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Role of nanotechnology in biomedical applications: an updated review

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Abstract

The particles in nanometre size can be developed to provide opportunities for research for developing specific and highly selective drug delivery systems or biosensors which are highly used in biomedical research. Nanoparticles are smaller in size and can cross the blood-brain barrier easily because of their size, this unique property can be utilized for developing novel drug delivery systems and modern biosensors with higher specificity. In this current review, we discuss the history and various types of preparation and applications of nanotechnology in different fields.

Introduction

The promise of breakthrough advances in health, communications, genetics, and robotics sparked the development of nanotechnology. Miniaturization appears to give cost-effective and faster-functioning mechanical, chemical, and biological components on the surface. Nanoscale things, on the other hand, have extraordinary self-ordering and assembly behaviors under the influence of pressures that are fundamentally distinct from macroscale objects. Nanotechnology is made possible by these distinct behaviors and extending our understanding of these processes will undoubtedly lead to new approaches to improving human life quality [1].

Individual molecules and interacting groups of molecules are crucial at these scales because it is in control over the underlying molecular structure that provides control over the macroscopic chemical and physical properties.

These nanomaterials can be made to interfere with tissues and cells at a molecular level with selective specificity for use in physiology and medicine, allowing a high level of unification between biological systems and technology.

Nanotechnology does not represent a single emerging field of science in and of itself, but rather a confluence of standard sciences, such as chemistry, physics, materials science, and Biology that brings together the necessary expertise to create these new modern technologies [2].

History

Nanotechnology is described as the study and control of matter at scales of 1 to 100 nanometres, where unusual occurrences allow for fresh use.

Richard Zsigmondy, the Nobel Laureate in Chemistry in 1925, was the first to suggest the concept of a "nanometre." He was the first to use a microscope to measure the size of particles like gold colloids, and he coined the term nanometre to describe particle size.

Richard Feynman, the Nobel Laureate in Physics in 1965, is the father of modern nanotechnology. Feynman's hypotheses have now been proven right, and this revolutionary thought demonstrated new ways of thinking. He is regarded as the father of modern nanotechnology for his hypothesis

Norio Taniguchi, a Japanese scientist, was the first to use the term "nanotechnology" to describe semiconductor processes on the order of a nanometre. As defined by him, nanotechnology is the process of separating, consolidating, and deforming one or more materials by using a single atom or molecule.

Fullerenes were discovered in the 1980s by Kroto, Smalley, and Curl, and in his 1986 book "Engines of Creation: The Coming Era of Nanotechnology," Eric Drexler from the Massachusetts Institute of Technology (MIT) drew inspiration from Feynman's "There Is Plenty of Room at the Bottom" and Taniguchi's term nanotechnology.

With the development of nanoscience and nanotechnology, the turn of the century saw a spike in interest. National research agendas were influenced by Feynman's fame and the atomic manipulation concept in the United States. [3].

2001 saw the approbation of the United States National Nanotechnology Initiative (NNI). It was expressed in the following way: An initiative to develop nanotechnology as a foundation for America's economy and national security, the National Nanotechnological Initiative is a federal government collaboration aimed at promoting national nanotechnology development.

The nanotechnology paradigm emerged in the 1960s, and in earnest, it began developing during the 1980s and 1990s. Thus, the pre-history of nanotechnology could be considered the period before the 1950s. Scientists and technologists helped create the conditions for regulated nanotechnology development owing to the scientific and technological revolution that marked the end of the 19th century and the beginning of the 20th century [4].

Nanoparticles (NPs) with sizes ranging from a few nanometers to several hundred nanometres serve as a link between bulk materials and atomic or molecular structures.

Small size, large surface area with free dangling bonds, and high reactivity make them stand out from bulk cousins [5].

Technology and engineering have recently put nanotechnology at the forefront of study.

Nanotechnology can reduce energy consumption and can be used to develop medications that can be more effective in treating significant health issues.

It will result in less expensive products with more functionality and lower energy and raw material consumption.

A variety of industrial processes have used green synthesis to synthesize and assemble nanoparticles.

In order to make this process easier, a number of clean, environmentally friendly, and non-toxic methods, such as those that use bacteria, fungi, and even plants, have been developed Using fungi for nanoparticle production results in a significant increase in productivity due to their higher protein production [6].

Green Synthesis

Nano- and microscaled inorganic materials have been synthesized naturally through a variety of techniques. As a result, the study of nanomaterial biosynthesis has become an increasingly well-developed and well-understood field of research.

Bio-organism synthesis is compatible with green chemistry principles. Nanoparticles are produced using non-toxic, environmentally friendly chemicals. A number of properties of nanoparticles made with green technology are that they are made in one process, which allows them to have higher stability and diameters accepted by a variety of applications.

In addition to chemical, physical, and biological methods, hybrid approaches can also be used to produce nanoparticles [7].

There are a variety of chemical processes used to make NPS, including electrodeposition, sol-gel deposition, chemical vapor deposition, Langmuir Blodgett method, catalytic route, hydrolysis co-precipitation method, and wet chemical process.

Chemical and physical processes have used high radiation levels and highly concentrated reductants and stabilizing agents that harm the environment and human health. Therefore, the synthesis of biological nanoparticles is a simple bio-reduction process, which uses less energy to provide eco-friendly nanoparticles.

Nanobiotechnology refers to the use of biotechnological instruments to synthesize nanoparticles or nanomaterials, such as proteins and lipids, through biological methods involving microbes, plants, viruses, or their by-products.

Various factors contribute to the superior performance of nanoparticles made through green technology.

It is possible to synthesize compounds out of bacteria, actinobacteria, yeasts, molds, algae, and plants. Reduction is a process that develops nanoparticles from molecules in plants and microorganisms such as proteins, enzymes, phenolic compounds, amines, and alkaloids.

Traditional chemical and physical procedures can produce nanoparticles with hazardous levels of toxicity due to chemicals used to reduce metal ions and stabilizing agents used to prevent the agglomeration of nanoparticles.

Since bacteria mature rapidly, have low culturing costs, and are easily manipulated in the growth environment, they are obvious candidates for the synthesis of nanoparticles [8].

Silver as an antimicrobial agent

Depending on the rate and amount of silver released, silver has antibacterial properties. In its metallic state, silver is harmless, but when it comes into contact with moisture from the skin or wound fluid, it becomes ionized.

By attaching to tissue proteins, ionized silver causes structural changes that result in cell deformation and death in bacteria. Denaturing DNA and RNA in bacteria is another way that silver inhibits bacterial replication [9].

The remarkable antibacterial and great physical properties of silver nanoparticles (AgNPs) make them useful in a variety of applications from home disinfectants to medical devices to water purifiers.

There is a risk of leakage into the environment when AgNP is manufactured and incorporated into commercial items as the rate of incorporation increases, thus raising health and environmental concerns [10].

Nanoparticles in Biosensing

The detection of biological agents, illnesses, and harmful compounds are important in biomedical diagnostics, forensic analysis, and environmental monitoring.

Typically, sensors consist of two parts: a recognition element that identifies the target, and a transduction element that signals when the target has been bound.

The physicochemical properties of these systems and their inherent improvement in signal-to-noise ratio make them intriguing candidates for sensing applications.

Colorimetric Sensing

In recent years, Mirkin and others have developed simple and incredibly sensitive colorimetric biosensors for oligonucleotides based on the oligonucleotide-mediated nanoparticle aggregation process.

Current diagnostic methods rely heavily on oligonucleotide sequence identification in the diagnosis of genetic and pathogenic diseases, as well as the quantification of polymerase chain reaction product yield.

For the detection of oligonucleotides, single-stranded DNA is functionalized into nanoparticles.

Adding the target sequence changes the color of the solution as the particles aggregate.

Through this approach, oligonucleotides were detected at sub-picomolar levels without the use of PCR. Additionally, this technology was used to examine colorimetric DNA binders and triplex DNA binders.

Fluorescence Sensing

Since metallic nanoparticles have exceptional quenching properties, they make ideal materials for the production of FRET-based biosensors, such as molecular beacons used in DNA detection.

Due to the hairpin structure of the linked DNA, the dye molecule is proximate to the nanoparticle surface in the absence of the target DNA strand, triggering fluorescence quenching.

The hairpin structure of the target DNA is freed up by hybridization, resulting in a substantial increase in fluorescence. This molecular beacon approach has been used to identify a range of single-strand DNA and DNA cleavage activities [11].

Metal Nanoparticles in Medicine

Because of their biocompatibility, small size, ability to surface functionalize, superparamagnetic behavior, and targeting capabilities, iron oxide magnetic nanoparticles have been extensively exploited in biomedical applications.

Iron oxide nanoparticles may be guided to the intended region of the application using an external magnetic field, lowering the likelihood of nontarget tissue side effects.

Photodynamic treatment (PDT) is a medical method that includes injecting a photosensitizer (such as photofrin) into the tumor.

Appropriate light irradiation (visible or near-infrared wavelengths) creates an exciting photosensitizer once it reaches the cancer tissue. An excited triplet photosensitizer creates highly reactive singlet oxygen, a well-known mediator of cell death, in the presence of molecular oxygen [12].

Synthesis of nanoparticles

Nanoparticles may be generated using either a "top-down" or a "bottom-up" technique.

Top-down synthesis

Nanoparticles are created by lowering the size of a suitable starting material. Physical and chemical treatments are performed to minimize the size of the item.

Because the surface chemistry and other physical features of nanoparticles are strongly reliant on the surface structure, top-down manufacturing techniques induce flaws in the product's surface structure, which is a significant limitation [13].

Bottom-Up Techniques

In contrast to "top-down" processes, "bottom-up" methodologies utilize synthetic chemistry and self-organization to build NPs from atoms or molecules.

Micelles, vesicles, and liposomes, polymersomes, polymer conjugates, dendrimers, capsules, and polymeric NPS are among the nanomaterials generated using "bottom-up" techniques [14].

Synthesis of Metallic Nanoparticles

Mechanical Milling

Benjamin and his co-workers at the Nickel International Company devised this approach in the 1970s. Because it could generate microscopic and homogeneous dispersions of oxide particles in nickel superalloys, the process was first named "mechanical alloying."

Different kinds of milling equipment are currently employed to mix, alloy, or decrease particle size. Particle shape variations are of particular importance in the production of nanomaterials. These characteristics change, depending on the capacity and effectiveness of grinding, but the arrangements may also be readily altered by the heat transmission involved.

The most prevalent milling process for generating nanoparticles is high-energy ball milling, which was long regarded to be a "dirty" procedure owing to iron contamination issues. The usage of tungsten carbide or steel carbide components, as well as an inert environment and/or high vacuum procedures, has decreased impurities to acceptable levels.

The technique includes putting a batch of metallic powder and a specified grinding media into a high-energy ball mill. The powder charge is directly impacted by the grinding balls utilized in nanomaterials manufacturing.

High-density materials, such as steel or tungsten carbide, are utilized to manufacture grinding bodies. The energy transmitted from the balls to the powder controls the kinetics of the mechanical grinding operation.

A variety of process factors impact energy transfer, including the sort of powder in the milling chamber, the grinding speed, the size and distribution of grinding balls by size, the type of milling: dry or wet, the temperature, and the milling process time [15].

Regenerative medicine

The use of cell therapy and tissue engineering technologies for the repair, improvement, and maintenance of cells, tissues, and organs is a burgeoning interdisciplinary field. It is potential to interact with cell components, impact cell proliferation and differentiation, and the manufacture and structure of extracellular matrix utilizing nanotechnology.

To target particular tissues and organs, current nanomedicine employs highly ordered nanoparticles such as dendrimers, carbon fullerenes, and nanoshells. These nanoparticles might be employed as antiviral, antitumor, or anticancer agents in diagnostic and therapeutic contexts. Complex nanodevices and even nanorobots will be built in the next years, initially from biological materials and subsequently from more durable materials like a diamond to obtain the most powerful consequences [16].

Conclusion

Nanoscience and nanotechnology, which deal with characteristics as tiny as one billionth of a meter, have been a distinct branches of study since the 1980s. From this period there has been considerable interest in these places. Recent applications of nanoscience include the use of nanoscale materials not only in electronics, and catalysis but also in biological research. Out of the ordinary techniques to distribute and composition of the drugs employing nanotechnology are altering the future of medicine. Many types of nanomaterials are being tested and researched every day to find novel applications in different fields of science.

Conflict of Interest

No conflict of interest has been declared.

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