of application fields in the near future. However, nanotechnology items are now on the market, but the sector is still undergoing a lot of intensive basic research. As a result of advances in nanotechnology, the life sciences are expected to feel the effects more and more strongly. Nanotechnology encompasses a wide range of technologies that can be used in a variety of industries. As a new field, nanotechnology has the potential to alter the economy and improve people's quality of life.

Nanotechnology-drug delivery

Drug delivery systems using nanotechnology have a lot of potential. The use of nanoparticles in targeted medication delivery at the site of disease can increase the uptake of poorly soluble pharmaceuticals, the targeting of drugs to a specific region, and the bioavailability of drugs. Adjuvant and delivery systems for vaccines **[15–17]**, nanostructured orthopaedics and wound management **[18, 19]**, controlled-release drug delivery systems **[20]**, circulation-enhancing and cell-targeting systems, as well as systems to improve the solubility of poorly water-soluble pharmaceuticals **[21]** are all being worked on.

Nanotechnology-diagnostic applications

The field of molecular diagnostics is one of nanotechnology's most rapidly expanding and innovative ones, requiring only a tiny amount of sample, a quick process, and a high degree of dependability for many sorts of analysis **[22 – 23]**. Lab-on-a-chip technology is utilised in a compact chip analyzer that can perform tests on samples in a matter of minutes **[24]**. For more efficient and reliable analysis, companies are creating new chip analyzers that only require samples the size of nanograms or picolitres. There are already a number of lab-on-a-chip devices available for use in analysis. The combination of lab-on-a-chip technology and bioinformatics used in combinatorial screening procedures can significantly speed up the creation of new drugs.

Applications of Nanotechnology in Medicine

Conventional drugs have low specificity, efficiency, and high toxicity, causing harm to a patient's health.

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Pharmaceutics may now be synthesized utilising nanotechnology because of its unique physical properties like improved specificity and sensitivity as well the ability to cure illnesses at the molecular level, making disease detection and treatment easier. Infectious diseases (e.g. HIV) and chronic diseases like Parkinson's Alzheimer's and diabetes have all been treated with nanotechnology **[25]**. As a result of nanotechnology, customised medicine delivery, diagnostics and tissue regeneration are now possible in molecular biology. It has been developed to use nanotubes and quantum dots as therapeutic agents **[26, 27]**. The various applications of nanotechnology in medicine are given below:

Treatment of Cancer

Nanoparticles' small size enables studying the physiology of malignant cells at the tumour location simple. Quantum dots have been combined with magnetic resonance imaging (MRI) to provide more detailed images of malignant cells at tumour sites. When compared to organic dyes, these nanoparticles emit greater fluorescence and require light as an excitation source. As a result, using fluorescent quantum dots as contrast media is less expensive and produces better images than using organic dyes. Quantum dots, on the other hand, are frequently made up of highly hazardous materials **[28]**. Nanoparticles have a greater surface area to volume ratio, which aids in functional group binding, followed by malignant cell binding. Furthermore, nanoparticles' modest size of 10 to 100 nm allows them to collect in malignant cells. Multifunctional nanoparticles could be created to aid in the diagnosis, imaging, and treatment of tumours in the future **[29]**. It is now possible to detect and diagnose proteins and other indications of malignant cells in their earliest stages from a single drop of patient blood using sensor test chips constructed from nanowires **[30]**. Nanotechnology-based drug delivery relies on (i) efficient drug encapsulation, (ii) successful drug delivery to the intended area of the body, and (iii) successful drug release in that place. In mice, gold-coated nanoshells with a diameter of 120 nm were employed to kill cancer cells. Malignant cells can be targeted with nanoshells that have been coated with antibodies or peptides. Radiation from an infrared laser adequately heats the gold in the tumour, killing any cancer cells within **[31]**. For the identification of tumors, cadmium selenide quantum dots have been employed. When malignant cells are exposed to ultraviolet light, they fluoresce.

Treatment of neurodegenerative disorders

Dendrimers, nanogels, nanoemulsions and liposomes are nano devices that can target the central nervous system (CNS) and help cure neurological illnesses. The delivery of nanomedicines to the CNS, whether in vitro or in vivo, has been accompanied by the processes of transcytosis and endocytosis **[32]**.

Treatment of Alzheimer's disease

Alzheimer's disease (AD) is the most common kind of dementia. Nanotechnology has a wide range of applications in neurology because of its ability to produce nanoparticulate entities that are very selective to brain capillary endothelial cells. These nanoparticles have a strong affinity for circulating amyloid -β (Aβ) forms, resulting in a "sink effect" that helps the patient recover from Alzheimer's disease. Since the development of nanoparticle-based bio-barcodes and immunological sensors in addition to scanning tunnelling microscopy technologies, in vitro detection of Alzheimer's disease has advanced **[33, 34]**.

Nanotechnology in Pharmaceuticals

Delivery of nano medicines with a size of 1-100 nm to the disease's target region without interfering with the physiology of nearby cells in nanopharmaceuticals. Nanoparticle-based diagnostic tools have been utilised to diagnose diseases at an early stage, and their diagnostic applications are based on traditional approaches. In the pharmaceutical industry, getting the right dose of an active medication to a specific disease location is still a challenge. Nanopharmaceuticals send the right dose of a drug to the right part of the body at the right time, reducing toxicity and other systemic adverse effects **[35, 36]**.

The pharmaceutical sector has numerous logical hurdles in providing high-quality medications to patients while being profitable. As a result, pharmaceutical companies are focusing more on nanotechnology applications to improve medication formulation and drug target discovery. Because the use of nanodevices and nanoparticles reduces the cost of drug discovery, it leads to a higher rate of

R&D success, resulting in a shorter time for both drug discovery and diagnostics.

Benefits and risks of nanotechnology

Toxin- and organism-trapping nanofilters are one of the many advantages of nanotechnology for both developed and developing countries. Other advantages include better transportation systems, cheaper, cleaner energy sources, safer drinking water, more effective healthcare, and a cleaner environment thanks to pollution-remediation nanodevices. The metal nanoparticles have inflammatory and toxic effects on human cells; nanoparticle-based chemical weapons are more destructive than current military chemical weapons; and carbon nanotubes, which are cytotoxic in nature, cause lung granulomas in experimental animals. Because nanotechnology has so many applications and benefits across a wide range of fields, investigations on its impact on society, ethics, and safety are essential.

3. Conclusion

At some point in the future, advances in nanotechnology will be so vast that they will have a profound impact on all areas of scientific and technological research and development. Nanotechnology has transformed the field of pharmaceutical sciences by creating effective Nano tools for delivering nanomedicine in the right amount to the right place. Diagnostics based on nanotechnology may be able to detect disease earlier than those based on conventional molecular diagnostics. The most important clinical uses of nanotechnology right now include biomarker development, cancer diagnosis, and infectious microorganism identification. Future diagnostic and therapeutic methods will be greatly aided by nanomedicines. Nanotechnology is rapidly expanding its scope in life science and cancer treatment with the help of nanoparticles. The use of Nano device-based technology provides a platform for biological system study and revolution. Nanotechnology has been utilized to prevent infection, reduce inflammation, and speed up the early creation of tissue, all of which help implanted tissue last longer. As a result, future research should be focused on developing advanced diagnostics and cost-effective medicines that are free of toxicity.

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Conflict of Interest

The authors declare no conflict of interest

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