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The Evolution of Nanomedicine with the Re-Evolution of Nanotechnology

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ABSTRACT : *Nanotechnology is an emerging field in science and engineering. It is the study of elements at atomic and molecular level. The key is to be able to both see and manipulate elements at nanoscale, in order to take advantage of their special properties. The evolution of nanotechnology has led to its use in the fields of optical, electrochemical, magnetic, mechanical, and medical. Among the most promising advances in nanotechnology, there has been a rise in success of application of the tiny materials, called nanoparticles and devices, in order to detect, diagnose and treat several diseases. Thus this re-evolution of nanotechnology has led to an application in medicine, which is commonly known today as nanomedicine. Thus, this paper brings about a review on the beginning of the nanotechnology and the evolution of nanomedicine from nanotechnology.*

KEYWORDS:*Nanotechnology, nanomanufacturing, nanomedicine, nanoparticles, nanomaterials, nanocarrier*

I. INTRODUCTION

Nanotechnology is a broader view to science where diverse fields of physics, chemistry, biology, materials science, and engineering converge at the nanoscale that is, a scale ranging from 1 to 100 nanometers. Nanotechnology involves the ability to view and control individual atoms and molecules. With the development of the scanning tunneling microscope (STM) and the atomic force microscope (AFM), which enabled the scientists to view the individual atoms, gave birth to the nanotechnology era. Thus nanotechnology is considered as the understanding and controlling of molecules and atoms at nanoscale. The process of manufacturing at such nanoscale is widely known as nanomanufacturing. Nanomanufacturing leads to the production of improved materials and new products. It involves constructing items from the bottom up, using techniques and tools being developed today to obtain high performance products.The application of nanotechnology to medicine is advancing today in many different areas. These advances are widely stated under the term nanomedicine. The developments in nanomedicine are converging to fill a long-acknowledged gap between the science and technology of the chemical scale and what has been accessible on the biological scale [4].

II. EVOLUTION

2.1 Nanotechnology

Although nanotechnology seems to have gained a widespread interest in the recent years, the concepts behind nanoscience and nanotechnology are dated back to 1959 when physicist Richard Feynman delivered a talk entitled “There’s Plenty of Room at the Bottom” at an American Physical Society meeting at the California Institute of Technology (CalTech). However the term ‘nanotechnology’ was coined over a decade later, by Professor Norio Taniguchi, in his explorations of ultraprecision machining. In 1981 as the scanning tunneling microscope developed, the evolution of nanotechnology began to turn out today as a revolution in the fields of engineering and technology, imaging, measuring, modeling, and manipulating matter nanoscale.In the year 2006, Mihail Roco of the U.S. National Nanotechnology Initiative, described four generations of nanotechnology development, as illustrated in Fig.1.

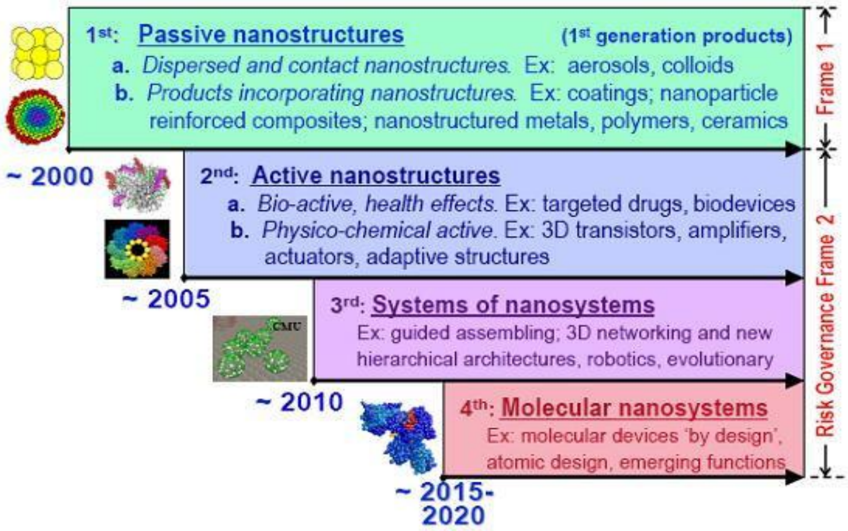

Figure 1: The four generations of nanotechnology as described by Mihail Roco
(Image courtesy: National Nanotechnology Initiative – www.nano.gov)

2.2 Nanomedicine

The medical application of nanotechnology is widely termed as nanomedicine. It ranges from medical applications of nanomaterials to nanoelectronics biosensors. The research and development of nanomedicine is broadly divided into three factors. The first impact of nanoscience on medicine is evolutionary. A second development is explicit and revolutionary, emphasizing great advances to be gained by radical new nanotechnology approaches. A third source of nanotechnology on medicine is indirect through the development and application of ever-improving nanotools and devices based on smaller and more precise technologies. These technologies impact research, diagnostics and therapeutics [4].

Harry F. Tibbals has noted in his book, the general requirements for use of nanoparticles in nanomedicine as follows:

- Nanoparticles used for medical applications in the body must be biodegradable or clearable, i.e. agents used must degrade over time with minimal toxic by-products.
- The nanoparticles should be colloidally stable in aqueous media and should remain stable when mixed with physiological buffer solutions.
- The nanoparticles should possess strong absorbance or fluorescence in the required wavelengths relative to tissue.
- Manufacturing steps must be free of toxic materials, which may leave residues in or on the final product.
- The surface coating of nanoparticles that are considered candidates for medical imaging or therapies should be readily functionalized for custom targeting.

III. NANOMATERIALS

Today researchers worldwide are manufacturing nanomaterials to make new products and applications, ranging from medical devices and drugs, to strong and lightweight materials that reduce fuel costs for cars and planes. Based on the shapes and dimensions, different types of nanomaterials are named, such as particles, tubes, wires, films, flakes, or shells that have one or more nanometer-sized dimension. Producing nanomaterials for use in biomedicine is a challenging task. However the recent advances in Nanotechnology-based drug carriers and materials have yielded more medical benefits especially the field of cancer therapy by improve the solubility of poorly soluble drugs, circulate in blood stream for longer time without being recognized by macrophages, as well as controlled release of drugs at an expected rate in the desired area. Nanocarrier systems can be designed to interact with target cells and tissues or respond to stimuli in well-controlled ways to induce desired physiological responses. [1].

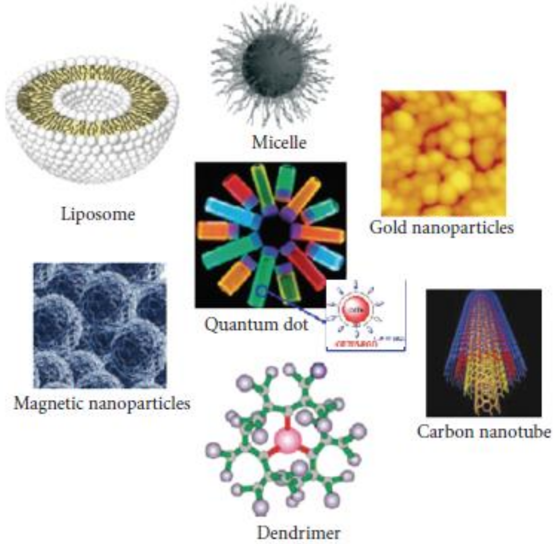

Figure 2: Different types of nanomaterials used in nanotechnology
(Image courtesy: [1])

3.1 Polymeric Nanoparticle

These particles are prepared from natural or synthetic polymers and have a size of less than 1 μm diameter. They have the ability to improve the specificity of action of drugs by changing their tissue distribution and pharmacokinetics. These nanoparticles have played pivotal roles in delivering antitumor drugs in a targeted manner to the malignant tumor cells, thereby reducing the systemic toxicity and increasing their therapeutic efficacy.

3.2 Micelles

Polymeric micelles are usually formed into core-shell structures by spontaneous assembly when its concentration is above critical micelle concentration (CMC). They have a number of unique features, including nanosize, easy manipulation of surface chemistry, core functionalities, as well as ease of fabrication, making them suitable as carriers for encapsulation, and delivery of water insoluble agents. The small size (<100 nm) allows micelles for efficient accumulation in pathological tissues with permeabilized vasculature via the enhanced permeability and retention (EPR) effect. Stimuli-responsive polymeric micelles are often designed for controlled release of drug into tumor tissue with external stimuli trigger, like temperature, pH, ultrasound, and special enzymes [1].

3.3 Gold Nanoparticles

Gold nanoparticles are available in a non-oxidised state. Gold nanoparticles exhibit unique physicochemical properties such as surface plasmon resonance (SPR) and the ability to bind amine and thiol groups, which allows surface modification and use in biomedical applications. Recently, there has been an explosion in Gold nanoparticle research, used widely in fields of imaging, bioengineering and molecular biology [2].

3.4 Carbon Nanotubes

These are cylinders of one several coaxial graphite layers with a diameter in the order of nanometers. They have unique electronic, thermal, and structural characteristics, due to which they can offer a promising approach for gene and drug delivery for cancer therapy. Carbon nanotubes are generally classified as single-walled carbon nanotubes (SWCNTs) with a single cylindrical carbon wall and multiwalled carbon nanotubes (MWCNTs) with multiple walls—cylinders nested within other cylinders.

3.5 Dendrimers

These are artificial macromolecules with tree-like structures in which the atoms are arranged in many branches and subbranches radiate out from a central core. They are synthesized from branched monomer units in a stepwise manner, as shown in fig.3 [1].

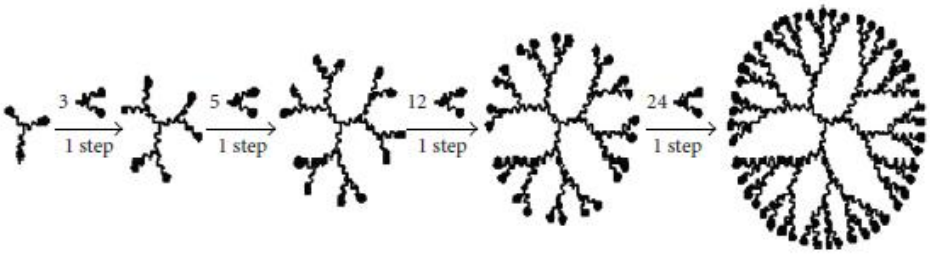

Figure 3: Stepwise synthesis of Dendrimers

3.6 Quantum Dots

These are inorganic fluorescent semiconductor nanoparticels composed of 10– 50 atoms with a diameter ranging from 2 to 10 nm. The color of fluorescence is determined by the size of particles and the type of materials, as shown in fig.4. They are widely studied for optical image application in living systems and are stable for months without degradation and alteration. With the help of near-infrared (NIR) optical imaging devices, QDs-based tumor imaging and treatment could allow for application in deeper tissues and may offer optical guide for surgery on organs.

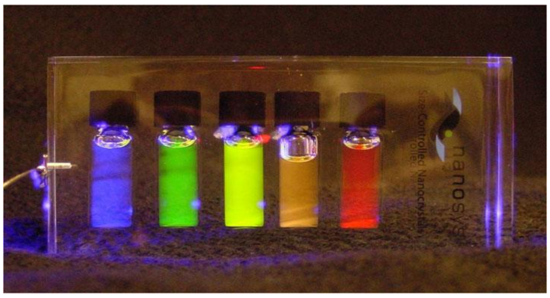

Figure 4: Quantum Dots
(Image courtesy: National Nanotechnology Initiative – www.nano.gov)

IV. NANOTECHNOLOGY IN NANOMEDICINE

The biological and medical research communities are continuously exploiting the unique properties of nanomaterials for various medical applications. Nanomedicine seeks to deliver a valuable set of research tools and clinically useful devices in the near future. Nanotechnology has provided the possibility of delivering drugs to specific cells using nanoparticles. The overall drug consumption and side-effects may be lowered significantly by depositing the active agent in the morbid region in required quantities. Quantum dots can be used in conjunction with MRI (magnetic resonance imaging), to produce exceptional images of tumor sites. These nanoparticles are much brighter than organic dyes and only need one light source for excitation. The downside, however, is that quantum dots are usually made of quite toxic elements.The nanotechnology reformulations of chemotherapeutics that have been approved by the US Food and Drug Administration (FDA) are Abraxane and Doxil are widely benefiting cancer patients. Abraxane is a protein-bound reformulation of paclitaxel, a powerful chemotherapeutic that is poorly soluble in water. It uses a nanoparticle made of the blood protein albumin to encapsulate and solubilize paclitaxel. Doxil is a nanosized liposome of the drug doxorubicin. Free doxorubicin, along with a broad class of similar molecules, is toxic to the heart and is known to damage cardiac muscles. Doxil, due to its nanoparticle delivery system, distributes differently in the body, so less of it reaches the heart [3].

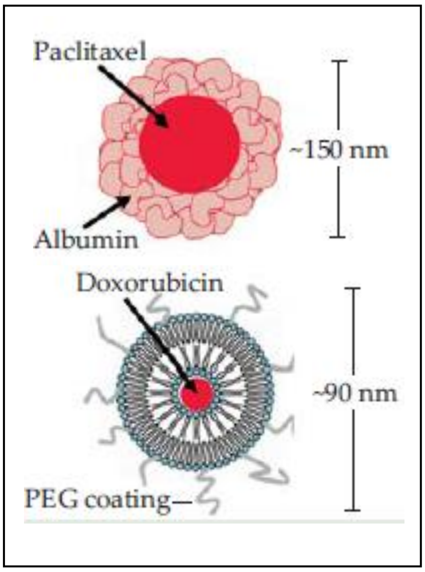

Figure 5: Examples of Nanomedicines: Abraxane (top) and Doxil (bottom)

V. CONCLUSION

Thus from the evolution and re evolution of nanotechnology, today we have a completely new field of nanomedicine which has been successful in detecting, diagnosing and treating various diseases. However, the application of nanoparticles in human body may cause adverse effects due to the toxicity caused by such particles. Thus with the evolution, researchers have to focus upon the safety measurements while application of this field.

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