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A Comprahensive Review on Nanotechnology

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A B S T R A C T

Nanobiotechnology is a recently coined term describing the junction of the two existing but isolated worlds of engineering and molecular biology. It is a combination of three words: “nano” tiny, “bio” is living things, and “technology” is about tools. It refers to the ability to create and manipulate biological and biochemical materials, devices, and systems at atomic and molecular levels. Thus, it is an integration of physical sciences, molecular engineering, biology, chemistry, and biotechnology, and holds considerable promise of advances in pharmaceuticals and health care. Nanotechnology helps in improving the drug solubility and bioavailability by enhancing the drug release, the formulation quality, decreasing toxicity, and efficient targeted therapy. Nanomaterials are at the leading edge of the rapidly developing field of nanotechnology. In this review we discussed the role of nanobiotechnology in molecular diagnosis, drug discovery, and development of nanomedicine and personalized medicine. The FDA approval is essential for clinical applications of nanotechnology and substantial regulatory problems could be encountered in the approval of nanotechnology-based products therefore we also discussed about the limitations of use of nanobiotechnology in drug discovery.

Keywords: Quantum dots, Nanoparticles, Nanopores, Nanoshells, Nanotechnology, Nanotubes

A R T I C L E I N F O

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1. Introduction

The word "nano" comes from the Greek for "dwarf". A nanometer is a thousandth of a thousandth of a thousandth of a meter (10^{-9} m).One nanometer is about 60,000 times smaller than a human hair in diameter or the size of a virus, a typical sheet of paper is about 100,000 nm thick, a red blood cell is about 2,000 to 5,000 nm in size, and the diameter of DNA is in the range of 2.5 nm [1]. Therefore, nanotechnology deals with matter that ranges from one-half the diameter of DNA up to 1/20 the size of a red blood cell.

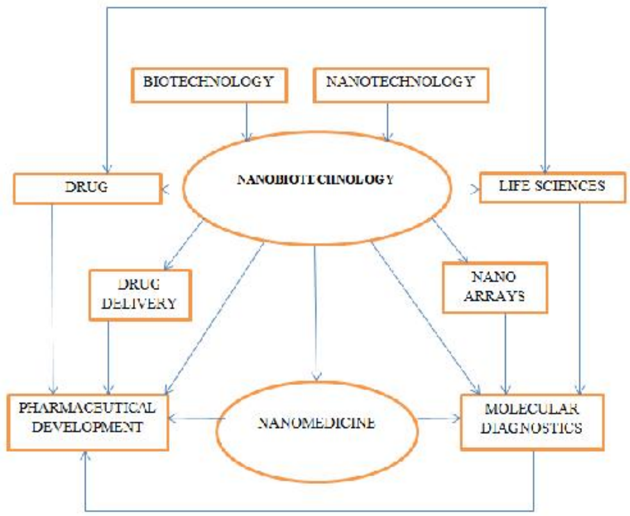

Figure 1: Combination of nanobiotechnologies for the development of nanomedicine [6].

Further, it is interesting to note that nanomaterials are so small, even bacteria would need a microscope to see them [2]. Nanoparticles are generally accepted as those with a particle size below 100 nanometers where unique phenomena enable novel applications and benefits. Nanomaterials on which most of the research has been carried out are normally powders composed of nanoparticles which exhibit properties that are different from powders of the same chemical composition, but with much larger particles. Nanobiotechnology is the branch of nanotechnology that deals with biological and biochemical applications or uses. It often studies existing elements of living organisms and nature to fabricate new nanodevices.

Nanobiotechnology is the branch of nanotechnology that deals with biological and biochemical applications or uses. It often studies existing elements of living organisms and nature to fabricate new nanodevices. It holds considerable promise of advances in pharmaceuticals and healthcare. It is widely seen as having a great potential to bring benefits to many areas of research and applications. It is attracting increasing investments from governments and private sector business in many parts of the world. Concurrently, the application nanobiotechnology is raising new challenges in the safety, regulatory, and ethical domains that will require extensive debates on all levels. The combination of nanobiotechnologies plays an important role indrug development and drug discovery as shown in Fig. 1. Thisarticle will provide an integrated overview of application of nanobiotechnology- based molecular diagnostics, drug discovery and drug delivery in the development of nanomedicine with there lationships [3]. There are two concepts commonly associated with nanotechnology:

- Positional assembly
- Massive parallelism

Positional assembly helps to get the right molecular parts inthe right places and massive parallelism helps to keep thecosts down [4]. Nanotechnology increases oral bioavailability of drugs due to their specific mechanisms. Nanostructures are able to penetrate tissues and are easily taken up by cells, allowing for efficient delivery of drugs to target sites of action [5].

Significance of Nanomaterials in drug delivery

The nano sized drug delivery systems are attractive to formulation scientists. The most important reason is that number of surface atoms or molecules to the total number of atoms or molecules increases in drug delivery systems [7]. Due to which surface area increases and size of the nanomaterial decreases. This helps to bind, adsorb and carry with other compounds such as drug, probes and proteins. The nanoparticles itself can be engineered to form nanoscale size materials too. The nanosized device systems having their sizes smaller than eukaryotic or prokaryotic cells [8], can eventually much more in amount reach in generally inaccessible areas such as cancer cells, swollen tissues etc. Due to their enhanced permeability and retention effect (EPR) [9] and can damage lymphatic drainage thus that can be used for administration of genes, proteins through the route. The nanomaterials used for this purpose, must be soluble, safe and biocompatible as well as bioavailable. They must not include blood vessel and less invasive and the toxicity associated with the nanomaterials for drug delivery should be very low so that they can be used to target the specific diseased tissue or all in a safe concentration [10]. They need protecting drug from enzymatic and hydrolytic degradation in the gastrointestinal tract and help in bypassing the "first-pass" metabolism in the liver. They generally remaining the circulation for longer time especially those coated with hydrophilic polymers [11] and hence suitable for enhancing the efficiency of drugs which can be used to monitor drug as sustained release formulation as well as for delivering DNA. When dissolution rate of drug enhanced, onset of therapeutic action increased, and the dose reduced. The premature loss of drug through rapid clearance and metabolism can also be prevented. They also increase retention due to bio- adhesion. Nano-scaledrug delivery systems such as fullerene, nanopores, nanotubes, nanoshells, quantum dots, nanocapsule, nanosphere, nanovaccines, nanocrystals etc. are believed to have potentials to revolutionize for drug delivery systems [12]. Further the nonmaterial on chips, nano robotics, andmagnetic nanoparticles are useful to attachment for specific antibody. The nanosized empty virus capsids and magnetic immunoassay are new dimensions of their use in drug delivery [13]. Thus nanomaterials can be used for strategic development of new drug delivery systems. The seare reformulating existing drugs to enhance the effectiveness, safety of drugs and decreasing the cost of health care [14].

2. Nano-scale drug delivery systems

1. Nanoparticles:

Nanoparticles have emerged as promising nanoplat forms for efficient diagnostics and therapeutics by merging the characteristic properties they possess at the nanometric scale with the feasible immobilization of specific ligands on the surface. Therefore, they have become ideal candidates for molecularly sensitive detection, highly efficient contrast agents for molecular imaging, as well as carriers for targeted drug and gene delivery, and the rapeutical reagents for targeted photothermal therapy. Nanoparticle usually forms the core of nano-biomaterial. It can be used as a convenient surface for molecular assembly and may be composed of inorganic or polymeric materials. It can also be in the form of nano-vesicle surrounded by a membrane or a layer [15].Nanoparticles that are commonly used for diagnostics are

- Gold nanoparticles
- Magnetic nanoparticles
- Quantum dot (QD) technology
- DNA-protein and nanoparticle conjugates

2. Fullerenes and Nanotubes

Fullerenes consist of carbon in the form of a hollow sphere or ellipsoidal tube. These are also known as ‘Bucky balls’ because of their similarity to the dome, design of Buck minster Fuller. Fullerenes are being investigated for drug delivery of antiviral, antibiotics and anticancer agents. Fullerenes have the potential to stimulate host immune response and production of fullerene specific antibodies. Soluble derivatives of fullerenes such as C_{60} have shown great utility as pharmaceutical agents. Carbon nanotubes can be made more soluble by absorption of carboxylic or ammonium groups to their structures and can be used for the transport of peptides, nucleic acids and other drug molecules. The capability of nanotubes to transport DNA across cell membrane is used for studies of gene therapy. DNA can be attached to the tips of nanotubes or can be incorporated within the tubes [16].

3. Nanopores

Nano-pores having diameter of 20nm consist of wafers with high density of pores which allow entry of oxygen, glucose and other chemicals such as insulin to go through. Nanopores can be used as devices to protect transplanted tissues from the mass immune system, at the same time, utilizing the advantage of transplantation. ß-Cells of pancreas can be enclosed within the nanopore device and implanted in the recipient’s body. Nanopores can also be employed in DNA sequencing. Nanopores are also being developed with an ability to differentiate purines from pyrimidines.

4. Quantum dots:

Quantum Dots (QDs), which are the most promising nanostructures for diagnostic applications, are semiconductor nanocrystals characterized by high photostability, single-wavelength excitation, and size-tunable emission. Quantum dots are of much interest for the properties that they possess. These properties include electrical and nonlinear optical properties. These unique properties of nano sized particles are partly the result of the unusually high surface to volume ratios for their particles, as many as one-third of the atoms are on the surface of the particle. As a result electrons and "holes" (holes result when an electron moves away from a bond, leaving a positively charged particle) are confined in a limited space inside the cluster. Quantum dots can emit light if excited, the smaller the dot, the higher the energy of the emitted light. This ability to create dots that emit a rainbow of colors suggests that they could be used as biosensors. Unlike the dyes currently being used as biosensors, quantum dots do not degrade as rapidly. Applications of QDs in molecular diagnostics

- Cancer
- Genotyping
- Whole blood assays
- Multiplexed diagnostics
- DNA mapping
- Immunoassays and antibody tagging
- Detection of pathogenic microorganisms
- Used as inorganic fluorophores

5. Nanoshells

Nanoshell particles are special class of nanocomposite materials. They consist of concentric particles, in which particles of one material are coated with a thin layer of another material using specialized procedure. Nanoshell particles are highly functional materials show modified and improved properties than their single constituent counterparts or nanoparticles of the same size. Their properties can be modified by changing either the constituting materials or coreto-shell ratio. Nanoshell materials can be synthesized from semiconductors (dielectric materials such as silica and polystyrene), metals and insulators. Generally dielectric materials such as silica and polystyrene are generally used as core because they are highly stable [17].

3. General applications

Sunscreen: Many sunscreens contain nanoparticles of zinc oxide or titanium oxide. Older sun screen formulas use larger particles, which is what gives most sunscreens their whitish color. Smaller particles are less visible, meaning that when you rub the sunscreen into your skin, it doesn't give you a whitish tinge. Ingredients like zinc oxide can leave a white shine behind. But sunscreens with zinc oxide nanoparticle srub on clear.

Self-Cleaning Glass:

A company called Pilkington offers a product they call Activ Glass, which uses nanoparticles to make the glass photocatalytic and hydrophilic.

Clothing:

Scientists are using nanoparticles to enhance clothing. By coating fabrics with a thin layer of zinc oxide nanoparticles, manufacturers can create clothes that give better protection from UV radiation. Some clothes have nanoparticles in the form of little hairs or whiskers that help repel water and other materials, making the clothing stain-resistant.

Scratch-Resitant Coatings:
Engineers discovered that adding aluminum silicate nanoparticles to scratch resistant polymer coatings made the coatings more effective, increasing resistance to chipping and scratching. Scratch-resistant coatings are common on everything from cars to eyeglass lenses.

Antimicrobial Bandages:
Scientist Robert Burrell created a process to manufacture antibacterial bandages using nanoparticles of silver. Silver ions block microbes cellular respiration. In other words, silver smothers harmful cells, killing them.

Swimming Pool Cleaners and **Disinfectants:**
Enviro Systems, Inc. developed a mixture (called ananoemulsion) of nano-sized oil drops mixed with a bactericide. The nano sized oil particles adhere to bacteria, making the delivery of the bactericide more efficient and effective.

Tennis: Nanotechnology is making a big impact on the tennis world. In 2002, the tennis racket company Babolat introduced the VS Nanotube Power racket. They made the racket with carbon nanotube-infused graphite, meaning the racket was very light, yet many times stronger than steel. Meanwhile, tennis ball manufacturer Wilson introduced the Double Core tennis ball. These balls have a coating of clay nanoparticles on the inner core. The clay acts as a sealant, making it very difficult for air to escape the ball.

Cure of cancer:
The delivery of any drug at the right time and in the target where it is needed and at the level that is required is essential to realize the full potential of therapeutic molecules. These requirements are more important in the case of cancer chemotherapies due to their high toxicity which could lead to serious side-effects. In the last few years, a great number of drug delivery technologies have been optimized including the micro and the nano-systems as well as polymer conjugation. Together these drug delivery systems would not only improve drug administration and the efficiency and safety of conventional chemotherapies, but also revolutionize the pharmaceutical and biomedical industries in can certherapies [18].

4. Future Perspectives

Nanotechnology will assume an essential place in drug delivery and human therapeutics. Although the development of drug delivery systems is just emerging, it shows a promising future. Nanotechnology, which is still in its infancy, provides opportunities for physicists, chemists and biochemists, etc. to develop systems that may eventually match in sophistication and precision of biological structures elaborated by nature. Nanotechnology is an emerging field that is potentially changing the way we treat diseases through drug delivery. However, significant challenges remain in pushing this field into clinically viable therapies. The design and testing of novel methods of controlling the interaction of nanomaterials with the body are some of the current barriers to translating these technologies to the rapies. Methods of targeting nanomaterials to specific sites of the body while avoiding capture by organs, such as the liver and spleen, are major challenges that need to be addressed. Nanoscale structures such as surface topography and patterning could be used to direct cell behavior. The incorporation of these strategies within tissue engineering scaffolds could further enhance their function. As Feynman had predicted, there has been plenty of room at the bottom to modify and enhance existing technologies by controlling material properties at the nanoscale. Therefore, with sufficient time and research, the promise of nanotechnology based medicine may become a reality [20].

Table 1A: Corrosion inhibition performance of some of the expired drugs

Agent	Sponsor	Uses	Technology	Approval date	Mode of application
SilvaGard	AcryMed, Inc	Antimicrobial	Metalic nanoparticle	May 2005	Transdemal batch
Doxil	Alza Corporation	Ovarian Cancer	Liposome	Febrauary 2005	Injection
Tricor	Abbott Laboratories	Cholesterol lowering	Polymeric encapsulated	December 2004	Oral capsule
Abraxane	APP	Breast cancer	Drug conjugated with albumin	January 2005	Injection
Estrasorb	Novavax Allergan	Reduction of vasomotor symptoms, such as hot flushes and night sweats in menopausal women	micellar nanoparticles (emulsion)	October 2003	Transdermal
Amphotec of	Sequus	Invasive aspergillosis in patients who are refractory to or intolerant of conventional Amphotericin B	lipid-based	November 1996	Subcutaneous suspension
Megace	Elan Corp Par Pharma	Anorexia	Nanocrystalline	September 1993	Oral suspension

5. Conclusion

Nanotechnology has revolutionized for the drug delivery system. Advancements in this area have allowed some Nano medicines in the market to achieve desirable properties like to reduce toxicity and improve the patient compliance, as well as clinical outcomes. The combination of nanoparticles in drug delivery technologies in preformulation work, not only accelerates the increase of new therapeutic moieties, but also helped in the reduction of attrition of new molecular entities caused by unwanted biopharmaceutical and pharmacokinetic properties. The applications of nanotechnology in drug delivery are widely expected to change the scene of pharmaceutical and biotechnology industries for the predictable future. Target-specific drug therapy and methods for early diagnosis of pathologies are the precedency research areas where nanotechnology would play a prominent role.

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