

NANOTECHNOLOGY IN BIOMEDICAL APPLICATIONS

The world is on the brink of a new technological revolution beyond any human experience. The genomic revolution, cellular drug delivery, spinal cord repair, stem cells, cancerous tumours, HIV, AIDS, anti-aging, etc., are some of the medical breakthroughs being brought to us by researchers working in the new emerging field of nanotechnology, a term first used by Dr Erick Drexler of Stanford University, California, USA.

Nanotechnology is molecular manufacturing or building things one atom or molecule at a time with programmed robots. It is the shotgun marriage of chemistry and engineering with enormous applications in medical sciences. A nanometer is one billionths of a meter, i.e. a thousand, million times smaller than a meter.

Nanomaterials or nanomachines are small and bumpy, about 3-4 atoms wide, solid, colloidal and too small to see with a microscope. The nanomaterials can be polycrystalline or amorphous and may belong to inorganic, organic or combination of both classes of materials. These are a fraction of the width of a human hair that would go into the human body to locate and carry out the molecular surgery, where it is required.

DNA microarrays or gene chips are used to study gene activity. It was first proposed in 1991 when the decoding of the human genome had just begun. In 1999, a group of scientists at the Massachusetts Institute of Technology (MIT), USA performed an experiment that helped establish the importance of microarrays to the research community, particularly to those carrying out research on cancer. The MIT group took Affymetrix (Affymetrix Inc, Santa Clara, California, USA) chips containing 6,8000 human genes and used them to analyze the expression of genes in cancer cells from two types of blood cancer, namely acute myeloid leukemia and lymphoblastic leukemia. A standard pathology examination finds it difficult to tell them apart. But the arrays showed a set of 50 genes that had different activity levels in these two types of cancers, and these genes could be used to distinguish symptoms accurately between the two diseases in patients.

One of the most stable and common DNA sequence variations across the human genome is called Single Nucleotide Polymorphisms (SNPs), which can also be studied by microarrays. SNPs are variations or mutations at a single spot in a gene's sequence. Since single-stranded DNA prefers to hybridize only with its perfect complement, arrays can determine the presence of such a mutation. SNPs are thought to be key to why people vary in their susceptibility to diseases. Nanoshells, a new application of nanotechnology, developed by Dr Naomi Halas and Dr Jennifer West, Rice University, Texas, USA, has provided instantaneous blood test results in 20 seconds. These are layered particles and can absorb the wavelength of light. They are designed by varying the thickening of the nano particle's layers. Antibodies remain active on nanoshell surfaces and can be detected by Raman spectroscopy in whole blood. Raman-scattered light tests the presence of viruses in a very analogous way. The nanoshells, which can be used in clinical or emergency medical testing, have a real impact in critical care medicine and general public health. In tissue engineering, Scaffold, an instantaneous HIV test, would certainly be a medical powerful tool in identification of this disease. Surgeons in Cornell Centre, New York, are able to avoid traditionally big incision by using a very small camera and putting a minor incision in the organs and they can watch the turnover and the disease on the video monitor. The patient does not feel pain even under such circumstances. According to Prof Stephen Woulfrom of Illinois University, USA, cellular operation system would finally become the base of computer, clubbing naturally operated systems like nervous systems and the genetic cells for reproduction of human beings. But how the reproduction as well as the work of repairs takes place is not known. Woulfrom said the word "Life" has to be eliminated. It is of no use; the machine would reproduce on our own instructions.

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rightly pointed out that, in future, the physicists may require help from biologists, since the cells do their work on nano level for all operations. Nanotransistor, developed at Central Electronic Engineering Research Institute (CEERI), Pilani, India, has been clubbed by plasma processing. It is highly economical.

In drug delivery, biomedical scientists are working on molecules that can be encapsulated within a shell such as liposome vesicles. The shells allow drugs to be released in a controlled fashion. Scientists are also searching ways to functionlise the shells for site-specific targeting and sensing applications. The shells could enter the cells and leave few molecules of a particular drug behind and then leave the cells intact and alive. Such novel drug delivery systems would provide opportunities to fight diseases like cancer, HIV and AIDS. Besides, the cost of drug development can be reduced by using nanochips to test various medications or combinations of chemicals. In future, better understanding of the interaction between the nanoparticles and the phagocytic cells is expected. Improved understanding of delivering the particles at target sites will also evolve a convenient method of site specific delivery. In this regard, The Photonic Materials Research Group at the Department of Materials, University of Leeds, UK has developed fluoride glasses as hosts for the 1.3 μm optical fibre amplifier, which is used in medical diagnosis. The range of applications of photonics extends from energy generation to communications and information system. The three systems of hydrophilic polymeric nanoparticles reviewed hold a great promise of maximizing drug effectiveness with minimising drug toxicity. Nanotechnology has already reached dynamism and new tools and discoveries are being published. Recently, scientists at Kassel University, Germany developed the smallest thermometer, which detects smallest differences in a microchip (so called hot spots). The researchers used a nano-wire (diam, 100 nanometer), which measures the temperature precisely up to 0.0010°C. Another method based on quantum-dots, the semiconductor crystals can analyze genes faster than gene chips and make it easier for researcher to alter their experimental designs, which may be more economical. Scientists from Indiana University Bloomington, USA, recently created a quantum-dot based analysis tool that identifies as many as 40,000 genes in 10 min, whereas gene chips can take as much as 24 hrs. Moreover, the speed and flexibility of quantum-dots are a great improvement

over gene chips. It is only over a long term, however, that the human genome will really make its mark on health care. Large-scale gene therapy is currently 20 to 30 years away, but when it finally arrives, hopefully it will totally transform the disease treatment. Gene therapy involves permanently changing the genetic code in a group of cells or in an entire organism, so that the body's own cells begin to produce a required therapeutic protein. In theory, scientists already have the technology to perform gene therapy (it is not much different from creating genetically modified crops) and there are a number of gene therapy clinical trials currently being conducted in Europe and the USA. However, there are currently too many hidden facts with the technology for gene therapy to become widespread any time in the near future. By using a person's saliva, body fluids or blood, nanobiosensors can be created to reliably detect, monitor, and measure pathogens such as viruses like AIDS, which averages 100 nanometers.

The global market for nanoparticles in biomedical, cosmetics, and pharmaceutical applications is expected to grow at 8.3 % per year, to US \$ 144.8 million in 2005. Other major markets for nanoparticles include electronic and magnetic applications, such as chemical, mechanical polishing slurries, magnetic tape coatings, and optical fibers. Electronic and magnetic markets generate a combined total of more than US \$ 330 million per annum in sales and are likely to grow 14.9 % per annum through 2005. Worldwide sales of products based on nanotechnology already amount to US \$ 30 billion in Europe, and growth rates of 10% are forecast.

Despite the potential benefits of nanotechnology, many ethical, religious, philosophical, and legal questions exist. "Whenever a very potent and powerful tool becomes available, ethical questions will arise", said Dr Banu Oranal, Director of Drexel's School of Biomedical Engineering Science and Health Systems, Philadelphia, Pa, USA. Nanotechnology has increased our understanding of the human genome, which may ultimately result in the eradication of many common diseases, but in the meantime we need to be on guard against potential misuse of genetic information and we should proceed with caution. Eventually, every country must decide how genetic information should be protected, and how it may be used. Besides, government must ensure that public realizes practical gain from their investment in genetic technology and the public also must understand the benefits of new technologies so

that unsounded fears will not develop. Nanotechnology heralds a new age of biomedicine with enormous benefits for the general public. It will allow researchers to identify all the genes contributing to a given disease for which they are at risk. It gives an opportunity to change our life style for better living or to take preventive medications to protect our health. Proper understanding of the genetic bases of hereditary diseases will also allow researchers to develop therapeutics at the molecular level, resulting in better treatments with negligible side effects.

Nanotechnology has a bright prospect; the only thing is to protect the human rights from the possible misuse of technological and scientific applications and their economic and commercial exploitation.

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