Study the applications of nanotechnology in medicine

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Abstract:

This study explores the diverse applications of nanotechnology in medicine. Nanotechnology, with its ability to manipulate materials at the nanoscale, has revolutionized the field of medicine by offering innovative solutions in diagnostics, drug delivery, imaging, and therapy. By employing nano-sized particles, such as nanoparticles and nanocarriers, medical researchers have achieved remarkable advancements in targeted drug delivery, enabling precise administration of therapeutic agents to specific cells or tissues. Moreover, nanotechnology has facilitated the development of advanced imaging techniques that enhance the detection and monitoring of diseases at the molecular level. This paper provides a comprehensive overview of the applications of nanotechnology in medicine, highlighting the potential benefits and challenges associated with its implementation. Additionally, it discusses the future prospects and the impact of nanotechnology in shaping the landscape of medical treatments.

Keywords: nanotechnology, medicine, drug delivery, imaging, therapy, nanoparticles, nanocarriers, diagnostics, targeted therapy, molecular detection

Introduction

Nanotechnology has emerged as a groundbreaking field with significant implications for various industries, and medicine is no exception. The ability to manipulate materials at the nanoscale, where one nanometer is equivalent to one billionth of a meter, has opened up new avenues for advancements in healthcare. Nanotechnology offers unprecedented opportunities to revolutionize the diagnosis, treatment, and monitoring of diseases by providing precise and targeted approaches. In the realm of medicine, nanotechnology involves the design, synthesis, and application of nanoscale materials, such as nanoparticles, nanocarriers, and nanodevices, to interact with biological systems at the cellular and molecular levels. These nanostructures possess unique properties and behaviors, allowing them to overcome many limitations associated with traditional medical approaches. One of the most significant applications of nanotechnology in medicine is in the field of drug delivery. Conventional drug delivery systems often lack specificity, leading to systemic side effects and limited efficacy. By utilizing nanoparticles as carriers, drugs can be encapsulated or attached to these nanostructures, enabling targeted delivery to specific cells, tissues, or organs. This precise delivery mechanism enhances therapeutic outcomes while reducing adverse effects on healthy tissues.

Moreover, nanotechnology has revolutionized medical imaging techniques, enabling earlier and more accurate detection of diseases. Nanoparticles can be engineered to carry contrast agents or fluorescent markers, enhancing the visibility of specific tissues or biomarkers. This capability allows for improved diagnosis, monitoring treatment response, and early detection of diseases such as cancer or cardiovascular disorders at the molecular level. Additionally, nanotechnology has paved the way for innovative therapies. Nanoparticles can be functionalized to carry therapeutic agents directly to disease sites, enabling localized treatment. This approach holds immense potential for the treatment of cancer, where nanoparticles can specifically target tumor cells, deliver chemotherapy agents, or even act as photothermal agents for targeted destruction of cancer cells.

However, alongside the tremendous potential, challenges exist in the development and implementation of nanotechnology in medicine. Safety concerns, such as nanoparticle toxicity and potential long-term effects, need to be thoroughly addressed. Regulatory frameworks must be established to ensure the safe and responsible use of nanomedicine.

In this study, we aim to explore the vast applications of nanotechnology in medicine, shedding light on its potential benefits, challenges, and future prospects. By better understanding the capabilities and limitations of nanotechnology, we can harness its transformative power to improve patient outcomes and shape the future of medical treatments

Definition of Nanoscience and Nanotechnology

The root 'nano' of the word "nanotechnology" is taken from a Greek word which refers to 'dwarf' or something tiny. It describes one thousand millionth of a meter. In fact, nanoscience and nanotechnology are not the same. Nanoscience is defined as the study of structures and molecules on the scales of nanometers which range from one to one hundred nanometers. Nanotechnology refers to the technological means which uses nanoscience in feasible utilizations like instruments…etc. (Mansoori, 2005:1-22) For example, one must know that the thickness of only one human hair is sixty thousand nanometers. The DNA double helix contains a radius of 1 nm as shown in Figure 1 (Gnach, 2015:1561–1584). The Democritus and the Greeks scientists of the fifth century B.C. are considered the pioneers of nanoscience when they regarded the issue of the continuity of material and therefore indefinitely breakable into very tiny parts, or constructed of tiny particles, which can't be divided nor broken, which are termed in the present time as "atoms".

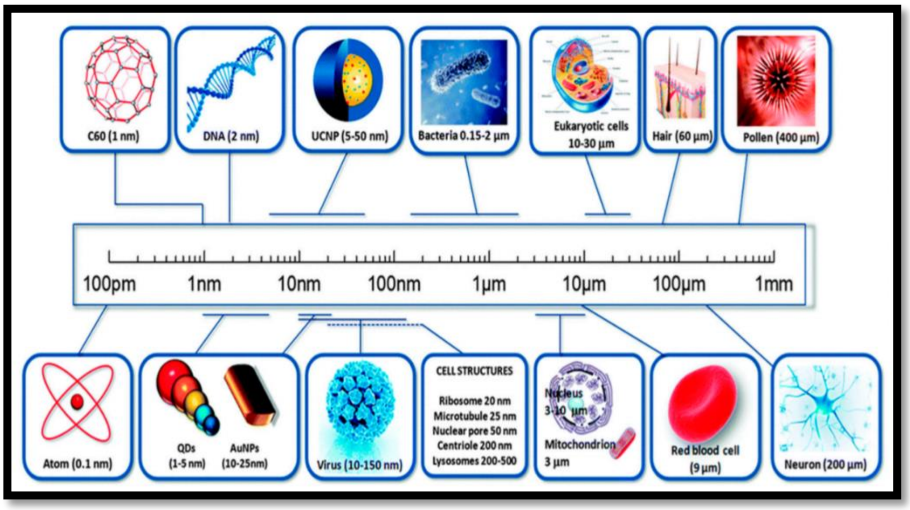

Figure 1 A comparison of sizes of nanomaterial Reproduced with permission from reference (Gnach, 2015: 1561–1584)

Scientists believe that nanotechnology will be within the most encouraging and favorable technologies in the twenty first century, due to its capability of making use of the theoretical framework of nanoscience and transform to beneficial utilizations. This can be achieved by monitoring, measuring, manipulating, compiling, managing and manufacturing material at the nanometer scale. The National Nanotechnology Initiative (NNI) in the U.S.A defines nanotechnology as “a science, engineering, and technology conducted at the nanoscale (1 to 100 nm), where unique phenomena enable novel applications in a wide range of fields, from chemistry, physics and biology, to medicine, engineering and electronics” (Bayda, 2020:2). This definition indicates that nanotechnology has two states. One of which is a state of scale where nanotechnology is related to utilizing structures by managing their volume and shape at nanometer scale. The other state is related to novelty where nanotechnology must manipulate tiny things by means which make use of certain features in accordance with the nanoscale (Allhoff, 2007: 185–210).

We should indicate the difference between nanoscience and nanotechnology. The word nanoscience refers to an intersection including materials science, physics and biology. Nanoscience addresses processing of materials at atomic and molecular scales. On the other hand, nanotechnology refers to the capability of monitoring, measuring, tackling, compiling, managing, and manufacturing material at the nanometer scale. The available information or accounts that illustrated the history of nanotechnology and nanoscience have not made a summary of both of them from the start to the present age with continuous happenings. Thus, there is an urgent need to outline the chief happenings in nanoscience and nanotechnology for a complete perception of their development in this area (Bayda, 2020:2).

History of nanotechnology

New science and technology often result from human dreams and imagination. Such dreams have created nanotechnology, a 21st-century frontier. Nanotechnology is a term which refers to grasping and managing of material at dimensions from one to one hundred nanometers where distinctive natural events enable new utilizations. In spite of the fact that human has exposed to nanoparticles during the history of mankind; it has impressively incremented since the industrial revolution. Nanoparticles have been studied before by many scientists. For example, Richard Zsigmondy, who won the Nobel Prize in chemistry in 1925, was the first who postulates the idea of a ‘‘nanometer’’. He introduced the concept nanometer clearly to describe the volume of the particle. He was also the first to measure the volume of particles like gold colloids by utilizing a microscope. Another scientist, Richard Feynman, who won the Nobel Prize in physics1965, is regarded as the father of modern nanotechnology. In the annual meeting of the American Physical Society in 1959 at Caltech, he give a lecture entitled, ‘‘There’s Plenty of Room at the Bottom’’, in which he presented the idea of treating material in an atomic way. His new concept indicated new approaches of thinking. Feynman’s assumptions have provided evidence to be correct. (Hulla, 2015:1318)

After about fifteen years from Feynman’s lecture, Norio Taniguchi, a Japanese scientist, began to utilize ‘‘nanotechnology’’ to depict semiconductor operations which happen over the arrangement of a nanometer. He emphasized that nanotechnology is composed of the manipulation, division, combination, and adapting of matters by one molecule or one atom. The golden age of nanotechnology has been started in the eighties of the nineteenth century when: (1) fullerenes was found out by Kroto, Smalley, and Curl; (2) ideas from Feynman's ''There is Plenty of Room at the Bottom'' and Taniguchi's concept of nanotechnology in his 1986 book entitled, ''Engines of Creation: The Coming Era of Nanotechnology" was utilized by Eric Drexler of Massachusetts Institute of Technology. The concept of a nanoscale ''assembler'' which could build a copy of itself and of other components of arbitrary complications was advocated by Drexler whose perspective of nanotechnology is known as ''molecular nanotechnology.'' After that, Iijima, another Japanese scientist developed the science of nanotechnology by improving carbon nanotubes. Also, there was a growing interest in the promising areas of nanotechnology and nanoscience at the start of the twenty first century. Feynman's status in the U.S.A and his concept of treating of material in an atomic way contributed immensely to formulate the qualities of a national science. The American president Bill Clinton emphasized that they will provide funding to research in this promising technological field on his speech at Caltech on January 21, 2000. Three years later, the American president George W. Bush agreed on law of the twenty first Century Nanotechnology Research and Development Act. This Act considered nanotechnology research as a national priority. Bush also proclaimed the National Technology Initiative which is now run by a committee. The head of this committee is the President's Cabinet-level National Science and Technology Council and its Committee on Technology. The duty of The Committee's Subcommittee on Nanoscale Science, Engineering, and Technology is to plan, budget, conduct, and review of the National Technology Initiative. It consists of delegates from twenty departments and independent organizations and commissions. (Hulla, 2015:1318)

The Importance of Nanotechnology

The following reasons indicate the importance of nanotechnology (Noha, 2009:17):

- Scientists all over the world assert that nanotechnology will give rise to a new scientific revolution in the following years, because of its unique principles and incredible potentials.
- The applications and inventions of nanotechnology are utilized in different areas of our life: medical, biological, agricultural, industrial, electronic, petrochemical and military.
- Nanotechnology may solve the problems of the times like the water crisis, energy resources, health, poverty and unemployment; it can also provide job opportunities, decrease the price of some products, improve energy resources, and discover new ways of treatment and water purification.
- Nanotechnology will impact the global economy of the present century, and the US National Science Foundation expects that the market for nanotechnology services and products will reach a trillion dollars by the year 2015, God willing. According to the Global Nanotechnology Market Report it reached $5.4 billion in China in 2005,

Characteristics of Nanomaterials

The structural sizes of nanomaterials are smaller than one hundred nm in not less than two aspects. These Nanomaterials are capable of having multiple structures and shapes; for example, platelets, needle-like tubes and spherical, among others. Chemical structure is another critical indicator for the description of Nanomaterials that consist of nearly all substance categories such as polymers, metals/ metal oxides, compounds, in addition to biomolecules. Nanoparticles, under circumferential conditions, are apt to connect with each other and constitute aggregates and agglomerates.

There are many shapes for these aggregates and agglomerates, ranging from dendritic structure to chain or spherical structures with volumes usually within the micrometer range. These characteristics of nanoparticles could be critically changed throughout surface adaptation. It is also important for the characterization of Nanomaterials to identify what conditions the nanoparticles are dispersed in; for example, in liquid, solid or gaseous status. The figure below outlines suitable factors for the characterization of Nanomaterials. (Pawan, 2013:66)

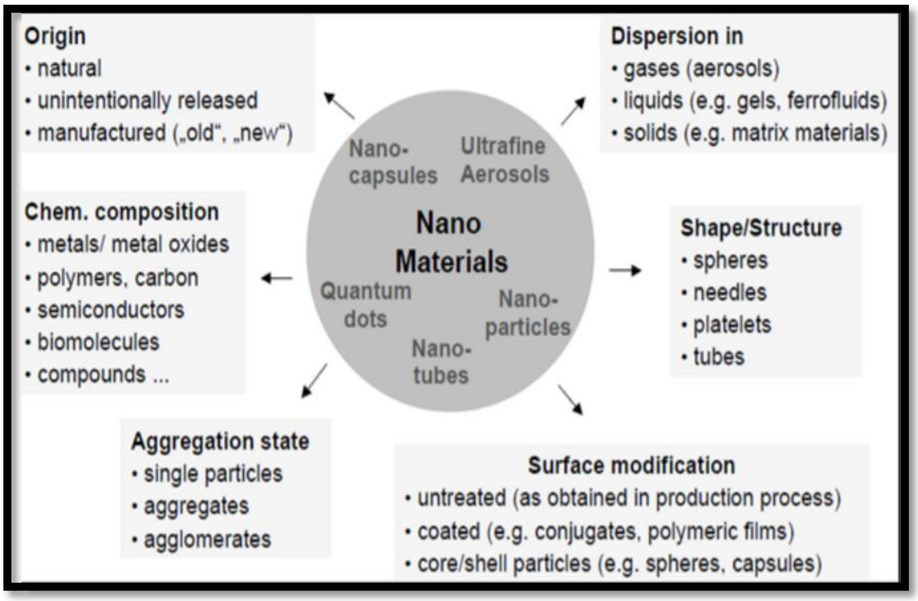

Figure 2: Characterization Parameters of Nano Particulate Materials (Pawan, 2013:66)

Classification of Nano Materials

Categorization of nano materials can be based on of dimension-wise into following types (Nikalje, 2015:83):

- The dimensions of nano rods and nano wires are less than one hundred nm.
- The dimensions of fibers, tubes and platelets are less than one hundred nm.
- The dimensions of quantum dots, particles and hollow spheres are from 0 or 3 Dimensions < one hundred nm.

Nano materials can be categorized according to the stage of composition into the following:

- Single stage solids for the nano material; such as amorphous particles, crystalline and layers.
- Multi-stage solids include covered particles and matrix composites.
- Multi-stage systems of nano material such as aero gels, colloids, Ferro fluids, among others.

Characteristics of Nanoparticles

- **Physical features:** Some nanoparticles have high solidness with little weight.
- **Chemical features:** The interaction of nanoparticles increases if they are homogeneous and of the same size.
- **Electrical features:** The possible energy of the ion can be managed by controlling the size and chemical nature of the secondary particle.
- **Thermal features:** when the size of a nanoparticle becomes smaller, its dissolution temperature decreases.
- **Magnetic features:** when the size of the nanoparticles becomes smaller, they become more magnetic.
- **Optical features:** if the size of the nanoparticle is less than the critical wavelength of light, the particle becomes transparent. (Noha,2009:25)

Applications of nanotechnology in energy and the environment

Nanotechnology will contribute largely in the following fifty years. The environment will be protected and enough power will be provided for an increasing world. The developed approaches of nanotechnology are capable of providing support to many fields such as power storage, changing it into other shapes, ecofriendly manufacturing of materials and improving the sources of renewable energy. Another usage of nanotechnology is to produce cheaper renewal power. Also, it can be used in solar technology, fuel cells, nano-catalysis and hydrogen technology. In addition, we can use the cells of carbon nano tube fuel to maintain hydrogen that can be applied in power cars.

We can also use nanotechnology in the field of photovoltaic, to make them not heavy, inexpensive and more effective. This can decrease the burning of engine pollutants through nano porous filters. The exhaust can be cleaned automatically with the aid of catalytic converters which contain nano scale noble metal particles and through catalytic coverings on cylinder walls and catalytic nanoparticles as additive for fuels. In addition, nanotechnology supports the improvement of new green and ecofriendly technologies which can reduce the unwanted pollution. The lightening of solid state is able to decrease the total consumption of electricity. Finally, the techniques of nanotechnology can result in a great decrease in the consumption of power for lighting (Nikalje, 2015:84).

Nanotechnology in health and medicine

There are now a lot of maladies like cancer, diabetes, Alzheimer's disease, Parkinson's disease, multiple sclerosis and cardiovascular diseases in addition to various types of dangerous infectious or inflammatory illnesses (for example, HIV) which pose a high number of complex and dangerous diseases that cause a main problem for humans. One of the practical implementations of nanotechnology is Nano-medicine which deals with medicine and health. Nano-medicine exploits nano electronic biosensors and nano materials. In the coming years, nano medicine will make use of molecular nanotechnology. In the field of medicine, there are many projected benefits of nano science application which are potentially helpful for all human species. Diagnosis improvement, appropriate healing and follow-up of illness can be achieved with the aid of nano medicine early detection and prevention. Some particles of nano scale are utilized as labels and tags. They can be performed biologically and quickly. The testing has turned to be more flexible and more precise. The invention of nano devices like gold nano particles helps gene sequencing become more effective. When these gold particles fixed with short parts of DNA, they can be utilized for discovering genetic sequence in a sample. Also, nanotechnology help in reproduction or repairing of damaged tissue. The artificially prompted cells are utilized in tissue engineering that can make a revolution in the field of artificial implants or transplanting organs (Nikalje, 2015:83).

Carbon nano tubes can help develop and improve the properties of biosensors. We can utilize these biosensors in the field of astrobiology because they can aid in studying the origins of life. In addition, this technology can be used to improve sensors for the diagnosis of cancer. CNT can be operationalized at the tip with a probe molecule In spite of its inactiveness. AFM was used in their study as an empirical platform. (Nikalje, 2015:83)

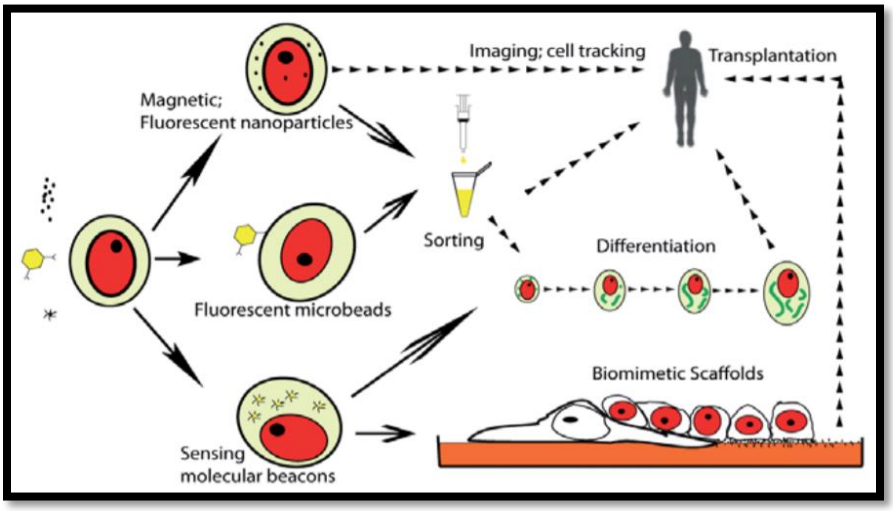

Figure 3: Applications of nanotechnology in stem cell biology and medicine. (Nikalje, 2015:84)

The role of nanotechnology is evident in the researches concerning stem cells. For instance, magnetic nanoparticles are successfully utilized to separate and combine stem cells. Quantum dots are utilized for tracing of stem cells, molecular imaging, providing drugs or genes into stem cells. Nano materials like fluorescent MNPs, fluorescent CNTs and carbon nano tubes have been utilized. Distinctive nanostructures were planned to control arrangement of proliferation. Distinguishing of stem cells is achieved by planning distinctive nano structures. These developments help speed up the advancement of stem cells to be utilized in regenerative medicine (Wang, 2009:593). The recent utilizations of nanotechnology in research on stem cell promise to break new ground in reformative medicine. Nanotechnology can be used as a beneficial means to image and trace stem cells, to distinguish certain cell lineage and finally to make sense of their biology. We hope this will result in therapeutics based on stem cells for preventing, diagnosing and treating of human illnesses (Ricardo, 2010:38-46).

Stem cell research can make use of nano devices in tracking and imaging them. It can be utilized in major science and translational medicine as well. We can change stem cells by merging biological molecules with nano carriers (Figure 6). Nano or tools can be utilized for intracellular access, sensing of biomolecules as well as smart provision. These technologies have greatly affected the microenvironment of stem cell and studies of tissue engineering. They will be largely applied in the field of biomedicine (Deb, 2012:1747-1748).

Application of Nanotechnology in Modified Medicated Textiles

Application of nanotechnology in newer antiseptic cotton has been improved and utilized for antiseptic textiles. A lot of developments have been achieved in the field of works using nanotechnology in new modified antibacterial textiles. Utilization of traditional antimicrobic factors to textiles has been already mentioned. One can develop this method by concentrating on inorganic nano constructed materials that obtain good antiseptic activity and utilization of these materials in the textiles (Nikalje, 2015:88).

Conclusions

Nanotechnology is a new integrative method, which includes an application built on the structures of molecules in nano-scale size range. In fact, nanotechnology considered as a new but fast evolving area, which includes manufacturing, manipulating and practical utilization of structure, instrument and system, by managing size and shape in nanometer scale. Nanoscience and nanotechnology have recently become very critical to medical device applications, such as diagnostic biosensors, drug provision systems.

Nano materials have augmented surface area and nano scale impacts, thus utilized as a successful means for improving the delivery of gene and drug, diagnostic biosensors and biomedical imaging. Nano materials contain distinctive biological and physicochemical characteristics in comparison to their bigger equivalents. Nano materials have features that can immensely affect their interplays with cells and bio molecules because of their specific shape, size, surface structure, chemical composition charge, solubility and agglomeration. Nanotechnology has a very brilliant future throughout its integrating with other technologies and the latter appearance of complicated and novel hybrid technologies. Biological technologies are integrated with nanotechnology which has already utilized to cope with genetic material. Nano materials are already being structured utilizing biological elements. The potentials of nanotechnology to engineer material at the smallest scale can make a revolution in fields like biotechnology, cognitive science and information technology. Also, nanotechnologies can lead to new fields and merge them with other fields.

References

1. Mansoori, G.; Fauzi Soelaiman, T. Nanotechnology—An Introduction for the Standards Community. J. ASTM Int. 2005,2.
2. Hulla, JE, et al. “Nanotechnology: History and Future.” Human & Experimental Toxicology, vol. 34, no. 12, Dec. 2015.
3. Gnach, A.; Lipinski, T.; Bednarkiewicz, A.; Rybka, J.; Capobianco, J.A. Upconverting nanoparticles: Assessing the toxicity. Chem. Soc. Rev. 2015, 44.
4. Allhoff, F. On the Autonomy and Justification of Nanoethics. Nanoethics 2007, 1.
5. Bayda, S.; Adeel, M.; Tuccinardi, T.; Cordani, M.; Rizzolio, F. The History of Nanoscience and Nanotechnology: From Chemical–Physical Applications to Nanomedicine. Molecules 2020, 25, 112.
6. Nikalje, Anna. Nanotechnology and its Applications in Medicine. Medicinal Chemistry. Volume 5(2): 081-089, 2015.
7. Wang Z, Ruan J, Cui D, Advances and prospect of nanotechnology in stem cells. Nanoscale Res Lett 4, 2009.
8. Ricardo PN e Lino F, Stem cell research meets nanotechnology. Revista Da Sociedade Portuguesa D Bioquimica, CanalBQ 7, 2010.
9. Deb KD, Griffith M, Muinck ED, Rafat M, Nanotechnology in stem cells research: advances and applications. Front Biosci (Landmark Ed) 17, 2012.
10. Pawan Sharma & Manish Bhargava, Applications And Characteristics Of Nanomaterials In Industrial Environment, International Journal of Civil, Structural, Environmental and Infrastructure Engineering, Research and Development (IJCSEIERD), ISSN 2249-6866, Vol. 3, Issue 4, Oct 2013.
11. Noha Al-Habashi, What is nanotechnology - a brief introduction in the form of simple lessons, 1st Edition, King Fahd National Library, Riyadh, 2009.