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NANOTECHNOLOGY AND ITS APPLICATIONS

Samiullah Naik[1], M Rafiq[2], Salib Shafi[3], Asif Rafiq[4]

[1]Division of Biotechnology, Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Shalimar Campus, Srinagar-190025.
[2,3,4] TSRI,SKUAST K Mirgund

ABSTRACT

Nanotechnology can be defined as the science and engineering involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization in at least one dimension is on the nanometer scale. This technology is opening new therapeutic opportunities for many agents that cannot be used effectively as conventional formulations because of their poor functionality. Nanoparticles formulations provide protection for agents susceptible to degradation, denaturation in regions of harsh pH, and also prolong the duration of exposure of a drug by increasing retention of the formulation through bioadhesion. Nanobiotechnology is the combination of engineering and molecular biology that is leading to a new class of multifunctional devices and systems for biological and chemical analysis with better sensitivity, specificity, and a higher rate of recognition. Nano-objects with important analytical applications include nanotubes, nanochannels, nanoparticles, nanopores, nanocapacitors, and nanofibers. The prefix "nano" derives from the Greek word for dwarf. One nanometer (nm) is equal to one-billionth of a meter, or about the width of 6 carbon atoms or 10 water molecules. A human hair is approximately 7000-nm wide. Atoms are smaller than 1 nm, whereas many molecules including some proteins range between 1 nm and larger. Most accounts of the history and origins of nanotechnology begin with Richard Feynman's historic 1959 lecture at the California Institute of Technology titled "There is Plenty of Room at the Bottom," in which he outlined the idea of building objects from the bottom up. Analyses of signaling pathways by nanobiotechnology techniques might provide new insights into disease processes, thus identifying more efficient biomarkers and understanding the mechanisms of action of drugs. Advances in the manipulation of the nanomaterials permit the binding of different biomolecules, such as bacteria, toxins, proteins, and nucleic acids. Nanotechnology is relatively new and although the full scope of contributions to these technological advances in the field of human health care remains unexplored, recent advances suggest that nanobiotechnology will have a profound impact on disease prevention, diagnosis, and treatment.

Keywords: ***Nanotechnology, Nanoparticles, Nanotubes, Nanochannels, Nanoparticles.***

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I INTRODUCTION

Nanotechnology is the study and application of extremely small things whose sizes are in the 1-100 nanometer (nm) range in one structure dimension and may be used to assess small units such as atoms and their fractions. The prefix "nano" is derived from the Greek word for dwarf. A nanometer is one thousandth of a micrometer (μm), one millionth of millimeter (mm) and one billionth a meter (m). To imagine the nanoscale, it must be remembered that the width of the DNA strand is 2.5 nm, its length is estimated to be 2 nm, while the width of the protein molecule is 5 nm (Paull, 2010) and the human hair has a diameter equal 100000 nm. Nanotechnology can be used in other science fields like chemistry, biology, physics, materials science, engineering etc (Sahoo *et al.*, 2007). Nanobiotechnology is the intersection of nanotechnology and biology. It is the combination of engineering and molecular biology that is leading to a new class of multifunctional devices and systems for biological and chemical analysis with better sensitivity, specificity, and a higher rate of recognition (Fortina *et al*., 2005). The history and origins of nanotechnology begin with 2000 years ago. Richard Feynman's historic lecture 1959 at the California Institute of Technology titled "There is Plenty of Room at the Bottom," in which he outlined the idea of building objects from the bottom up. This brilliant suggestion did not gain much traction until the mid-1980s, when Eric Drexler published *Engines of Creation* in 1986, a popular treatment of the promises and potentials of nanotechnology. Drexler envisioned a molecular nanotechnology discipline that would allow manufactures to fabricate products from the bottom up with precise molecular control (Morrow *et al*., 2007).

II HEADINGS

Brief History of Nanotechnology

2000 years Ago	Sulphide nanocrystals were used by Greeks and Romans to dye hairs
1000 years Ago	Gold nanoparticles of different sizes used to produce different colors in stained glass windows
1959	''There is plenty of room at the bottom'' lecture by R. Feynman
1974	Taniguchi uses the term nanotechnology for the first time
1981	IBM develops Scanning Tunneling Microscope
1985	''Buckyball''-Scientists at Rice University and University of Sussex discover C_{60}
1986	''Engines of creation''-First book on nanotechnology by K. Eric Drexier
1989	Atomic Force Microscope invented by Binning, Quate and Gerbe
1991	Carbon Nano tubes was discovered by S, Lijima
1999	'Nanomedicine''-1st nanomedicine book by R. Freitas
2000	'National Nanotechnology Initiative'' launched
2009	Nanoparticles are used to target drug delivery to cancer tissue in vivo increasing cancer cell killing and reducing non specific toxicity

Source: British Standards Institution

III APPLICATIONS OF NANOTECHNOLOGY

3.1. Medical Applications

Nanotechnology offers potential developments in pharmaceuticals, medical imaging and diagnosis, cancer treatment, plant growth enhancement, implantable materials, tissue regeneration, and multifunctional platforms combining several of these modes of action. (Singh and Nalwa, 2011).

3.1.1. Diagnosis

One primary goal in nanotechnology is the design of methodologies to diagnose a number of diseases at an early stage with cheaper material and more sophisticated equipment that is possible today (Niedzwiecki *et al*., 2013). Aaron et al. (2007) have shown that 25-nm gold nanoparticles when conjugated with anti-epidermal growth factor receptor monoclonal antibodies can be efficiently used as *in vivo* targeting agents for imaging cancer markers, specifically epidermal growth factor receptors. The Au nanoparticles result in a dramatic increase in signal contrast compared to other antibody-fluorescent dye targeting agents (Suh *et al*., 2009) Nanobodies have the potential to be a new generation of antibody-based therapeutics and to be used in diagnostics for diseases such as cancer. The advantages of nanobodies to developing therapeutics are the extremely stable and bind antigen with nanomolar

affinity, a high target specificity and low toxicity, the ability to combine the advantages of conventional antibodies with important features of small-molecule drugs, and their ability to be produced cost effectively on a large scale (Jain. 2005). An option for the use of antibodies in molecular biomedical is aptamers. These molecules are chemically stable and easily produce single-stranded nucleic acid molecules (Arrondo and Alonso. 2006). One example of an application of aptamers in diagnosis is the work of Niedzwiecki and colleagues. In this work, nanopores and aptamers were combined to detect a single molecule of the nucleocapsid protein 7 (NCp7), a protein biomarker of the HIV-1 virus, with high sensitivity (Niedzwiecki *et al*., 2013). An interesting tool being developed today to be utilized in tumor diagnosis is RNA nanoparticles (Guo *et al*., 2012., Zhou *et al*., 2011., Shu *et al*., 2011). Although several researchers are adverse to RNA nanotechnology, due to the susceptibility of RNA to RNase degradation and serum instability, Shu and colleagues have developed a toolkit to obtain stable RNA nanoparticles (Shu *et al*., 2013). In this work, 14 homogeneous RNA nanoparticles were obtained, which targeted cancer exclusively in vivo without accumulation in normal organs and tissues. Functionalized nanoparticle aggregating fluorescence imaging techniques, known as quantum dots, have the potential for real-time and non-invasive visualization of biological events *in vivo*. The nanoparticles can provide a solid support for sensing assays with several kinds of ligand molecules attached to each nanoparticle, simplifying assay design (Wang *et al*., 2013). They can also withstand significantly larger number of cycles of excitation and light emissions than typical organic molecules, which more readily decompose, increasing the labeling ratio for higher sensitivity in complex biological systems (Fakruddin *et al*., 2012). Another advantage is that these miniaturized fluorescent nanoparticles can also be easily taken up by cells through endocytosis and subsequently used for site-specific intracellular measurements and long-term tracking of biomolecules in real time (Wang *et al*., 2013).

3.2. Gene Therapy

Gene therapy is a recently introduced method for the treatment or prevention of genetic disorders by correcting defective genes responsible for disease development based on the delivery of repaired genes or the replacement of incorrect ones (Ariga. 2006). The most common approach for correcting faulty genes is insertion of a normal gene into a nonspecific location within the genome to replace a nonfunctional gene. An abnormal gene could also be swapped for a normal gene through selective reverse mutation, which returns the gene to its normal function (Hanakawa *et al*., 2005). Mammalian cells typically have a diameter of a few microns and their organelles are within the nanometer range. The use of nanodevices has the advantage of entering the cells more easily when compared to larger devices and they can, therefore, interact better with the cells or at least in a different way (Kompella *et al*., 2013).

3.3. Drug Delivery

Drug delivery is the method of transporting a pharmaceutical compound in the body to safely achieve a therapeutic effect in humans or animals. Controlled delivery systems are used to improve the therapeutic efficacy and safety of drugs by delivering them to the site of action at a rate dictated by the need of the physiological environment (Vasita

and Katti. 2006) which in turn would reduce both toxicity and side effects (Saiz *et al*., 2013). Electrospun nanofibers may serve as a promising delivery vehicle as a result of their 3D nano-sized features that closely resemble those of the ECM (Cunha *et al*., 2011). By this technique it is possible to incorporate biological molecules by using an emulsion or directly in a polymer solution (Amna *et al*., 2012., Qi *et al*., 2006). Co-axial also is used in drug delivery due its capacity of producing micro/nanotubes, drug or protein-embedded nanofibers, and hybrid core–shell nanofibrous materials (Chakraborty *et al*., 2009). Structures built by electrospinning or co-axial permit the liberation of growth factors as epidermal growth factor (EGF), fibroblast growth factor (FGF), transforming growth factor (TGF), bone morphogenetic protein (BMP), and neurotrophins and neurokines, among others, used for neural, (Wittmer *et al*., 2011) endothelial, (Metcalfe and Ferguson. 2007) and bone formation, (Saiz *et al*., 2013) etc. Another nanotechnology tool which is under intense investigation for drug delivery is nanoparticles. They can principally be fabricated by lipids and polymers (Mashaghi *et al*., 2013., Shi *et al*., 2010). Polymeric compounds that are currently being used in drug products include poly(DL-lactic-coglycolic acid) (PLGA) polyvinyl alcohol, poly(ethylene-co-vinyl acetate), polyimide, and poly(methylmethacrylate) (Kompella *et al*., 2013). Co-delivery is an alternative for the administration of different drugs, which by conventional therapeutic method cannot be used together. Therefore, nanoscale systems can be used to facilitate the delivery of incompatible drugs. They can also be used in theranostics, in which the particle is used as a device to diagnose and treat the disease at the same time (Shi *et al*., 2010).These techniques are also used for the liberation of pharmacological agents against several diseases, such as bacterial infection, (Kim *et al*., 2004) inflammations, (Camenzind *et al*., 1997) and principally cancer, (Amna *et al*., 2012) among others. They are also being investigated as a tool for the delivery of drugs through the blood-brain barrier. (Philosof-Mazor *et al*., 2013).

3.4. Tissue Engineering

The growing trend of increasing life expectancy of the population as well as the serious limitations in the use of allografts, autologous grafts, or xenografts has led scientists around the world to invest more in the search for alternatives. Therefore, research in this area aims to apply the principles of cell transplantation and engineering to construct biological substitutes (Atala. 2005., Langer. 1999). Thus, the focus of tissue engineering (TE) is to repair or reconstruct lost or damaged tissue through the use of growth factors, cell therapy, injectable biopolymers, and biomaterials, which serve as support for the development of the cells (Venugopal, *et al*., 2012).Cells interact with the environment around them through thousands of interactions on a nanometric scale. Therefore, the goal of TE on a nanoscale is to create biomaterials that direct interactions between cells and their micro-environment, by the creation of nanoscale molecular signals of biological interest. Thereby, the cells receive, process, and respond to information presented in the surrounding environment, these actions being essential for the control of cell behavior (Wheeldon *et al*., 2011). From the techniques used to construct biomaterials to be cultivated with cells, electrospinning is the most widely studied. It is a highly versatile method of transforming solutions, mainly made from polymers, in continuous filaments with diameters ranging from a few micrometers to nanometers. Through this method, the fibers can be obtained randomly or in an ordered way (Greiner and Angew. 2007). Another interesting

observation of Baker *et al*. (2010). when studying the use of polystyrene to create electrospun scaffolds with varying spatial configurations was that scaffolds with longitudinally aligned fibers demonstrate similar strength to native bladder tissue and greater strength than transversely aligned and randomly aligned scaffolds and also that cell alignment was greater when grown on scaffolds with aligned fibers. One in five people will develop heart failure in their life time. Such a high risk is fueled by the intrinsic inability of the heart to regenerate itself after injury (Zhang *et al*., 2011). Because of this high incidence, the main goal of bioengineers in this field is to engineer tissues that are capable of establishing normal heart contractile function and prevent pathological remodeling. The alignment of cardiomyocytes is important for the contraction and impulse propagation along the long axis of the cells (Vunjak-Novakovic *et al*., 2010). Aligning cardiomyocytes in 3D provides adequate functionality to replace damaged tissues, (Zhang *et al*., 2011) and the electrospinning technique has been shown to be efficient in creating scaffolds that supply this necessity (Zong *et al*., 2005). Structures, such as core–shell, associated with cells are also applied in the treatment of myocardial infarction, (Ravichandran *et al*., 2013) increasing cell transplant retention and survival within the infarct, compared to the standard cell injection system (Ravichandran *et al*., 2012).

IVCONCLUSION

Nanotechnology is a global business enterprise impacting universities, industry, and regulation agents. Nanobiotechnology is still at its early stages of expansion; however, the development is multi-directional and fast-paced. Nanobiotechnology will provide opportunities for developing new materials and methods that will enhance our ability to develop faster, more reliable, and more sensitive analytical systems. Although there are many exciting potential biological applications of nanomaterials, one needs to discern genuine scientific promises from hype and to constantly improve the fundamental understanding of the interactions of nanomaterials with intracellular structures, the process, and the environment.

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