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Opinion

Nanobiotechnology: The Next Industrial Revolution

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Received: January 11, 2017; **Published:** January 25, 2017

Abstract

Nanotechnology means manipulating things at the molecular and atomic levels for the production of nanomaterials with wonderful properties. A living cell is the unique collection of nanomachines. For example the ribosome has the dimension of few thousand cubic nanometers and it can manufacture almost any protein as per instruction. A number of nanomachines are engaged in a variety of functions like conversion of carbohydrates to CO2 and use the heat generated in the biochemical reactions to perform life functions. There are many more nanomachines working in a biological system. These machines are highly sophisticated and have the capacity of self duplication in "bottom up approach". Those who want to create defined nanostructures should prefer this biological approach rather than "top down approach". The discovery of nanoorganism will give a sharp understanding for creation of sophisticated nanostructures. Nanoscissors developed in the biotechnology department at the university of Tokyo is a molecular scale scissors which is photo-responsive and extend or folds when light of different wavelengths fall upon it. The photoresponsive molecule is azobenzene. It will be a marvelous tool in genetic engineering.

Nanotechnology promises to revolutionize the way we detect and treat diseases. Tiny robots are on the anvil that would scour the insides of the human body seeking out troublesome germs and destroying them with laser. Such nanorobots could also deliver drugs at specified targets thus multiplying the effectiveness of drugs manifold and also leaving the surrounding healthy tissues untouched. Diseases like cancer would be the primary beneficiaries where a technique like chemotherapy kills even healthy cells in the vicinity of cancerous tumours. Especially relevant to Indian conditions this is a technology that involves pumping of nanomaterials into the ground where they can convert hazardous chemicals in the ground water into benign products.

Keeping in mind about all these consequences an optimized process has been developed for the biotechnological production of gallic acid (which is used mainly in pharmaceutical industries for manufacturing trimethoprim) by (Mishra P. and Mishra B.) [1] from the tannery effluents with the help of immobilized microbial cells, comparable to nanobiomachines. They can also be used for bioremediation of tannins from tannery effluents and tannin contaminated soils. In the years to come the nano-organisms may play a pivotal role in shaping the economy of a nation.

Keywords: *Nanobiotechnology; Nanoorganisms; Molecular Scissors; Azobenzene; Gallic Acid; Bioremediation*

Introduction

Nanobiotechnology involves biological research for use in technical applications and is described by the term 'Bio 2 Nano'. The prefix bio has slowly crept in between the words 'nano' and 'technology' providing a common arena for the researchers of nanotechnology and biotechnology and giving birth to the revolutionary living science Nanobiotechnology. Nanobiotechnology as part of Nanotechnology has gained increasing importance during last ten years, particularly in medical and pharmacological research opening novel prospective in analytics and therapy. It is an interdisciplinary field of research and is based on the co-operative work of chemists, physicists, biologists, medical doctors and engineers. At the interface between biotechnology and nanotechnology, nanobiotechnologists carry out researches on the phenomenon of self assembly or self organization of biomolecules in order to adapt these principles to the technical production of nano scale materials (nano particles, nano pores, nano shells, nano structures, etc).

Nanotechnology is a technology involving materials and devices at the nanoscale (1 - 250nm). The term nanotechnology was coined by Tokyo Science University Professor Norio Taniguchi to describe the dexterous manufacturing of materials at the nanometer level. In 1986 K. Eric Drexler wrote “Engines of Creation: The coming Era of Nanotechnology”, a work that introduced the public to the wider possibilities in the field. He talked about building machines, on the scale of molecule- a few nanometers wide, motors, robots, arms and even whole computer, far smaller than cells [2,3]. In spite of wide accusations and denunciation Drexler remained firm in his conviction and worked round the clock for developing incredible nanodevices. Nanotechnological researches is being carried out in many laboratories around the world particularly in U.S., Japan and Europe. Three fields of research have been seen as most relevant like protein design, biomimetic chemistry and atomic imaging and positioning. Major advances in protein design have been made in the last three years. Biomimetic or supramolecular chemistry is bringing some of the characteristics of natural molecular machines to new designed ones. Individual atoms are being seen and increasingly positioned using new scanning probe microscopes. Therefore nanotechnology can best be considered as a “catch all” description of activities at the levels of atoms and molecules that have applications in the real world. Obviously nanotechnology is an anticipated manufacturing technology, leading to the production of machines or devices at the nanometer scale. Manufactured products are made from atoms. The properties of those products depend on how those atoms are arranged. If we rearrange the atoms in coal we can make diamond. If we rearrange the atoms in sand (and add a few other trace elements) we can make computer chips. If we rearrange atoms in dirt, water and air we can make potatoes. In the quest of the materials with novel properties, the two approaches have been used for creating nanodevices. Scientists refer to these methods as the ‘top down approach’ and the ‘bottom up approach’. The top down approach involves decreasing the particle (material) size to the nano range in order to have devices with desired novel properties. This approach has traditionally been used in making parts for computers and electronics. The bottom up approach involves assembling structures atom-by-atom or molecule-by molecule to design novel materials. This approach is followed by the living system and may prove useful in manufacturing devices used in medicine.

There is no limit as to what we can achieve by the above two methods. The greatest motivation for novel designs at nanolevel comes from the living system because life consists of a whole collection of nanomachines. Let us consider following facts:

(i). Living cells replicate independently and use compounds in the nanorange for the formation of genetic material, protein, cell enclosures including cell membrane in the bottom up approach. A seed stores the instructions to create a vast tree like Banyan or Margosa and also for a simple plant like tomato and potato. Thus with right instructions an assembler could make products in an analogous way. Thus they can be called as assembler. The nanotechnologist should create such self replicating assemblers. Development of this technology will result in building of products as cheap as the copying of files in a computer. Really it is a renaissance of technological revolution bringing together the Information Technology (IT), Biotechnology (BT) and Nanotechnology (NT) giving a common ground for research and development, the Information nanobiotechnology (INBT). We may call it computational nanobiotechnology (CNBT), wherein with appropriate molecular CAD software, molecular modeling software (including available computational chemistry packages e.g. molecular mechanics, semi empirical and ab initio programmes) and related tools, one can plan the development of molecular manufacturing systems on a computer just as Boeing might ‘build’ and ‘fly’ a new plane on a computer before actually manufacturing it. The INBT is going to determine the way we live and prosper in future.

(ii). Human brain is the best and the fastest computer.

(iii). The eyes and the connected vision machinery is the most sophisticated camera.

(iv). Heart is the most efficient pump which starts functioning in the mother womb and works with utmost fidelity for the whole life. Think when INBT makes such machine which requires neither rest nor repair.

(v). How nature (biological system) stores information and fabricates structures at the nanoscale?

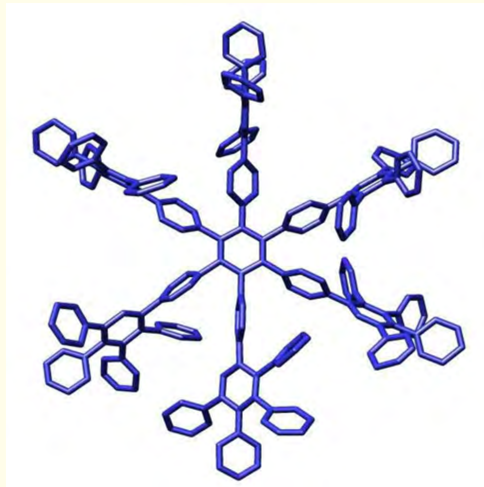
(vi). Ribosome is a nanomachine which can manufacture almost any protein by bringing together the instructed aminoacids in a precise linear sequence.

The basic functional unit of all the above systems are biomolecules or supramolecular assemblies in nanoscale. So the simple mantra is to understand the nanoscience of the living system and then mimic and even excel in designing nanosized novel materials and intelligent devices for engineering and biomedical applications. According to Eric Drexler, the nanotechnology will render the traditional manufacturing process obsolete. Because the techniques of nanotechnology will be able to copy themselves, assemblers will be inexpensive. In its advanced form, nanobiotechnology is expected to offer better built, longer lasting, ecofriendly, safer and smarter products for home, communication, medicine, transportation, agriculture and for industry in general. The production of nanocement is in offing. It is made with environment friendly nanoparticles that offer very high resistance. This type of cement will result in reducing the global green house effect and thus we can achieve 100% of Kyoto protocol.

Nanobiotechnology may have its biggest impact on the medical industry. The technology is widely recognized as a great opportunity for disease prevention (e.g. improved food safety), early disease detection (e.g. sensors for cancer detection) or medical treatment (e.g. controlled drug delivery by nanocapsules) it could also mean the end of diseases. For instance if somebody suffered from cold or fever, he/she would just have to drink a tea spoon of liquid containing an army of molecule sized nanorobots programmed to enter into body's cells and fight viruses. In case of genetic diseases, the patient would have to ingest nanorobots that would burrow into DNA and repair the defective gene. This technique could even eliminate traditional plastic surgery, as medical nanorobots could change one's eye colour, alter the shape of the nose, or even give a complete sex change without surgery. It would be interesting in surgery if one could swallow the surgeon itself. This nanosurgeon when put inside the blood vessel it goes into the heart and looks around. It finds out which valve in the faulty one and takes a little knife and slices out. Other small machines might be permanently incorporated in the body to assist some inadequately functioning organs. This is what INBT is doing. A DNA based computer that can perform a billion operations per second is already a reality. We would have nanocomputers interfacing directly with brain, thereby vastly increasing human intelligence. So far as the detection and eradication of cancer, the most dreaded disease of the century, is concerned the nanobiotechnology seems to be a boon to the ailing humanity. To detect cancer, scientist can design beads containing quantum dots (tiny crystals that glow when they are stimulated by UV light) to bind to sequence of DNA that are associated with cancer. When the quantum dots are stimulated with light, they will emit their unique bar codes, or labels, making the critical, cancer associated DNA sequences visible. The vast number of possible combinations of quantum dots mean that scientists can create many unique labels, which can be used at the same time. This will allow scientists to look simultaneously at numerous regions of DNA. This will be important in the detection of cancer, which results from many different changes within a cell.

Nanobiotechnology may also be useful for developing ways to eradicate cancer cells without harming healthy, neighbouring cells. Scientists hope to use nanobiotechnology to create therapeutic agents that target specific cells and deliver the toxin in a controlled, time release manner. INB Technologists aim eventually to create single agents that are able to both detect cancer and deliver treatment. The ultimate goal of this research is the creation of nanodevices that will circulate through the body, detect cancer associated molecular changes, assist with imaging, release a therapeutic agent, and then monitor the effectiveness of the intervention.

Research is being done on a number of nanoparticles that will facilitate drug delivery. One such molecule with potential to link treatment with detection and diagnosis is known as a dendrimer. A useful feature of dendrimers is their branching shape, which gives them vast amounts of surface area to which scientists can attach therapeutic agents or other biomolecules. A single dendrimer can carry a molecule that recognizes cancer cells, therapeutic agent to kill those cells and a molecule that recognizes the signals of cell death.



Dendrimer: Crystal structure of First Generation Polyphenylene Dendrimer. (Courtesy: Mullen., et al. – Eur. J. Chem., 2002)

Researchers hope to manipulate dendrimers to release their contents only in the presence of certain trigger molecules associated with cancer. Following drug release, the dendrimers may also report back whether they are successfully killing their targets. The molecular scale nanoscissors developed by Prof. Takuzo Aida and his team of the Department of Chemistry and Biotechnology at the University of Tokyo will be actually a marvelous tool in the hands of genetic engineers [4]. The scissors measure just three nanometers in length, small enough to deliver drugs into cells and manipulate genes and other biological molecules. This scissors like nanomachine uses a photoresponsive chemical group that extends or folds when light of different wavelengths fall upon it. The photoresponsive molecule is azobenzene. The discovery of nanobes and nanobacteria is challenging our perception of life and making it polemical. Microbes have already expanded our understanding of the harsh conditions that can support life. So if nanobes do exist as living biota, they will broaden our perspective on the scale of life. Robert Folk, a sedimentary geologist from Austin, Texas, is known as father of nanobacteria. Folk asserts that nanobacteria are the key players in mineral formation of geological strata. Using acid etching and gentle cold shadowing techniques he was the first to demonstrate the presence of 0.05-0.2 um spherical structures in an assortment of geologic materials. Nanobacteria have been found in human blood and may be related to health issues such as the kidney stones due to their biomineralization process. Nanobacteria are also thought contribute to cataracts.

The utility of nanotechnology is unlimited. The nanotech based soil binder 'soil set' can be used in mountain area to prevent soil erosion. Nanosensors are used for monitoring soil quality and plant health. Dr. Wei-Xang Zhang, ETC, Ottawa, Canada, has pioneered a nano clean up method of injecting nano-scale iron into a contaminated site. These iron nanoparticles flow along with the ground water and decontaminate the soil, which is much less expensive than digging out the soil to treat it. The nanomembranes can be used for water purification, desalination and detoxification. The nanomagnets coated with chitosan can be used to remove oil and other organic pollutants from aqueous environments. The airborne nanorobots could be programmed to rebuild the thinking ozone layer. It is the nanotechnological achievements that you are going to get self cleaning glasses, clothes that never get dirty and also measuring pulse and respiration rate, corrosion less paints and paints that change colour on command.

After performing variety of experimental designs set up Mishra and Mishra [1] have optimized a process for the biotechnological production of gallic acid by using the native as well as the mutant microbial communities. Gallic acid (3, 4, 5 trihydroxy benzoic acid) is an organic acid of immense commercial importance. It has a broad spectrum of utility in pharmaceutical, food and other industries. It is used in the production of Trimethoprim (TMP), a broad spectrum antibiotic. A combination of TMP and sulphonamide is active against many otherwise resistant bacteria. The immobilized microbial cells, comparable to nanobiomachines, have been used for the production of the enzyme tannase (Tannin Acyl Hydrolase). This tannase converted the hydrolysable tannins of the tannery effluents into gallic acid. They can also be used for bioremediation of tannins from tannery effluents and tannin contaminated soils [5-11].

The nanotechnology is a marvelous technology provided it is used judiciously and ethically for the welfare of humanity and not for warfare.

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Volume 5 Issue 4 January 2017