Nanotechnology; The possible, the plausiable and the present

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PASS

Research Paper

Based On

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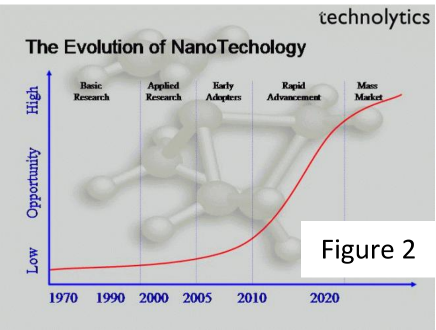

Figure 2

ABSTRACT

This paper is based on nano-technology and its future. We have looked at tissue-engineering, DNA-modification, healing and drug-delivery systems with one question in mind; just what, exactly, is possible? After looking at the different limitations and requirements of each differennt technology, there is onlyone possible conclusion; whilst one 'God-like' nano-particle will not be possible, many combined could easily alter the shape of the human-race.

INTRODUCTION

In the films we watch and the TV shows splashed across our screens, there's always one ultimate use of nanotechnology; 'superhealing doctor-bots'. These are most often put across as some glowing light and able to bring anyone back from the brink of death. But how plausible is this? We have decided to research the limitations to the medical use of nanotechnology by comparing this ultimate goal to existing technology. We will make an extrapolated decision as to whether or not this 'Star Trek science' will be plausible or if at all possible in the future. The main topic "Nanotecnology; the possible, the plausible and the present" will look at what people beleive can be achieved in relation to what it is possible to achieve and also examine what is already been used in modern science technology today. Atomic force microscopes and laser teezers may sound like something from a sci fi movie, but are currently been used to allow the manipulation of indiviual atoms to give some materials desirable properties. Nanotubes are also currently been produced. These consist of folded tubes of carbon, and are 100 times stronger than steel but are one sixth of the weight.

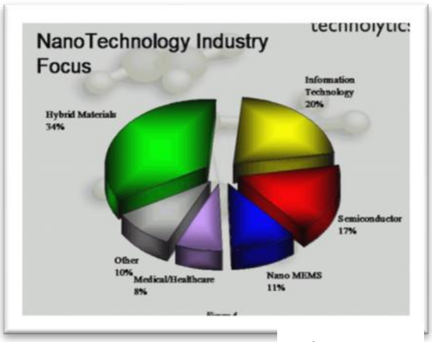

Figure 1

Nanotechnology involves "manipulating matter at an atomic level". It isnt simply scaling things down, it involves working with the basics and builiding up in the same way nature does. Neither is nanotechnology limited to one specific scientific field; it can be used in all matter of things from self-cleaning glass to insulin pumps to help diabetics. As prospective medics and vets, we have decided to base our research on ways in which nanotechnology can help change future medicine. We intend to take a perfected ideal and strip it back to realism. Our main focuses will be on tissue engineering, healing and DNA analysis and how these could combine to create an 'ultimate super-nano bot'.

Nanotechnolgy first became heard of when Richard Feynman presented his talk on "there's plenty of room at the bottom" (1959). The idea was then furthered by Eric Drexler who suggested the posibility of "Nanosized objects that were self replicating. The creation of the "Buckyball" and carbon tubes then followed in the 1990s. Since then, nano-tech has accelerated through the ranks of science. It is predicted to increase to such a point where by 2020, it will become a mass market, as shown in figure 2. This has already been shown in modern industry as machines and computers become smaller and smaller with every new model. Nanomaterials can now be produced in different sizes, shapes and with different surface properties.

Buckyballs are perhaps the most well known example of nanotechnology. Consisting of 60 carbon atoms joined in a series of interlocking hexagons and pentagons, their hollow interior allows sustances to be transported inside of them. This could be used to help medicine by carrying substances to hard-to-reach destinations within the body with absolutely no invasive procedures needed. When compressed to 70% of its original size, the buckyball becomes more than twice as hard as its cousin, diamond.

Currently, only 8% (as shown in figure 1) of all nanotechnology industry is medically focused. This however is expected to change in future years as nanotechnology becomes more accepted in medicine. Other focuses include hybrid materials such as for use in solar cells (semi conductor nano crystals), information technology i.e making microchips smaller and semiconductors for example in touch screens. This can be seen in figure 1.

DISCUSSION

Nano-technology and Tissue Engineering

Nanotechnology promises to completely change the face of modern medicine and one way in which it will do this is through tissue engineering. Tissue engineering is an emerging multidisciplinary field involving biology, medicine, and engineering that is likely to revolutionize the ways in which we improve the health and quality of life for millions of people by restoring, maintaining, or enhancing tissue and organ function. The latest development is the manufacture of spinal cord receptor tissue, (the tissue that is damaged when someone has a spinal cord injury). This important part of the body sends messages from the brain down the spinal cord to give instructions on movement. A new theory suggests that through the manipulation of carbon atoms, the tissue can be created and then injected into the area of spinal cord injury. This would then grow and link up with the main spinal cord, allowing messages to be sent from the brain to the legs allowing the patient to walk again.

There are also various other similar tissue engineering research projects currently ongoing. These include skin, bone, nerve, cardiac and vascular tissues. The growth of heart and lung tissue is a project currently in progress and it is hoped that one day, you will be able to have a heart and lungs grown and stored, ready for if you're in need of a transplant, either due to disease or injury. These so called "Tissue farms" will rely on carbon nano – materials for the growth of the transplant tissue and it is predicted that carbon nanotechnology will become an established and growing field in years to come. This has already begun, with scientists now able to strip a heart of its cells and use them as a scaffold to build a whole new heart which would then be transplanted into a patient in the same way as a donor heart. The British heart foundation is currently fronting an appeal which involves looking at the heart's of zebra fish which are capable of heart regeneration. Tissue engineering could play a vital role in this project, as scientists believe that by harvesting the key genes and chemical messages, they too could create tissues to help hearts to heal themselves.

Scientists learned how to make skin cells 'revert back' into stem cells .Unlike stem cells found naturally in the body, stem cells found in the umbilical cord and iPS cells can keep on multiplying indefinitely in the lab, then researchers can nurture them to "differentiate" into particular types of cell, including heart cells. It is hoped that then they could be altered to create heart cells that can self heal to a certain extent. Another large focus is on tissue engineered skin substitutes, in particular for burns treatment. Currently, Autografts are used in burns treatment; however, these are in a very limited supply and result in a secondary wound from harvesting. Autologous tissue engineered skin substitutes (ATESS) are currently been looked at as a substitute for Autografts. In extensive burns, it has been shown that these are a life- saving feature used when very few alternatives exist. This research is currently being carried out by Professor Wang who has been studying the field since 1995, and he believes the main limitation of traditional techniques stems from "the inability to make a complex tissue as a result of a 'top-down' approach, leading to slow progress in tissue engineering." Whereas nanotechnology is the opposite.

Another current tissue engineering project is the Cornea engineering project. This is currently being funded by the EU and is set to transform the way eye surgery is carried out. The research is looking to create a fully constructed human cornea that could be used to replace a damaged cornea and improve the sight of patients. There is currently a worldwide shortage of

donors, (increased further through corrective surgery which leaves the corneas unsuitable for transplant) and it is hoped that the results of this project will be embraced by surgeons.
Although the majority of these projects are still in the research stage, it is almost certain that many will become the basis of medicine in the future. The concepts of tissue engineering aren't completely new in the medical field, for example, autografts have been in use as burn treatment for a number of years and are still been improved on today. Taking all this into account, it is difficult to predict where this could end. May we one day create better athletes with bigger hearts and lungs? The use of carbon nanotechnology and tissue engineering would certain help to increase our life expectancy, if indeed we can find ways of manipulating our own cells to find ways of self heal and self preservation.

Nanotechnology and Drug Delivery
Nanotechnology has already been seen to have had a massive inpact on modern medicine. It is currently being used to increase effectiveness of drug delivery by using controlled release polymer systems to deliver drugs in the optimum dosage over longer periods of time. Nanoscale materials can be used as drug delivery systems to develop highly selective theraputic and diagnostic modalities.
It is predicted that in years to come, it will have a significant impact on the drug delivery sector, affecting just about every route of administration from oral to injectable. It has recently been discovered that perhaps the shape of the nanoparticles also has an effect, with rod shaped particles being more likely to penetrate cells than sphere shapes. It is important that a drug penetrates target cells effectively and doesn't end up as a target itself, only to be destroyed by the immune system. Particles are engineered so that they are attracted to diseased cells, which allow direct treatment of those cells. This technique reduces damage to healthy cells in the body and allows for earlier detection of disease. This is particularly important in cancer treatments, where it is hoped that nanotechnology can help to target specific cancerous cells using DNA recognition systems. This new system involves using Quantum Dots (qdots) to seek out cancer cells. However, this is still in the research stage and can only be done in laboratory tests and use in vitro (in a living creature) is limited. If this is successful, it could see the number of cancer survivors significantly increase.

Nano-technology and the Heart
An up to date research project is the use of self-assembling amphiphiles for use in wound-healing and heart attacks. Amphiphiles are lipid-based molecules with a hydrophobic tail and a hydrophilic tail.
When injected into the eyes of mice, the molecules formed fibres which acted like a scaffold to encourage the growth of brand new blood-vessels. The scaffold formed by the nanofibres is described as being similar to 'collagen fibrils and hydroxyapatite crystals in bone.' The same research-team, now interested in whether or not the self-assembling fibres could aid in healing after a heart-attack has occured, injected some mice with the fibres and kept others as a control group. Heart-attacks were then induced in the mice and it was noted that those injected previously with the fibres were more likely to recover -and at a quicker rate- than those that weren't.
Currently, around 700,000 – 110,000 people have heart-attacks in the UK each year so a treatment such as this, if perfected, would be a great benefit to the NHS budget and the quality of life of thousands.
Researchers at the University of Santa Barbara and Harvard Medical school have also being researching ways in which amphiphiles can be used to reduce the risk of a heart-attack in the first place. At Santa Barbara, amphiphiles have had proteins attached to them that can bind with the built up plaque at 'weak-spots' and help remove it whereas Harvard have been

looking into binding amphiphiles with a different protein that can bind to membranes damaged by atherosclerosis and reduce the amount of scar-tissue present as scar tissue is often responsible for narrowing the lumen of arteries.
As coronoary heart-disease (CHD) becomes more and more common due to the general lifestyle becoming sedentary and the diet filled with transverse-fats, a treatment for it will extend the human life-span considerably and improve living conditions.

Nano-technology in Healing

Nanotechnology is already being used in wound-healing. One such example is nano-crystaslline silver which is used as a disinfectant already. It's proved to be 95% effective against MRSA and is also proven to reduce the effect of contact-dermatitis at least as well as exiting treatments such as steroid cream.
Ellis-Benhke has been developing a solution called NHS-1 that creates a fine mesh of nanofibres that can stop bleeding within 10 seconds. This was first tested on the brains of hamsters and rats; the veins of the superior sagittal sinus were exposed and cut. In the first group (a-e in Figure 3) the iced-solution containing the nano-particles was added and bleeding stopped within ten-seconds. A control group was used (f-j in Figure 3) and the subjects bled for more than three minutes. The experiment was then re-done on spinal-cords, the liver, (with a variety of wounds being inflicted on the liver and all bleeds ceasing with ten seconds) and the high-pressure femoral artery. The best thing about this nano-technology is that it's perfectly safe for the body. When added, the solution turns into a gel and then is either used in rebuilding tissue or is safely excreted in the urine. It's also 'immunologically-inert', avoiding the problem of anti-rejection. It can cut down time spent in surgery (which makes it cost-effective) and it's transparent, meaning it can be operated through. So the only question is, why isn't this miracle solution used?

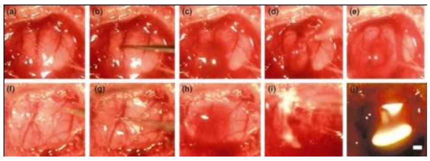
Figure 3

This could have serious impact in places such as the front-line when soilders are shot and in conditions difficult to cope with exstensive bleeding. It would buy time for doctors and serious medical-treatment to get there. Going further, one could even suggest that it could be useful in space-travel in the not so distant furutre where major-medical supplies can't be carried but there's a high-risk enviroment.

Nanotechnology and DNA

Deoxyribonucleic acid, DNA for short, is the building blocks of life. It codes for protiens, defines your genetic make up, and essential makes you who you are. Made up of only three molecules this essential piece of life has a diameter of only 0.000000002m. Yet in Nanotechnology DNA acts as more of a structural substance, as the double helix of nucleotides provides a very strong structure that can be altered to contain a certain combination of nucleotides, this could be used for purposes that still can not be comprehended. The extremely useful aspect of DNA is that its double helix can be 'unzipped' and so two unzipped strands can be manipulated to fit together. Nano structures would provide the right guidance to get these strands together and thus create the wanted combination. Once these strands have been put together in the correct order the DNA can be used to do many different jobs. DNA could be used to support molecules that have problems crystalising, could be 'edited' to create specialised human beings, and could be used to create super fast biological computer systems.
A main, possible, idea now being developed in the medical Nanotechnology field is quantum dots. This is using tiny crystals to look for attatchments to the DNA which can be an early warning system for people who are in danger of developing a serious disease, or a way to

monitor how well a cancer treatment is working. The main scientist working on the project is Jeff Tza-Huei Wang, in an interview he said; ‘If it leads to early detection of cancer, this test could have huge clinical implications.’ This process is developing rapidly and it has been quoted that is could be fully functional and a mainstream process within 5 years, and even capable of telling doctors which disease/cancer the person is in danger of developing. This incredible technology is still being developed, but in the future could one of these quantum dots be attatched to every person in the world, and every person constantly monitored for disease and DNA malfunctions? Would this end cancer? Could these quantum dots be edited so that they could contain or join to buckyballs that contain a cure for cancer? This would, effectively, provide an artifical immunity against cancer, and revolutionise medicine.

A final product that has been hinted toward for DNA Nanotechnology is essentially the perfect human being. This would be built up using specially modified DNA, which would have been built using ‘Nanobots’ to modify the nucleotides and create the correct sequence of bases. The beginnings of this DNA manipulation is already commencing in the form of ‘designer babies’, the idea that the DNA the egg and sperms cells carry could be altered to provide the correct comdination of bases to create the perfect child for the parents. Another idea is a Biological machine, which would be controlled by the modified DNA in place of a computer system. These machines would be faster, more durable, and capable of much more indepth calcultions and processes than their modern day counterparts. DNA does carry an electrical impulse and so could be linked up to other electrical equipment, yet a problem with this is that it interfears with the Nanotechnology and so DNA altering, other than urging them into the correct position, is still something that a lot of work needs to be put into. These ideas are quite far fetched, and could be considered in the range of science fiction.

CONCLUSION

So basically, in the future we could be humans with regenerating-hearts, specilaized-organ farms, enhanced vision, artificial immune systems, biological early-warning systems and the ability to stop bleeding in ten seconds. Taking this into account, do you think the human race will still be humaized?

Whilst it may seem far-fetched, ridiculous and like something from a science-fiction novel, it is, in fact, all possible, all plausible and *all* being tested at present. In their own right, each different project is striving towards its own goals and ideals, but essentially, combined, what are we creating? The ultimate ‘all-healing, super-powerful, nano-bot’ depicted in films and televions, might not be plausible because different fields require different structures and applications to allow them to work at their optimum. For example, NHS-1 must be applied directly to the bleeding site through a spray whereas the self-healing heart muscle must be inbuilt in the DNA.

The next question we must ask ourselves is if we create all of the above, then are we effectively taking away what it means to be human and playing with something we don’t fully understand? Our lives are governed by disease, injury and death and if we take away these obstacles, are we fooling around with Mother-Nature?

Charles Darwin’s Theory of Evolution states that species must change and adapt to their surroundings. So is this simply the next step in our evolution or are we taking things into our own hands? One of the biggest questions surrounding nano-technology is the long-term effects and the over-all safety of artificial technology mixing with biology. Whilst some of the technologies are already fully-biologically safe, the effect of some of them – such as the modification of human DNA or having so many tiny molecules in delicate areas such as the lungs which could lead to toxicitiy – are definately not safe. This could lead to the risks outweighing the benefits

So finally, we must go away with one question remaining; What *are* the limits?

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