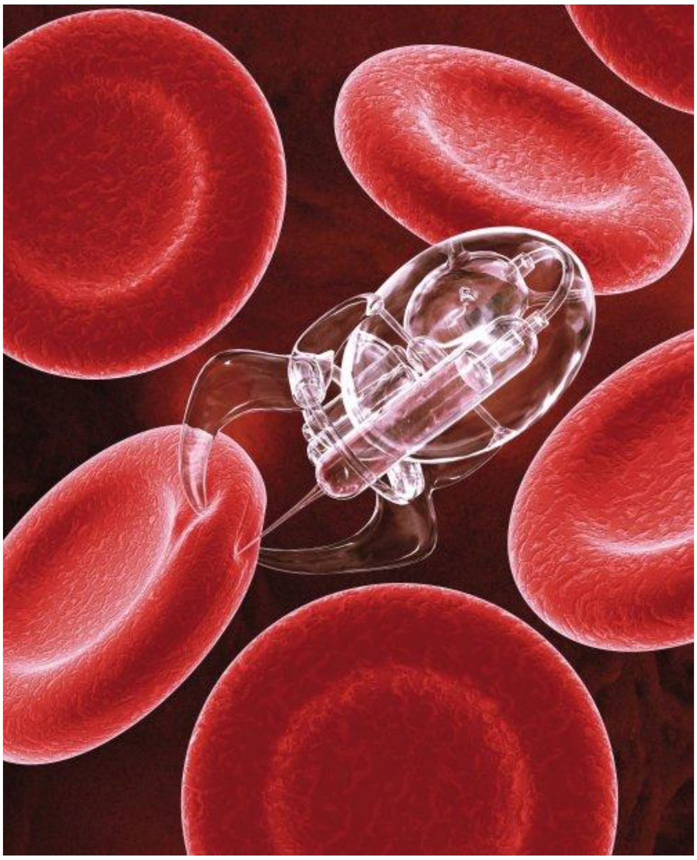
CAN NANOTECHNOLOGY REVOLUTIONISE MEDICINE?

Discussing the applications and ethical implications of using Nanotechnology in medicine.



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PASS

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Abstract

This paper will be discussing ground breaking issues in the field of research medicine. The ideas of nanotechnology introduced to the scientific world recently will be analysed to discover whether or not this research has any chance of revolutionising medicine. Nanotechnology refers to manipulating matter at the atomic scale and therefore has particular relevance to medicine in 'nanosurgery' as well as other applications. However, new technologies always carry new risks and concerns. Such as unknown health effects and concerns with introducing manufactured nanoparticles with the immune system, for example. Some people may also raise issues that there are many ethical implications of this new research into 'nanomedicine'. Overall this paper sets out to discuss, criticise and encourage the research and future use of nanotechnology in medicine and will try to answer the question, "Can Nanotechnology revolutionise medicine?"

Introduction

There are many undiscovered issues in the world of medicine. Researchers have spent years trying to find new, improved procedures not only to facilitate but to enhance the world of medicine. This is why the new research into the field of nanotechnology has caught the eye of many research doctors to be the next way in which medicine could be revolutionised. The oxford dictionary defines nanotechnology as *"Nanotechnology is the blanket term used to describe the precision manufacture of materials and structures of molecular dimensions."* More specifically it is defined as the research and development in the 1-100 nm range. Nanotechnology uses structures that have virtually novel properties because of their small size and builds on the ability to control and manipulate matter on the atomic scale.

The Nobel Prize winning physicist, in 1959, Richard Feynman introduced the idea of the physical possibility of making and manipulation things on a small scale by arranging the atoms 'the way we want'. His article entitled 'There's plenty of room at the bottom' was groundbreaking at that time and still is one of the major stepping stones in scientific history. Many people now describe the field of nanotechnology as 'the science of the very small with big potential'. Therefore, this paper will discuss whether the new methods in nanotechnology can be used in our quest to revolutionise medicine and help to save lives.

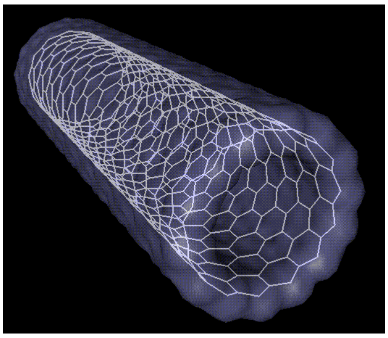

Figure 1

The implications and possible applications of nanotechnology are immense. Nanotechnology has the potential to provide significant advances over the next 50 years. One example is buckminsterfullerene, C_{60}, which involves the addition of pentagons into the hexagonal structure of graphite forming a closed spherical cage. The discovery of this commonly known as 'Bucky balls' led to the discovery of a whole family of structurally related carbon nanotubes as shown in figure 1. This triggered a whole series of molecules including structures with multiple walls of concentric tubes have been produced. This has changed the world of electronics as they have produced a structure which is 100 times stronger than steel but only one sixth of the weight.

This is now why this research is of particular relevance to medicine due to the relative sizes of the molecule being produced relating to the sizes of body cells. The application of nanotechnology in medicine, commonly known as nano-medicine has produced some pioneering ideas some which are theoretical and some which is already being tested and could be implemented into real medicine very soon. This involves the use of nanoparticles using the same materials as mentioned above this involves manufactures nano-robots to make repairs even at a cellular level. There are many applications of which a few will be discussed in this paper. Examples of which include,

- Quantum dot nanoparticle probes used to target and image tumours through the incorporation of antibodies that bind to the target cancer cells.
- Enhanced drug delivery systems,

- New therapy techniques, diagnostic and imaging techniques, anti-microbial techniques, cell repair,
- Nanorobots in medicine treat heart disease (ref. Title image).
- Nanonephronology the branch of nanomedicine and nanotechnology that deals with the study of kidney protein structures at the atomic level; nano-imaging approaches to study cellular processes in kidney cells; and nano medical treatments that utilize nanoparticles and to treat various kidney diseases.
- Optical Tracking of Organically Modified Silica Nanoparticles as DNA Carriers: A Nonviral, Nanomedicine Approach for Gene Delivery
- 'Nanopore' device to analyse DNA.

All of which involve some form of life extension by curing life threatening disease.

The advent of such new methods brings with it many ethical implications as well as individual pros and cons of using nanoparticles in the human body. This is why all new methods need extensive testing and some will never be possible due to these implications. This paper will examine these implications as well as many other methods and will try to arrive at an overall answer of the question 'Can nanotechnology revolutionise medicine'

Discussion

There are a variety of different methods in the vicinity of nanomedicine which could be considered as viable to enhance, improve and eventually revolutionise medicine. Here, in this section the paper will discuss these methods as well as introducing possible points for not using these methods.

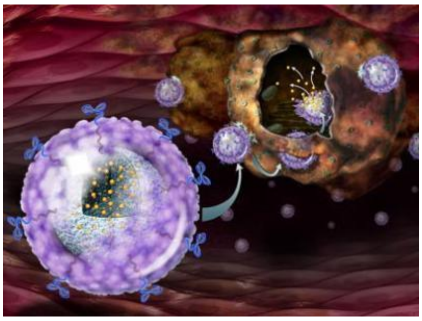

Figure 2- Nanoparticle Drug Delivery

The main problem hindering medics now is improving existing systems and one such system is of drug delivery. If we take the example of cancer, which is the most common example of this problem. If a drug is administered (orally or injected) then the drug is targeted to the cancerous cells. However this obviously will not happen as the drug will be introduced into the bloodstream and evidently some healthy cells will also die or get damaged. Therefore a viable method has been required and lots of effort has been placed to find the ideal drug delivery system. One application using nanoparticles is where nanoparticles are used to deliver drugs. The best thing about this is that they can not only deliver drugs but also can be forced to deliver items such as heat, light and other substances to the exact targeted location desired. Particles are engineered at the atomic scale which allows them to be attracted to diseased cells. This is done ingeniously using conventional liposomes, polymeric micelles, and nanoparticles, now called "nanovehicles". The future of drug delivery systems, as far as nanotechnology is concerned, is to develop nano manufacturing processes that can synthesise nano drug delivery systems. The current technology of fabrication and manufacturing of engineering materials at the nano scale is advanced enough to develop nano scale processes for producing products to be used in the pharmaceutical industry.

Nanoparticles have unique properties in that they can be used to improve drug delivery. Where possible larger particles could be seen as 'alien' to the body and blocked against. Nanoparticles are so small they can be taken up by the body. This will aid the development if complex mechanisms in getting drugs through the cellular membrane and into the cytoplasm where it will have more effect. This increases efficiency and if the drug can target particular cells the strength of the drug can be increased as there will be no risk of affecting the healthy cells and hence a lowered risk of severe side effects. Specific properties of the drug can also be changed according to the needs of the patient for example a drug with poor solubility due to its structure can be aided by a drug delivery system with both hydrophilic and hydrophobic ends. This also reduces the risk of tissue damage by the drug as the drug release can be regulated externally which will obviously eliminate the problem. However new drugs will have to be made and/or discovered due to the needs and changes of pharmacokinetics of the drugs. This is beneficial as the development of nanotechnology and nanomedicine will allow it to become the leading face in developing new drugs with more useful properties and fewer side effects which is always a bonus.

The nanoparticles to deliver chemotherapy drugs is now under serious development and tests are being done to target the delivery of chemotherapy drugs and this has been developed to a good stage as the final approval for use of nanoparticles on cancer patients is pending. The leading company in this particular field, CytImmune, has already published results of their fist targeted chemotherapy drug. The detailed prosthetics of this system is very complicated but a basic explanation is that the drug is encapsulated in a nanoparticle which helps it to pass through the stomach and not to be digested here in order to deliver the drug into the blood stream. This allows the oral administration of drugs which otherwise would have to be injected due to the stomach. The nanoparticles used is like the one in figure 3 which allows the drug to be caged as well as regulating the drug delivery. The uses of this do not stop at cancer drug delivery but are vast and truly revolutionise this sector of medicine. A company which has progressed to the clinical testing stage with a drug for treating systemic fungal diseases is BioDelivery Sciences, which is using a nanoparticle called a cochleate. This is not a new idea but an improvement upon existing conventional methods of drug delivery.

Figure 3- The nanoparticle Fullerene (eg)

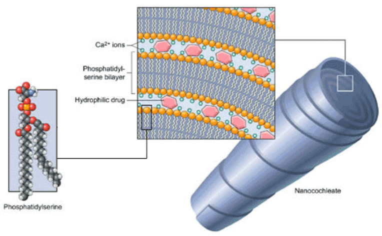

Figure 4- The nanoparticle structure and location of cochleate (eg)

Another application of nanotechnology in medicine is to use it for diagnostic imaging and possible therapy techniques. As mentioned before in the introduction, Quantum dot nanoparticle probes can be used to target and image tumours through the incorporation of antibodies that bind to the target cancer cells. The q dots are used to locate cancer tumours these are nanoparticles with quantum confinement properties, such as size-tuneable light emission. These are particularly important in medicine is because they can get into the bloodstream easily and when used with MRI, magnetic resonance imagery, they can produce exceptional images of tumour sites which will provide an exceptional database for medical practitioners to use for possible detection of tumours and for the treatment of tumours. This works as here the nanoparticles itself is coated with a peptide (protein) that binds to a cancerous tumour. Then the magnetic properties of the iron oxide come into play as it enhances the images produced by the MRI scan. Any means of improving the image will be of vital importance to a doctor as the more information the better.

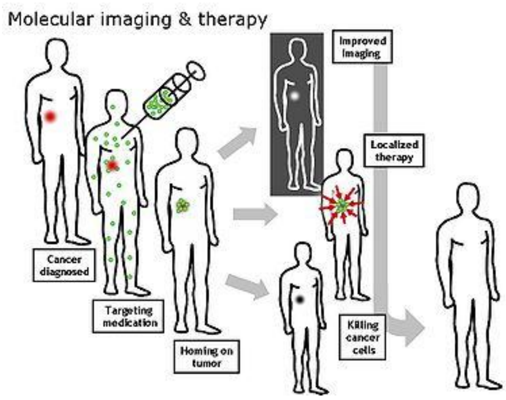

Figure 5- The future of Cancer Treatment?

Figure 5 illustrates schematically the possibility of treating patients diagnosed with cancer by using a nanoparticles induced targeting medication which induces a homing on the tumour. This can then provide a plethora of different possibilities for the doctor to use in order to improve the current situation. They can produce improved imaging techniques, localised therapy leading to the eventual killing of the cancer cells.

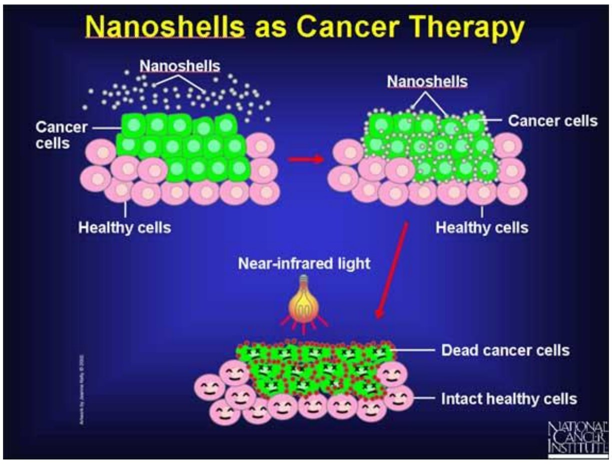

Figure 6

If we now focus on specialised therapy techniques, using nanotechnology. Buckyballs as described in the introduction can be used to trap free radicals (An atom or group of atoms that has at least one unpaired electron and is therefore unstable and highly reactive. In animal tissues, free radicals can damage cells and are believed to accelerate the progression of cancer, cardiovascular disease, and age-related diseases.) One example is that buckyballs will be able to block the free radicals produced after an allergic reaction and block/prevent inflammation that often results after an allergic reaction. This is revolutionary for the world of medicine as anything that can be used to reduce side effects and overall effects will be increasingly beneficial. Nanoshells can also be used to concentrate the heat from infrared light to destroy cancer cells. This will be targeted so that it will provide minimal damage to surrounding healthy cells. Figure 6 shows how these work as they are attracted to cancer cells and concentrate the infrared heat to eventually kill the cells. Nanoparticles can also be used by being activated by x-rays to generate electrons causing destruction of cancer cells to which they are attached to. This may eventually replace radiation therapy which is commonly used as treatment for cancer. This is important for medicine as it will have less impact and damage upon healthy tissue. Nanotechnology can also be used to reduce bleeding in trauma patients more quickly by the increased absorption of water which causes the blood in the wound to coagulate more quickly. One example of this being produced is to implement them in medical gauze that uses these alluminosillicate particles.

We can now delve into the sector of medicine which needs arguably the most research. This is regeneration medicine as the body is incredible in its ability to regenerate body tissue. However we know that not everything can be regenerated by the body. Hence the development of nanofibers which stimulate the production of cartilage in damaged joints is very important. A north western university has been able to design new nanoscopic fibers which stimulate stem cells present in bone marrow to produce cartilage containing type 2 collagen, the major protein in cartilage. This has been developed to be included in a gel which is injected into the area of damaged joint. This extracellular matrix, which mimics what cells usually see, binds by molecular design one of the most important growth factors for the repair and regeneration of cartilage. By keeping the growth factor concentrated and localized, the cartilage cells have the opportunity to regenerate. This system is at the heart of this research and is very important in nanotechnology procedures used in the field or medicine and has truly revolutionised medicine. There are many other products involving nanomaterials being developed to fight various diseases.

There are also many anti-microbial techniques which can be used to kill bacteria is also evolving. One of the first products to be developed in nanomedicine is the use of nanocrystalline silver which acts as an anti-microbial agent for the treatment of wounds. Another use of nanoparticles is the electrostatic binding of DNA onto the surface of the nanoparticles, due to positively charged amino groups, is also shown by intercalating an appropriate dye into the DNA and observing the fluorescence resonance energy transfer between the dye (energy donor) intercalated in DNA on the surface of nanoparticles and a second dye (energy acceptor) inside the nanoparticles. Imaging by fluorescence con-focal microscopy shows that cells efficiently take up the nanoparticles in vitro in the cytoplasm, and the nanoparticles deliver DNA to the nucleus.

Molecular nanotechnology can be used to engineer molecular assemblers. Nanorobots has quite speculative uses in medicine but it may totally v=change the world of medicine if it is realized. This is the part of nanotechnology which can be readily realised as possibly being 'star trek' medicine. However it does have brilliant possibilities to revolutionise medicine. Nanomedicine would manufacture Nanorobots to be introduced into the body to repair and detect damaged or infected tissues. Various cell repair machines can also be used. So far according to current medical research doctors can only encourage tissues to repair themselves with the use of drugs and surgery. However, with molecular machines they could be the chance of more direct repairs. The theory of this seems to work already as molecular machines are capable of entering the cell as doctors have stuck needles into cells without killing them for ages. Therefore, since nature has demonstrated the basic operations needed to perform molecular-level cell repair, in the future, nanomachine based systems will be built that are able to enter cells, sense differences from healthy ones and make modifications to the structure.

While research scientists are very excited about the potential of nanotechnology, there are some concerns about the problems that these new technologies might possibly cause. New technologies like these always carry new risks and concerns. There are unknown health effects and concerns that the human immune system will be defenceless against nanoscale particles. As they have very different properties from their related bulk materials, they need to be handled differently. The lack of knowledge about how nanoparticles might affect or interfere with the biochemical pathways and processes of the human body is particularly troublesome. Scientists are primarily concerned with toxicity, characterization and exposure pathways. Other than the obvious potential risks to patients, there are other toxicological risks associated with nanomedicine.The toxicity of the materials, for example, depend on the size of the particles. Many applications only require a small number of the nanoparticles so this will reduce the risks considerably. However some do involve large numbers of nanoparticles and could pose severe risks upon the body. We will never know whether or not these risks out way the benefits without further research and tests.

Enhancements in nanomedicine are more commonly concerned with the creation of bodily parts and functions that were absent or damaged with the aid of nanoscale medical devices, some people may argue. The usage of nanotechnology to implant diagnostic tools to make possible the collection and detection of individual cellular material, this can then be surveyed and monitored by being sent directly to a computer database. This may introduce problems with privacy and confidentiality. Ensuring privacy here will be of utmost importance if this was to be implemented in other situations in the future.

The 'sackler colloquium' on promises and perils (A series of talks in 2007) in nanotechnology for medicine introduces some of these issues that there are unforeseen consequences with this technology. This sparked many other issues in this area of ethics. Some people also argue that the stereotypical utopian idea that an extended lifespan from and economical and political perspective as a nightmare rather than utopia. Some cynics may support these ideas and may think what could be done with the help of nanomedicine in order to alleviate human pain. This paper has mentioned the brilliant prospective for molecular nanotechnology. This may trigger specific ethical thoughts and effects as having nanoelectronics inside the body performing nanosurgery may not be approved by many people not only on the ethical perspective but the health and safety issues as well.

This discussion is at the heart of medical research now and it is ground breaking research which could revolutionise medicine.

Conclusion

In conclusion, this paper discussed the future prospects of nanotechnology in medicine. Summarising all of the procedures and methods described here, this paper arrives at the conclusion that nanotechnology can revolutionise medicine. This generic technology applied to medicine has many applications as discussed in this paper. This type of technology will be able to bring a new world to medicine. This will be able to eventually increase life expectancy, reducing pain and making treatment easier. No matter how many years it will take before we get there, nanomedicine will usher in a new area in health care that will be highly accurate, less painful, less toxic, and with fewer side effects than their current counterparts. Pharmaceuticals will be more effective and less toxic; disease monitoring can be done on a highly sensitive and specific level; and surgical procedures that require poking and cutting will become a thing of the past. Many of the problems and issues that we currently have in medicine can only be solved using the ideas and theories presented in nanotechnology. Therefore we have to analyse and positively criticise these methods as they are probably the future of medicine.

There are although the problems described with this and there are specific pros and cons with this. This includes the possible health effects that could happen as well as the ethical implications of this work. This is also quite a delicate matter at the moment as at the heart of the technology used is the manipulation of matter at an atomic level. Some people may have some problems with these changing and introducing Nanorobots onto tissues for example. However for scientists researching into medicine these enhancements are vital for them. The procedures mentioned here will make medicine remarkable if they can become reality.

Therefore even with these doubts this paper concluded that nanotechnology will be part of the next revolutionary step for medicine.

This Paper has been written and researched by Anish Kundu

References

- Brown, B. & Ford, M (2009) Higher Level Chemistry For the IB Diploma, Gateshead, Pearson Baccalaureate
- Introductory Perspective: The Sackler Colloquium on Promises and Perils in Nanotechnology for Medicine
  Robert H. Austin, Shuang-fang Lim
  Proceedings of the National Academy of Sciences of the United States of America, Vol. 105, No. 45 (Nov. 11, 2008), pp. 17217-17221
- Nanotechnology, A hard pill to swallow http://www.i-sis.org.uk/nanotechnology.php
- What is nano? http://www.cnano-rhone-alpes.org/spip.php?article57&lang=en
- Nanotechnology in Medicine – Nanomedicine
  http://www.understandingnano.com/medicine.html
- Ethical and Scientific Issues of Nanotechnology in the Workplace
  Paul A. Schulte, Fabio Salamanca-Buentello
  Environmental Health Perspectives, Vol. 115, No. 1 (Jan., 2007), pp. 5-12
- Nanoparticles: Health Effects: Pros and Cons
  Maureen R. Gwinn, Val Vallyathan
  Environmental Health Perspectives, Vol. 114, No. 12 (Dec., 2006), pp. 1818-1825
- Nanomedicine, http://en.wikipedia.org/wiki/Nanomedicine
- Nanotechnology, http://en.wikipedia.org/wiki/Nanotechnology
- Allergy Nanomedicine: Bucky balls Dampen Response of Cells That Trigger Allergic Reactions
  Alexandra Goho
  Science News, Vol. 172, No. 1 (Jul. 7, 2007), p. 5
- Nanotechnology Drug Delivery,
  http://nanoparticledrugdelivery.blogspot.com/2007_12_01_archive.html
- Nanotechnology: What it can do for drug delivery,
  http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1949907/
- What are nanoparticles?,
  http://www.malvern.com/labeng/industry/nanotechnology/nanoparticles_definition.htm
- Optical Tracking of Organically Modified Silica Nanoparticles as DNA Carriers: A Nonviral, Nanomedicine Approach for Gene Delivery
  Indrajit Roy, Tymish Y. Ohulchanskyy, Dhruba J. Bharali, Haridas E. Pudavar, Ruth A. Mistretta, Navjot Kaur, Paras N. Prasad, Peter M. Rentzepis
  Proceedings of the National Academy of Sciences of the United States of America, Vol. 102, No. 2 (Jan. 11, 2005), pp. 279-284
- http://www.cytimmune.com/go.cfm?do=Page.View&pid=19
- http://www.cytimmune.com/download/posters/ASCO_Poster.pdf
- Bioral, http://www.biodeliverysciences.com/Bioral.php
- QDot, Nanocrystals,
  http://www.invitrogen.com/site/us/en/home/brands/Molecular-Probes/Key-Molecular-Probes-Products/Qdot.html
- http://www.understandingnano.com/nanomedicine-nanoparticles-iron-oxide-mri.html
- http://www.z-medica.com/
- Ethical aspects of nanotechnology in medicine,
  http://www.nanowerk.com/spotlight/spotid=3938.php
- Nanotechnology & Society - Current and Emerging Ethical Issues
  Allhoff, Fritz; Lin, Patrick (Eds.)

Total Word Count For Reference: 3649