Unveiling the Marvels and Mysteries of Nano medicine

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ABSTRACT

Nanomedicine is the branch of study that uses nanotechnology to support and improve molecular levels of human health. Applications of nanotechnology in medicine today and in the future include research on diagnostic tools, medication delivery systems to boost gene therapy, and tissue engineering technologies. Nano toxicology is now-a-day inadequate in helping academia, managing bodies in illuminating the mechanism of action, maintaining its hazards and benefits, in consequence increasing the benefit of these material in medicine without dealing public health and environmental honor. Nanoparticles effect the plant growth, their impregnation and releases harmful ions. Nano medicines provide benefit to human being but can also causes damage to various essential organs of the organisms.

Introduction

The Greek prefix "nano" means "dwarf" or "very small" and relates to one millionth of a meter (10^{-9} m). The two terms, nanotechnology and nanoscience, must be distinguished that is nanoscience is applied in nanotechnology to create practical products like electronics and other objects, is the study of structures and molecules on sizes between 1 and 100 nm [1]. The use of nanotechnology in healthcare to advance a number of fields, including the treatment of a variety of diseases, including cancer, is the focus of the specialized medical specialty known as nanomedicine [2, 3] and auto-immune disorders. When the first nanomedical medications were licenced by regulatory agencies in the 1980s, the industry was only beginning to take off. [4]. Additionally, the creation of the mRNA vaccinations used during the COVID-19 epidemic was greatly aided by nanotechnology [5], confirming its continued importance in the fields of research and biomedical innovation.

Nanotechnology is used in biomedicine for a variety of purposes, although it is often used to transport or protect bioactive chemicals to specific tissues. The objective is to create nanoscale platforms capable of interacting with biological systems in a variety of ways, for as by changing pharmacokinetics or by selectively activating certain biological pathways [6].

Historical Perspective:

Romans that used nanoparticles and structures in the fourth century AD provided one of the most fascinating instances of nanotechnology in the ancient world. The Lycurgus cup, a piece of ancient glass art in the British Museum's collection, is one of its most outstanding examples. Dichroic glass refers to two different types of glass that may change color depending on the lighting. As a result, the Cup seems to have two separate colors: red-purple in indirect sunlight and green in direct sunshine. In 1990, researchers used a transmission electron microscope (TEM) to investigate the cup in order to better understand the dichroism events. Due to their unique optical and electrical properties, they are among the most interesting nanoparticles. According to the lighting, Faraday showed how gold nanoparticles may produce a range of colored liquids [7]. Since Feynman's first hypotheses, nanotechnology had developed until 1981, when researchers at the IBM Zurich Research Laboratory developed the Scanning Tunneling Microscope (STM), a novel type of microscope [8, 9]. While purifying single-walled carbon nanotubes in 2004, Xu et al [10] unintentionally discovered a new class of carbon nanomaterials known as carbon dots (C-dots) with a size below 10 nm [10]. The areas of nanoscience and nanotechnology saw a rise in courtesy towards the begin of the twenty-first century. President Bill Clinton spoke in favor of financing nanotechnology research at a verbal communication at Caltech on January 21, 2000. The 21st Century Nanotechnology Research and Development Act was contracted into law by President George W. Bush three years later. Numerous studies have recently brought attention to the enormous promise that nanotechnologies have for biomedicine in terms of the detection and treatment of numerous human ailments [11].

Nanoparticles in Medicine:

Applications:

Below is a list of some of the uses of nanomaterials in biology or medicine:

Fluorescent biological labels:

They are used to track various biological molecules such as DNA, proteins and cells. When these labels attach with the molecules so researchers visualize them by using fluorescent microscopy [12, 13].

Drug and gene delivery:

With the help of nanoparticles both the drug and gene delivery take place in a correct pattern so the therapeutic effect take place properly [14, 15].

Bio detection of pathogens:

Through the nanoparticles we can detect the pathogen and disease-causing microorganisms such as viruses, bacteria and fungi [16].

Detection of proteins:

Nanoparticles help to detect proteins by enhancing surface area which allows for a greater number of protein binding sites and increasing signal amplification [17].

Probing of DNA structure:

By nanoparticles we can probe DNA structure by the process of surface functionalization, enhanced spectroscopy and nanopore sequencing [18].

Tissue engineering:

Nanoparticles assist in tissue engineering by surface modification of tissue, stem cell differentiation and gene delivery [19, 20].

Tumor destruction via heating (hyperthermia):

Nanoparticles destroy the tumor by targeting the tumor with the help of external energy source, energy absorption and localized heating [21].

Potential Hazard:

Nanomaterial's toxicity, safety, and environmental effects:

Regardless of several benefits, the adverse aspects associated to the toxicity of nanomaterial remnants one of the significant concerns that may constitute adverse threat to humans and surroundings [22]. Leakage, spillage, circulation, and nanoparticle agglomeration are all risks. Introduction of nanoparticles through the skin, ingestion, inhalation, or other routes into the circulation might harm different important organs over time [23]. Due to the nanoparticles' toxicity, chemicals become highly reactive and reactive oxygen species are produced.

In the early 20th century, when many individuals perished from nephrotoxicity, or kidney toxicity brought on by the use of antibiotics, the QST began researching the hazardous effects of chemicals and chemical compounds in general [24]. As a result, this occurrence spurred the pharmaceutical industry to evaluate the toxicity of compounds in animal models before trying them on humans. It also inspired various pieces of legislation to limit the toxicity of the chemicals. The remedy Thalidomide, which was pre-owned to treat morning sickness and other pregnancy-related signs, created teratogenic consequences, and more than 10,000 instances were identified. It is crucial to remember that the animal tests carried out in rats at the time could not have predicted these lethal consequences of thalidomide [25]. Additional significant dispute is that presently heap of animals are used for toxicity testing, and there is a gesture towards declining the use of animal testing in dissimilar kinds or different breeds of toxicity (3Rs principle). The charge is also a influential factor since there is a lot of supply asset to esteem and improve new chemicals risk assessment [26]. We have the definition that "the aim is to deliver a quantitative accepting" and this is why the subject of quantitative systems toxicology evolved in the last ten years. We have

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discussed the significance of those timely events in organisms' responses to a chemical's harmful effects and in their transition from molecular to phenotypic observation. This is a comprehensive technique that may be used to evaluate the environmental toxicity of many compounds, but we'll concentrate on how it might be used in the field of chemical risk assessment today [27].

General Types of Synthesis of Nanoparticles:

The nanomaterials are synthesized by multiple methods [28] (Figure 1).

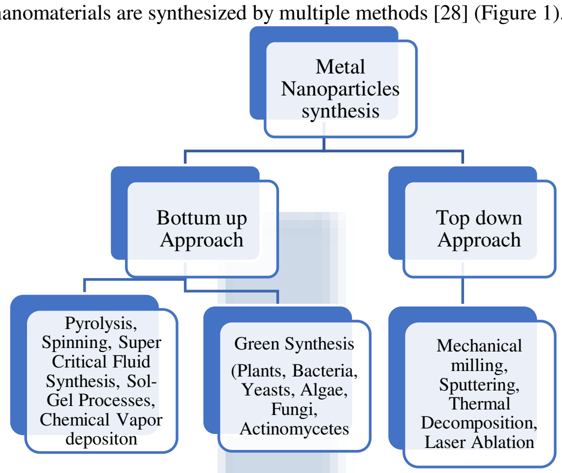

Figure 1. Methods of synthesis of Nanoparticles

Types of Nanoparticles:

Silver Nanoparticles:

The metallic form of silver is impenetrable in water, but its salts, such as silver nitrate (AgNO3) and silver chloride (AgCl), are water resolvable. Metal silver is used often nowadays in fungicides, coinage, and operating prosthetics and straps [29]. In contrast, these metal salts have also been used to serve a diversity of diseases and circumstances, including gastroenteritis, gonorrhea, and epilepsy. Because of their high absorptivity, soluble silver compounds run the danger of harming one's health when consumed through food. Silver has long been regarded as a harmless and efficient bactericidal metal since it is not poisonous to mammalian cells. In particular, it is particularly noxious to bacteria like *Escherichia coli* and *Staphylococcus aureus* [30].

Antimicrobial properties of silver nanoparticles:

(a) The adherence of extremely small silver nanoparticles to bacteria's cell walls hinders bacterial growth and multiplication, changing the cell wall such that it can no longer shield the inside of the cell;

(b) By disrupting bacterial DNA's normal function, silver nanoparticles that enter a bacterial cell can cause DNA damage or even cell death; and

(c) The interaction of Ag+ ions with sulfur-containing proteins in the bacterial cell wall resulted in long-lasting damage to the bacterial cell wall. When assessing the antimicrobial activity, this hypothesized mechanism is also determined to be the primary antibacterial mechanism [31].

Gold Nanoparticles:

The generation of nanoparticles, their growth, and their stabilization in nanometric dimension have been described using an appropriate method. Additionally discussed are the uses of gold nanoparticles in catalysis, antimicrobial defense, and cancer prevention. To our knowledge, no reports of the evaluation of these plants have been made thus far. Antibiotics are frequently employed to prevent the spread of these infections, but because of the appearance of multidrug-resistant (MDR) bacterial strains, they have frequently lost their efficacy [32]. Therefore, there is a pressing need right now for the creation of a novel bactericidal drug that is effective against MDR bacterial strains. Gold nanoparticles are always at the forefront of the fight against bacterial infections as an alternative to antibiotics.

Antimicrobial Action:

According to a study, using gold nanorods to treat bacteria causes gold particles to adhere to their cytoderm due to electrostatic attraction [33]. The form, function, and permeability of the cells are altered as a result of this attraction, together with the other two forces that is van der Waals forces and hydrophobic interactions which eventually result in cell demise [34, 35].

Conclusion and future outlook:

The manufacture of nanomaterial for use in healthcare applications is not formally regulated, which is a global problem. Some nanomedicines are classified as medical devices by various government authorities while others are classified as medications. Small compounds frequently do not have worldwide licenses because of this, but the nanomedicine community urgently needs coordination crossways the governance zone to support growth to proceed as expected. Nanomaterial is not new, and the present regulatory framework cannot accommodate the necessity and urgency for some diseases or conditions' therapies. Although there have been some initiatives to establish National Characterization Laboratories among academic groups and government organizations, more specific and strict direction is required from the major regulating organizations, such as the FDA and medicine and healthcare products regulatory agency (MHRA). In order to advance these objectives and provide official direction to the research community, a worldwide consortium for the regulation of nanomaterials should be established. Over the past two decades, billions of dollars have been invested in the creation of nanomedicine, but unless regulatory agencies provide clear leadership and direction, these efforts will fail to produce products that reach the merchandise, and forthcoming asset will be directed elsewhere.

References

[1] Mansoori GA, Soelaiman TAF. Nanotechnology--An introduction for the standards community: ASTM International; 2005.

[2] Faria RS, de Lima LI, Bonadio RS, Longo JPF, Roque MC, de Matos Neto JN, et al. Liposomal paclitaxel induces apoptosis, cell death, inhibition of migration capacity and antitumoral activity in ovarian cancer. Biomedicine & Pharmacotherapy. 2021;142:112000.

[3] Longo JPF, Muehlmann LA, Calderón M, Stockmann C, Azevedo RB. Nanomedicine in cancer targeting and therapy. Frontiers in Oncology. 2021;11:788210.

[4] Figueiro Longo JP, Muehlmann LA. Nanomedicine beyond tumor passive targeting: what next? : Future Medicine; 2020. p. 1819-22.

[5] Figueiró Longo JP, Muehlmann LA. How has nanomedical innovation contributed to the COVID-19 vaccine development? : Future Medicine; 2021. p. 1179-81.

[6] Anselmo Joanitti G, Ganassin R, Correa Rodrigues M, Paulo Figueiro Longo J, Jiang C-S, Gu J, et al. Nanostructured systems for the organelle-specific delivery of anticancer drugs. Mini reviews in medicinal chemistry. 2017;17(3):224-36.

[7] Faraday M. X. The Bakerian Lecture.—Experimental relations of gold (and other metals) to light. Philosophical transactions of the Royal Society of London. 1857(147):145-81.

[8] Binnig G, Rohrer H, Gerber C, Weibel E. Tunneling through a controllable vacuum gap. Applied Physics Letters. 1982;40(2):178-80.

[9] Binnig G, Rohrer H, Gerber C, Weibel E. Surface studies by scanning tunneling microscopy. Physical review letters. 1982;49(1):57.

[10] Xu X, Ray R, Gu Y, Ploehn HJ, Gearheart L, Raker K, et al. Electrophoretic analysis and purification of fluorescent single-walled carbon nanotube fragments. Journal of the American Chemical Society. 2004;126(40):12736-7.

[11] Kinnear C, Moore TL, Rodriguez-Lorenzo L, Rothen-Rutishauser B, Petri-Fink A. Form follows function: nanoparticle shape and its implications for nanomedicine. Chemical reviews. 2017;117(17):11476-521.

[12] Bruchez Jr M, Moronne M, Gin P, Weiss S, Alivisatos AP. Semiconductor nanocrystals as fluorescent biological labels. science. 1998;281(5385):2013-6.

[13] Wang S, Mamedova N, Kotov NA, Chen W, Studer J. Antigen/antibody immunocomplex from CdTe nanoparticle bioconjugates. Nano letters. 2002;2(8):817-22.

[14] Mah C, Zolotukhin I, Fraites TJ, Dobson J, Batich C, Byrne BJ. Microsphere-mediated delivery of recombinant AAV vectors in vitro and in vivo. Mol Ther. 2000;1(5):S293.

[15] Pantarotto D, Partidos CD, Hoebeke J, Brown F, Kramer ED, Briand J-P, et al. Immunization with peptide-functionalized carbon nanotubes enhances virus-specific neutralizing antibody responses. Chemistry & biology. 2003;10(10):961-6.

[16] Edelstein RL, Tamanaha CR, Sheehan PE, Miller MM, Baselt DR, Whitman L, et al. The BARC biosensor applied to the detection of biological warfare agents. Biosensors and Bioelectronics. 2000;14(10-11):805-13.

[17] Nam J-M, Thaxton CS, Mirkin CA. Nanoparticle-based bio-bar codes for the ultrasensitive detection of proteins. science. 2003;301(5641):1884-6.

[18] Mahtab R, Rogers JP, Murphy CJ. Protein-sized quantum dot luminescence can distinguish between" straight"," bent", and" kinked" oligonucleotides. Journal of the American Chemical Society. 1995;117(35):9099-100.

[19] Ma J, Wong H, Kong LB, Peng KW. Biomimetic processing of nanocrystallite bioactive apatite coating on titanium. Nanotechnology. 2003;14(6):619.

[20] De La Isla A, Brostow W, Bujard B, Estevez M, Rodriguez JR, Vargas S, et al. Nanohybrid scratch resistant coatings for teeth and bone viscoelasticity manifested in tribology. Materials Research Innovations. 2003;7(2):110-4.

[21] Yoshida J, Kobayashi T. Intracellular hyperthermia for cancer using magnetite cationic liposomes. J Magn Magn Mater. 1999;194:176-84.

[22] Gardner J, Dhai A. Nanotechnology and water: ethical and regulatory considerations. Application of Nanotechnology in Water Research. 2014:1-20.

[23] Ali I. New generation adsorbents for water treatment. Chemical reviews. 2012;112(10):5073-91.

[24] Petejova N, Martinek A, Zadrazil J, Teplan V. Acute toxic kidney injury. Renal failure. 2019;41(1):576-94.

[25] Swaters D, van Veen A, van Meurs W, Turner JE, Ritskes-Hoitinga M. A history of regulatory animal testing: What can we learn? Alternatives to Laboratory Animals. 2022;50(5):322-9.

[26] Granath B, Jalkesten E, Cotgreave I. Strategic focus on 3R principles reveals major reductions in the use of animals in pharmaceutical toxicity. PLoS ONE. 2014;9(7):e101638.

[27] Perez Santin E, Rodríguez Solana R, González García M, García Suárez MDM, Blanco Díaz GD, Cima Cabal MD, et al. Toxicity prediction based on artificial intelligence: A multidisciplinary overview. Wiley Interdisciplinary Reviews: Computational Molecular Science. 2021;11(5):e1516.

[28] Singh R, Shedbalkar UU, Wadhwani SA, Chopade BA. Bacteriagenic silver nanoparticles: synthesis, mechanism, and applications. Applied microbiology and biotechnology. 2015;99:4579-93.

[29] Forough M, Farhadi K. Biological and green synthesis of silver nanoparticles. Turkish journal of engineering and environmental sciences. 2010;34(4):281-7.

[30] Amany A, El-Rab SFG, Gad F. Effect of reducing and protecting agents on size of silver nanoparticles and their anti-bacterial activity. Der Pharma Chemica. 2012;4(1):53-65.

[31] Li Q, Mahendra S, Lyon DY, Brunet L, Liga MV, Li D, et al. Antimicrobial nanomaterials for water disinfection and microbial control: potential applications and implications. Water research. 2008;42(18):4591-602.

[32] Piddock LJV. Multidrug-resistance efflux pumps? not just for resistance. Nature Reviews Microbiology. 2006;4(8):629-36.

[33] Gu X, Xu Z, Gu L, Xu H, Han F, Chen B, et al. Preparation and antibacterial properties of gold nanoparticles: A review. Environmental Chemistry Letters. 2021;19:167-87.

[34] Jency DA, Sathyavathi K, Umadevi M, Parimaladevi R. Enhanced bioactivity of Fe3O4-Au nanocomposites–A comparative antibacterial study. Materials Letters. 2020;258:126795.

[35] Joshi AS, Singh P, Mijakovic I. Interactions of gold and silver nanoparticles with bacterial biofilms: Molecular interactions behind inhibition and resistance. International Journal of Molecular Sciences. 2020;21(20):7658.