

# Nanotechnology in Medicine and its Future

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PASS WITH DISTINCTION

RESEARCH PAPER  
BASED ON PATHOLOGY LECTURES  
AT MEDLINK 2010

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## Abstract

This research paper discusses the use of nanotechnology in medicine and explores the possibilities of nanotechnology in the future. By definition from 'Center for Responsible Nanotechnology', Nanotechnology is the engineering of functional systems at an atomic scale. Recently, nanotechnology has become a leading development in medicine; something that was only previously used in products in its passive form has advanced into applications in active forms such as its uses in drug delivery and diabetes. Some of this current research into nanotechnology is discussed as well as ethical issues which could prevent its future development.

This article also speculates further possibilities of nanotechnology in medicine in both treatment and diagnosis. By way of Gedankenexperiment, the author, using knowledge gained from Medlink as well as independent research, attempts to suggest ways to improve current applications of nanotechnology in medicine. In particular, the possible use of nanotechnology in the control of severe epileptic seizures is discussed. In the author's opinion, it is not inconceivable that, like many other diseases, epilepsy could well be a 'disease of the past' in the future.

## Introduction

The pathology lectures presented at Medlink gave me an insightful view of how nanotechnology, something so small, could create treatments for big problems in medical practice. So, researching for this paper has enabled me to investigate the possibilities of nanotechnology in medicine.

Nanotechnology is essentially the 'building' of atoms from the bottom up with atomic precision. This theoretical idea derived from physicist *Richard Feynman* in 1959 during his talk '*There's Plenty of Room at the Bottom*'(4) .Here he said '*I want to build a billion tiny factories, models of each other, which are manufacturing simultaneously. . . The principles of physics, as far as I can see, do not speak against the possibility of manoeuvring things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big.*' The U.S National Nanotechnology Initiative describes any nanotech to be anything smaller than 100nm with novel properties.

During the 1980s, the idea of nanotechnology became more accepted as Eric Drexler proposed the building of machines on a molecular scale in his book '*Engines of Creation*'. Along with the invention of the scanning tunnelling microscope in the 1990s, the discovery of the Buckminsterfullerene (figure 1) and carbon nanotubes were made possible by *Richard. E. Smalley*.

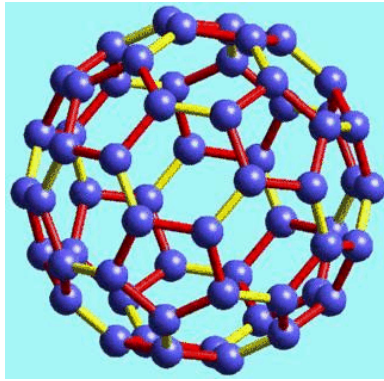


Figure 1

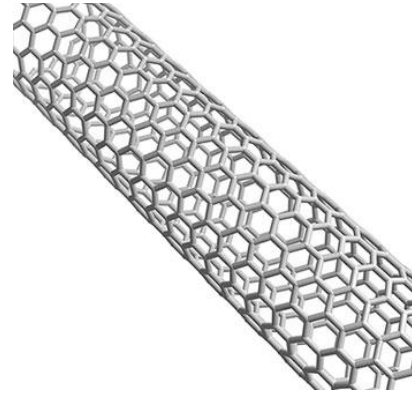


Figure 2

Both being allotropes of carbon, the Buckminsterfullerene and the carbon nanotube have novel properties which potentially enable them to have a wide variety of uses, not just in medicine. Nanotubes are hollow cylindrical structures made up of fullerenes and have properties such as a high tensile strength, high electrical conductivity and high ductility.

Proposed ideas of drug delivery by Buckminsterfullerenes in active forms are likely for cancer treatment. Due to their small size, they can enter the body easily delivering the anti cancer drug within the hollow cavity more precisely to the target. This will create minimal side effects for the patient.

The development of nanotechnology has been described by *Mihail Roco* (4) from the U.S National Nanotechnology Initiative as Four generations (figure 3).

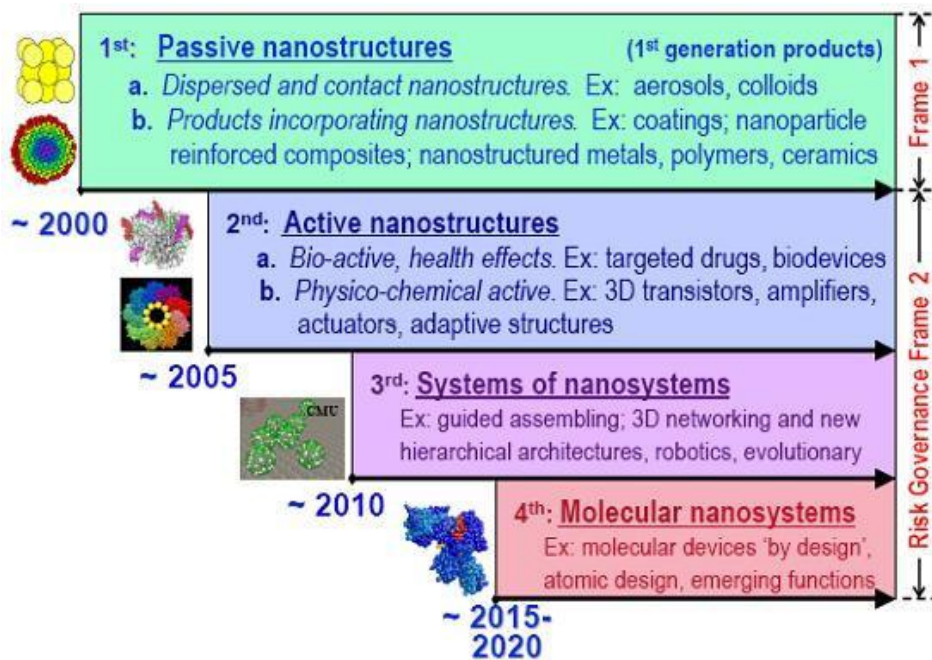


Figure 3

Figure 3 displays some sort of hierarchy of nanotechnology, much like a hierarchy of animals. It shows that like nature, nanotechnology is evolving from small to large by nature architecture. At present, more and more discoveries in nanotechnology are being found and built atom by atom. Nanotechnology is not only used for medical purposes. The use of nanotubes can also be used to enhance computer power and the use of nanomaterials enables military equipment to be more lightweight.

'Nanomedicine' is the term used to describe the applications of nanotechnology in medicine. This seems to be the next advance for nanotechnology and will prove to be extremely beneficial for the future. Even though 'nanomedicine' is still developing, there are current uses of 'nanomedicine' at the moment. Aside from medical treatment, nanotechnology is also being used for therapy and diagnosis. Nanofibers (figure 4) are currently being used to stimulate the growth of cartilage in damaged joints so healing time is reduced. To aid diagnosis, iron oxide nanoparticles are being used in MRI scans for cancer tumours as they improve the contrast of the image (figure 5). This makes diagnosis much easier as cancer tumours can be identified earlier than beforehand.

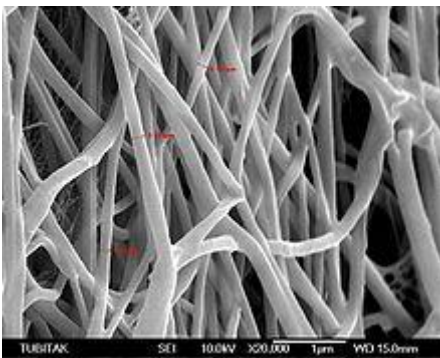


Figure 4

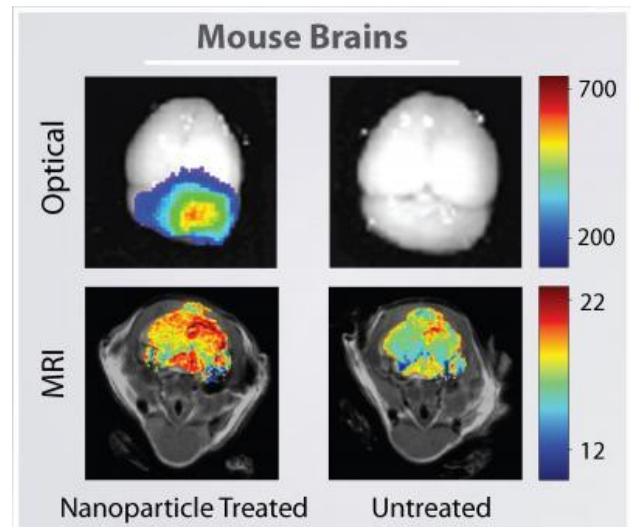


Figure 5

## Discussion

Regarding future medical applications of nanotechnology, I have decided to carry out a Gedankenexperiment on the possibilities of using nanotechnology to control and prevent seizures caused by epilepsy in the brain. My aim is to use current research to develop my ideas on creating a device that can detect epileptic seizures and release appropriate drugs in order to do this.

Epilepsy is a chronic neurological disease that is currently defined as having recurrent seizures. These seizures are caused by excess electrical activity in the brain and so can cause disruptions in signals within the brain. There are three main types of seizures that can be described as being partial, generalized or secondary generalized. Partial seizures occur when only a specific area of the brain has epileptic activity. This category is divided into two sub-groups that are simple and complex partial. If the patient is conscious during their epileptic seizure, it is described as being simple partial. A complex seizure is when the patient becomes partially unconscious and may not remember anything during the seizure. In comparison, generalized seizures happen in a more general area of the brain, affecting both hemispheres. Sometimes, partial seizures can become generalized seizures, and this is known as a secondary generalized seizure.

Epilepsy is a multifactorial disease that affects roughly 500 thousand people in the UK alone and is believed to be caused by many factors. These include brain tumours, strokes and severe head injuries. Despite this, approximately 60% of epileptic sufferers have idiopathic epilepsy. This means that the cause is unknown.

Currently, there is no treatment for epilepsy, but seizures can be controlled by the administration of Antiepileptic drugs (AEDs) by various routes including oral, buccal, rectal and parenteral. AEDs are carried by the blood in order to reach the brain through the vast network of capillaries that are found there. However, AEDs are only active if they can reach the brain through this blood brain barrier which often presents as an obstacle for drug delivery.

The blood brain barrier shown in figure 5 is made up of capillaries around which tight joints are formed; unlike capillaries in normal circulation. The main role of the brain blood barrier is to regulate which substances are able to pass through to the cerebrospinal fluid. This means that pathogens such as bacteria are prevented from entering the brain that could

seriously harm it. Large hydrophilic molecules are also unable to cross the blood brain barrier. However, essential metabolic molecules which are fat soluble such as oxygen can diffuse through. Due to this tightly regulated mechanism, drugs delivery to the brain can be denied.

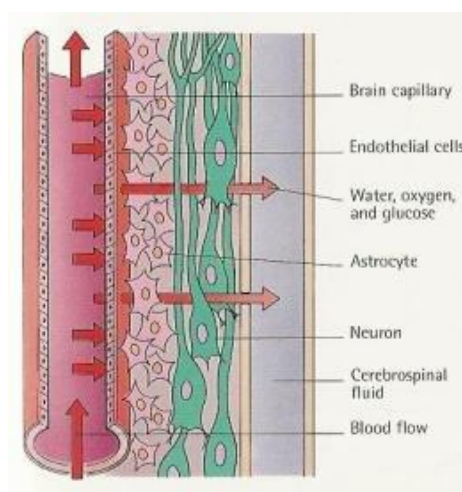


Figure 6

AEDs can give rise to side effects. Commonly reported side effects include headaches, gastro-intestinal disturbances and rashes. More severe side effects include blood disorders such as megaloblastic anaemia, leucopenia and thrombocytopenia as well as hepatotoxicity. More recently the *'Los Angeles Times'* (7) has reported that the AED topiramate triples the chance of birth defects in newborns in comparison to other AEDs. In addition, there is no reliable way to predict what side effects or their severity a person may get by taking these drugs. Drug delivery systems delivering drugs specifically to the brain minimizing peripheral side effects are thus highly desirable.

Attempts of administrating drugs to weaker areas of the blood brain barrier are being developed in order to improve delivery to the brain. Circumventricular organs are where the blood brain barrier is weak and so substances diffusing in and out of the tissue are not so tightly regulated. It is here where nanotechnology could potentially become a solution to control epileptic seizures.

As briefly mentioned before, Buckminsterfullerenes (C<sub>60</sub>) are spherical molecules composed of 12 pentagons and 20 hexagons. This structure is known as a closed cage structure. The hollow middle cavity of the Buckminsterfullerene means that drugs like AEDs could be transported within. Firstly, the Buckminsterfullerene will overcome the blood brain barrier physically since it is only 1nm in diameter. However, another problem arises since the Buckminsterfullerene is not a lipid soluble molecule and so must be specially coated so that drug diffusion into the cerebrospinal fluid is possible. We can study the liposome to enable us to further develop this idea so that the Buckminsterfullerene can pass the blood brain barrier.

Liposomes are small fluid filled vesicles which are bound by a phospholipid bilayer, also found in cell membranes. They are currently used in drug delivery because the phospholipid bilayer enables drugs to be encapsulated inside where the hydrophilic region as shown in figure 7. This means drugs can be contained in an aqueous solution and will not escape due to the presence of the hydrophobic tails. The outside of the liposome is also hydrophilic.

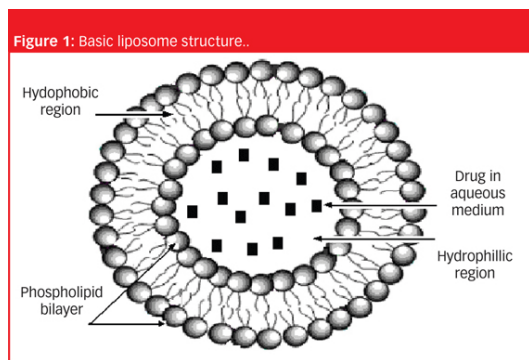


Figure 7

As well water soluble molecules, liposomes can also contain fat soluble molecules between the hydrophobic tails of the phospholipid bilayer. It does this by being multi-laminar, having multiple bilayers. Lipid soluble substances are held in the white areas whereas water soluble molecules are held in grey regions as shown in figure 8. This kind of structure could be applied to the Buckminsterfullerene which could be coated in a bipolar lipid so that drug

### Architecture of NanoSorb™ Molecule

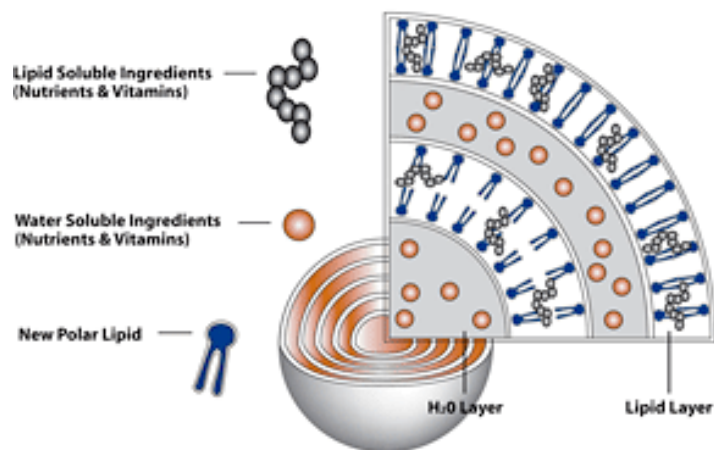


Figure 8

diffusion across the blood brain barrier is possible as it is made lipid soluble.

In order to prevent having any epileptic fits, one must first be able to detect them. Recent development has shown that EEG analysis can predict the onset of epileptic seizure with high sensitivity and specificity. Nanotechnology can be applied here by means of a nanochip. A nanochip is a computer chip which uses MEMS (Micro-Electrical-Mechanical-System) to store large amounts of information. The nanochip can be programmed to monitor pre-seizure EEG changes. As soon as pre-seizure activities are detected, the nanochip can provide a stimulus for the release of AEDs. Such a nanochip can perhaps be implanted under the scalp.

To incorporate drug delivery, the nanochip could be placed near or inside a nanopump which can facilitate the release of AEDs in response to the triggering signal from the nanochip. The nanopump is currently being developed by *Debiotech* for diabetics so that their blood sugar levels can be maintained. The prototype is one quarter of the size of the regular diabetic pump. It is made up of SOI (Silicon On Insulator) wafers. These wafers increase precision of the drug delivery in the nanopump as well as enabling it to be as small as possible. Once a rise in blood sugar levels occurs, the nanopump will automatically inject insulin into the bloodstream. When it becomes available, diabetics can do away with the constant use lancets and needles for monitoring blood sugar levels and for injecting insulin. Likewise, for the prevention of epilepsy, once pre-seizure EEG activities are detected, the nanopump could release AEDs in the form of lipid coated Buckminsterfullerenes to the target region of the brain. These two models are somewhat similar and hence I do believe that nanotechnology can successfully be applied to the treatment and prevention of epilepsy.

form of lipid coated Buckminsterfullerenes to target the region of the brain affected. And so, using current research of the Buckminsterfullerene, nanochips and the nanopump, I have proposed an idea for the prevention of epileptic seizures combining these nanotechnologies.

However, there are limitations to this idea. Firstly, if the whole device is implanted below the scalp and AEDs are administered when needed; the drugs will soon run low and must be replenished. The exact location where this device should be is also unknown, but should probably be implanted near an area of where known excess electrical activity takes place before the seizure; and also close to a the weaker areas of the blood brain barrier so that delivery of AEDs is more efficient.

As with many scientific advances, ethical issues will always arise. Firstly, nanotechnology could pose as potential dangers if being used in the military. Miniature weapons and explosives could be created as well as monitoring and tracking devices which could be used unethically. People also fear that nanotechnology could provide us with the ability to give 'god-like' powers, especially with recent talks about how nanotechnology could be developed to make humans immortal.

Despite this, I believe that the benefits that nanotechnology has to offer us far outweigh the bad; mainly due to the potential treatments that it could provide in the medical field. Diabetics can finally control blood sugar levels hassle free and a way of destroying cancer tumours will certainly have a positive effect.

## Conclusion

Reflecting on the research I have carried out on nanotechnology and its ethical issues, I believe that it will be extremely beneficial for nanomedicine in the future. Not only can nanotechnology give us potential treatments for diseases but could also revolutionise computers and everyday materials (nanomaterials).

For my Gedankenexperiment, I proposed to incorporate various nanotechnologies that could be useful for the prevention of epileptic seizures. I did this by first researching the Buckminsterfullerene as they are currently being developed for drug delivery and could possibly transport AEDs. However, although a Buckminsterfullerene was physically able to pass the blood brain barrier, other problems arise because drug delivery to the brain is inefficient due to the barrier being tightly regulated. I tackled this by looking at the liposomes which is at present used for drug delivery. Liposomes are unique in that they can have multi-laminar phospholipid bilayers and so fat soluble medication can be transported within them. The importance of the medication being fat soluble was due to the blood brain barrier which would only allow lipid soluble molecules through. Because of this, the Buckminsterfullerene could be coated with lipid so that it can diffuse through the blood brain barrier. For the Buckminsterfullerene to be released, it must have a stimulus. This would be the excess electrical signals coming from the brain which causes an epileptic seizure. These signals could be detected by EEG electrodes which can connect to a nanochip. The nanochip could store information as to where these excess electrical signals are coming from. They have the capacity to store large amount of information as shown by the use of nanochips for computers. The nanochip could then interact with the nanopump, stimulating it to release the AEDs in the form of Buckminsterfullerenes. If

this idea was put into practice, epileptic sufferers would practically gain a seizure free life and would not have to put up with the uncertainty of epileptic seizures. In the UK, approximately 1 in 131 people have epilepsy and it causes around 500 deaths per year alone and so with the use of nanotechnology, many lives could be saved. This idea however needs much further development as it does raise some difficulties such as the loading and replacement of drugs into the nanopump. This may prove difficult if located beneath the scalp. Despite this, I believe that nanotechnology could also gain widespread usage in other medical treatments such as other endocrine disorders, cardiac arrhythmias, anaphylaxis, acute coronary syndrome and possibly many other conditions.

Ethical issues regarding nanotechnology may hinder their development that *Mihail Roco* states previously. These include worries of danger, such as miniature explosives for the military and worries that nanotechnology will make us inhuman. These drawbacks should not prevent the further development of nanotechnology for medical uses because I believe it could be the vital treatment for diseases and could improve people's quality of life. The world of nanotechnology is endless; this is just the beginning of a whole new future.

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