

NANOTECHNOLOGY -
BRINGING THINGS
DOWN TO SIZE

BY

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PASS WITH MERIT

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ABSTRACT

Nanotechnology is a relatively new advance in the field of medicine. However, there are many different ways and many different conditions in which nanotechnology can be used for treatment. A continually developing practice is the use of nanotechnology in drug delivery. There are many different conditions where sufferers could benefit from the use of nanotechnology. This paper will identify and discuss this method as an alternative and future prospect of drug delivery for different conditions.

INTRODUCTION

Nanotechnology is the manipulation of matter at an atomic scale. One nanometre is equal to 10^{-9} m; the diameter of a single human hair being 200,000nm. Nanotechnology is not about trying to minimise the size of objects, but looking at bringing together many small molecules to create a bigger picture. Nature works on the principle of using lots of smaller matter together to create a bigger object. Here is where we have taken our developmental inspiration from nature, manufacturing ways in which matter can be manipulated at its smallest level to have a big impact over all. The decrease in size of structures is simply an effect of nanotechnology. If it is found that the same outcome can be achieved from a smaller process, there is no reason for the structure to be any larger. The world of science is riddled with constantly evolving understanding of nanotechnology. Both chemists and physicists can have their part in making nanotechnology a more widely recognized and accepted concept. The physical science of nanotechnology focuses on the atoms themselves. The chemical science of nanotechnology, however, focuses more on the structure of the molecule as a whole. It also investigates the physical and chemical properties on the molecule and the possible uses, bases itself on these. When studying nanotechnology it is sometimes hard not to get carried away into a world of fantasy science. A world where everything is miniscule, where humans are seen as giants, covered in metal plates and wires, controlling different aspects of our existence. However, the uses and developments in nanotechnology can be useful in the real world too.

Nanotechnology is behind the scenes of many everyday products. An example comes from products marketed as scratch-resistant or ultra-smooth (E.g. self-cleaning glass). In these cases nanotubes are aligned on the surface of the material to create an ordered and level surface. Nanotechnology also has its part to play in cosmetics. Nanoparticles are

used in many new sun-screens. Here, nanoparticles of titanium dioxide are used; they reflect the light and ultraviolet radiation to stop it being absorbed by the skin, all without the normal white streaks of sun-screen. Nanoparticles are also used in make-up products. Products which claim to have 'perfect coverage' use nanoparticles so that the product forms a layer over the skin.

The first development of nanotechnology came in 1985, where four scientists from Rice University, Houston discovered a stable form of carbon with an Atomic Mass of 720. Later work conducted by Smalley found a sphere of twelve pentagons and twenty hexagons was the only way the atoms could be arranged to form this structure, matching all the properties found. The stability of the structure came from the closed-cage arrangement, shown in Figure 1.

Figure 1

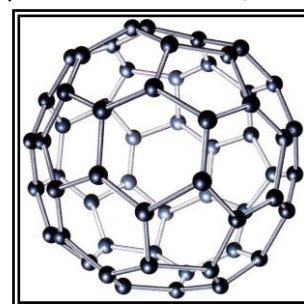
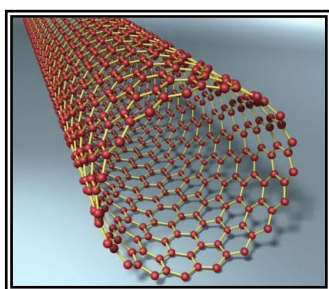


Figure 2



After this enormous development into investigating structures of carbon, other research was fast to follow. In 1991, a Japanese scientist, Sumio Iijima discovered carbon nanotubes. These were what looked like layers of graphite folded into tubes. They often had two or three layers to them, and varied in width from three nanometres to thirty. Figure 2 shows the arrangement of the carbon atoms, here seen as red in the molecule. Nanotubes have now been found to be able to be formed from other materials; one example is deoxyribonucleic acid (DNA).

Nanotechnology and medicine are no strangers to each other. For many years, development of Nanotechnology in medical uses has been explosive. With so many fields of medicine which could be revolutionised, it is difficult to grasp the concept of the future of medicine without nanotechnology in it. Developments in Nanomedicine are revolutionary. There are many prospective uses for Nanotechnology in different fields of medicine, allowing explosive progress in every branch of medicine. Rheumatology, Orthopaedics and Pharmaceutical medicine are all branches where nanotechnology can be easily utilised in treatment, which is effective for both the patient and consultant. Nanotechnology is a generic method easily applied to medicine at every level. Diagnostics, Detection, Drug delivery and other further treatment, all have progress

to be made from the increasing use of nanotechnology. Many conditions and diseases can be treated, both short-term and long-term using nanotechnology. Coronary Heart Disease, Brain Disease and COPD are all diseases which will benefit enormously. As well as these long term diseases, short term trauma can also be revolutionised by the use of nanotechnology. Nanotechnology can also be used in bone and cellular repair, improve recovery of the patient, and reducing formation of scar tissue from injuries as tissue and bone can be supported and re-built. An extensive list can be produced of different conditions and diseases which would benefit one way or another from developments in nanotechnology. Nanotechnology looks to be the future of medicine as a whole.

Development of nanotechnology in medicine requires advanced equipment. Tools such as Laser Tweezers and Atomic Force Microscopes are two examples of the high tech equipment needed to make nanomedicine possible. The Atomic Force Microscopy is a method of measuring the surface landscape. The microscope has a minute tip, radius of 20nm, which is traced along the surface of an object. The tip is monitored and scanned, for the interactions of the tip with the surface. These results can then be used to produce an image of the surface in microscopic detail. Laser Tweezers (also known as Optical Tweezers), are used for a different purpose. This tweezers are able to capture and trap nanoparticles of matter, conveying its precise dimensions. Laser tweezers are also used to project matter to a specific place. The light shone onto the particle becomes refracted; however the momentum of the light is transferred to the nanoparticle which is precisely placed on the surface, whether that is material or tissue.

In the current economic climate, progressive treatments can be very expensive in long term plans, perhaps even considered a drain of money on the medical services; money which could be used for other ends. Development of nanotechnology in drug delivery and other fields could help reduce the impact on the economy, by providing a long-term alternative. Conditions such as Diabetes, Parkinson's and Alzheimer's could all be forerunners in the use of nanotechnology as drug delivery. Nanotubes can provide routes for medication to be delivered, meaning that the medication can be concentrated to the area where it is specifically needed. This will provide a more continuous and efficient method of delivering medication to patients.

For a long time nanotechnology has been a focus of research, with millions being spent on the research. In 2005, the National Cancer Institute invested £144.3 million in research for nanotechnology. This was with a focus of pursuing possible uses for nanotechnology in fighting cancer. Current research on nanotechnology is taking place in nearly a dozen different fields of medicine. One example is the advances in treatment of cancer. A newer development is Doxil. Here, nanoparticles of lipids (which also contain a polyethylene glycol coating) are used to invade the specific area of the body where the disease lies. This practice was approved by the Food and Drug Association (FDA) in 2004. More recent research was a development in drug delivery systems. Work by Dr Hanadi Sleiman has discovered a development where by drugs can be fired at specific diseased cells. This research was published in April 2010 and has become known as 'Magic Bullets'. DNA is used as a building block for creating the nanotube. Nanoparticles of drugs are captured by the nanotube and rapidly fired in a different and specific direction, aimed at the area where the diseased cells are. This reduces a drugs impact on healthy tissue and promotes a speedier recovery with fewer long term effects of the treatment. Figure 3 shows a section of the nanotube which has captured a particle, which it can then fire at the diseased cell.

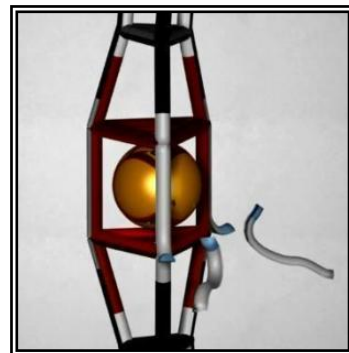


Figure 3

I have chosen to focus my research into nanotechnology for drug delivery. This use for nanotechnology is rapidly progressing and so is guaranteed to be a big part of future medical methods. Having an understanding into this method of drug delivery can allow me to have a better knowledge when starting my prospective career. Even though drug delivery is a small focus out of all the possible uses for nanotechnology, there are many different aspects. Developments with drug delivery will lead to radiation and other sources being used and transmitted via nanotubes and Buckminsterfullerenes.

DISCUSSION

One way nanotechnology is sure to be used in the future is a method of delivering drugs to patients. This promising development in pharmaceutical medicine can offer an amazing, revolutionary way in which people can receive their medication. Nanotubes can be drilled into the skin and particles of different medication can be delivered via these

tubes. Smaller amounts of the drug are needed as the tubes can direct the medication to the specific area. Specific cells can be targeted by using biosensors on the surface of the nanoparticles. An example of a biosensor is an antigen. There are a huge number of different antigens and any one can be isolated to use on the surface of the nanoparticle. As a specific biosensor can be used this means that any specific cell can be targeted, by matching the biosensor to that of the cell. As less medication is needed and so the delivery is also more economical. In this current economic climate cost cutting solutions are being looked for in every direction. Although initially this will be an expensive area of research, money will be saved in the future from the reduced cost of pharmacy charges and wasted medication. The medication can be directed to a very small area the delivery will make this method of drug delivery more efficient and more beneficial for the body. The body can often become swamped with huge amounts of a drug, even though only a small amount is actually needed and utilised. By cutting down the volume of the drug given, the body will be able to use it more efficiently and effectively. Also, reducing the quantity of drug given to the patient would reduce side effects, which are undesirable effects from a drug. As the body is not swamped by large amounts of a drug, the side effects will be reduced as there are less amounts of the drug in the patients system. Although this is an invasive method, there is no risk of infection. Bacteria are approximately 10 micrometres, and so are too large to fit into the tubes which have a diameter of 20 nanometres.

However, there is the opportunity of expansion in the uses for nanotubes. Drug delivery is fast developing, with ground breaking research having been highlighted earlier. Now that this is evolving, there is the potential for other sources, such as light, heat and other electromagnetic radiation to be sent via nanotubes. The development in diagnostic medicine would be enormous if these developments were to occur. Light being sent via nanotubes would allow detailed images to be taken for specific parts of the body. There would also be less harm to the patient as the waves can be directed more specifically. Electromagnetic radiation developments would not only allow advances in diagnosis in cases such as X-ray images and Positron Emission Tomography, but would also allow treatment such as radiotherapy to progress. Radiotherapy, even though it is a very effective treatment, can have many side effects for the patient: radiation burn, fatigue and digestive disruption are a few. Using nanotubes to direct the radiation to a more specific area would dramatically reduce side effects, and even though they may still occur, they will not be as prominent. When

radiotherapy is used in sensitive areas, such as breast or prostate, the side effects can become very dangerous. Using the nanotubes to direct the radiation will reduce the effects, and in these cases will reduce pain and problems for patients.

Buckminsterfullerene's can also be used to deliver drugs. This is where DNA is formed into 'Y' shape structures and join together to form the closed cage structure of the Buckminsterfullerene. Drug particles can be enclosed in this close cage structure and these can be used to delivery drugs to targeted tissues as they have better drug targeting properties. The drug particles enclosed in the Buckminsterfullerene can be injected into the patient. The cage structure will give drug particles protection so that it is not assimilated into adjacent tissues. The DNA of the cage structure can be manipulated to match the DNA of the patient. This allows the drugs to reach deep into the body as they will be recognised as self material and so will not be attacked by antibodies or digested by enzymes loose in the blood. The cage of the buckminsterfullerene cage will be encapsulated into the diseased cells. The DNA will subsequently be broken down by the enzymes in the cell. When the Buckminsterfullerene reaches the tissue the cage structure can be assimilated into the tissue DNA and the drug will be released. Another way of targeting the cells is the use of monoclonal antibodies. These can be incorporated into the cage structure of the buckminsterfullerene. Monoclonal antibodies only target one specific antigen, therefore they can be used to target diseased tissues based on their antigens, and also minimising effects on healthy cells as they won't be targeted.

Diabetes is one condition being developed more then others. Nanopumps are used to deliver insulin. They can be in the form of patches, chips or even tattoos. This development has attracted an enormous amount attention for the huge effects this research would have on people's everyday life. So why can't this be expanded to incorporate other conditions with sufferers in similar positions when it comes to their medication? Figure 4 shows a nanopump. It is displayed on a persons thumb, highlighting its small size.

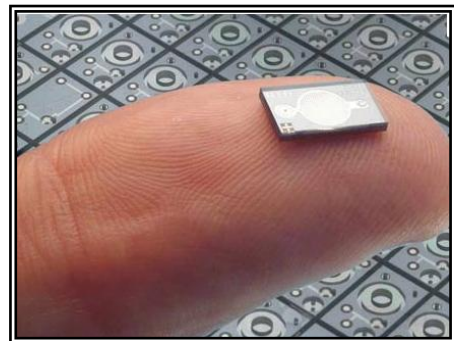


Figure 4

One condition that's has dramatically risen since its awakening in the 1980's is Human Immunodeficiency Virus (HIV). HIV is a lentivirus which

attacks the immune system of the sufferer. HIV primarily affects helper T cells and macrophages. These two types of cells are crucial for the mechanism of the human immune system. These cells are the first cells exposed to an infection, and it is the helper T cells that trigger the rest of the immune cells to respond to an infection and work at killing pathogenic cells. The virus exists either as free virus particles in the blood or as a virus in infected cells. The virus can be found in blood, semen, vaginal fluid or breast milk. Unprotected sex, contaminated needles, breast feeding or by perinatal transmission are all ways of a person becoming infected by the virus. Exposure to any instruments of this nature poses a very high risk of contracting the virus. For many years research has been done, into HIV and Acquired Immunodeficiency Syndrome (AIDS). Scientists, Diagnosticians and Haematologists have studied the virus investigating the symptoms and looking for treatments and possible cures. At this present moment there are no known cures for the disease; sufferers have the virus for their entire life. HIV and AIDS sufferers are very open to common illnesses, that ordinarily people would not be concerned with. Illnesses such as influenza and the common cough or cold can leave HIV and AIDS sufferers bed-bound for weeks, as their immune system is not strong enough to fight the infection. HIV and AIDS sufferers are obliged to take medication to boost their immune systems so that they can live a normal, healthy and active life. Tablets are available to reduce the affects of the virus and some even available to prospective mothers who want to prevent the virus spreading to the foetus. However, it is no lie to say that the virus will control and dictate areas of the sufferer's life; medication simply works to try and reduce this. Research has been done into curing HIV, however many risk factors are associated with the practice as it involves blood transfusions and bone marrow transfusions. There has also been a recent piece article published in the Student British Medical Journal (January 2011) of research of a new drug which was found to offer high degree of protection to HIV sufferers. Research into this finding was published in the New England Journal of Medicine on the 23 November 2010. Nanotechnology also has its part to play in helping to treat this condition. Nanopumps offer long term drug delivery to many patients with different long-term conditions, and seeing as the prevalence of HIV and AIDS is on the increase; expansion into using them for this condition only makes sense. Tablets given to sufferers are antiretrovirals, to provide protection to pathogenic bacteria which have invaded the body. However, tablets do not offer a steady and constant supply of the medication. As the tablet is digested and absorbed into the blood, there is a peak in the

level of medication in the instances after the tablet is taken and a trough just before next dose. My thought is to use Nanopumps to deliver these antiretrovirals and patients. Nanopumps can be used to allow constant delivery of antiretrovirals. Nanopumps are small chips which can be placed on the skin. They have nanotubes extended out of them which are drilled into the skin; this is where the medication can be delivered by. As previously discussed, this is effective at stopping infection as bacteria are too large to fit into the nanotubes. Nanoparticles of the medication can be tailored to fit down these tubes, into the body providing the body with a constant supply of medication. There is a common social stigma associated with contraction of HIV. Nanopumps are very small which means that they are not obvious to onlookers, and they can be placed on the body where they are out of view. This will allow people to manage their condition much more discretely, where only their doctor and close relatives need to know. For this development to take place, a medical experiment will have to be performed. This requires people to test this method of drug delivery. Participants do not necessarily have to have HIV or AIDS and blood samples taken from participants will show levels of white blood cells. If the medication has been successfully delivered then these levels will be higher than without exposure. Participants should be of many ages and ethnicity to ensure ability to generalise to the wider community that could be concerned with the research. Participants should be selected after a voluntary sampling method used, such as an advert in the paper. Participants should have the research fully explained to them, to allow them to make an informed decision about their choice to participate. Any people not wishing to go through with the experiment should be allowed to leave. Those wishing to participate will be given nanopumps which provide an immune booster. They will be left to carry out their normal day to day activities, but should be monitored to observe efficiency and allow any problems to be quickly identified. My prediction is that the delivery of the medication will be successful, allowing a huge step in the treatment of HIV and AIDS. Nanotubes should provide a more efficient method of antiretrovirals as they give a path directly into the blood stream through the blood vessels surrounding the muscular tissue.

Development in nanotechnology uses in medicine can only go so far without the need for humans to test methods on. This is difficult and can be partly resolved by using animals, an example being pigs. However, nothing quite matches the need for the real thing. Nevertheless, Ethical guidelines, written in 1985, clearly state that people should be protected

from harm in experiments. Testing nanotechnology on humans, even though millions of pounds, and countless hours have gone into research, is still dubious due to the unknown consequences and efficiency of the methods. A way around this problem would be to obtain written consent from the participant and their family. Some people may have thought of using already deceased to practice on, however guidelines still state that written consent is needed from the family to allow this. There is also a problem from the point of view of the research of using deceased patients. Post mortem, the body begins to change as decay starts to occur; tissue density and structure will start to change. Therefore practicing and investigating methods using deceased patients may cause unreliable results, and leading to inaccurate practice.

CONCLUSION

Nanotechnology is the future of medicine. There is an unimaginable list of possible uses for nanotechnology both in and away from medicine, many now starting to be developed. The diversity of this research is mind-blowing; development ranging from cancer treatments to repair of fractures. To sum up my ideas, drug delivery is a huge pioneer for nanotechnology in medicine. Even though this is only one branch of research, development within this field is enormous. Many different conditions are eligible for using nanotechnology for the drug delivery. Nanotechnology research is going to have problems, as scientists and researchers may get carried away with all the possible uses. Either that or the possible uses do not materialise how imagined. These are hurdles which the researcher will have to overcome; remembering nanotechnology is a very new concept and sometimes just doesn't turn out how we thought. Ethical Guidelines can also restrict experiments in research due to the possible harm to people taking part. However, fully informed, written consent given would allow experiments to occur. For informed consent to be given, the patient needs to have every detail of the experiment explained to them in terms that they understand. This also includes warnings of possible dangers of the experiment, and what could happen if things go wrong.

My main thought into the development of nanotechnology is in treatment of HIV and AIDS. Cases of HIV and AIDS have increased since the 1980's and with no identified cures, efficient treatment is necessary. Nanotechnology definitely has its part to play with helping to control and monitor this condition, with a possible experiment discussed.

This research paper was mainly focused on the use of nanotechnology in drug delivery, and even though this is only one branch the potential for the use of nanotechnology is huge, not just with the use of nanopumps, and nanotubes but also in the manipulation of medication and tissue.

Modern medical advances are getting more and more ground-breaking; sometimes it is hard to keep up. However, with the fascinating work that is occurring; only a small percentage of which I have identified and discussed, provides an endless look into the future of medicine. The thoughts of where we could be in twenty years or so, when it comes to methodology of medical practices, are mind-blowing.

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