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Applications of Bionanotechnology in Nanomedicine: A theoretical analysis

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Abstract: **Nanotechnology is one of the most recent innovative disciplines in engineering with substantial benefits especially in nanomedicine. It holds a great potential with its application to create materials and devices within the range of the "nano" metric system. The creation of these vast materials can be applicable in diverse fields of science such as biology (bionanotechnology), nanoelectronics, and nanomedicine. This field seeks to combine both engineering and medicine to solve scientific and day-2-day problems. This paper reviews the applications of bionanotechnology in nanomedicine because; it is one of the mostly studied applications of nanotechnology, which is in biomedical sciences. Various areas such as drug development, drug production, drug delivery, and clinical diagnostics are analysed in the paper. The review paper highlights the relevance of nanotechnogy as an engineering field which is applicable in the field of biology and medicine.**

***Keywords*: Nanotechnology; bionanotechnology; nanobiotechnology; nanomedicine; drugs.**

I. INTRODUCTION

Nano is a metric system used in science and engineering, which is a Greek word for "dward" [3]; it uses the prefix (10^{-9}). This prefix is important as its helps to determine the range of nanoparticles to be produced in nanomaterials. Nanotechnology is an attractive field in engineering that bridge with biology and medicine. Furthermore, it is a 21st century and one of the most promising engineering fields with lots of applications, especially in molecular biology and its related fields [1,3,5].

The interesting thing about this subject is that, it is very difficult to understand how small nanotechnology is, it looks small because of the metric system, but produces result that is imaginable. This subject reminds us of the atoms, which is the smallest indivisible particle. Nanotechnology makes use of the theory of atoms to control atoms and molecules, because everything on earth is a constituent of atoms. The paper concentrates on one of the applications of nanotechnology, which is nanomedicine.

Although there are other areas in which nanotechnology is applicable, but the most studied subject of application is in biomedical sciences. This field has devas implementations of nanotechnology in both pharmaceutical and biomedical industries. Nanotechnology has so much potential to offer to humanity especially when dealing with health issues. It is not only limited to nanomedicine, but also beneficial in electronics and those specialized in water treatment as shown in Figure 1.0. Further details of applications in nanomedicine are discussed in section III.

The rest of the paper is organised as follows: Section 2 deals with background information on bionanotechnology, while Section 3 focus on nanomedicine as an application in bionanotechnology. Section 4 deals with challenges in nanomedicine, while Section 5 finally concludes the paper.

II. BACKGROUND OF BIONANOTECHNOLOGY

This section explains and clarifies two very close concepts in nanotechnology that are often and easily confused by people. The concepts are nanobiotechnology and bionanotechnology. Bionanotechnology and nanobiotechnology are terms in nanotechnology that are used pari-passu. At the end of this section, there should be a clear distinction of the terms and the similarity between them. Figure 1.0 shows the relationship between bionanotechnology and nanobiotechnology.

A. Concept of Nanobiotechnology:

The prospect in nanobiotechnology is graving high research in this field of specialization, because medicine is a non-avoidable field that is very important to humanity. Nanobiotechnology is mostly confused or missed-used by many individuals. It is a branch of nanotechnology that deals with biotechnology and nanotechnology. This is simply the utilization of biological and biomedical applications [3, 5]. To make the explanation simpler, nanotechnology is just an application of nanotechnology in the field of biology. It is an interesting field that plays an important role in the study of life [1].

Nanobiotechnology deals with both biological and chemical information, which are used in molecular diagnostics and healthcare [4]. It plays a vital role in the detection of Deoxyribonucleic acid (DNA) with the use of nanofluid device, and genetic to fabricate synthetic structures [2, 4]. DNA itself has significant role in the manufacture of electronic products and devices.

B. Concept of Bionanotechnology:

It was earlier mentioned that nanotechnology is simply using engineering principles to solve problems in biology and its related fields. It deals with study of biology and biological related fields in solving engineering problems.

This branch of nanotechnology deals with mechanical properties, electrical simulation, and all types of macromolecules to solve the challenges in electronics, chemical engineering (water) , biology, and medical fields. This branch also tries to bridge the gap between engineering and biology and its related fields.

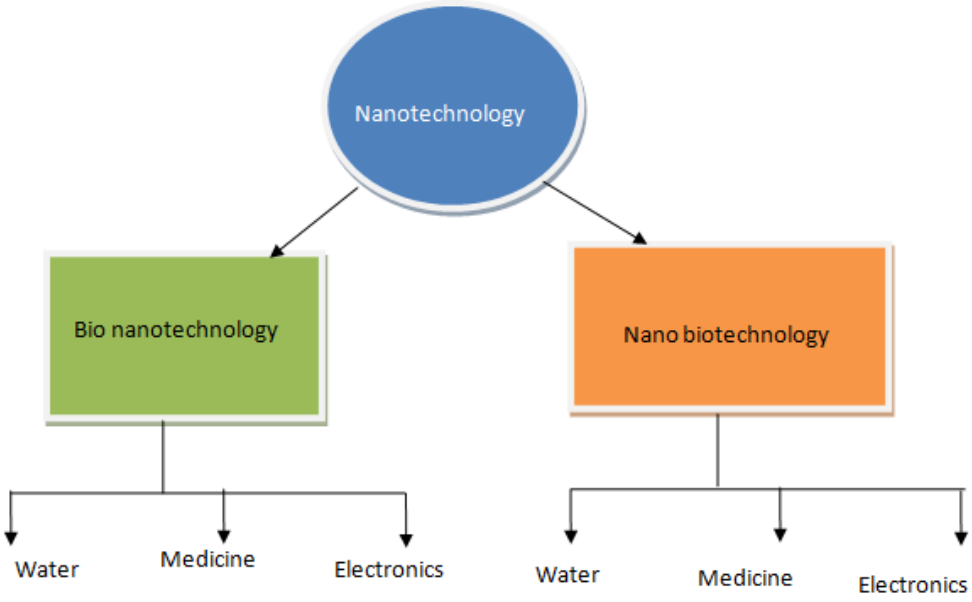

Figure 1: Relationship between Bio nanotechnology and Nanobiotechnology [26].

In summary, the main difference between nanobiotechnology and bionanotechnology is that the later deals with improving biotechnology, while the former deals with natural or biomimetric systems with the aim of developing nanoscale structures.

III. NANOMEDICINE: AN APPLICATION IN NANOTECHNOLOGY

This section provides an overview of the application of nanotechnology in nanomedicine. At the end of the section, there should be relevant information on the various biomedical fields that have applications to nanotechnology.

Nanotechnology deals with manipulating atoms and molecules in applying nancoscale materials to evolve what is known as nanomedicine [15]. Application of nanotechnology in nanomedicine is explained in this section.

A. Application of bionanotechnology in nanomedicine:

In [6], Polysorbate 80–coated polybutylcyanoacrylate, which is a drug made from molecular particles was used as an injection drug into the brain of rat. This drug enables the transport of quaternary ammonium into the brain. Another application in nanomedicine was shown in [7]. Authors presented a Macromolecular Therapeutics in Cancer Chemotherapy that was

used to visualize the accumulation in tumour. They were able to recover a little macromecules from tumour tissues. The contribution to knowledge was to help in cancer growth due to accumulation of tumour-bearing. In [8], the review paper focused on the development of nanoparticles for diagnostics and screening purposes. In the paper, the authors identified significantly, the areas of nanomedicine as it enhances the quality of human life.

Also in [9], the paper focused on drug therapy and diagnosis of pathologies where nanotechnology plays a significant application in nanomedicine was the concentration of the article. Different nanotechnology-based drug delivery and imaging approaches were identified. They also elaborated on the financial implication and how the economy has adverse effect on the effectiveness of the pharmaceutical and biomedical industries. Another application of nanomedicine was studied in [10]. Authors' research was on Dendritic cells (DCs) and poly (D, L,-lactic-co-glycolic acid) (PLGA). From the results obtained, they affirmed that PLGA nanoparticles have efficient delivery systems with the ability to target vaccine antigens in DCs and also the vivication of potent T cell responses.

Further application of nanomedicine was demonstrated in [11]. This paper elaborated on performance of nanosystems as a carrier of mucosal vaccine delivery. Since lots of the available vaccines are unstable, the paper proposed a strategy for more efficacious nasal vaccine delivery to elevate the current muddle in vaccine distribution.

Another application of bionanotechnology is in Pharmacology. Pharmacology is the branch of medicine that is associated with the uses, effects, and modes of action of drugs. Pharmacology is the science of drug action on biological systems. In [12, 13, 21], authors adopted pharmacology and therapeutics in validation of the use of nanoparticles in nanomedicine. The pivot was on the use of potential toxicity of nanoparticles. Figure 2.0 shows the application of biomedical sciences in nanotherapeutics.

One of the most deadly and life-threatening diseases at the moment is cancer. It is the second most deadly illness globally. Cancer is a multifactorial pestilence spawn by a complex mixture of genetic and environmental factors [24, 25]. Authors identified chemotherapy as one of the most efficient for treatment of cancer, although there are three strategies based on treatment of cancer, radiotherapy, surgery, and chemotherapy [15, 18]. Authors also identified the potency of nanoparticles as productive in the early detection of cancer cells, and how the research in nanotechnology-based approaches is on the increase due to the pervasive contingency of cancer illness.

In [14], authors emphasised on the application of nanotechnology in biomedical sciences. The encapsulation in the paper was on the rate at which nanostructure particles are used in the treatment of cancer and bone regeneration [16]. The article is accentuated on contribution to knowledge in treatment of diabetics. They highlighted measures for a wide range of treatment of diabetes and cancer. The paper focused on the available drug delivery technologies and also information on the most advanced drug delivery devices.

Further information on application of nanotechnology in nanomedicine was presented in [17]. A reservoir-based system was developed by authors that facilitate the treatment of ocular, and also the delivery of various drug schemes. The proposed scheme was as a result of the difficulty in treatment of ocular that was discerned, and they thought of having a patient therapy to elucidate this problem. This similar research was presented by authors in [19] regarding the delivery of ocular drug. From the paper, it disclosed that due to the several formulations in the delivery of ocular drug, there is much expansion in research for development of drug releasing devices.

Nanoparticle-based drug delivery system is very methodical in the treatment of Tuberculosis (TB). Record shows that that one-third of the world population has affliction with Mycobacterium Tuberculosis (MTB). It has an annual record of more than eight million new cases and two million death cases [20]. Nanomedicine is able to introduce long-duration drug formulations, which help to release the antimicrobial agents in a leisurely and firmly manner. From the paper, a colloidal drug delivery system was proposed to decipher the problem of prescribed regimes in the treatment of TB.

B. Prospects of bionanotechnology in nanomedicine:

From the applications discussed in the previous section, there are prospects in bionanotechnology. From the discussions in that section, some of the prospects are:

i. **Pharmacologist.** We have seen earlier that bionanotechnology has application in drug development and production, and those with the expertise have prospects in working with the engineers in this regard.

ii. **Pharmacist:** We also saw drug delivery and prescription. This pave way for those that studied pharmacy to have jobs because of the expertise.

iii. **Researcher**: We saw how research was done to evolve with appropriate therapy for cancer and diabetics. Before any therapy is proposed, reliable result is produced with validation. Researchers in the medical sector have prospects in this regard. A good example is seen in Figure 3 .0 where therapy must first be approved before use.

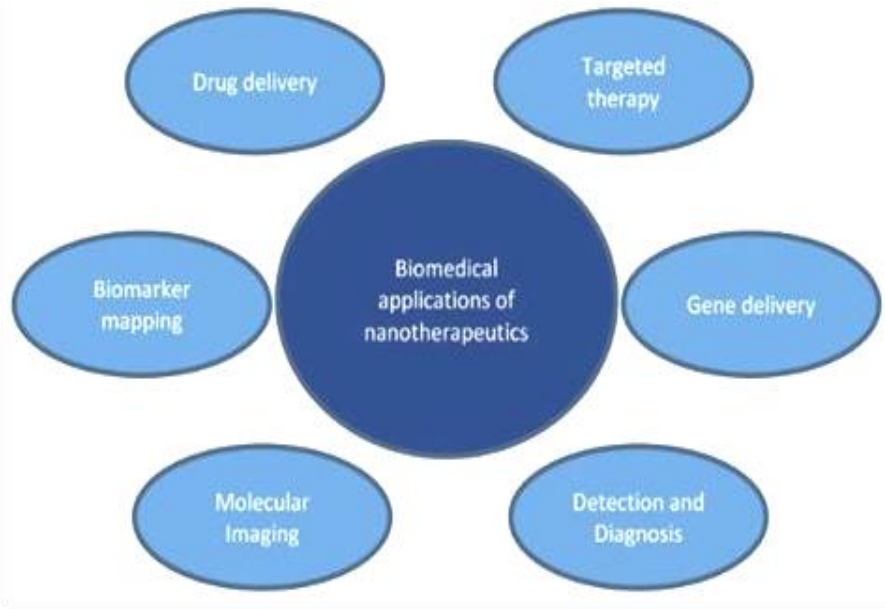

Figure 2. Biomedical application of nanotherapeutics [21]

Table I Examples of nontargeted nanosystems in clinical use for anticancer therapy

Name	Formulation	Bioactive compound	Indication	Status
	Liposomes			
DaunoXome®	Non-PEGylated liposomes	Daunorubicin	Kaposi's sarcoma	Approved
Myocet®	Non-PEGylated liposomes	Doxorubicin	Breast cancer	Approved
Onco TCS®	Non-PEGylated liposomes	Vincristine	Non-Hodgkin's lymphoma	Approved
Depocyt®	Non-PEGylated liposomes	Cytarabine	Leukemia	Phase III
			Glioblastoma	Phase I/II
Doxil®/Caelyx®	PEGylated liposomes	Doxorubicin	Breast cancer, ovarian cancer, multiple myeloma, Kaposi's sarcoma	Approved
Thermodox®	PEGylated liposomes	Doxorubicin	Liver cancer, breast cancer	Phase III
SPI-77	PEGylated liposomes	Cisplatin	Ovarian cancer	Phase II
NL CPT	PEGylated liposomes	Irinotecan	Glioma	Phase I
	Polymeric nanoparticles			
Genexol-PM®	PEG-poly(lactic acid)	Paclitaxel	Breast cancer, lung cancer, ovarian cancer	Phase II
NK105	PEG-poly(aspartic acid)	Paclitaxel	Gastric cancer	Phase I
			Breast cancer	Phase III
NK911	PEG-poly(aspartic acid)	Doxorubicin	Various solid tumors	Phase II
Opaxio™	PGA-paclitaxel	Paclitaxel	Lung cancer, ovarian cancer	Phase III
CRLX101	PEG-cyclodextrin	Camptothecin	Non-small-cell lung cancer	Phase II
NC-6004	PEG-poly(glutamic acid)	Cisplatin	Pancreatic cancer	Phase II
ProLindac™	HPMA	DACH-Pt	Ovarian cancer	Phase II
	Other			
Abraxane®	Albumin-based	Paclitaxel	Breast cancer	Approved
Paclical®	Micellar retinoid-derived	Paclitaxel	Ovarian cancer	Phase III
NC-4016	Micellar PEG/polyamino acid	Oxaliplatin	Various solid tumors	Phase I/II
Oncaspar®	PEG-L-asparaginase	Asparagine specific enzyme	Acute lymphoblastic leukemia	Approved

Note: DaunoXome® (Galen US Inc., Souderton, PA, USA); Myocet® (Sopherion Therapeutics Inc., Princeton, NJ, USA); Onco TCS® (Inex Pharmaceuticals Corp., Burnay, BC, Canada, and Enzon Pharmaceuticals Inc., Bridgewater, NJ, USA); Depocyt® (Pacira Pharmaceuticals Inc., San Diego, CA, USA); Doxil®/Caelyx® (Janssen Biotech Inc., Horsham, PA, USA / Janssen-Cilag Pty Ltd, Macquarie Park, NSW, Australia); Thermodox® (Celsion Corporation, Lawrenceville, NJ, USA); Genexol-PM® (Samyang Biopharmaceuticals Corporation, Jongno-gu, Seoul, Korea); Opaxio™ (Cell Therapeutics, Inc., Seattle, WA, USA); ProLindac™ (Access Pharmaceuticals Inc., Dallas, TX, USA); Abraxane® (Celgene Corporation, Inc., Berkeley Heights, NJ, USA); Paclical® (Oasmia Pharmaceutical AB, Uppsala, Sweden); Oncaspar® (Enzon Pharmaceuticals Inc., Bridgewater, NJ, USA).
Abbreviations: PEG, poly(ethylene glycol); HPMA, hydroxypropylmethacrylamide; DACH-Pt, diaminocyclohexane-platinum.

Figure 3 Examples of nontargeted nanosystems in clinical use for anticancer therapy [21]

IV. CHALLENGES IN NANOMEDICINE

This section highlights the challenges and draw backs in the application of nanomedicine to the field of nanotechnology.

A. Potential danger to life

In [13], authors identified the potential danger of nanomaterials if accidentally released into the environment; hence they recommend that before use, it is very important to determine the possible toxicity of nanotechnology-derived products.

B. Availability of man power (expertise):

From [15], we can see that if there are no expertises to use the device, then it would be difficult to implement findings in nanotherapeutic, hence expertise is one of the challenges faced in nanomedicine.

There is also the expectation of new solutions in this field as mentioned in [22], but the challenge would also be expertise to tackle the new proposed solutions. And in [23], authors identified the challenges faced by stakeholders in translational nanomedicine. The result was obtained from interviews with 46 stakeholders from Europe and North America.

C. Economic drift:

There is the tendency of economic shift among pharmaceutical companies as chemotherapy agents evolve, which could lead to revenue displacement.

V. CONCLUSION AND FUTURE WORK

This section summarises key points about nanotechnology and bionanotechnology. It also highlights the focus on future research in nanotechnology.

A. Conclusion:

The application of nanotechnology in biomedical sciences especially in nanomedicine cannot be overemphasized. The systematic review carried out in this paper on various applications of nanomedicine reveal that nanotechnology with its vast potential in nanoparticles is a current hope in medical application especially in cancer and diabetic therapies, which was earlier discussed.

This paper also explained and clarifies between nanobiotechnology and bionanotechnology. The central key in both technologies is that both are branches of nanotechnology with most focus on biomedical sciences. They both concentrate on the biological systems (cells, bacteria, and viruses) and how it works.

Bionatechnology can therefore be regarded has a potential source of solution in nanomedicine for drug production, drug delivery, cancer, and diabetic therapies. From the discussions made so far, it reveal that due to the importance of bionanotechnology, it would lead to job prospects in both engineering and biomedical sciences especially those in these fields of specialization.

B. Future work:

In the future, concentration would be on specific application in nanotechnology, example DNA electronics, which is an interesting research field. It deals with production of electronic products and devices from DNA molecules.

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