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Advanced Nanomorphologies in Nanomedicines: A Short Review

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Abstract *The emergence of nanotechnology in the field of medicines gives the idea of revolution and far-reaching supremacy to conventional and traditional practices of diagnosis and medication. Nanomedicine is poised to transfigure and reform the existing medical procedures, with its much safer profile, accessibility being the modest and economical. Nanomedicines with its intriguing properties has exceptionally improved the drug delivery systems. A diversity of innovations in every medical specialty attribute to the potent impact of nano range applications in medicine field. Nanoparticles are generally accepted in the size range of 1–100 nm although nano morphologies above this range are also widely studied in biomedical field. Nanomedicine will face many challenges in future by regulatory agencies and public and is lacking essential data about pharmacokinetic and pharmacodynamics profiles and toxicity of nanoparticles yet is seems that this advanced technology will be proved more promising, novel and revolutionary to the antecedent medical procedures.*

Key Words: Nanomedicine, Pharmacokinetic, Toxicity

Introduction

The word 'Nano' refers to extremely small entity, one billionth part of any substance. Nanoparticle is defined as the microscopic particle measured on nanoscale. The nanoscience has different limitations in different fields such as 1- 100 nm in physics and chemistry, 0.1 – 100 nm in some early monographs and 1-1000 nm in biomedicine literatures. The bottom-up lines with atoms one by one.100 nm or below at bone marrow level and 100 -200 nm at reticular epithelial system (Moghimi 1995). Nanotechnology is an evolving field in medicines and seems to revolutionize the present pharmaceutical industry. The concept of nanotechnology proved to be propitious in various fields of diagnosis, targeted delivery and pharmaceutical manufacturing. Nano pharmacology is gradually emerging with nanotechnology applications in field of nanomedicines, it focuses on interactions between traditional drugs and physiological systems at nanoscience level (Mohanraj and Chen 2006).

Nanomedicine is an interdisciplinary field which is attributed to convergence of nanotechnology in field of medicines. Richard Feynman in 1959, put forward the idea of experimentation and application at nanoscale by his lecture entitled 'There Is Plenty of Room at the Bottom'. He proposed the idea of experimentation and chemical synthesis at nanoscale by manufacturing such devices which have the capability to work at nanoscale (Olsman and Goentoro 2018). Most of inner processes of cell occur at nanoscale since dimensions of significant molecules i.e., water, proteins, hemoglobin are already in nanoscale range. So, it seems very beneficial to monitor and manufacture considering the interactions at natural level, i.e., nanoscale (Moghimi 1995, Moghimi, Hunter et al. 2001). Radically beneficial hall marks of nanomedicines include enhanced bioavailability, receded toxicity, improved dose response and increased solubility in comparison with conventional therapy. Nanomedicines hold the key to a number of recent and future breakthroughs in medicines (Morigi, Tocchio et al. 2012).

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Progress and advancements of nanomedicines can be presented as first-generation products such as dispersed and contact nanostructures i.e., colloids and product incorporating nanostructures i.e. polymers and nanostructured metals in era of 2000. Bioactive and physiochemical adaptive structures i.e., targeted drugs, bio devices, amplifiers and actuators (2000-2005). The most advanced and revolutionary concepts of guided assembling i.e., robotics and evolutionary biosystems emerged and capture the attention in era (2005- 2010) (Kalita 2019). An exceptional idea of 4th generation (2010-2020) Nanomolecular system i.e., molecular devices 'by design' is still the focal point of nano-research and seems to prove outstanding and phenomenal step in nanomedicine. Another major contribution of nanomedicines is in the form of nanomedical devices and medical nanomaterials (Sun, Han et al. 2021). Nanopores are earliest therapeutically used medical devices used utilizing bulk micromachining to fabricate the small cellular chambers with single crystalline silicon wafers. The chamber interface with surrounding cellular environment through polycrystalline silicon membrane filters which are designed to present high density of nanopores ranging up to 20 nm (Figure 1). These pores are large enough to allow passage of molecules i.e., water, oxygen, insulin and small enough to act as barrier for immune system particulates such as immunoglobulins and graft- borne virus particles (Iwabuchi, Kawamata et al. 2021).

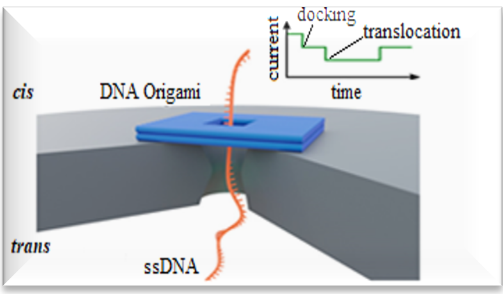

Figure 1: DNA Origami Docked Onto Solid State Nanopores Serves as a Gatekeeper for Different actions (Adapted from American Chemical Society 2020 (Shen, Piskunen et al. 2020)

Emerging Techniques in Nanomedicines: From Artificial Binding to Dendrimers

Artificial binding sites and molecular imprinting is another early goal of nanomedicines focusing on study of biomolecular receptor work, and to build artificial binding sites on made-to –order basis to achieve specified desired results. Molecular imprinting is an existing technique which employs the interaction of functionalized monomer with target molecule with help of non-covalent forces. The complex is then cross linked and polymerized and it leaves behind a recognition site. Each such site employs an induced molecular memory which has ability to bind selectively to target receptor (Lay, Ni et al. 2016). Quantum dots are another innovation of nanomedicines ranging in size of few nanometers like that of some proteins and DNA particle size. The principal theory of quantum dots application refers to excitation of these tiny particles via fluorescence and linking them to bio molecules to form long lived sensitive probes with magnified identification power in comparison to traditional dyes. Fullerenes are 1 nm Bucky balls, made from few dozen carbon atoms, C60 nanoparticles, attractive and satisfactory candidates for therapy because of low toxicity, high physiological and radiation stability and extremely small size (Das, Bandyopadhyay et al. 2018). The more advanced and refined application is dendrimer. Dendrimers are globular molecules with a size ranging in typical protein size, but due to presence of strong chemical forces their unfolding is not as easy as that of natural proteins. It branches successively from inside to outside and is used to bind biological molecules (Sharma 2021).

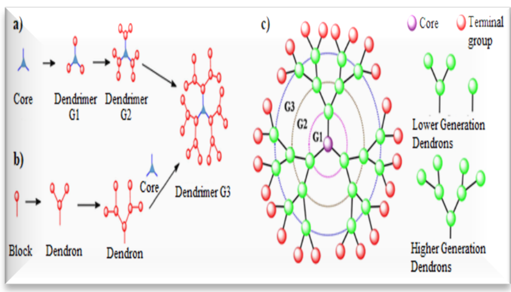

Figure 2: A representation of Synthesis of Dendrimers a) Divergent b) Convergent Synthesis, and c) Dendrons G1, G2 AND G3 Representing first Second and third Generation (Adapted from American Chemical Society (Sapra, Verma et al. 2019)

Cancer Diagnosis and Treatment

Nanoparticles comprising of organic and inorganic materials have proved their propensity for cancer diagnosis and treatment. The results of use of nanotechnology for this purpose proved positive and encouraging, and this has led to use and research for Nanotechnology in treating and diagnosing cancer (Brannon-Peppas and Blanchette 2004). The accomplishment of nano systems is owing to its smaller size, biocompatibility, selective tumor accumulation and reduced toxicity. Cancer is defined as large group of diseases that are characterized by cellular malfunction. Healthy cells are programmed to know "what to do and when to do". Cancerous cells do not have this programming and hence they grow in an uncontrolled fashion leading to unregulated cell growth which leads to formation of tumors. In cells proteins are Nanomachines that act as transporters actuators and motors. They are responsible for monitoring and repair processes of cell (Hassanpour and Dehghani 2017). Nanoparticle is a polymerized colloidal particle which may has drug encapsulated or conjugated on surface (Kumari, Yadav et al. 2010). Nanotechnologies used for cancer diagnosis and treatment are quantum dots, nano shells, dendrimers, nano sponges and nanowires (Ansari, Chung et al. 2020). Nano shells are gold coated silica, set in drug containing tumor targeted hydrogel polymer, accumulate when injected and they melt the polymer by absorbing infrared of specific frequency, releasing the drug. Their distinction is their use for micro metastasis, which are too small to be removed. Biological processes, including those vital for life and those that cause the cancer, occurs at nanoscale range. Thus, in fact, we are composed of a multitude of biological Nano-machines (Chauhan). Nanotechnology provides the platform to study and manipulate macromolecules in in the start and early progression stages of cancer. Nanotechnology can provide expeditious and sensitive observation and diagnosis of cancer-related molecules, enabling scientists to detect molecular changes even at very small scale. Nanotechnology is capable to generate absolutely exotic, innovative and exceedingly potent and effectual therapeutic agents (Pelaz, Alexiou et al. 2017).

Ultimately and uniquely, the use of nanoscale materials for cancer, is attributed to its ability to be easily functionalized and rapidly modulated; its capability to deliver and / or act as the therapeutic, diagnostic, or both as theranostic nano systems; and its ability to rack up passively at tumor site, to be actively focused and directed to cancer cells, and to be delivered across traditional biological barriers in the body such as dense stromal tissue of the pancreas or the blood-brain barrier that highly regulates delivery of biomolecules to central nervous system (Xin, Yin et al. 2017).

Nanorobots: A Future Vision

Robotics deals with construction, disposition, manufacturing and application of robots. Nanorobots are tiny machines designed at nanoscale dimension to diagnose and cure the disease by working. These machines are in research and development phase but some primitive nanorobots' are being tested. The robot is being assumed to detect the cause of fever, moving to the appropriate system and provision of dose of medication directly to infected area (Rahul 2017). Initially, nanorobots were supposed to float passively through the blood stream. Recently, nanorobots are made with strong propulsion force to move them through blood stream and other biological hurdles such as different biological fluids, extracellular matrix and biological membranes. Power supply and navigation system are two major concerns of nanotechnologists (Wang, Wu et al. 2020). Nanorobots could get the power directly from blood stream another option is to obtain energy by a reaction synthetically. Spectrum of activity of these robots can range from breaking up of clots to combating and fighting cancer and aids. They can be designed for toxicity detection. These robots may provide absolute detection and ultimate perfection in treating and combating the diseases. They might be able to detect and modulate human's neuro electrical signals with maximum efficacy (Singh, Ansari et al. 2019). In future, probably they will revolutionize the present concept of diagnosis and treatment.

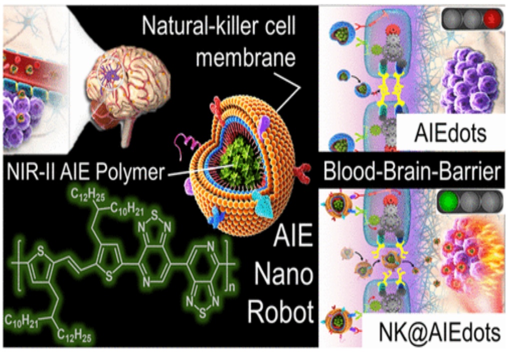

Figure 3: A Graphical Representation of Natural Killer Cell Mimics Nanobots with Induced Emission Characteristics (Adopted from American Chemical Society 2020 (Deng, Peng et al. 2020)).

Conclusion

Nanomedicine is under research for various applications. Nanomedicine has shown promising results previously untreatable diseases. Nanotechnology is shrinking the interphase between medical and natural sciences, thus, leading to development of interesting theranostic techniques. Many nanomedicine products have made it to clinical trials and many more are under development. Nanotechnology carries the hope for affordable, personalized, safe, point-of-care and long-term improvements to health status of population. Combing together the targeted drug delivery along with noninvasive imaging play an important role in nanomedicine mediated interventions in delivering the right drug in right dose to the right targeted point, right patient and time. By studying at intracellular and molecular levels nanomedicine producing results that is helpful in improved performance of diagnostic tools and testing. The clinical emergency utilizing the point of care testing to produce significant results that enabling with appropriate results and quick time response without the use of trained laboratory equipment and technical personnel. Challenge of converting basic laboratory research into commercially viable nanomedicine products seems inspiring but realization of full potential of nanomedicines will come sooner than later. Nanomedicine is expected to shake up and restructure the landscape of diagnosis, treatment and theranostic in the current decade.

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