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Nanotechnology:
Revolutionizing Drug Delivery, Diagnostics, and Therapeutics

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Abstract
Nanotechnology has emerged as a game-changer in medicine, providing novel solutions in medication delivery, diagnostics, and treatments. This mini-research article investigates the revolutionary influence of nanotechnology on healthcare, emphasizing current advances and discoveries in the use of nanoscale materials and technologies. Nanotechnology is altering the healthcare scene, offering more effective therapies and better patient outcomes. It ranges from tailored drug delivery systems to sensitive diagnostic instruments and cutting-edge therapeutic techniques. The article highlights recent applications of nanotechnology in medicine, including drug transport, diagnostics, and therapeutics, current interests, discoveries, advantages, challenges, and future prospects. All the research and information gathered are based on online and offline valid sources.

Keywords: Nanotechnology, Medicine, Nanomedicine, Drug Delivery, Diagnostics, Therapeutics, Cancer Therapy, Heart Disease, Tissue Engineering, Protein Detection, Nanoparticle-Based Vaccines, Cell Manipulation, Antibacterial Treatment, Metallic Nano Dendrites, Molecular Medicine, Nanobiotechnology, SNA-NCs (Self-Navigating Nanocarriers), Nanotechnology-Enabled Constructs.

Introduction
Nanotechnology is the contrivance and engineering of materials at the nanoscale, which is generally less than 100 nanometers in diameter. This technique has opened up interesting prospects in the fields of medication delivery, diagnostics, and therapies in medicine. The capacity to manipulate matter at the atomic and molecular levels has resulted in the creation of revolutionary disease-fighting tactics with previously inconceivable accuracy and efficiency.

As stated by Rizzo et al. (2013), understanding the field of medicine has appeared to be a life-changing choice. It has provided new ways of detecting target diseases and altering the therapeutic outcome. With the combination of nanotechnology and medicine, a new term, "nanomedicine," has achieved prominence and is applied to applications of nanotechnology in medicine surrounding both therapeutics and diagnostics.

Current applications

The implementation of nanotechnology in medicine comprises the use of specially tailored chemicals to provide novel medicines and technologies that may lower toxicity while also improving therapeutic efficacy and delivery. According to Anjum et al. (2021), nanomaterials are progressively utilized for diagnostic, visualization, and targeted medicine delivery purposes. Nanotechnology facilitates the advancement of customized medicine, in which patient medication is prepared to the patient's genetics along with illness profile. Many functional nanotechnological applications in cancer research have been found so far, including technology for tumor detection and cancer biomarkers.

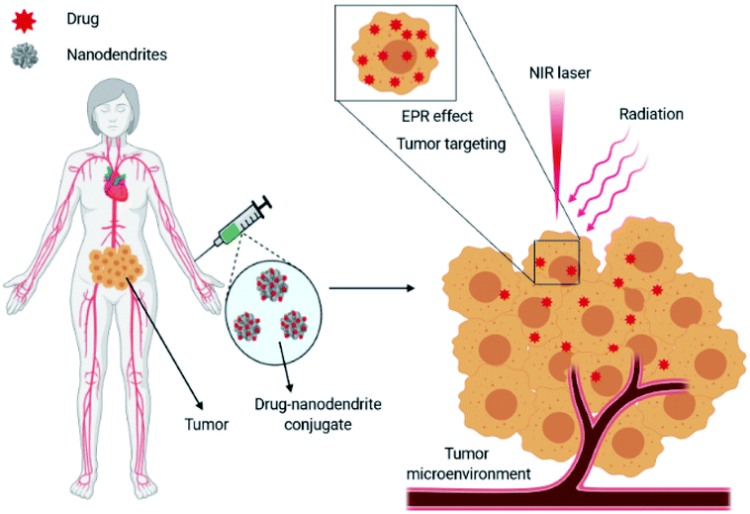

Figure 1: Source: Metallic nano dendrites as therapeutic agents in cancer treatment.: Oladipo, A. O., Nkambule, T. T., Mamba, B. B., & Msagati, T. A. (2020). Therapeutic nanodendrites: current applications and prospects. *Nanoscale Advances*, *2*(11), 5152–5165. https://doi.org/10.1039/d0na00672f)

Application involves representation techniques to make therapeutic approaches and devices that may lower risk while improving the power and execution of medications is one example of nanotechnology's utilization in medicine.

- **Cancer Therapy:** The concept is to engage nanoparticles to supply medications directly to cancer cells, keeping healthy tissues and organs unhurt. (Chitkara et al., 2019)
- **Nanotechnology and Heart Disease:** In the case of heart diseases, nanotechnology is used to transport drugs to the damaged area with the help of certain nanoparticles known as a Tissue plasminogen activator (TPA). These nanoparticles break clots and increase blood flow. (Zdrojewicz et al., 2015)
- **Tissue engineering:** Artificial implants (reconstructed joints, vascular discs, and bolts) are one of the most compelling advances in tissue engineering.
- **Protein detection:** To detect protein-protein interactions (PPIs) researchers are engaging nanotechnology to remove proteins that let cancer cells grow in the body.
- **Cell manipulation:** By changing the structure of biological cells, nanoparticles recruit capsules to distribute and transport components in a specific location of the body.
- **Antibacterial Treatment:** Nanocrystalline silver was first used as an anti-inflammatory drug for chronic wounds, becoming the first nanomedicine application of nanotechnology in medicine.
- **Nanomedicine:** Though nanomedicine practices are relatively new in pharmaceuticals, this industry is growing rapidly. According to Zdrojewicz et al. (2015),
    - Nanomedicine can target and destroy cancer cells successfully and accurately, without harming other cells like chemotherapy or other traditional cancer therapy
    - Nanomedicine can be used to diagnose and treat atherosclerosis and lower risks of cardiovascular diseases.
    - Nano-particle-based vaccines are a huge achievement against SARS-COV-1 & SARS-COV-2.

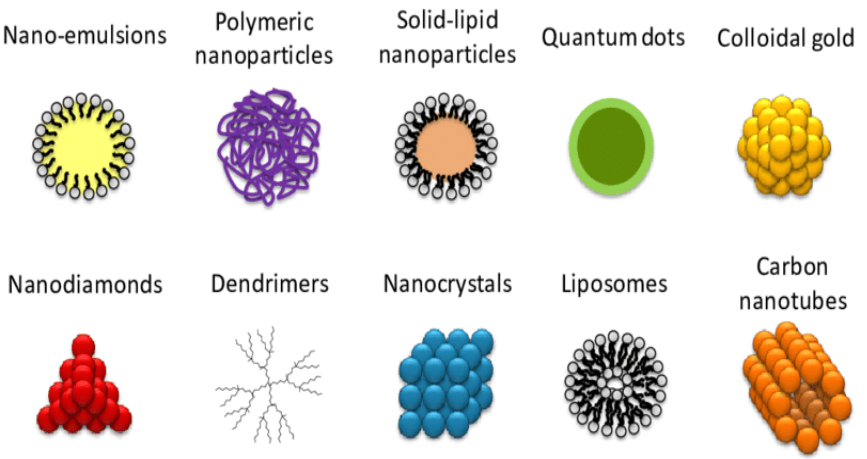

Figure 3: Source Some common Nanomedicines: *Schematic-representation-of-the-most-commonly-used-nanomedicine-types-composed-of.png(850×387)*. (n.d.). https://www.researchgate.net/publication/313022151/figure/fig2/AS:614265513844758@1523463719674/Schematic-representation-of-the-most-commonly-used-nanomedicine-types-composed-of.png)

- **Metallic Nano dendrites (NDs):** When contrasted with nanorods, nanostars, and nanoshells, sophisticated structures such as Nano dendrites can significantly improve photo absorption.

Nano dendrites (NDs)	Composition	Applications
AUNDS	Gold	Imaging and photo thermal therapy
PINDs	Platinum	Radiotherapy
AuNDs	Gold	Photo thermal and chemotherapy
PdAuNDs	Gold-over branched palladium	Photo thermal therapy
Au@PtNDs	Gold-core platinum shell	Imaging and photo thermal therapy
PtRuNDs	Alloyed platinum-ruthenium	Imaging, photo thermal, and radiotherapy
Au@PdNDs	Gold-core palladium shell	Stimuli-responsive drug delivery

Table 1: A summary of the Various metallic Nano Dendrites and Their Applications

Interest in this application

According to the article of Intelligence (2022), Some pharmaceutical/biotech companies researching the medicine sector using nanotechnology:

- **AlfaSigma SpA (Italy):** This corporation discovers drugs for different therapies and Clinical trials are used in hospitals, universities, and public and commercial health institutes to conduct medication research and development. It operates on the basis of plant production in Alanno, Pomezia, and Sermoneta. The FDA has recorded nanomedicines such as Adagen, Abelcet, and DepoCyt.
- **Dompe Farmaceutici SpA (Italy):** A company bringing innovative therapeutic solutions for the treatment of unusual diseases. Respiratory illnesses, cancer, diabetology, ophthalmology, organ transplantation, chronic obstructive pulmonary disease, and pulmonary arterial hypertension are among the research topics of this organization. Lumason is one of the FDA-approved nanomedicines.
- **GE Healthcare LLC (USA):** It is a multinational healthcare company that develops, produces, and manufactures diagnostic imaging and clinical equipment, as well as starting drug development, biopharmaceutical production, and cellular technologies.
- **Horizon Pharmaceuticals Inc (US):** This is a CDMO company. Its commodities are utilized in the pharmaceutical sector. Nanomedicines recognized by the FDA include Krystexxa.
- **Janssen Pharmaceuticals Inc (US):** It is an initiative of Johnson & Johnson which is a drug development company that provides treatments for acid reflux disease, infectious diseases, bipolar I disorder, schizophrenia, Alzheimer's disease, epilepsy, as well as migraine prevention and treatment. It also works in different sectors including, cardiovascular and metabolism, immunology, infectious diseases, vaccines, neuroscience, oncology, and other therapeutic areas. Janssen is based in Titusvi.

Discoveries in this application

According to Comprehensive Cancer Information (n.d.),

- The first nanotechnology-based cancer treatments have passed a regulatory examination and are now available on the market. Doxil and Abraxane are two examples of such medications.
- Nanotechnology has made it possible to create very sensitive biosensors and diagnostic instruments for detecting biomarkers, infections, and disease-related chemicals.

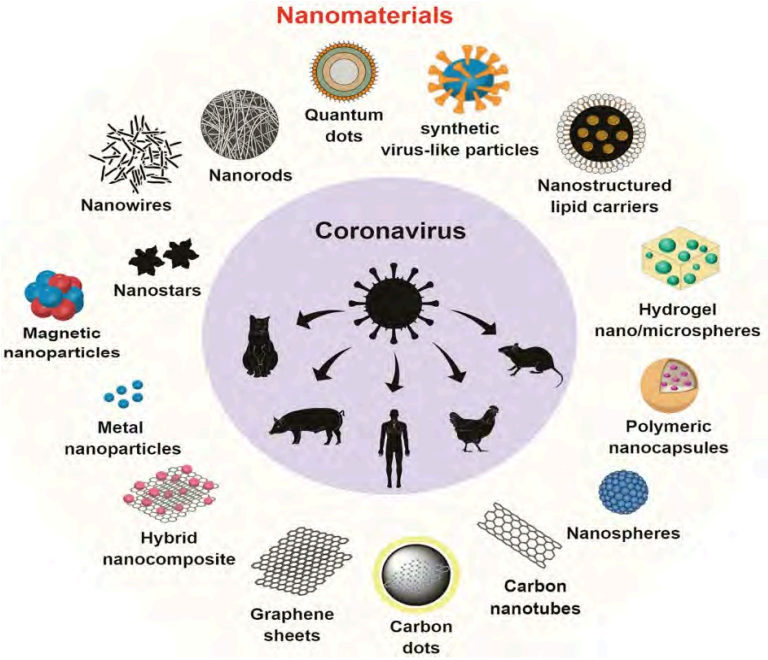

Figure 4: Source: Discovered advances in nanotechnology in Medicine since the pandemic): Anjum, S., Ishaque, S., Fatima, H., Farooq, W., Hano, C., Abbasi, B. H., & Anjum, I. (2021). Emerging applications of nanotechnology in healthcare Systems: grand challenges and perspectives. *Pharmaceuticals*, *14*(8), 707. https://doi.org/10.3390/ph14080707)

- Nanoscale tools and devices have been investigated for use in minimally invasive surgery and targeted tissue ablation, with the goal of minimizing the invasiveness and recovery time associated with typical surgical techniques.

- ❖ Several nanocarrier-based medications are already on the market, including Doxil, Dauno-Xome emend, Myocel, Oncaspar, and Combidex.
- ❖ Theranostic nanoparticles combine diagnostics and therapies in a single nanosystem, enabling real-time monitoring of treatment efficacy and therapy modification as needed. This method is very promising in cancer therapy.
- ❖ According to a September 2021 update, nanotechnology-based medication formulations for several forms of cancer were really in clinical trials and had acquired FDA Investigational New Drug (IND) authorization.

Advantages

- ❖ Nanomedicine enhances drug activity against pathogens.
- ❖ Nanomedicine is used to regulate trained immunity against various diseases

Figure 5: Source : Benefits of Nanotechnology in Medicine):*Diagram-displaying-multiple-applications-of-Nanotechnology-in-Medicine.tif (850×870)*.(n.d.). https://www.researchgate.net/publication/342538665/figure/fig1/AS:907937220395011@1593480510987/Diagram-displaying-multiple-applications-of-nanotechnology-in-Medicine.png)

- ❖ It can be used to treat targeted cells in cancer, without risking damage to the rest of the body.
- ❖ It also improves bioavailability.
- ❖ Nanotechnology is also used for cost saving and to fasten DNA sequencing & to supply scaffolding for tissue regeneration or wound treatment.
- ❖ Researchers at the Naval Research Laboratory (NRL) are evolving nanotechnology-enabled constructs that coherently combine biological molecules, i.e. proteins and DNA, with nanoparticles.
- ❖ To ensure that we can use nanotechnology properly, scientists are investigating how nanomaterials affect animal cells and tissues as well as those of plants like soybeans. They are also developing recommendations.

Limitations

For drug delivery:

- ❖ Nanomedicine is a new branch of research so a lot of things are unclear. There's a huge amount of investment and funding that goes into nanomedicine. Thus, they are often not very affordable to those who need it the most. (Anderson et al., 2016)
- ❖ Nanomedicine tends to have a very short shelf life and is easily destructible. Because of their instability, it is difficult to preserve nanomedicine for a long time.
- ❖ Manufacturing, storing, and administering nanomedicine is too expensive and takes a lot of skill.

For Diagnosis:

- ❖ Perfusion scan has low sensitivity, is strenuous in younger patients & technically demanding
- ❖ Magnetic resonance imaging takes a long duration of examination, can skip small peripheral emboli, and has less availability (Laroui et al., 2013).
- ❖ CT pulmonary angiogram can skip small peripheral emboli, radiation exposure, specifically in young females & renal insufficiency is neurologically contraindicated

For Therapy.

- Unfractionated heparin (UFH) has a risk of bleeding, unable to be administered outside of a medical setting & frequent monitoring is needed (Laroui et al., 2013).
- The low molecular weight of heparin makes it difficult to achieve therapeutic levels in infants.
- Direct oral anticoagulants cannot be monitored, are not permitted for use in individuals under the age of 18, and carry a risk of bleeding.

Future Prospects

- Nanomedicine is predicted to be crucial in customized medicine. Healthcare practitioners can enhance treatment results and prevent unwanted effects by customizing therapies to an individual's unique genetic and molecular profile. Nanotechnology will allow for the creation of patient-specific tailored medicines and diagnostics.
- Uses for imaging, i.e. quantum dot technology, are currently being licensed, and soon there will be applications for tracking cellular activity in tissue. (Anjum et al., 2021)
- The creation of very precise and sensitive equipment for detecting nucleic acids and proteins is currently being researched.
- Nanostructured catalytic systems or artificial motors, maybe used for cancer diagnosis to neutralize chemical weapons.
- SNA-NCs are very hopeful devices for skin gene therapy, treatment of various rare hereditary skin diseases, i.e. Pachyonychia congenita, and for treatment of diabetes-related ulcers. (Anjum et al., 2021)

Conclusion

Nanotechnology is a relatively young branch of research that focuses on manipulating things at the atomic and molecular levels. From the perspective of Fakruddin et al. (2012), It is undeniable that nanomedicine has the potential to dramatically enhance modern medicine, making it one of the primary areas of nanotechnological research. Nanotechnology is often utilized to manufacture formulations with dimensions smaller than 100 nm. On the other hand, concurrent innovations in the field of molecular medicines, which deal with medical treatments focused on molecular structures and disease

progression mechanisms, necessitate the creation of new technologies to achieve their therapeutic goals.

References:

1. Anderson, DS, Sydor, MJ, Fletcher, P., Holian A. (2016). Nanotechnology: The Risks and Benefits for Medical Diagnosis and Treatment. *Journal of Nanomedicine & Nanotechnology*, Missoula, MT, USA. https://www.walshmedicalmedia.com/open-access/nanotechnology-the-risks-and-benefits-for-medical-diagnosis-andtreatment-2157-7439-1000e143.pdf
2. Anjum, S., Ishaque, S., Fatima, H., Farooq, W., Hano, C., Abbasi, B. H., & Anjum, I. (2021). Emerging applications of nanotechnology in healthcare Systems: grand challenges and perspectives. *Pharmaceuticals*, *14*(8), 707. https://doi.org/10.3390/ph14080707
3. Chitkara, Deepak, Mittal, Anupama, Mahato, Ram, I. (2019). *Molecular Medicine for Cancer: Concept and Application of Nanotechnology*, NW, Florida 33487-2742, USA, Publisher: CRC Press.
4. *Comprehensive cancer information*. (n.d.). National Cancer Institute. https://www.cancer.gov/
5. Fakruddin, Hossain, Z., & Afroz, H. (2012). Prospects and applications of nanobiotechnology: a medical perspective. *Journal of Nanobiotechnology*, *10*(1), 31. https://doi.org/10.1186/1477-3155-10-31
6. Intelligence, G. T. (2022, October 10). Nanotechnology in medicine: Who are the leading private companies? *Medical Device Network*. https://www.medicaldevice-network.com/comment/nanotechnology-in-medicine-who-are-the-leading-private-companies/?cf-view
7. Laroui, H., Rakhya, P., Xiao, B., Viennois, E., & Merlin, D. (2013). Nanotechnology in diagnostics and therapeutics for gastrointestinal disorders. *Digestive and Liver Disease*, *45*(12), 995–1002. https://doi.org/10.1016/j.dld.2013.03.019

8. Rizzo, L. Y., Theek, B., Storm, G., Kiessling, F., & Lammers, T. (2013). Recent progress in nanomedicine: therapeutic, diagnostic, and theranostic applications. *Current Opinion in Biotechnology*, *24*(6), 1159–1166. https://doi.org/10.1016/j.copbio.2013.02.020
9. Zdrojewicz, Z., Waracki, M., Bugaj, B., Pypno, D., & Cabała, K. (2015). Medical applications of nanotechnology https://doi.org/10.5604/17322693.1177169

Authors' Biography:

Meer Zeshanul Wazid, an ambitious undergraduate biotechnology student, currently studying at BRAC University. His ultimate goal is to contribute to revolutionary biotech research and discoveries by combining his academic knowledge, laboratory skills, and love of creativity. Moreover, he has the potential and experience to coordinate events, Trustworthy, Enthusiastic, Punctual, Self-motivated, Critical Thinking, Organizational Behavior, Adaptable, Compassionate to teamwork, time management, enthusiasm for biotechnology, and proactive and growing leadership qualities as well.