

The Current State of Bionanotechnology

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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. Biomolecular Nanotechnology—or Bionanotechnology—is a term coined for the area of study where nanotechnology has applications in the field of biology and medical sciences. One can also say that “Bionanotechnology” is derived by the combination of two terms: “nanotechnology,” and “biotechnology.”

BACKGROUND

The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big.

By saying the above lines, Richard Feynman, Nobel Prize winner in Physics, clearly expressed the importance of decreasing the size of a material to very small scale.

In mathematics, “nano” is defined as one billionth of a meter or 10^{-9} meter. However, the term “nanotechnology” has no one definition attached to itself. If you ask a number of scientists and scholars to define the meaning of nanotechnology, you are bound to receive a range of definitions for the term. However, a basic definition of nanotechnology can also be stated as “**engineering of functional systems at the molecular scale.**”¹ The following two lines help in expressing the idea of how small a nanometer really is:

1 meter = 1 billion nanometers²

Width of Human Hair = 80,000 nanometers³

Nanotechnology is often referred to as a general-purpose technology. That is because in its advanced form it will have significant impact on almost all industries and all areas of society. It offers better built, longer lasting, cleaner, safer, and smarter products for the home, for communications, for medicine, for transportation, for agriculture, and for industry in general.

Imagine a medical device that travels through the human body to seek out and destroy small clusters of cancerous cells before they can spread. Or a box no larger than a sugar cube that contains the entire contents of the Library of Congress. Or materials much lighter than steel that possess ten times as much strength.

- U.S. National Science Foundation

Nanotechnology 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. However, in the past few years, there also have been some great discoveries and inventions in this area of study.

APPLICATIONS OF BIONANOTECHNOLOGY

Bionanotechnology deals with nanomaterials and their applications in life sciences. The applications^{4,5} of bionanotechnology are vast. However, the bionanotechnology applications (Lin & Datar, 2006) can be broadly categorized into two main areas: therapeutics and diagnosis.

Nanotherapeutics

Nanotherapeutics is an application of bionanotechnology in which the diseases can be treated by the use of various techniques at molecular level. Nanotherapeutics can be categorized into three main areas of study and development: *drug therapy*, *gene therapy*, and *immunotherapy*. However, the current research is being conducted mainly in the former two areas of nanotherapeutics. In *drug therapy*, the potential of water-insoluble drugs or unstable drugs can be greatly enhanced by reducing the size of the drug or by encapsulating the drug particle. In *gene therapy*, functional genes can be efficiently delivered to correct genetic disorders like hemophilia. This can be done by condensing the DNA into nanoparticles,⁶ and hence controlling its composition for effective gene delivery.

Nanodiagnosis

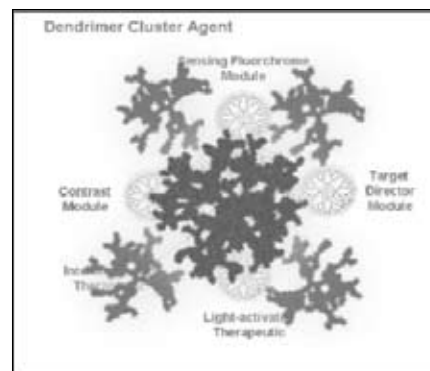
Because of nanotechnology, diagnosis of a disease will become not only easy, but also highly effective. We will be able to detect a malfunction in even a single cell at the very moment it becomes defective. As a result, we will be able to diagnose a disease effectively in its prime stage which would thus result in an early treatment of the disease, like cancer (Grodzinski, Silver, & Molnar, 2006; Jain, 2005), hence increase the chances of survival.

The reason for early diagnosis due to the implementation of nanotechnology is that nanotechnology operates on the same scale as biology. Moreover, due to the small size of nanoparticles, they will be able to gain access to areas of the body—such as the brain and individual cells—that have proved difficult to reach with current technologies.

In the paragraphs to follow, there has been an attempt made in order to give an insight of what is currently being done in the field of Bionanotechnology.

- **Dendrimers:** (Svenson & Tomalia, 2005; Figure 1) It is a three-dimensional, branched nanoscale molecule resembling the structure of a “tree.” The term “dendrimer” comes from a Greek word meaning “tree.” 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). Researchers at Northwestern University are work-

Figure 1. Baker's dendrimer: Multifunctional cancer treatment (Courtesy: Nanotechnology takes on cancer)



ing on cancer detection, and stopping it before it starts using dendrimers.

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.

- **Patient-specific medicine (Baba, 2006):** Every individual has a different genetic structure which is responsible for things like color of the hair, eye's color, shape of nose, and so on. Hence, each human being has a distinct predisposition to a disease. Therefore, 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.
- **Bionanosensors⁷:** 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

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