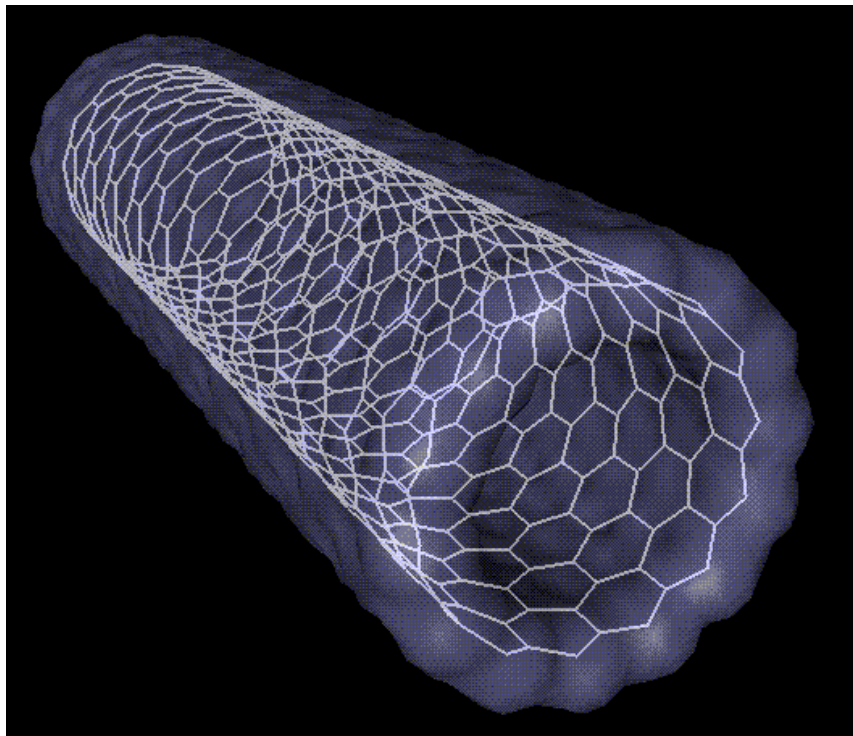


THE FUTURE OF NANOTECHNOLOGY AND THE USES  
NANOMAGNETS

BY NAVIN PANCHARATNAM

PASS

(96 words over limit)



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## ABSTRACT

The use of nanotechnology, especially in medicine can provide new and exciting possibilities. The potential applications of nanotechnology are endless, and can be exploited further to enhance current medical knowledge. My research gives an introduction into what nanotechnology really is and how it is impacting our everyday life. The main focus of this research paper embodies the future ideas in improving healthcare using nanotechnology and using specific techniques involving nanomagnets to treat consequential diseases.

## INTRODUCTION

Nanotechnology is playing a larger and larger role in medical innovation as well as other applications. Nanotechnology is the study and uses of structures between 1 nanometre (billionth of a metre) and 100 nanometres in size, it studies the manipulation of matter on an atomic scale. Over the last century scientists have been working and studying nanoparticles, but the effectiveness of their work had been restricted due to the technology and their inability to see the structure of nanoparticles. However, recent technology and the development of high resolution microscopes enable observations of particles as small as atoms, this has allowed scientists to observe and manipulate what they are working with. Nanotechnology may be able to create new materials and devices which could be used in a vast range of applications, such as in medicine.

**FIGURE 1**

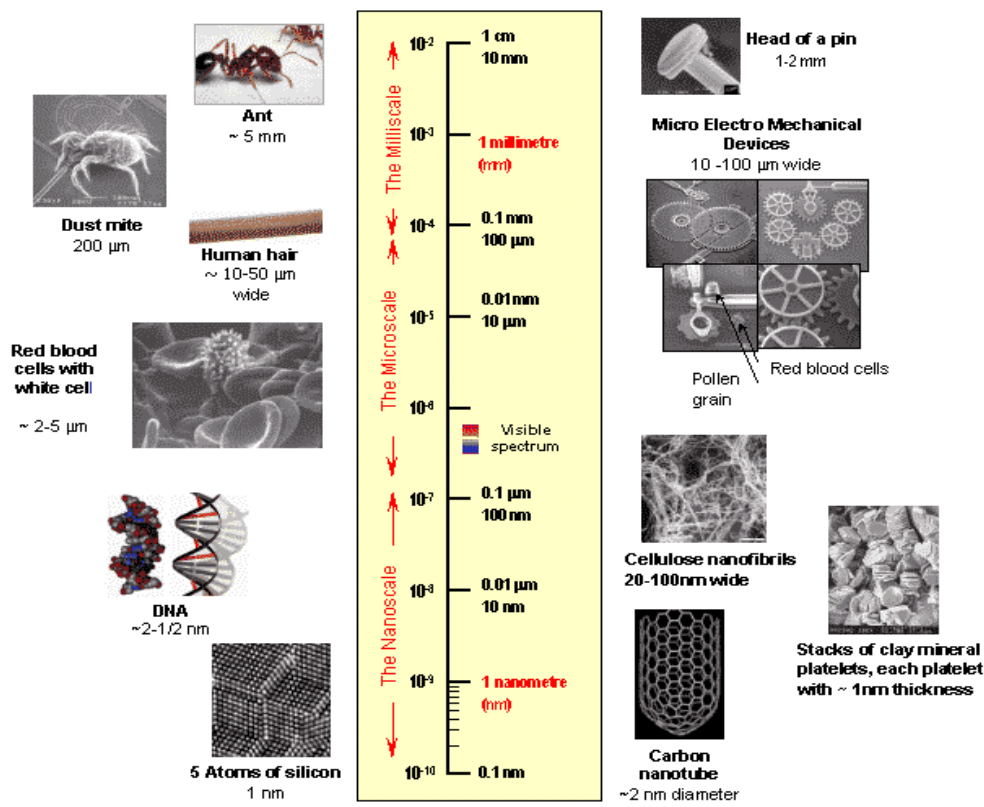
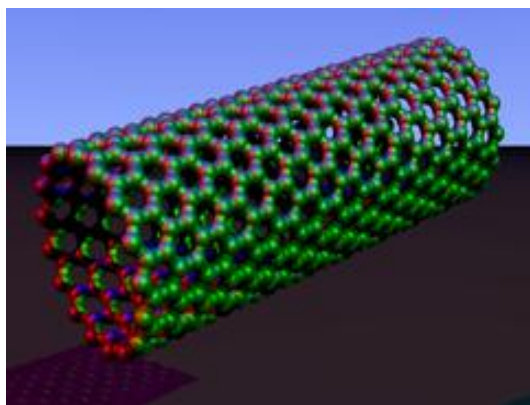


Figure 1 gives an idea of the type of scale which nanotechnology works in.

Over the last decades, many concept ideas about nanotechnology have been put forward. However, the first use of the concepts found in nanotechnology was in the speech “there’s plenty of room at the bottom” by Richard Feynman at California Institute of Technology on December 29, 1959. In Feynman’s speech he described a process which enables us to manipulate atoms and molecules, using one set of precise tools to build and operate another proportionally smaller set, and so on down to the needed scale. The word “Nanotechnology” was popularized by K. Eric Drexler in 1980, he described building machines to a molecular scale, for example a few nanometres wide motors or whole computers far smaller than a cell. He then spent the next ten years analysing and describing the devices which he talked about in 1980. Nanotechnology is so new; no one is really sure what will come of it. Even so, predictions range from the ability to reproduce materials like diamonds and food to the world being devoured by self-replicating nanorobots. Nanotechnology and nanoscience started in the early 1980s with two major developments; the birth of cluster science and the development of the scanning tunneling microscope. The term “cluster science” is referred to in chemistry and physics. In physics a cluster denotes small particles, any particle between 3 and  $3 \times 10^7$  atoms. In chemistry a cluster is an ensemble of bound atoms intermediate in size between a molecule and a bulk solid, for example carbon and boron atoms form fullerene and borane clusters. The scanning tunneling microscope is a very useful instrument and plays a very large role towards nanotechnology. A scanning tunneling microscope (STM) is able to image surfaces at atomic level; it was developed in 1981 by Gerd Binnig and Heinrich Rohrer. The STM has a high resolution of 0.01nm, with these high resolution individual atoms within materials can be observed and manipulated. Also the conditions needed for the STM to function are convenient as they can be used in air, water, and various other liquid or gas ambient, and work at temperatures ranging from near zero Kelvin to a few hundred degrees Celsius. The STM led to the discovery of carbon nanotubes, nanotubes are allotropes of carbon with a cylindrical nanostructure. Nanotubes are part of the fullerene family and have novel properties making them important in many applications particularly in nanotechnology.

**FIGURE 2**



**FIGURE 3**

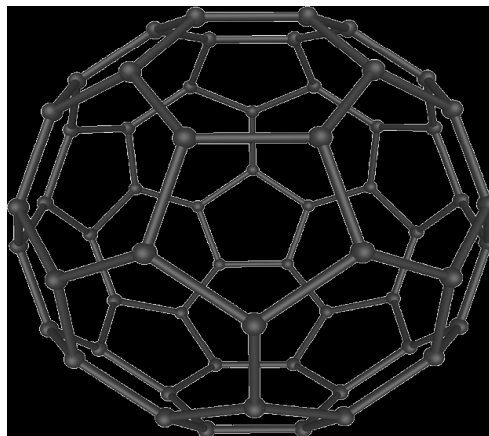


Figure 2 shows a Carbon nanotube (left) and Figure 3 a Buckminsterfullerene (right). Both are structures in the fullerene family. The Buckminsterfullerene has a molecular formula of C<sub>60</sub>; the van der Waals diameter of this molecule is around 1 nanometer. <sup>[1]</sup> Carbon is crucial for one of the most promising branches of nanotechnology. Most of the current research on nanotechnology involves tubes, balls and wires which are composed of carbon atoms. The carbon tubes are known as the carbon nanotubes or buckytubes, the longer thinner tubes are known as nanowires. The balls made up of carbon are sometimes known as fullerenes or buckyballs, the buckminsterfullerene is a popular example of a buckyball. In August 1985 the existence of buckyballs was proved by Richard Smalley, Harry Kroto and Bob Curl, they proved it by composing an experiment. Their experiment was done by vaporising carbon with a laser which produced small traces of buckyballs which was enough to prove their existence. The uses of buckyballs can be endless, they have incredibly significant properties, for example some nanomaterials are as strong as diamond, and they can especially contribute to medical research and usage. Current research involves the development of modified buckyballs for antioxidants for usage in human. When a buckyball encounters a free radical the unpaired electron joins to the delocalised electron on the buckyball, making it soluble in water, resulting in a good property for medical use. Buckyballs are also used for drug delivery; this process involves the buckyball to be modified. The buckyball encases a small dose of the drug needed to be delivered and because the buckyball has been modified it only releases the drug onto the site required. These processes express the significance of buckyballs and carbon in nanomedicine.

## **NANOTECHNOLOGY DEBATE**

Different people have different views about nanotechnology. Firstly, the definition of nanotechnology is defined in two different ways; some people define it as any activity that involves manipulating materials between one nanometre and 100 nanometres. However the original definition of nanotechnology involved building machines at molecular scale and the manipulation of materials on an atomic scale.

Some people debate over the various opinions about exactly what nanotechnology can achieve. Some people believe that nanotechnology is the key to extend the human lifespan or to produce replicator-like devices that can create almost anything from simple raw materials. While others believe that nanotechnology is a tool used to help us do what we do now but faster and better.

Another area of debate concerns the timeframe of nanotechnology- related advances. Will nanotechnology have an impact on our lives in a few years or will nanotechnology take considerably longer.

Finally, summing up the opinions of everyone is people think nanotechnology may cause more harm to the environment and the human society than the good which comes out of it. There are many ethical reasons behind this.

## **DISCUSSION**

Nanotechnology is a very broad subject and can lead to many possibilities in the future. However, nanotechnology can lead to many potential dangers to our society or there may be some ethical reasons opposing the concept of nanotechnology. The use of nanotechnology must be controlled, we must examine the potential consequences of nanotechnology and try and

minimize its damaging effect on society. The threats from the production of nanotechnology are the consequences of catastrophic accidents and misuse of the created products.

### **ETHICS AND POTENTIAL DANGERS OF NANOTECHNOLOGY**

One of the risk problems associated with nanotechnology is the fear of the uncontrollable spread and the growth of self-replicating nanosystems and the uncontrolled function of nanorobots. Also most reports on nanotechnology stress the importance of investigating the possible toxic nature of nanoparticles. Further research of the toxic nature is still essential. Biological warfare and terrorism caused by nanotechnology is not only a future issue but of current interest, especially since the terrorist attacks in the United States on September 11, 2001, and the subsequent mail deliveries of anthrax powders. Another consequence of nanotechnology is that it could lead to privacy problems, improved communication capabilities may result in invasion of privacy, the ethical problem is that the invasion of privacy could grow due to future developments in nanotechnology, for example nanomicrophones.<sup>[2]</sup> Another ethical issue is in regards to enhancement of human capabilities and transhumanism caused by nanotechnology and in gene enhancement.

The discussion of the possible toxic nature of nanoparticles may be compared with the discussion of the toxicity of asbestos, research on nanoparticles show that they can cause health to harm. Nanoparticles have been shown to absorb into the liver of some animals and have shown brain damage to fish exposed to them after 48 hours.<sup>[3]</sup> If the nanoparticles take up our cells they can enter our food chain through bacteria and result in health problems like hormones in meat. Breathing high levels of asbestos fibres for a long period of time may result in scar tissue and cancer in the lungs. The popular and highly useful carbon nanotube looks very much like asbestos fibres, if this gets released in the air then it could cause a lot of damage to human health.<sup>[4]</sup> As mentioned earlier, some nanomaterials are as strong as diamond; if this is true then disposing of such materials may be hard as they may not decompose as well as other materials. Nanotechnology is very new and advanced science and some people may see it as having “god-like powers,” this is why some people may oppose to the use and research of nanotechnology. The most obvious negative in future nanotechnology is weapons. Nanotechnology can not only minimize miniaturizing guns, explosives, and electronic components of missiles.<sup>[5]</sup> They can develop disassemblers to attack physical structures or even biological organism at the molecular level.

### **NANOMEDICINE**

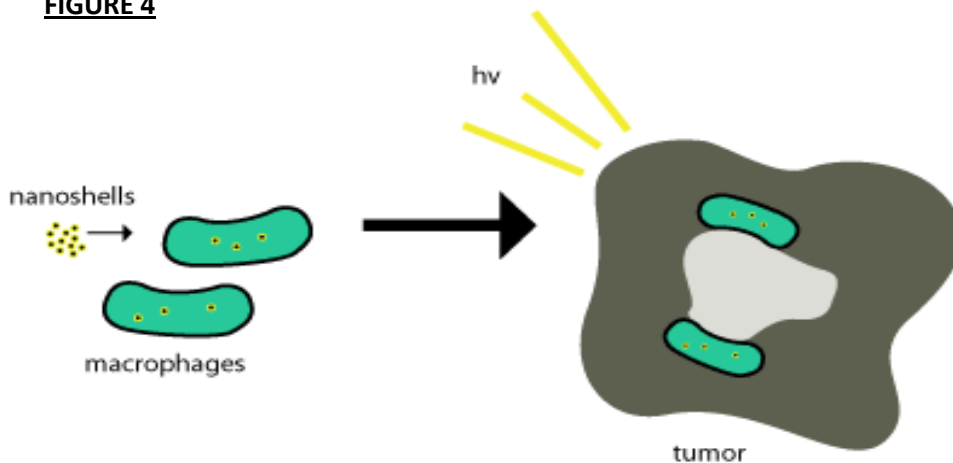
Nanomedicine is the design and manipulation of nanoparticles (i.e., nanotechnology), particularly as applied to the medical diagnosis and treatment of disease.<sup>[6]</sup>

The use of nanotechnology can have many implications in the field of medicine and revolutionize the way we detect and treat damage to the human body and disease in the future. Some techniques are concept ideas, predicting the future of nanotechnology, whereas others are actually being tested and used today. One application of nanotechnology in medicine currently being developed is drug delivery. This involves employing nanoparticles to deliver drugs in the

form of heat, light or other substances to focus on specific cells. The nanoparticles are

engineered such that they are attracted to the diseased cell, which enables direct treatment for these cells and less damage to the healthy cells. Such nanoparticles can be used to treat cancer cells and detect for early signs of cancer. However these chemotherapy drugs are under development and their final approval with use on a cancer patient is pending. There are many therapy techniques which can be improved or used in future. Such techniques include manipulating nanoshells to concentrate heat from infrared light to destroy cancer cells, the advantages of this process is it causes minimal damage to the surrounding healthy cells. I feel the use of nanoshells will have a large impact on the future of treating cancer. Nanoparticles are also vital for medicine in the future, they can be used in many applications, such as killing cancer cells when activated by x- rays or reducing bleeding by absorbing the water in the blood in a wound to clot quickly or even to stimulate an immune response when inhaled to fight off respiratory viruses. Another fascinating application of nanotechnology is cell repair; nanorobots can actually be programmed to repair specific diseased cells. One potential application on nanotechnology is in the production of nanomagnets, having done lots of research I can see how these can be used and manipulated to be applied in medicine.

**FIGURE 4**



A nanoshell is a type of spherical nanoparticle consisting of a dielectric core which is covered by a thin metallic shell (usually gold).<sup>[7]</sup> Figure 4 illustrates cancer treatment with nanoshells and shows how gold nanoshells are shuttled into the tumour by the process phagocytosis. Phagocytes engulf the nanoshells through their cell membrane forming macrophages, these are then taken into the cell where enzymes metabolize it releasing the nanoshells and shuttling them back out of the cell, however for the nanoshells to destroy the cancer, they need to have entered the tumour.

## **NANOMAGNETS**

A nanomagnet is a submicrometric system that presents spontaneous magnetic order (magnetization) at zero applied magnetic field (remanence).<sup>[8]</sup> Nanomagnets are incredibly

useful in all applications and are now playing a large role in medical innovation. After doing research on nanomedicine, I feel that in the future nanomagnets will greatly contribute to medical usage. Current research on nanomagnets has proven to be very useful however more is needed to put them into practice.

### **PURIFYING BLOOD**

Scientists have succeeded in clearing a toxin from blood in just a few minutes, using specially produced nanomagnets. The nanomagnets are just 30 nanometres in diameter, and less than a gram of them is enough to clear the blood of the entire human body of a specific toxin within a few hours the procedure appears promising, if the method can be put into practice, it could one day help people with blood poisoning quickly and efficiently.<sup>[9]</sup>

Pathogens which enter the bloodstream can cause infections, and a standard cure for this is to remove the disease causing factor from the patient's blood. To try and prevent the patient from suffering from the consequential symptoms they try and remove the disease causing factor as quick as possible. Toxins or pathogens can be selectively removed from the blood within minutes. Modified nanomagnets can access substances of different masses and sizes whereas current blood purification techniques are hampered by filter cut offs or slowly moving diffusion in the membrane. The benefits of using nanomagnets is the nanomagnet-based purification method avoids fouling of filter membranes and benefits from a high external surface area, and a correspondingly fast diffusion, the nanomagnets large surface area enables efficient absorption.

**FIGURE 5**

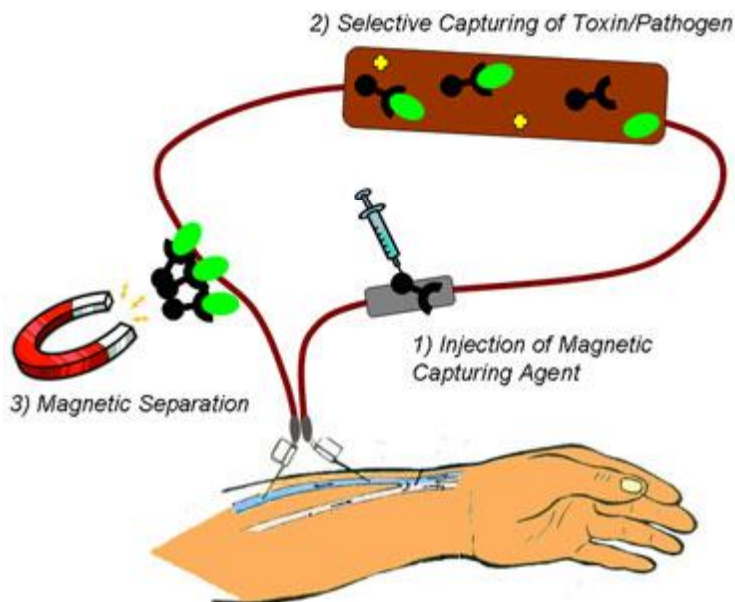


Figure 5 illustrates how the nanomagnet purifier works. Since blood has a high viscosity, it was hard for the magnets to completely bond with the corresponding toxin. The nanomagnets had to be relatively strong and when mixed with the blood they had to be gently swung. "The speed with which the molecules bond to the magnets depends on their binding constant", says Herrmann. "The higher the constant, the faster the antibody of the magnet, for example, binds to the antigen. "After the nanomagnets had completely bonded to the corresponding toxin, they were "fished" out of the blood with a permanent magnet fitted to the exterior of the vessel.<sup>[10]</sup>

Moreover, after this process, scientists have examined any possible negative effects on the physiology of the blood. During their research they could not find any negative effects, neither the red blood cells nor the blood coagulation were impaired. There was some doubt that the magnets may release too much iron into the blood during the process, this was unfounded. Nevertheless the nanomagnets were encased in a carbon shell and are very resistant to acid and temperature. Even so, over half the magnets were dissolved in the blood, the amount of iron therefore released would be insignificant. The procedure has yet to be applied to a living organism, if so it could be an ideal supplement to conventional treatments in the case of serious poisoning, sepsis, metabolic disorders and autoimmune diseases.

### **STEM CELL TREATMENT**

Microscopic magnetic particles have been used to bring stem cells to sites of cardiovascular injury in a new method designed to increase the capacity of cells to repair damaged tissue.<sup>[11]</sup>

Research on stem cells published in *The Journal of the American College of Cardiology: Cardiovascular Interventions* shows a technique which demonstrates how nanomagnets are used to repair damaged tissue. Endothelial progenitor cells (a type of stem cell) have been magnetically tagged with a tiny iron-containing clinical agent, and then successfully targeted to a site of arterial injury using a magnet positioned outside the body.

Panagiotis Kyrtatos, from the UCL Centre for Advanced Biomedical Imaging and lead researcher of the study, added: "This research tackles one of the most critical challenges in the biomedical sciences today: ensuring the effective delivery and retention of cellular therapies to specific targets within the body. <sup>[12]</sup> Cell therapies could greatly benefit from nanomagnetic techniques which concentrate cells where they are needed most. The nanomagnets not only assist with the targeting, but with the aid of MRI also allow us to observe how the cells behave once they're injected."

### **Stem cells to treat heart disease**

Endothelial progenitor cells are important for the formation of blood vessels and since 1997 have

been found to circulate in the blood. It was then further shown that endothelial progenitor introduced from bone marrow helps regenerate blood vessels in in a mouse's damaged tissue.

**FIGURE 6**

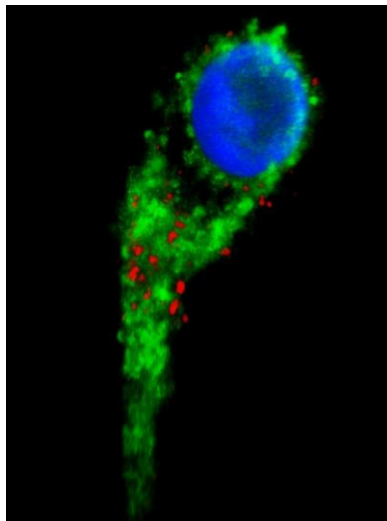


Figure 6 shows an endothelial progenitor cell coated in nanomagnets (red).

During a myocardial infarction, the heart tissue is damaged since blood supply to some of its areas was blocked. Endothelial progenitor cells derived from the patient's own bone marrow can help in regenerating blood vessels and rebuilding damaged heart tissue. Research has found that injecting the stem cells into the coronary artery at the site that had caused the heart attack helps re assemble the patient's heart function.

As the endothelial progenitor circulates in the blood, it is hard to recruit them directly to the injured organ. This is where nanomagnets become useful; research was done on mice with endothelial progenitor cells coated with nanomagnets. After injected with nanomagnet coated EPC (endothelial progenitor) into the rat's heart the amount of cells recruited to the damaged tissue was measured. The results showed that for 12 minutes outside the rat's heart the researchers managed to recruit five times more cells. These results indicate that this method can be used further to help regenerate heart tissue and help treat heart disease.

## **CANCER TREATMENT**

Carbon coated nanomagnets may offer a new form of cancer treatment. This technique involves using heat to target and destroy cancer cells. The therapies employ powerful, roughly spherical nanomagnets to help kill carefully targeted cancer cells.<sup>[13]</sup> Research presented at the 103rd Annual Scientific Meeting of the American Urological Association (AUA) suggests that nanomagnets consisting of metallic iron and a protective carbon coat could serve as a safe and effective hyperthermia agent.<sup>[14]</sup> Metallic iron in nanoparticles is useful as it would allow heating at greater temperature; and coating the iron with carbon would prevent the iron from rusting, which can hinder the effectiveness of the therapy. There have been many other techniques employing the same ideas to treat cancer with nanoparticles. Such concept ideas account the use of tiny nanomagnets which are designed to roam through the body's blood vessels in search of tumour cells. After the nanomagnets have latched on to their targets, the magnets can be heated from outside the body using a magnetic field; this would eradicate the cancer cells without harming the surrounding tissue. This technique is still at the earliest stages and the first clinical trials will start in three years on lung cancers patients. Tests on animals, exploiting these techniques, have been very successful and have shown to kill tumour cells.

**FIGURE 7**



Figure 7 shows how nanomagnets do not affect the healthy cells. Blue fluid with therapeutic nanomagnets targets tumour cells (right) but the nanomagnets leave the healthy cells (left)

The use of nanomagnets in cancer treatment is very useful as it can specifically destroy the cancer cells without harming the healthy non-cancerous cells around it. This is an advantage to current techniques, for example chemotherapy. In order to ensure this, researches composed an experiment to test the nanomagnets compatibility with normal tissue. Human PC-3 prostate cells and a non-malignant fibroblast cell line were incubated with the carbon coated nanomagnets and, after the incubation period, the cells did not experience major cytotoxic (cell-destroying) effects. .<sup>[15]</sup> The results showed that with the presence of nanomagnets the cells surrounding the cancerous cells were not impaired. This breakthrough could provide an effective treatment option for many types of cancer, without the destruction of surrounding cells associated with chemotherapy or invasive surgery.

### **Nanomagnets produced by bacteria**

New studies by scientists in the UK and France have shown it is possible to fine tune tiny nanomagnets made by bacteria, this new and exciting technology could one day be developed to

target cancer tumours. This process works efficiently as some bacteria have the ability to digest iron into tiny nanoparticles of magnetite that are enclosed in lipid vesicles. These "magnetosomes" as they are called, have considerable potential for medical use because of their greater compatibility and convenient narrow and uniform shape compared to manmade versions. Bacteria use these "magnetosomes" to help them look for environments rich with oxygen.<sup>[16]</sup>

The potential of these magnetosomes can be incredibly significant for use in medicine. If the magnetic properties of the magnetosomes can be controlled it can prove to be very useful, and especially efficient for cancer treatment. Scientists have shown that they could add to the magnetosomes with cobalt, which has been proved to increase their ability to stay magnetized when they are removed from a magnetic field.

They concluded their findings:

"Provide an important advance in designing biologically synthesized nanoparticles with useful highly tuned magnetic properties."

"They could be guided to the tumour using magnetic force, and once there, by reversing the magnetic field they could be heated up and kill the cells. Another application could be to use them to transport drugs to the precise site of the tumour."<sup>[17]</sup>

## **CONCLUSION**

This research paper supports the utilisation of nanotechnology applied in medicine and the impacts it has on our current and future environment. Although some argue that the concept of nanotechnology may lead to consequential dangers, in my opinion I feel it is a vital aspect for the future of medicine.

Nanotechnology has the potential to help minimize the occurrence of many deleterious diseases, such as heart disease.

## **FIGURE 8**

<b>TOP 3 CAUSES OF DEATH IN WOMEN - 2005</b>
Heart disease - 16%
Cerebrovascular disease - 12.9%
Flu/pneumonia - 7.9%

<b>TOP 3 CAUSES OF DEATH IN MEN AND WOMEN - 2005</b>
Heart disease - 20.2%
Cerebrovascular diseases - 7.9%
Lung cancer - 6.9%

Figure 8 shows that heart disease is the highest killer in men and women and many predictions show that cancer will be the highest killer in the next few years. <sup>[18]</sup> As shown in paper, the use of nanomagnets can be used to treat cancer as well as heart disease, which would be very useful for the future of medicine. I also found nanomagnets significant as I feel they can help progress in the fundamental aspects of medicine, such as manipulating stem cells. However, nanomagnets are concept ideas and haven't been fully tested and trialled for usage.

Nanomedicine and nanotechnology in general, is new and there is little experimental data about unintended and adverse effects exists. The lack of knowledge about how nanoparticles might affect or interfere with the human body is particularly important, if nanotechnology is to be used. Scientists are primarily concerned with toxicity, other than the obvious potential risks to patients, there are other toxicological risks associated with nanomedicine. There are also concerns over the disposal of nanowaste and environmental contamination from the manufacture of nanomedical devices. These all are reasons why some may argue against nanotechnology.

However I feel nanotechnology should be exploited and studied more and tests on nanomedical products should take place. In my opinion this would greatly increase medical knowledge and treatment in the future. Nanomedicine is a very broad subject and just by studying and analysing nanomagnets I have been able to conclude many reasons to why it should be used. The risks of nanotechnology I feel can be controlled. Nanotechnology should only run by non-profitable, responsible organizations, such as the government. This may help to minimize the threat of nanotechnology weaponry in our society.

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