

# NANOTECHNOLOGY AND MEDICINE

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PASS

(62 words over limit)

RESEARCH PAPER  
BASED ON  
PATHOLOGY LECTURES  
AT MEDLINK 2010 or MEDISIX 2011

## ABSTRACT

*Nanotechnology is at the forefront in numerous fields, none more so than in medicine. Its minute size and stability allows it to achieve many tasks which had been possible before. In medicine, limitations which were present previously may be overcome, and the amalgamation of nanotechnology with existing drugs and research can aid both diagnostics and treatment in a plethora of fields. Gene Therapy is currently limited and dangerous to many if used; however, nanoparticles used as vectors in delivery of genes can potentially eliminate this problem. Diseases of the heart, Alzheimer's disease and Cancer are also directly affected by the developments of nanotechnology – from the usage of nanobots to pairing with monoclonal antibodies. Finally, we must consider the ethics of nanotechnology and its threat to our economy, our environment and our health.*

## INTRODUCTION

The concept and ideas of nanotechnology was first derived from a speech gave by the American physicist Richard Feynman in 1959. The speech was named “There’s plenty of room at the bottom”, and it is in this speech that the key principles and developmental structures of nanotechnology were laid out for the decades to come. From the speech he stressed the significance of "manipulating and controlling things on a small scale" moreover, he tells us much of “the great interest about the strange phenomena that occur in complex situations” from the study of nanotechnology. Feynman posed the creation of a *nanomotor* and even the miniaturisation of the letters of the Encyclopaedia Britannia so that it can fit on the point of a pinhead.

However, it is from the ability to see things at an atomic scale due to the invention of the scanning tunnelling microscope in the 1980s by IBM Zurich scientists that paved the way for nanotechnology.

### How does it work?

A nanometer is one billionth of a meter. Nanotechnology works on this small scale, at which atoms and molecules exist. The main aim of nanotechnology is to build objects which are small enough to exist at this level, but also to work in this small scale environment with and around the atoms and molecules.



Figure 1

Everything that exists is made up of billions of atoms and molecules; this is to say that they are the building blocks to our universe. Since nanotechnology could be able to rearrange and reconstruct these molecules, if we are able to build the machines able to do so, the possibilities are endless. We would be able to possess the quality of building objects right from scratch, on a molecular level, and altering parts to suit our needs.

The properties of any object depend on the arrangement of different atoms within that object. By modifying the atoms, in theory we could create completely different objects, or we could create the same object, but with different properties, ones which suit us and our needs. For example, carbon atoms are arranged in a specific way to produce graphite. If you change the arrangement of those carbon atoms, you can get a diamond structure. Both objects have the same atoms, but are just arranged differently. If we could change the arrangement of graphite, in theory we could make it into a diamond structure.

### Nanotechnology in Medicine

Nanotechnology works in medicine as the same way as seen in above. Scientists have taken the wonders of nanotechnology and just applied them to a medical circumstance. Nanoparticles which have been designed, programmed and manufactured are released into the body with the aim of delivering a drug to a specific point of the body. Not just to an arm or a foot, but on a cellular level, to certain infected parts.

One of the ways it is done is by using *Nanobots* (as seen in Fig 1). Nanobots are almost like tiny futuristic robots which have been designed to manipulate matter on a molecular level. Not only that, but in theory they could rearrange atoms inside the body and create a whole new molecule. They can also be used to trap medicine inside the Nanobot, so that when it reaches the infected part, it releases the medicine. This is useful in two ways. Firstly the medicine become more effective as all of it goes to the infected part. Secondly, it minimises the damage done to the healthy cells in the body.

Finally, nanobots could also trap a virus such as the Human immunodeficiency virus (HIV), and then destroy itself and thus the virus also.

Another way in which nanotechnology could help in medicine is by using a "*buckminsterfullerene*" or "Bucky ball". These are hollow spheres which are made of 60 carbon atoms arranged in hexagonal formation of graphite ball. resembling a soccer

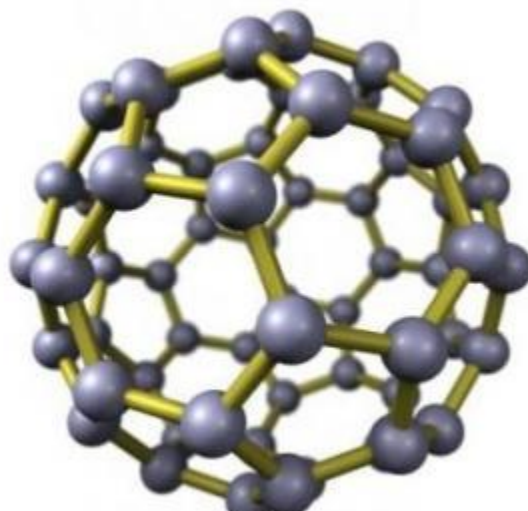


Figure 2 (Bucky ball)

Nanoparticles are used in drug delivery, mainly to improve drug 'bioavailability' which means that the drug is at the place most needed in

The body and where it will do the most good. This drug delivery and the maximisation of bioavailability can be achieved using Nano-technological devices. Each year \$65 billion is lost due to poor bioavailability by our current drugs. We measure the strength of our drug delivery systems from their ability to change the pharmacokinetics and biodistribution of the drug. Due to nanoparticles being very small, cells can take in these particles where larger particles would have been too big. These 'nanodrugs' will work by set mechanisms and will be specific in their usage; the development of nanotechnology will be at the forefront of new drugs with a higher efficiency and more useful behaviour.

Proteins are a significant in terms of our bodily and cellular functions, and the manipulation of proteins can be useful in treating illnesses such as cancer. The controlled delivery of these macromolecular proteins, or biopharmaceuticals, using nanomaterials is a rapidly evolving field called nanobiopharmaceuticals. The development of Carbon Nanotubes is also significant and has impacted many areas of medicine especially in diagnostics and disease treatment. As DNA cannot pass through the cell membrane, Gene therapy is greatly improved through modified Carbon Nanotubes where it acts as a transporter.

## DISCUSSION

### *Gene Therapy and Nanotechnology*

Gene Therapy is the manipulation of genes within a chromosome in order to achieve a positive effect for the patient, where the proteins that are controlled by the DNA are changed in a way that does so. Genes are a specific set of instructions that are inherited randomly from both parents which code for proteins. Genes may be defective and therefore the proteins they code will pose a problem to cells. Gene therapy treats this and on-going research is providing a more secure framework for this newer area of medicine. Nanotechnology will play a vital part in the development of Gene Therapy and many scientists and researchers are placing their attention in this field.

The current issue with Gene Therapy is that there are many unwanted side effects that accompany the way the gene manipulation is achieved. One of the major problems with Gene Therapy is the inflammatory response to viral vectors. Gene Therapy works by inserted a gene in a non-specific location to replace an abnormal gene, or it may be used to swap an unhealthy gene for a healthy one through the phenomena of homologous recombination. A vector on which a gene can be carried is used to insert genes into desired cells. The vector is usually a virus; the commonest ones used are the **Adenovirus**, the **Retrovirus**, the **Adeno-Associated Viruses**, and the **Herpes Simplex Viruses**.

Here is a brief idea of how Gene Therapy functions:

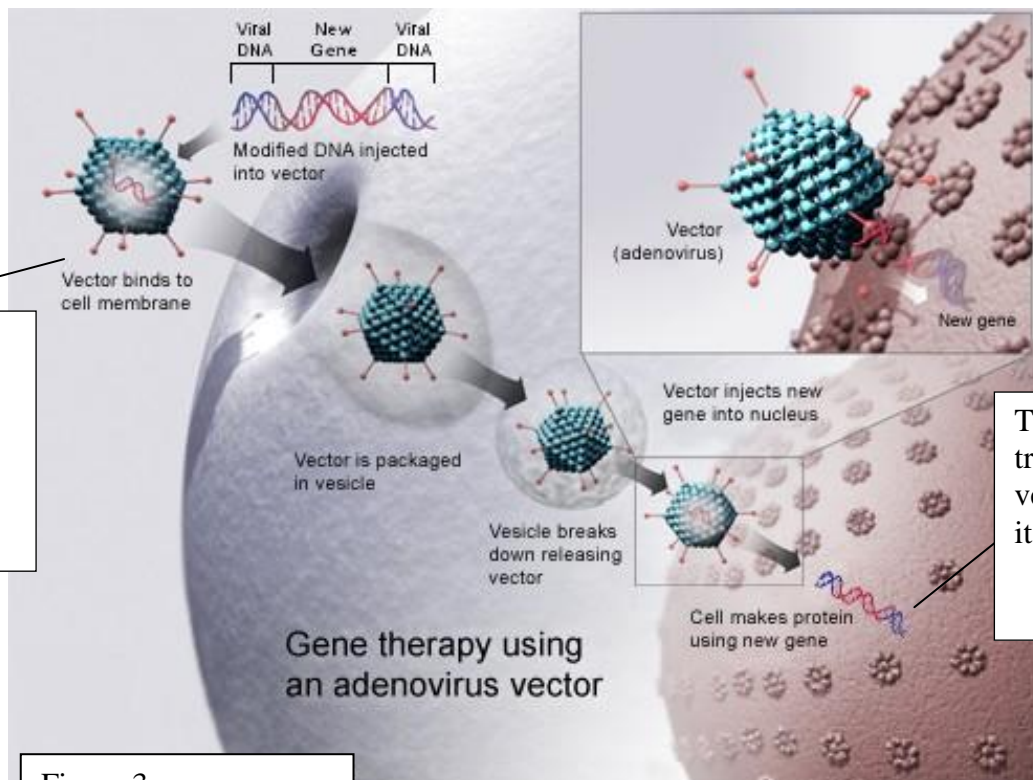


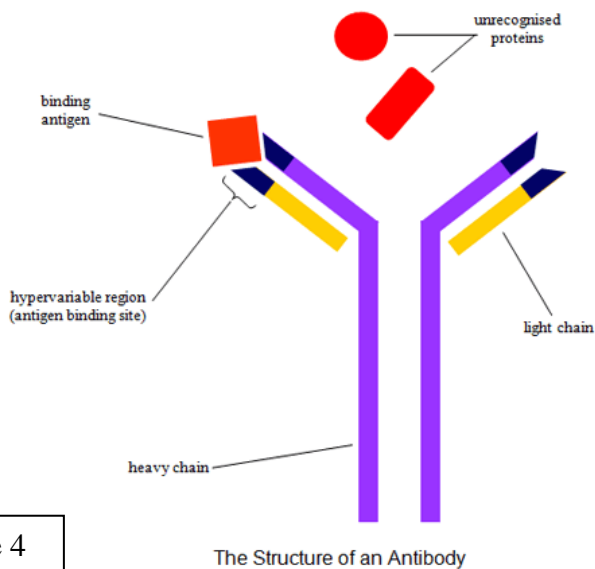
Figure 3

In 2005 a trial with the Adenovirus vector caused an American patient to suffer from an inflammatory response in the lung from which he did not recover. Also, another trial where children with ‘baby in a bubble’ syndrome were reported have higher cases of leukaemia, possibly due to the retroviral therapy. This trial was halted and led to the Food and Drug Administration (FDA) having to review it until further notice.

Nanotechnology is significant in that it can provide the benefits of the viral vectors with minimal side effects. An MIT group have discovered a polymer named C32 that provides little toxic effects to the patient whilst being able to efficiently deliver genes to cancer cells. It achieved this by condensing DNA, and then allowing the resulting nanoparticles to form and to enter the cell through endocytosis. The researchers at MIT were able to deliver a modified diphtheria gene which is only common to prostate cells. This Gene Therapy was successful in suppressing and containing tumours in the prostate, and in 40% of cases, the cancer cells even shrunk in size. As Dr Janet said *"C32 delivered DNA intratumorally around four-fold better than one of the best commercially available reagents, jetPEI (polyethylene mine), and 26-fold better than naked DNA,"*

Future developments on nanotechnology in Gene Therapy are numerous, many of which are cancer based, such as the particles being adapted for a non-reactive type of brachytherapy. Nanoparticles may also be used to attack tumours which have metastasised and that may be taken intravenously.

Nanoparticles can also be manipulated into layers or films. They may contain Nano-sized layers of DNA which can be contained in a water-soluble polymer. If used correctly they will be able to direct genes to specific locations within the body. Researchers at Wisconsin University were able to use the current procedure of using nanoscale films for coating metal stents which are used to unclog arteries, and adapt it for even more uses in the medical fields. The Nanofilm is effective as it works in conjunction with body tissue. The body tissue causes the DNA to be released and to be delivered in polymers to the location required in the body – the DNA or genes instructing the required proteins that need to be synthesised. A logical progression from the above would be to find methods of accurately locating cells which have been infected, namely cancerous cells. The Nano-sized polymers could be attached to a monoclonal antibody. The attachment of the nanoparticle to a monoclonal



antibody would require the polymer itself to be manipulated to have an active site which is complementary to the antibody. An antibody is made up of two polypeptide chains and has a variable region as well as a constant region.

The nanoparticle could be engineered to be able to attach itself as a characteristically non-harmful antigen from having a complementary region, and be able to attach onto a monoclonal antibody. It may be attached via electron cutting, and from careful usage of electron microscopes.

The monoclonal antibody can be taken, through a medical drug, intravenously and the antibody itself will be attracted

Figure 4

themselves only to cancer cells. The nanoparticle polymer will then release its DNA or genes on contact with water, due to it being soluble and breaking down. The genes themselves would be able to synthesise proteins which are able to suppress the cancer cell. These proteins may include ones which are originally made by 'tumour-suppressor' genes which are rendered inactive due to a fault or mutation. Also, the healthy genes contained within the nanoparticle may be able to replace the 'proto-oncogen' genes which had been activated due to mutation in the first place to cause cancer growth.

Nanoparticles which are smaller than 50 nanometres can readily enter body cells, and in

turn will have an effect on a bimolecular scale on the surface of cell and within the cell. An ability to be able to be non-invasive in treatment offers much clinical and developmental

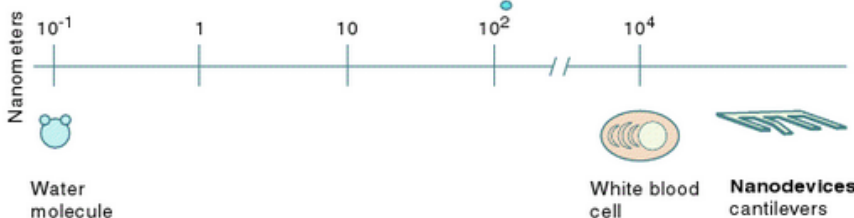


Figure 5

potential in revolutionising the way we think and do treat patients – especially those affected by cancer.

Nanoparticles can prove very useful in diagnostics as well as treatment. A silicon chip type configuration can be used to contain various nanoparticles and all containing monoclonal

antibodies able to detect, and is used widely, various diseases due to it attracting various antigens.

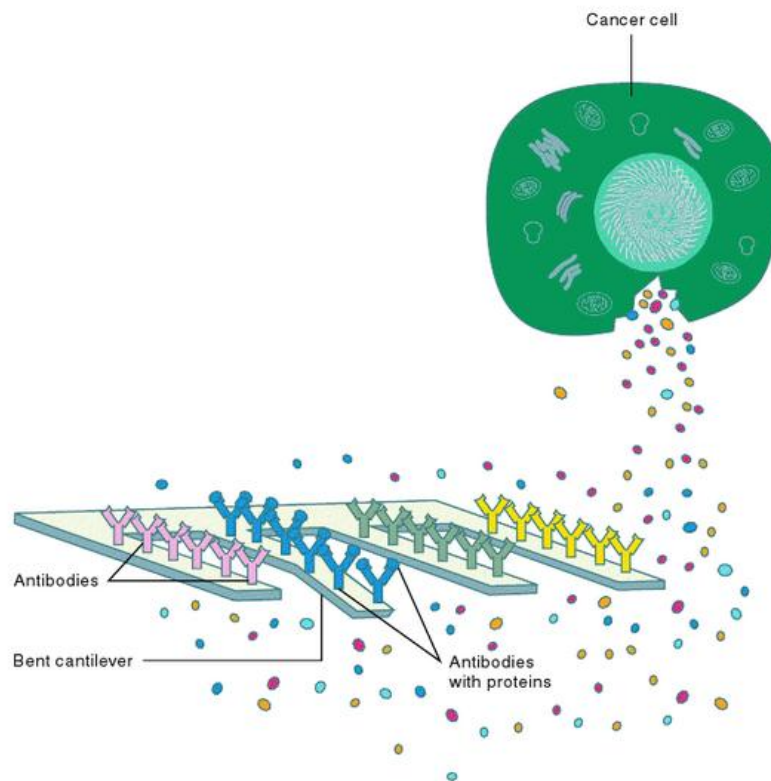


Figure 6

Alzheimer’s disease and Nanotechnology

Alzheimer’s disease is a fatal illness that gradually destroys brain cells, causing various problems to the sufferer, including loss of memory and changes in behaviour. Alzheimer’s is the most common form of dementia, in fact over 50% of dementia cases are Alzheimer’s disease. The group most at risk are the elderly and it is thought that there are around 820,000 people in the UK living with dementia. Currently, the early screening and early diagnosis of dementia is almost impossible, let alone the possibility of curing a sufferer, due to a lack of technological development. However, could the newly emerging field of nanotechnology hold answer?

Alzheimer’s disease, like a stroke or a brain tumour causes cognitive impairment; however, the aspect that differentiates it from these other two conditions is brain shrinking in specific areas. This can be seen on an MRI scan. Furthermore, a functional MRI scan can be

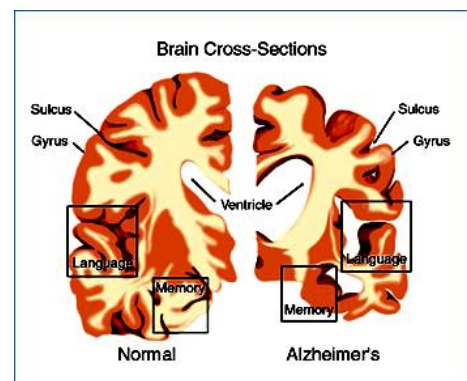


Figure 7

used to stress networks in the brain to see evidence of dysfunction before the loss of tissue. Alzheimer's disease kills nerve cells in the brain with a build-up of a protein called beta-amyloid. This is deposited and hence accumulates in areas of the brain responsible for the production and recall of memory. These areas are; the frontal cortex, which is responsible for the recognition of a given event; the occipital cortex, which is responsible for the visual input in the memory; and the hippocampus and the precuneus which integrate this into a cohesive memory. When attacked by the beta-amyloid, the hippocampus goes into hyperactivity, therefore it is compensatory in the primary stage of the disease, but this is a sign of later impending failure.

In order for somebody to be cured of this illness, the beta-amyloid needs to be removed from the brain. Some scientists believe that in order to do this, antibody therapy needs to

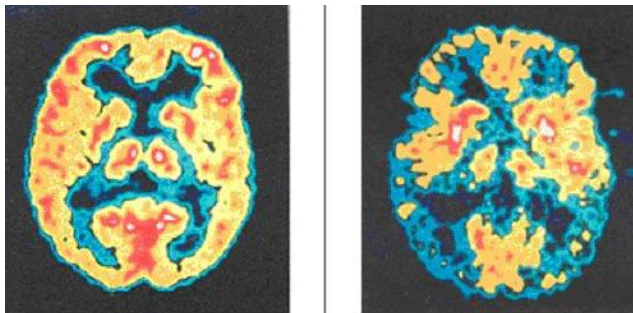


Figure 8

*Brain scans using Positron Emission Tomography (PET) show how Alzheimer's affects brain activity. The left image shows a normal brain, while the right is from a person with Alzheimer's. The blue and black areas in the right image indicate reduced brain activity resulting from the disease. Images courtesy of Alzheimer's disease Education and Referral Centre, National Institute on Aging.*

be employed. In which, in basic terms, the antigen on the beta-amyloid molecules will bond to the complimentary antibody rather than the brain. Nanotechnology, which enables one to control matter from 1 nanometre and above, allows very intricate movement, at an atomic level. This means that matter can be manipulated, measured or even destroyed in miniscule proportions. Potentially, very small nanoparticles that are able to cross the blood-brain barrier to reach the brain could be attached to molecules that can recognize and destroy the amyloid plaque of the illness – (the antibody). Furthermore, nanoparticles have great potential to aid the discovery of tiny concentrations of Alzheimer's biomarkers and could be able to detect one or more biomarkers simultaneously.

In my opinion, the optimum way forward to monitor and ultimately prevent Alzheimer's disease is to create a safe and implantable Nano-scale biosensor into the brain to measure levels of beta-amyloid. Therefore providing a very early diagnosis of the disease, hence subsequent action can be taken very quickly.

### Heart disease and Nanotechnology

The heart is one of the most important muscles in body. It has the vital role of pumping blood around your body. Oxygen rich blood is carried to all parts of your body. Once the oxygen reaches the cells in your body, it is used up and carbon dioxide is given off. This diffuses into the blood which is then pumped into lungs, where it diffuses into alveoli and is exhaled. The oxygen which has been inhaled diffuses into blood and cycle repeats.

Cardiovascular disease/Coronary Heart Disease (disease of the heart) is the biggest killer in the UK. It results in 94,000 deaths each year. 1 in 5 men die from it, as well as 1 in 7 women.

Coronary Heart Disease arises when your arteries (vessels which carry oxygenated blood) become narrow, or blocked, due to an atheroma. An atheroma is a fatty/lipid deposit which occurs within the artery wall. The build-up causes the wall to protrude into the lumen (centre of the artery). This may harden and form a plaque, which in time can either rupture, causing a blood clot; or the plaque could detach all together and block the entire artery. At which point the patient will begin to have chest pains (angina) and will finally have a myocardial infarction (heart attack).

Nanotechnology could be used in three main ways with regard to Coronary Heart disease:

- 1) Preventing Coronary Heart disease and a heart attack.
- 2) Helping a patient to recover after the attack has taken place.

- *Preventing Coronary Heart disease and a heart attack.*

The main problem with Coronary Heart disease is that the fatty/lipid deposit builds up in the artery wall without showing any symptoms. A Nanobot could be entered into blood stream and then attach to a red blood cell so that it is passed all around the body, through the arteries. It could be programmed to detect the atheroma once it comes into contact with it. Although it would not always be 100% effective, as it is not always in contact with the artery wall, it would still work. Once the Nanobot have detected the atheroma, it could stick to the artery wall. Then it could do 2 things. 1) The Nanobot could contain chemicals which dissolves the fatty/lipid deposit (atheroma). 2) It could suck the fatty/lipid liquid into the body of the Nanobot; at which point the Nanobot could destroy itself and thus the atheroma.

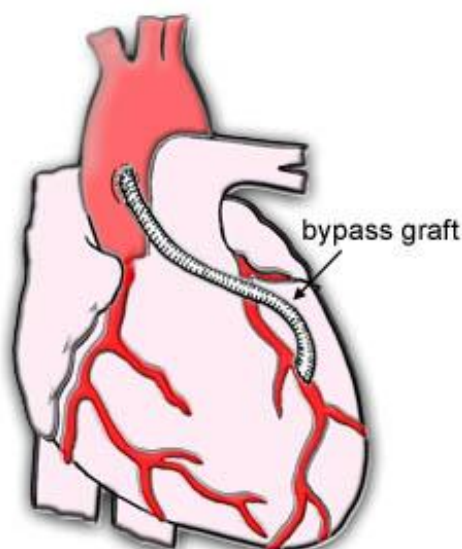
Both methods will reduce the narrowing of the artery, increase blood pressure, and reduce chance of a heart attack.

- *Helping a patient to recover after the attack has taken place*

After a heart attack has taken place, many cardiac cells are left permanently damaged. The cells in the heart depend on oxygen rich blood, and during a heart attack the coronary arteries are blocked and thus no oxygen rich blood can get to some areas of the heart. The damage of cardiac cells is dependent on the area of the clot and also the size of the coronary artery.

Once these cells are to heal, but it forms normal heart tissue. work as effectively as the heart, as a muscle

Not only that, but arteries are also they were originally. that sometimes when



damaged, the heart begins scar tissue instead of This scar tissue does not normal heart tissue, and is now considerably weaker.

after a heart attack, the considerably weaker than What usually happens is the arteries are still

Figure 9 (A bypass after surgery)

blocked, the patient undergoes surgery to bypass the affected artery and create a new route of blood flow.

In some cases where the artery is no longer blocked, but still narrow and weak, a stent may be placed directly into the artery. A stent is a mesh tube used to widen a narrow or weakened artery. Its aim is to restore the original fast flow of blood around the body.

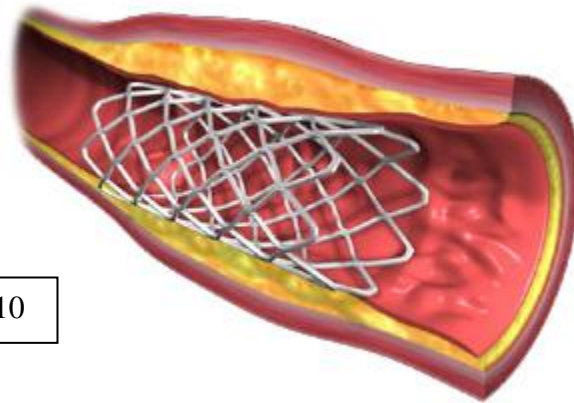


Figure 10

Nanotechnology could be used here in many different ways. Instead of trapping chemicals inside a Bucky ball or Nanobot, we could take a more biological approach to it. Stem cells are undifferentiated cells which have the capacity to differentiate into any cell. They are extremely useful in the way that they can repair damaged tissues, organs or even limbs. If we could come up with a way to eject stem cells directly into the damaged area and conduct those stem cells to differentiate into cardiac cells, they could replace the lost cardiac cells after a heart attack. One of the ways we could do so would be to attach a stem cell onto Nanobots; much like a drug is attached to a monoclonal antibody. We could then direct that Nanobot to the right area at which point it could release the stem cell.

## CONCLUSION

Nanotechnology is, without a doubt, an essential part of the development of medicine in the years and decades to come. The minute sizes of a nanoparticle make possible numerous things which would not have been considered before in the scientific realm. The uses of nanotechnology stretch far and wide, with new ideas always being put forward. Nanotechnology can be used for drug delivery, where the particles can be engineered to directly attack pathogens, or infected cells; they can be used for therapy, namely Gene Therapy where they can act as vectors for genes to be carried safely and efficiently; they can be used for diagnostic and imaging, where we can locate tumours more efficiently, perform tests using monoclonal antibodies and numerous other ideas.

The potential cures for Alzheimer's disease do sound all well and good, however, ethically; this is a very controversial subject. Most religions condemn such unnatural technology, portraying the message that it is wrong to manipulate molecules atom by atom, as if a piece of machinery. In 2003, nanotechnology was supported by the Prime Minister Tony Blair, yet combated by Prince Charles with the argument, backed up by many environmentalists and world religions that it is unethical to 'Play God'. Finally my own opinion is that

nanotechnology should be further developed in order to come closer to curing such diseases as Alzheimer's.

The treatment of heart disease in nanotechnology has a substantial impact, but there are also problems which must be realised and solved. In preventing a myocardial infarction and preventing CAD:

- You may need many nanobots to extract the entire fatty lipid liquid.
- You may need to find a chemical which reduces the atheroma.
- Destroying the Nanobot may cause damage within the body.
- The liquid would still be around the body and would need to be extracted.

Even from helping a patient recover poses some potential problems, etc.:

- It would be extremely hard to direct the Nanobot and stimulate the stem cell just by using the Nanobot.
- There is no way of knowing when we have reached the damaged areas, and we would risk creating a large tumours growth inside the patient if we do not release the stem cell at the right point.

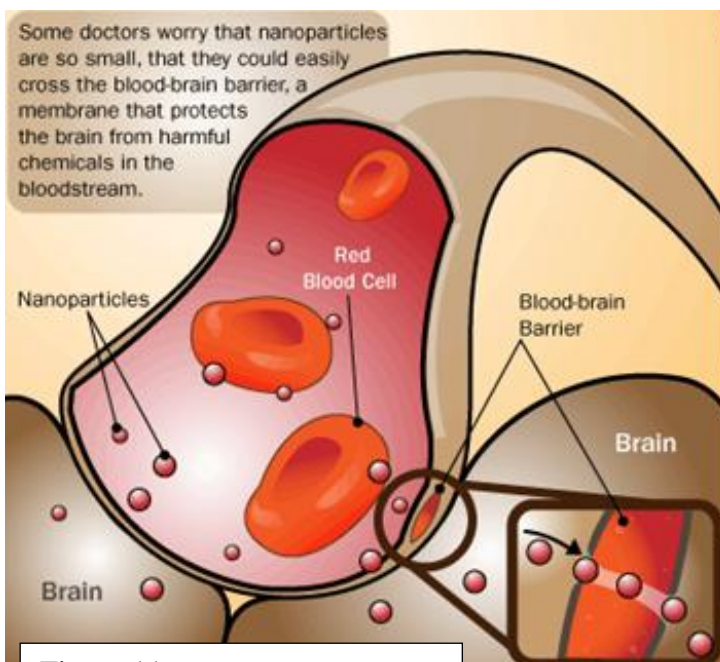


Figure 11  
(www.howstuffworks.com)

Although nanotechnology holds many benefits for the development of not just medicine, but many other fields, there are ethical issues that surround it and that are hard to ignore. From the new technology, many political and economic situations may arise such as arms races, abundance of cheap products, and social disruption due to new products. If we can build anything at the click of a button, what happens to all the manufacturing jobs?

Although exaggerated, the grey goo concept proposed by Eric Drexler, the man who conceived the word "nanotechnology", is where self-

replicating nanoparticles attract carbon molecules to build it up and eventually lead to it wiping out all organic

material.

Nanoparticles themselves could also potentially be dangerous to the human body and the environment. It is feared that nanoparticles are so minute, that during things such as cancer treatment, the particles may dislodge and end up in the human brain, damaging it as seen in **Figure 11**. If nanoparticles managed to leak into rivers, it may potentially damage river bacteria, leading to the base of the food chain being affected. Due to the significant

advancements in materials due to nanotechnology, *"our traditional ways of thinking about hazardous materials are going to have to broaden a bit,"* said Dr. John Balbus, a director of a health organisation. The understanding of nanoparticles must be complete otherwise unwanted effects may arise.

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