Critical Role of Bionanotechnology in Healthcare and Society

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INTRODUCTION

Bionanotechnology is a combination of three terms: "bios" meaning "life," "nano" (origin in Greek) meaning "dwarf," and "*technologia*" (origin in Greek—comprised of "*techne*" meaning "craft" and "*logia*" meaning "saying"), which is a broad term dealing with the use and knowledge of humanity's tools and crafts. Bionanotechnology is a term coined for the area of study where nanotechnology has applications in the field of biology and medical sciences.

Healthcare is defined by the Oxford Dictionary as the "care for the general health of a person, community, etc., especially that is provided by an organized health service." Moreover, *Healthcare* can also be defined as the prevention, treatment, and management of illness and the preservation of mental and physical well-being through the services offered by the medical, nursing, and allied health professions[1].

BACKGROUND

The healthcare industry is one of the world's largest and fastest-growing industries[2]. However, since ages the gravest dilemma of the healthcare system has been its soaring costs. Healthcare forms a major part of a country's economy by consuming over 10 percent (Figure 1) of gross domestic product (GDP) of most developed nations. In 2003, healthcare costs consumed 15.3%[3] of the GDP of the United States, the largest of any country in the world. In 2001, for the Organisation for Economic Cooperation and Development (OECD) countries the average was 8.4%[4] with the United States (13.9%), Switzerland (10.9%), and Germany (10.7%) being the top three (See Appendix A).

Figure 1. U.S. healthcare costs[3]

1950	$12.7 billion	4.5 percent
1965	$40 billion (est.)	6 percent
1980	$230 billion	9 percent
2000	$1.2 trillion	14 percent

At present, the U.S. healthcare system has three prime goals: the provision of high-quality care, ready access to the system, and reasonable costs. Therefore, discovering or inventing new ways which would offer effective and efficient quality healthcare treatment is becoming a main concern, not only in the U.S., but also worldwide, as the expenditure in healthcare is increasing exponentially (Wickramasinghe, Choudhary, & Geisler, in press).

ROLE OF BIONANOTECHNOLOGY IN HEALTHCARE

Bionanotechnology deals with nanomaterials and their applications in life sciences. Bionanotechnology being one of the most promising and growing industry today, a large amount of work that is being carried out in this area. Bionanotechnology is currently in its prime with researches being carried out all over the globe in this field. The applications[5,6] of bionanotechnology are vast. The following outlines what is currently being done in this field:

- **Dendrimers:** (Svenson & Tomalia, 2005) It can act as a good *drug delivery agent* as well as a

time-release delivery agent. It is normally used in therapeutic developments which are targeted to cancer cells (Baker, 2003). Dendritic polymers are also used for the development of nanosensor/NEMS systems for noninvasive, continuous monitoring of astronauts for the biologic effects of space travel.

- **Gold nanoshells:** They are nanoparticles made of silica (glass) which are completely coated with gold (Ha, Jeong, & Chung , 2005; Jain, 2005). Researchers are trying to make use of gold nanoshells for the detection as well as treatment of cancerous cells.
- **Patient-specific medicine:** (Baba, 2006) Personalized medicine or Patient-Specific medicine simply means the *prescription of specific therapeutics best suited for an individual*. Xiaolian Gao, professor of chemistry, has developed a chemical process for building a device that could help doctors predict a patient's response to drugs or screen patients for thousands of genetic mutations and diseases, all with one simple lab test—on a DNA chip. The ultimate vision of this research is the development of Patient-specific medicine.
- **BioNanosensors[7]:** Researchers in many universities and R&D laboratories are trying to develop sensors based on nanotechnology which, when implanted under the skin of a human being, will be able to detect the level of glucose, hormones or cholesterol. Nanosensors (Clark, Singer, Korns, & Smith, 2004; Jain, 2005; Kohli & Martin, 2005; Kvennefors & Persson, 2004) can play a vital role in the treatment of genetically-based diseases like sickle cell anemia, due to their characteristics of have high sensitivity and specificity.
- **Smart drugs[8,9]:** Drugs when injected inside the human body will be able to predict the specific location where the human cells have been contaminated, and then release a precisely targeted drug dose (Peppas et al., 2004).
- Biochemist Susan Hardin and four University of Houston colleagues are developing a new technology for direct molecular sensing that could be used to sequence an individual's entire genome—the gathering of all the genetic information contained in a person's DNA—in less than 24 hours, rather than 2–3 days.
- **Quantum dots[10]:** "Quantum dots" are nanoparticles made out of semiconductors having unique electrical and optical properties (Jiang, Papa, Fischer, Mardyani, & Chan, 2004; Jain 2005; Chan, 2006; Weng & Ren, 2006). They are specifically used for *imaging purpose* inside the human body. They demonstrate extremely high sensitivity.
- *S***ilver nanoparticles***:* As the term suggests, they are nanoparticles derived from the silver atom. A study conducted by the University of Texas and Mexico University found that silver nanoparticles can kill HIV-1, and is likely to kill virtually any other virus.
- **Regenerative medicines:** (Emerich & Thanos, 2003; Rajangam, Behanna, Hui, Han, Hulvat, Lomasney, & Stupp, 2006; Yamato & Okano, 2006) Regenerative medicine helps natural healing processes to work faster, or uses special materials to regrow missing or damaged tissue. Scientists at Northwestern University are working towards the development of regenerative medicines. They have successfully *grown nerve cells* using an artificial three-dimensional network of nanofibers. They have also developed a liquid that forms a gel-like mass of nanofibres on contact with water, which could provide the most promising vehicle yet for the *regeneration of damaged spinal cords*. Many scientists working in the area of regenerative medicine are trying to develop *artificial scaffolds* that store or attract cells, and then control their growth and final identity.

With such great applications, bionanotechnology can help in the reduction of the soaring costs of healthcare. It can help the healthcare system in the production of better and smarter drugs. Expenditures can be highly reduced along with the improvement in the quality of healthcare by the inventions of smaller devices for healthcare purposes and better surgical interventions. Moreover, with faster curing time, the number of days a patient would have to stay in a hospital will lessen significantly, resulting in lower costs of healthcare.

Although most bionano products are currently under research or production, there number has been increasing exponentially in the market. Some of the bionano products that are currently available in the market are *Abraxane* developed by Abraxis Bioscience[11], *M-DNA* developed by Advance Technologies[12], *PuraMatrix*[13] is 3DM Inc.'s patented product line of synthetic self-assembling peptide hydrogels invented