

# Nanotechnology: The Start of a New Revolution?

By

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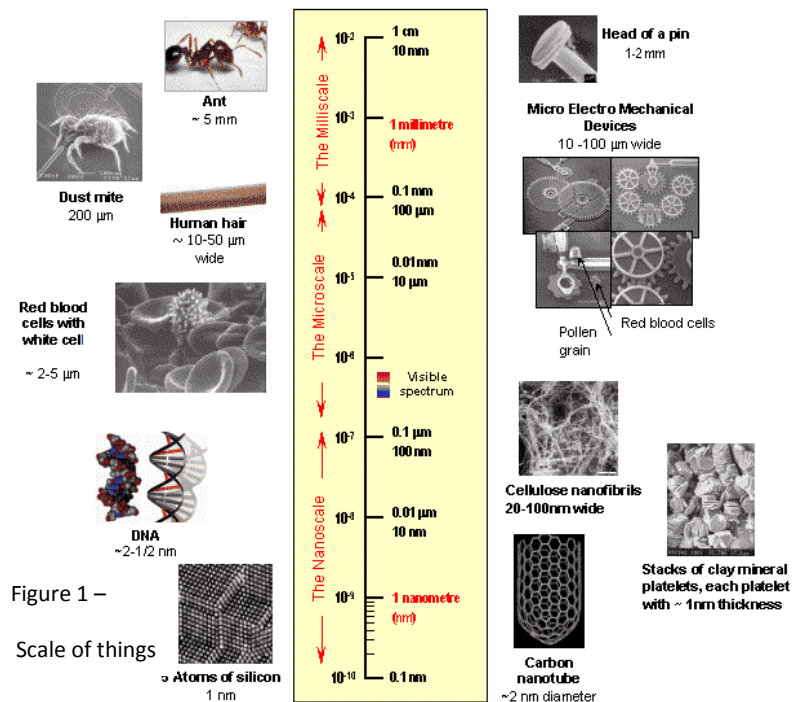
Research Paper Based on Pathology Lectures at Medlink 2010

## Abstract

This paper has two main purposes. The first is to describe what Nanotechnology (NT) is and how it works. I began this project with barely any knowledge around the subject of NT and from the lectures at Medlink 2010 I greatly understood that NT is the upcoming and most profound area of science in the research world at the moment. The second is to describe how NT will revolutionise medicine. I have wanted to work in medicine for as long as I can remember and by the time I get there NT could be a leading method of medication. As I have learnt more and more about NT I have been increasingly led to the conclusion that NT is going to cause a scientific revolution but there will be drawbacks and disadvantages that follow this siege just like in any other rebellion.

## Introduction

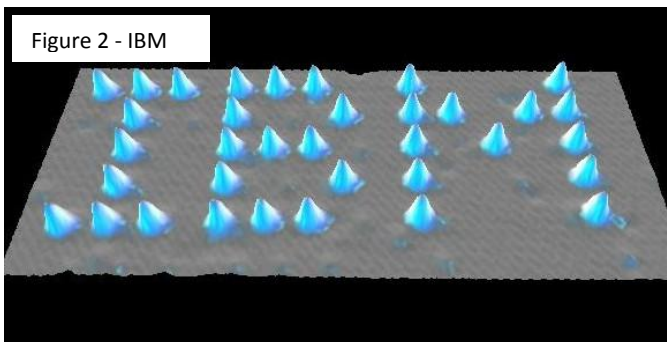
NT is a subtopic in the area of nanoscience. Nanoscience has actually been around for hundreds of years. Scientists such as Einstein incorporated the size of a sugar molecule into his doctoral dissertation and calculated that the molecule is the size of one nanometer. The new thing about nanoscience is the determined spotlight on the developing application of technology which includes all the leaps in the right machinery needed to make



NT work. The definition of NT can be complicated and result in different meanings to different people therefore the National Nanotechnology Initiative designed a committee and they said that NT is the understanding, research and control of material in the range of 1nm to 100nm. It is the engineering and manipulation of this matter at this atomic scale to create structures that have unique novel properties owing to their tiny size. One nanometre is the same size as one-billionth of a metre. The naked eye can only see approximately 20 microns and a micron is around one-millionth of a metre. Even using an optical microscope we still can only see approximately 1 micron.

To understand NT you need to understand what matter is. Matter is everything, our clothes, food, air; it is anything that has a mass and volume. It can also be said that it has three

principal forms, gas, liquid or solid. Matter has properties and these properties are dependent on their size therefore properties of matter change when they reach the nanoscale and this is where you reach the area of Quantum Mechanics, which is the study of matter and radiation at the atomic level. The raw materials of NT are the chemical elements and these elements are known as the building blocks of matter. An element only consists of one type of atom, the simplest substances, therefore whenever you talk about an element it will always be an element even when associated with the nanoscale. The smallest quantity of an element is an atom and an atom is the microscopic structure found in all matter. Atoms are tiny; they can range from 1 to several nanometres wide so a nanoparticle is made up of a number of atoms that measure between 1nm-100nm in diameter.

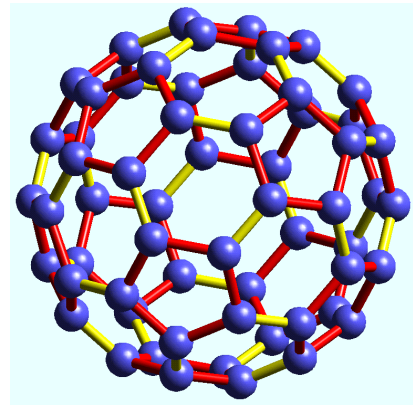


In 1989 a group of scientists at the IBM Research Centre in San Jose, California designed an experiment that involved the manipulation of atoms. They took 35 atoms of the gas Xenon and used them to write the letters 'IBM'. In order to get the atoms into the correct position they had to

use a specialised tip on a scanning tunnelling microscope (STM) to push and move around the atoms. Each atom was moved precisely into position, half a nanometre away from one another. In the picture above, each bump is an individual atom.

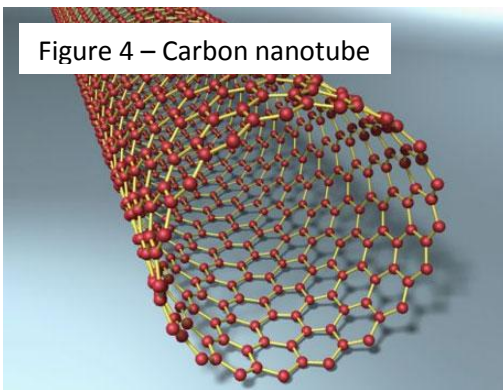
In that last paragraph I mentioned a STM; this is one of the tools that can be used in NT. This tool is involved in Microscopy. These tools reveal the composition of matter by allowing you to see the surface features of atoms or molecules. The STM offers the best resolution out of all the available measuring and imaging tools. STM uses an electric current that starts to flow when the tip gets close to a conducting surface. The tip is approximately the size of a single atom and it sits on a piezoelectric tube. When voltage is passed through the tube you can adjust the electric current to keep it constant, keeping the tip at a constant distance away from the sample being scanned. The movement of the piezoelectric tube is recorded and then an image can be created showing the surface of the sample. With this method you can see individual atoms on the surface. Another method is a Scanning Electron Microscope (SEM) creates images of tiny matter by shooting them with beams of electrons and can show features on a scale as small as 10nm. The electrons of the beam break off the electrons of the matter under investigation, the dislodged electrons are then passed onto a positively charged grid in which they are translated into a signal. Once signals have been found from different sides of the sample the SEM can build up an image of the surface on a computer. Other techniques include Transmission Electron Microscope (TEM), Atomic Force Microscope (AFM) and Magnetic Resonance Force Microscopy (MRFM). These are only microscopic techniques. There are also techniques involved in Spectroscopy.

Figure 3 - Buckyball



Carbon atoms are very important in NT. Buckyballs and carbon nanotubes are two different types of molecules that are made up of carbon atoms and they lead to lots of different applications in NT. A buckyball is the shortened name for buckminsterfullerene. It contains 60 carbon atoms with each carbon being bonded to 3 other carbon atoms, very similar to the structure of graphite. But, in a buckyball the carbon atoms form a sphere that is approximately 1nm in diameter. Owing to the properties of carbon atoms (they can bond to lots of different types of atoms), researchers are using them to create customised molecules.

Figure 4 – Carbon nanotube



In 1959 a man called Roger Bacon was the first to produce images of carbon nanotubes and his work was then followed on by lots of scientists and researchers. In the 1980s Howard Tennant requested a patent for a method produce carbon nanotubes and then in 1990 Richard Smalley contemplated the concept that if buckyballs became big enough, they could turn into carbon cylinders. In 1991 Sumio Iijima (a researcher from the NEC's Fundamental Research Lab) collected up all the theories and came up with an explanation of what nanotubes actually are. To do this he placed a sample of carbon soot that contained buckyballs in an electron microscope and produced photographs of buckyballs but also was drawn to some strange needle-shaped structures that were also in the picture. These needle shapes were cylinders of carbon atoms that were formed at the same time as the buckyballs. Similar to buckyballs these cylinders had their own lattice of carbon atoms with each carbon atom bonded covalently to 3 other carbon atoms. Therefore buckyballs and carbon nanotubes are very similar but, the ends of the nanotubes do not form a sphere, they never close and therefore have a cylinder shape.

There are different types of nanotubes. Some are single-walled carbon nanotubes (SWNT) or they are multi-walled carbon nanotubes (MWNT). SWNT consist of a single cylinder and MWNT consist of multiple concentric cylinders.

Dr. Mihail Roco is a man who works as a senior advisor for the National Science Foundation (NSF) and he came up with the thought that NT will develop in staged. According to him we are now in the third stage of development. The first stage consisted of the use of nanostructures and simple nanoparticles that were designed and formed to carry out one task. In the second stage, scientists and researchers have found ways in which to construct nanoscale building blocks that are able to be assembled in different structures. They can be flat or curved structures like bundles and tubes and these hold huge potential for

revolutionary drug delivery systems in medicine. The third stage, in which we are in now, involves the development of nanosystems that have thousands of interacting components that will lead on to molecular nanodevices that can operate in a similar way to a human cell. Then he has also come up with a fourth stage that predicts from 2015 to 2010 the NT field will continue to expand in a way that includes molecular nanosystems serving distinct services all around the world.

## Discussion

A recurrent dream in the existence of humans is that human beings want to live long; healthy, happy, pain-free lives and those humans will continue to invest time and money until they have obtained this goal. NT seems to be giving us a sense if this dream almost becoming reality.

NT is also going to become commonly used in drug delivery. The main goal is to find ways to get the necessary drug to the specific sites of the body that need them so, a delivery mechanism needs to be developed that holds the drug, this needs then to be able to be inserted into the blood stream and then has to be able to release the drug at the specific site that needs it. If we can design this mechanism we can revolutionise the drugs needed to kill cancer cells like chemotherapy. This not only kills cancer cells but kills healthy cells too and also has severe side effects. If these drugs can be directed straight to the cancer site then the effect on healthy cells will be greatly reduced and side effects could hopefully be decreased.

The building block to the delivery mechanism are molecules called amphiphiles. Amphiphiles have a hydrophilic head and a hydrophobic tail. These can dissolve in water but they prefer to keep their hydrophobic tails away from the water molecules therefore they group together and create spherical structures called micelles. At high concentrations micelles can form bilayers, which is a reverse-micelle surrounded by a regular-micelle. These are called vesicles which are actually very similar to biological cells. Vesicles are a microscopic structure that is able to package delivery drugs to specific locations around the body. They can go through both endocytosis and exocytosis processes. They act as liposomes.

The main thing attacking the bodies of the population now is cancer. The body is always producing new shells to replace old ones, the damaged ones and the ones deliberately killed by apoptosis. But, sometimes mutations can occur resulting in new cells being produced that the body doesn't need and the old cells don't die away. This is the general basic definition of cancer. Cancer cells are able to completely bypass apoptosis and form an unwanted mass of tissue known as a tumour. The National Cancer Institute (NCI) has made a list of the 4 areas of the body that are most common to form cancer. They are: prostate gland, breast, lung and colon. Nanospectra Biosciences, Inc., is a company that focus on the potential for nanoparticles to eradicate cancer. One of the things they are researching

involves a glass bead that has been coated in gold. These are called Nanoshells. The plan is that they can be used to absorb the cancer cells and used for imaging the cancer cells. They can do this because they use gold. Gold is an inert metal that is able to absorb light and it is also biocompatible with the body therefore can stay in the body without causing things like corrosion. At Nanospectra Biosciences, Inc. they create the nanoshells. They do this by growing perfect silica or glass cores. These cores are then coated in an amine which acts as an attachment mechanism and the process of attaching groups of molecules with a specific function is called functionalisation. A carbon-60 is used as the support structure and the functionalising the side chains. The amine acts as glue, attaching the gold particles to the glass core. This then has to undergo further chemical reactions making more gold particles attach to the core and then resulting in a shell being formed approximately 10nm thick. At the moment this nanoshell is not really doing anything until medical applications are applied. Antibodies are attached to the outside of the nanoshell because they are the body's way of detecting foreign substances. These complete shells are then injected into the body. They attach themselves to the cancer cells and only the cancer cells, they do not attach themselves to any other type of cell in the body.

They have already experimented on mice with which they injected them with tumour cells. When the tumours reached a particular size the nanoshells were injected and after 6 hours (allowing enough time for the nanoshells to reach the cancer cells), an 808nm laser was used to activate the nanoshells. Their results showed that the mice treated with nanoshells had no sign of the tumour and lived the full 60 days, the mice that were only treated with a laser or without any treatment at all were euthanized by Day 19 or when the tumour had grown to more than 5% of their body weight. This treatment gives massive hope into the eradication of cancer. After years of development and experimentation this could be a method in which cancer could be abolished. The procedure involves very minimal invasiveness and actually has shown to destroy cancer cells. Cancers that appear on the body's surface have the greatest potential of eradication because the laser light is most effective in these areas (includes breast and prostate). Another advantage is that they can be used as treatment in detection. Scattering can be used to find where nanoshells congregate therefore patients could visit their doctors periodically, be injected with nanoshells to search for different types of cancer and these could then absorb the tumours within a very short period of time. Up until now Human trials have not been underway.

Glucose is the primary source of energy in the human body and when the glucose blood levels are not regulated properly a person can develop diabetes. The American Diabetes Association estimated that there are approximately 17 million people in the USA with diabetes a third of which are unaware that they have the condition. At the moment there is no cure. NANOBOTS? A group of researchers are trying to use nanobots as a treatment for diabetes. These nanobots are embedded into nanobiosensors in the body to monitor the body's glucose levels. The sensors provide signals that can send messages to the patient's mobile phone. If the glucose level is too low then the nanobots activate the mobile to give

out a tune and alerts the patient to take action. This has the potential to become a more convenient and safer way for collecting data from the patient.

For a diabetic, monitoring blood glucose levels can be tiring. Researchers in Georgetown Advanced Electronics Laboratory (GAEL) are working on developing a biosensor device that monitors blood glucose. The biosensor is a small adhesive patch which is designed to be able to be worn anywhere on the body. The biosensor samples tiny volumes of fluid that just lie beneath the skin. Advantages of this development include that it is small, convenient, pain-free and non-invasive.

Cardiovascular disease (CVD) kills millions of people every year and NT has found a way that could possibly prevent these deaths. CVD is sometimes caused by the building up of atheroma in the arteries surrounding the heart. Current procedures take time in order to get right which creates massive pressure when you have someone who is a stroke victim and needs immediate, fast help. A solution that researchers are working with now is that you should just work with the vessel that is blocked by using a stent. A stent is an expandable wire mesh that is inserted into the vessel and keeps the vessel open. The procedure involves a balloon being placed at the site of the blockage, it is then inflated to make enough space for the stent, and the balloon is then deflated and removed leaving the stent in position allowing blood to flow normally. This is a good approach but with NT we can make it much better. Stents are not problem-free because they can cause a serious condition called Thrombosis.  $\diamond$ . A company in San Antonio, Texas called Advanced Bio Prosthetic Surfaces (ABPS) are coming up with a solution to the problems associated with stents. They have used the combination of technology from the semiconductor industry alongside the medical industry and came up with the extraordinary idea of using shape memory alloys as the material for stents. Shape memory alloys are a really good idea because they are able to move and change shape but they will always return to their original shape. At ABPS they have come up with a new method of making stents that involves NT. They take a shape memory alloy such as Nitinol, make it into the correct shape needed and then cover the stent with nanocorporous coating. This makes the stent less likely to cause inflammation to the vessel and also makes it thinner, stronger and more flexible. Another advantage to these new stents is that it promotes surrounding tissue incorporation and endothelialisation.

## Conclusion

NT is going to change the world. The methods that I have described show that two of the biggest killers, cancer and CVD could partially be eradicated within the next few years. This led me to think about other conditions that NT could help, like obesity. One day it could be possible for methods to be created that increase metabolism, burn fats within the body at a faster rate or even reduce the size of the stomach. These would all lead to a healthier population, increasing work force and life expectancy. It could be possible for medication to be delivered to a patient with a mental illness, making them more stable. NT could be used

to increase fertility, changing IVF into a method with fewer risks. NT could even be used in cosmetics, for example change the way in which botox is injected or how make-up is applied to the skin. Another huge killer is malnutrition. What if NT could be used to provide ways in which nutrients could be given to small children or ways in which it could help the production of food and crops. NT can lead to an increased standard of living, longer life expectancy, healthier population, stronger workforce and so on. Advantages could also include less cost towards the NHS in the long run as less money will be needed to be spent on cancer sufferers and their treatment, there will be less strain on nurses and doctors in hospitals, less money will be needed to be spent on the elderly as they will be healthier. Disadvantages of NT do include the expense of discovering the different methods of its application. Also because it is a relatively new we are unaware of the long term effects of NT. At the moment the advantages outweigh the disadvantages but we cannot forget the disadvantages, they have to be taken into account to a higher extent when human lives are involved.

NT is going to change the world in ways that I never thought could happen. It really is going to revolutionise the methods of treatment making it easier, more comfortable, and more successful with fewer side effects and a decreased chance of infection. It is going to eradicate illnesses, help conditions and increase the quality of life.

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