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# Bionanomedicine: A "Panacea" In Medicine?

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## Abstract

Recent advances in nanotechnology, biotechnology, bioinformatics, and materials science have prompted novel developments in the field of nanomedicine. Enhancements in the theranostics, computational information, and management of diseases/disorders are desperately required. It may now be conceivable to accomplish checked improvements in both of these areas utilising nanomedicine. This scientific and concise review concentrates on the fundamentals and potential of nanomedicine, particularly nanoparticles and their advantages, nanoparticles for siRNA conveyance, nanopores, nanodots, nanotheragnostics, nanodrugs and targeting mechanisms, and aptamer nanomedicine. The combination of various scientific fields is quickening these improvements, and these interdisciplinary endeavours to have significant progressively outstretching influences on different fields of research. The capacities of nanomedicine are immense, and nanotechnology could give medicine a completely new standpoint.

*Keywords: nanomedicine, nanotechnology, nanoparticles*

## Introduction

The first utilisation of the trademark frameworks in 'nano-technology' (but preceding use of that name) was in "There's Plenty of Room at the Bottom," a speech given by physicist Richard Feynman at an American Physical Society meeting at Caltech on December 29, 1959.[1] Nanotechnology refers broadly to a field of applied science and technology whose unifying theme is the control of matter on the molecular level in scales smaller than 1 micrometer, normally 1 to 100 nanometers, and the fabrication of devices within that size range.[2] Nano-medicine is the design and development of theranostics tools diverged by the nanoscopic scale of its delivery vehicles and diagnostic agents.[3,4] Briefly, Nanomedicine is an applied, practiced, and utilised nanotechnology in the field of medicine.[5]

Nanomedicine has provided some novel explanations and solutions. There are a lot of pharmaceutical companies endeavouring to advance targeted drug delivery using nanotechnology. Some of the existing drugs based on nanotechnology have the potential to revolutionise our understanding of human health and disorders. It also offers an assurance of a transformed portrait of better health care, health economics, and personalised medicine, with the eventual aim being an upgraded quality-of-life.[6] Advances in the progression of lipid-based nanome dicine, nanostructured drugs with effective site-targeting, nanopharmaceuticals, nano-imaging, nanoplat forms, nano-theranostics and nano-drug delivery, nano-immunochemo-therapy, and post-nano approaches [such as multistage vector (MSV) platform] will run and enhance the future development of nanomedicine, personalised medicine, and targeted therapy.[7–10]

**Nanoparticles**. Nanoparticles (NPs) are particles, typically less than 200 nm in diameter, which usually comprise of lipids or polymers. NPs are capable of delivering drugs over epi-endothelial barriers and spatially limit through active-passive targeting.[11] Polyvalent ornament of an NP's surface with a ligand can assuage binding to a biomarker that is particularly overrepresented in targeted cells, and activate receptor-mediated endocytosis. It has extensive significance for targeted delivery. The ligands used to adjust NPs include antibodies, aptamers, engineered antibody fragments, peptides, proteins, and small molecules.[12,13]

Some of the NPs are elucidated herein. Arginine–glycine–aspartate-grafted NPs can target avb3 integrin over-expressed by the tumour endothelium, and extravasate more conveniently. They invade the tumour through the retention effect and augment permeability.[14] A nanomedicine contrived of pegylated chitosan NPs with conjugated anti-transferrin receptor antibodies are able

to carry a blood–brain-barrier-impermeable caspase inhibitor to the brain.[15] The arrangement of solid lipid NPs are laminated with the mucoadhesive polymer chitosan for intestinal absorption of insulin.[16-18] Application of nanocrystalline solid dispersions, PEG-PLGA NPs, nanoparticle precipitates, particles, and liposomes can be applied for the management of pulmonary arterial hypertension.[19-20]

**Benefits of Nanoparticles**. Benefits include the advancement of nanoparticles for screening and theranostics purposes, DNA sequencing applying nanopores, manufacture of drug delivery systems and single-virus detection, the significance and current advances in gene/drug delivery to cancer cells, the molecular imaging and diagnosis of cancer by targeted functional nanoparticles, the development and potential applications of nanoscale blueprints in medical management and diagnosis, the use of nanoparticles for stem cell tracking, differentiation, biosensing, transplantation, magnetic nanoparticle and quantum dot-based applications in tissue engineering and stem cells in humans, similar to nano-regenerative medicine.[21]

**Nanoparticles for siRNA Delivery**. Some requirements of nanoparticles to permit small interfering RNA (siRNA) consignment into the tumour include being very minuscule (size no bigger than 1000 nm), biocompatible, biodegradable, depletion of immuno stimulatory properties, and can avoid rapid hepatic/renal clearance. Some of them are lipid complex (cationic liposomes, lipoplexes, etc.), conjugated polymers (cholesterol, polymer-PEG, etc.), and cationic polymers (chitosan, atelocollagen, etc.).[22]

Nanoparticles serve as conveyance vectors for siRNA and present plentiful benefits over stripped siRNA conveyance because of its capability to adjust siRNA while disseminating higher groupings of siRNA, specifically into tumour destinations. Furthermore, some of these nanoparticles can be changed with high fondness ligands to correctly target siRNA, specifically in the tumour. These nanoparticles can serve to advance controlled discharge, and when planned accurately they can give a protected and solid stage for siRNA conveyance for the management of cancer and other disorders.[23, 24]

**Nanopores.** The stream of DNA via nanopores can be utilised to separate low duplicate quantities of DNA, allowing extremely fast genome sequencing. The primary exhibit of this guideline utilised a variety of round and hollow gold nanotubules with inward widths as little as 1.6 nanometres. Positive ions were rejected, and negative ions were transported through the membrane at the point when the tubules were charged positively. Interestingly, only positive ions went through when the film was adversely charged.[25] Recently, nanopore-based electrochemical and nucleic acids sensors can be used to detect nucleic acids selectively. It is a potentiometric sensing blueprint from Nernst–Planck/Poisson perspective for nucleic acid hybridisation.[26]

**Nanodots**. Fluorescent nanoparticles, for example, 'quantum dots',[27] PEBBLES (probes encapsulated by biologically localised embedding) and perfluorocarbon particles, possibly conquer these issues. 'Quantum dot' nanocrystals',[28] for the case, are made to a few nanometres in diameter with an almost boundless scope of pointedly characterised hues. The particles are edgy, utilising white light and can be connected to biomolecules to frame seemingly perpetual delicate probes. On a fundamental level, separate natural occasions can be checked, all the while labelling distinctive proteins or DNA sequences with nanodots of a particular colour. Nanodots are suitable platforms for advancement of photoluminescence-based sensing schemes.[29]

**Nanotheragnostic**. Nanotheragnostic (theragnostic nanoparticles), or theragnostic nanomedicines, are incorporated nano particulate frameworks that analyse, convey a focus on treatment, and screen reactions to treatment.[30] Nanotheragnostic regimens are useful for management of cancer, inflammatory liver disease,[31] cardiovascular diseases (i.e. atherosclerosis, thrombosis), and have a promising application in arthritis (e.g. rheumatoid arthritis), neurodegenerative diseases, age-related macular degeneration, psoriasis, atherosclerosis, and various bloodstream bacterial infections.[32,33]

The four fundamental components that ought to be satisfied in the structure of nanotheragnostics are the biodegradable nanocarrier material (based on hybrid materials, an inorganic component, and an organic matrix), the signal emitter or imaging agent (exclusive optical, magnetic, or radioactive hallmark), the medication or remedial molecule, and changes to the later component based on passive-active delivery strategies.[34, 35] Magnificently, theragnostic nanotools would result in a multimodality imaging procedure mixed with a multidrug nanocarrier, in addition to supplementary treatment techniques (i.e. photodynamic treatment, hyperthermia, and photothermal treatment). Nanotheragnostics and image-guided drug delivery are relied upon to empower "precise and personalised" medicine.[35,36]

**Nanodrugs and Targeting Mechanisms**. Nanodrugs in destructive tissues has uptake and aggregation. The two can happen through two systems, i.e. "uninvolved focusing on" and "dynamic focusing on". Aloof focusing on depends on both the size of the medication bearers and the cracked neovasculature of the tumour. Inactive aggregation at the tumour site is anticipated to occur through Enhanced Permeability and Retention (EPR) effect. With the more drawn out blood course time accomplished by stealth alteration (e.g. PEGyla tion), expanded gathering of NPs is conceivable through the EPR effect. EPR happens because of the expanded

vessel defectiveness and debilitated lymphatic function typically observed in tumour tissue; this allows nano-materials to enter and amass there.[21,37,38]

Dynamic focusing of nanomaterials is being inves tigated as a strategy to allow spatial localisation by purposefully homing NPs to actively diseased regions while obliterating off-target adverse effects in healthy tissue. It is achieved by functionalization of their surface with bioactive molecules, using engineered antibodies, transferrin, folic acid, and enzymes which perceive and interplay with cancer-specific targets overexpressed on the surface of cancerous cells.[39]

The recent bioactive molecule, QD242-encapsulated polymeric nanoparticles (NPs) functionalised with a peptide (Cys-Plec-1 targeted peptides or cys-PTP), carefully fastened to Plectin-1 (Plec-1). Plec-1 is a Biomarker of Pancreatic ductal adenocarcinoma (PDAC).[40] Active targeting to accomplish efficacious nanome dicine congeries in tumour tissue is confutable, as some experts strive to construct original and creative approaches for active tumour targeting.[21,31] The most commonly used targeting moieties are mono-clonal antibodies or antigen binding fragments, antibody fragments, and single chain variable fragments for active targeting. The latter being favoured because of its decreased immunogenicity and high target specificity.[21,31]

**Aptamer Nanomedicine**. Aptamer nanomedicine is a rising, and propitious class of therapeutics used to locate the difficulties faced by recent cancer treatments. It might address restrictiveness of different ligands for targeted treatment in oncology and profoundly perfect with combined medication treatment. Nevertheless, the strategy would require a better comprehension of drug-loading efficiency, drug-releasing mechanisms, and carrier design.[41,42]

Micro-RNA (miRNA), small hairpin RNA (shRNA), small interfering RNA (siRNA), and antisense oligonucleotides are engineered for knocking down a specific gene (deleting a gene function) to murder definite types of cells. Conversely, plasmid DNA or mRNA are used for transfection to deliver a certain gene (enumerating a gene function) to heal a disease. Up to now, most research focuses on the development of aptamer-mediated miRNA, shRNA, or siRNA delivery systems for gene silencing applications. This is an emerging class of gene therapy that is particularly reassuring for cancer treatment.[41,42]

The antinucleolin aptamer, AS1411, coupled to this liposomal design, for breast cancer cell targeting, executed cancer cells with high specificity. This aptamer-doxoru-bicin liposome formulation hindered breast tumour growth prompted by oestrogen, as no significant or important growth of the tumour was detected in the group treated with the aptamer-doxorubicin liposome, while the size of the tumour in the control group raised 166%.[21,43,44] Another example is 5-fluorouracil (5-FU) combined with AS1411 aptamer (NP-5-FU-APTAS1411), which can be used to effectively manage gastric cancer.[45]

Related to drug delivery, the most effortless strategy for aptamer-based nucleic acid delivery is to connect the therapeutic nucleic acid directly to the aptamer. This is famous as an aptamer-therapeutic nucleic acid chimaera. The experts have created functional DNA nano structures to convey the chemotherapy medication to resistant cancer cells. These nanostructures comprise of two components, a DNA aptamer and a double-stranded DNA (dsDNA). Recently, nucleic acid–based nano devices have prompted energising molecular biotech nologies to the top of the line biological imaging.[42, 46, 47]

The chimaeras Chi-29b and GL21.T-let are supple mentary examples of direct conjugation of the aptamer to a therapeutic nucleic acid. Chi-29b consists of an antimucin 1 (MUC1) aptamer and miRNA miR-29b for ovarian cancer treatment.[21,42,48] It becomes illuminating that the critical steps for clinical translation of nanotherapeutics need further inter national and interdisciplinary efforts, where the entire stakeholder community is involved from bench to bedside. The period of nanomedicine is ready to develop and mature in the following couple of decades; integrating elements of personalised and precision medicine. It will influence the therapeutic world in an effective and everlasting way.

**Transcriptomics Tools for Nanomedicine**. The design of nanobiomedicine-based drugs could only be feasible with the certain incorporation of solid assistant tools.[49] Bioinformatics, as the interdisciplinary field of biology and computer science, is playing a cardinal role in designing nanobiomedicine-based drugs.[50,51] Due to the rising importance of the transcriptomics approach, bioinformatics is adjusted to cope with this development as well.[52] The Vienna RNA Package is one of the tools that could be utilised to design siRNA.[53] The theoretical basis for siRNA design is a solid comprehension of chemical kinetics and thermodynamics, especially the modelling of transition states between compounds.[54] The Vienna RNA Package also provides tools for secondary structure prediction, multiple sequence alignments, and others. However, the rising importance of transcriptomics is still strongly correlated with the recent advances in proteomics. The important role of Transcription factor proteins, such as Dicer and Argonout, for regulating non-coding (NC)RNA is still considered by the scientific community as important.[55] Comprehension of Protein Domain annotation would eventually shed light to the narration of the transcriptomics mechanistic insights.[56] Thus, the dynamism of nucleic acids has already been unveiled with the DNA-biped nano-

modeling.[57] These theoretical bases are important as the cornerstone for nanobiomedicine-based drug development.

The application of transcriptomics-based bioinformatics in drug design is already in sight. Pharmaceutical research has provided the clinical application for cancer, HIV/ AIDS, hepatitis, and others.[58] However, due to the incomplete understanding of nano-based modelling of drug-target interaction, only a handful of products are available on the market.[58] The different nature of molecules in nano-scale size should be considered when constructing a solid computational model. Thus, a new field that incorporates bioinformatics and nanomedicine has already born. Nanoinformatics is the intersection between bioinformatics and nanobiotechnology.[59] The advancements in nanomaterials have made it possible to scale them into the realm of nanobiomedicine.[60] However, real applications of nanoinformatics remain to be seen. These nano-based computations need strong computational power as provided in the computer clusters and supercomputers.[61]

**Proteomics-based Computation for nanobiome dicine-based Drug Design.** The growing field of transcriptomics still needs advancement in proteomics. Most of the drugs in the market still target protein receptors and enzymes for knock-down of the disease. Three important methods for the computation of drug design, namely Molecular Docking, Molecular Dynamics, and ADMET are constructing their models based upon protein-ligand interactions.[62-64] Molecular docking method has successfully simplified the labourous High Throughput Screening (HTS) process that is necessary to identify the most feasible lead compound. Meanwhile, molecular dynamics has given vivid illustrations towards the mechanistic insights of molecular interactions. ADMET computation has simplified the research of drug metabolism as well. The commonly used drug types are natural products, semi-synthetic, and synthetic molecules.[65,66] Some ground-breaking drug candidates are peptide and nucleotide-based molecules.[67,68] The comprehension of the molecular mechanism on a sub-atomic level with those methods will always be an important contribution to the advancement of modern drug design.

**Future of Bionanomedicine: Intersection of Big Data and Automatisation of Laboratory protocols**. On one side, the growing data and tools of sophistication of GenBank will enable researchers to compute the best information to the scientific community. On the other side, increasing automatisation of laboratory protocols will release the researcher from the laborious hours of bench work. In the end, the researcher could be more focused on the novelty of their idea, and less on the laborious techniques. Nanobiomedicine is the interface between basic science and applied science, and also between computational and wet laboratory methods. This multidisciplinary effort could be a major trend in the scientific community.

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## Conflicts of Interest Statement

The Authors declare that there is no conflict of interest regarding the publication of this paper.

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