THE FUTURE OF NANOTECHNOLOGY IN MEDICINE WITH REGARD TO THE REGENRATION OF HUMAN ANATOMY ON THE NANOSCALE.

BY

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Abstract

Nanotechnology is one of the fastest growing areas of scientific research with an increasing level of interest and respect (as well as funding) going towards manipulation of structures on this scale. Looking at this miniscule scale it is easy to see how nanotechnology has opened up a whole new area of experimentation and development with matters on an atomic and molecular level. Despite this obvious skill, as with many new areas of research there are various ethical debates surrounding nanotechnology, especially in medicine as the research concerns human life, which will be debated later in the paper. In this paper the future development of nanomedicine will be explored, with the central concept being the development of nanotechnology with regard to rapid prototyping of tissue and manipulating the human anatomy on such a small scale that it can be regenerated or replaced easily.

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Introduction

Nanotechnology is rapidly growing in size and level of public interest and outside investment. It has been described as the new industrial revolution with some predictions of the nanotechnology worldwide market growing so much in the future that it is now known the current economy would suffer significantly without it. The government have tried to become more involved and supportive. The Nanotechnology Mini-Innovation and Growth Team (Mini-IGT) have strongly recommended how the government can ensure future success and growth of this new industry in Britain. This came in the form of a report analysing Britain's world status in nanotechnology research and how the government can use their new Nanotechnology Strategy to meet targets for 2020 also set out in the report. (1) Nanotechnology has become a worldwide interest with an estimation of 130 nanotech-bases drugs and delivery systems being developed around the world, in accordance with the Nature Materials journal in April 2006. Over 200 countries are involved. Proof of the vast investment nanotechnology has become is shown by nanomedicine being worth roughly 6.8 billion dollars in 2004. (4)

Nanotechnology is increasingly varied with an assortment of disciplines inclusive of the development of materials to gaining control of any substance on an atomic scale. Nanotechnology initially started with the study of nanoparticles and their unique physical and chemical properties due to their size; however, the area has now broadened to encompass different purposes with regard to materials, devices or systems. The area is now less study and more exploration and experimentation with new ideas. (3) This means it has the potential to be highly beneficial in many areas ranging from medicine to electronics but the complexity and youth of the science prevents certain types of nanotechnology being practiced without warranty or being protested against by various groups. The purpose of this paper is to look more deeply into the applications of nanotechnology in medicine, or nanomedicine, and the newest research in this area; this can be weighed against the anti-nanotechnology issues or ethical concerns in order to debate whether or not the potential advancements outweigh these risks. (4)

Nanotechnology is dealing with data and application on the atomic scale with one nano (a nanometre is a millionth of a millimetre (1x10^-9 m)) being made up to measure three atoms. (5) It hasn't been that long since scientific development split the atom but already we are starting to learn how to manipulate atoms as the building blocks of all matter and with this manipulate the building blocks of our own life, cells and DNA. As nanotechnology deals with matter on such a miniscule level it could potentially liberate doctors to use molecular machines to repair damaged whole cells, and no longer leaving the healing process up to cell self repair. Nanotechnology has the potential to unlock a new world of nano-scale data in cellular molecular machinery as well as hopefully reducing the time taken for cell reconstruction.

Nanomedicine ranges in itself incorporates a range of different applications of nanotechnology depending on the field of medicine and the problem to be solved. The main applications of nanomedicine include nanomaterials, nanoelectronic biosensors, neuro-electronic interfaces, nanoparticle targeting, the use of nanorobots and the application of nanotechnology in surgery, visualization, drug delivery, protein and peptide delivery and the molecular imaging and research of cancer. (4)

The main issue addressed in this article is the current faults in the practice of modern medicine and how hopefully nanotechnology can help prevent or resolve these. Some of the trials faced in modern medicine are: severe lack of funding; high risk of infection in many procedures; fight against time taken for cell self repair and regeneration; the lack of accuracy in some testing methods; and the current demand of society for physical perfection. Current research is going into uses of nanotechnology in the form of nanomachines could help create solutions to some of these issues. These molecular machines could be used by doctors and other health professionals to encourage cell self repair in a shorter time period by entering the cell, currently impossible by surgeons because of the small scale, and encourage building or rebuilding of specific molecules of cells. This technology is still in the experimental and research stage but the hope is that in the future molecular machines could become increasingly specialized and will be able to enter cells, utilize the unhealthy cells and detect and fix one molecular malfunction or disorder. Nanotechnology controls these machines and the technology could expand to the repair whole cells and then onto tissues and organs. The potential to revolutionize medicine is clear. (4) Figure 1 shows a diagram of one of these molecular machines and the basic structure. (2).

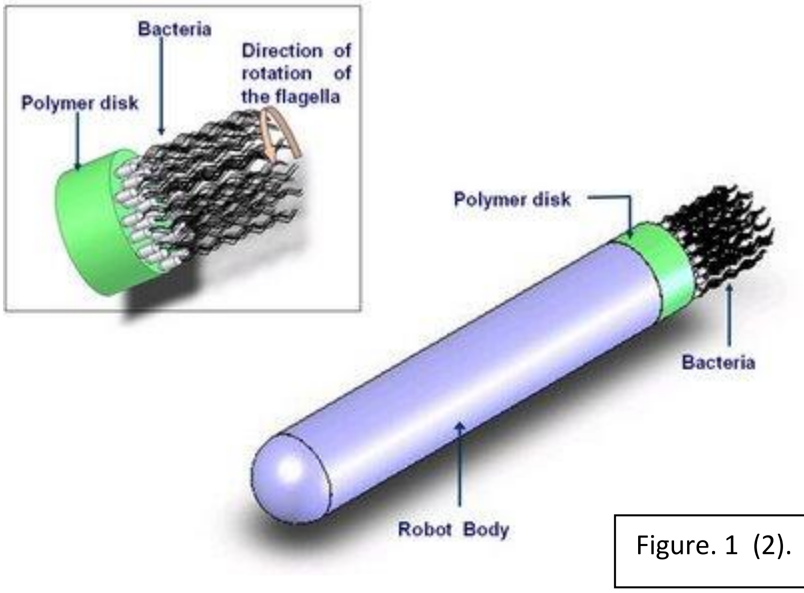

Figure. 1 (2).

Current nanotechnology research is going towards more effective skin grafts, as the usual practice of skin being grown from the patient's own cells then transplanted proving to be time consuming and wide open to a risk of infection. The potential nanotechnology has to engineer new skin cells by allowing skin grafts to grow on polymeric material mean that these problems are reduced as it is faster and less open to infection. The use of nanotechnology for reconstruction of soft tissue, as above mentioned, by use of EUV (extreme ultra violet), with the establishment of nano-structured surfaces means that rapid prototyping can be accomplished and scientists could begin to regenerate or replace parts of the human anatomy. Here the possibilities are endless as the need for skin, tissue or even organ transplant could be greatly reduced. All this current research and more will be examined more closely in the discussion.

Discussion

In accordance with the World Health Organisation there are 322,000[(12)] fatalities worldwide as a result of fire traumas, many of these however could have been avoided by surgeries, which is where the use of nanotechnology comes in.

Often burn victims have inadequate skin left to build a graft over the damaged area and so skin must be grown from patients' own cells and then transplanted. Although being relatively successful, this technique is not ideal, as the long delay for the skin to be grown immediately increases the risk of infection and dehydration, putting the patient under more stress and hindering their recovery time. Thus the application of nanotechnology in engineering skin cells in to growing on polymeric materials begins to play its part. Polymeric materials enhance the rate at which the cells multiply [(12)] enabling a graft to be formed and transplanted under a shorter time period decreasing the risks of the patients' condition deteriorating further. What more is that each different polymeric material allows for cells to differentiate and transform in to different human cells such as: ones adapted to the human heart, kidney or liver, opening up such a vast range of possibilities for the future. Never the less, there remain to be limitations as material defects lead to a lengthy process and occasionally an inefficient one with some cells behaving erratically during development. Polymeric materials are currently used in artificial implants but the progression of knowledge, and technology in the field will mean decreased rejection rates and the ability for implants to interact perfectly with individual parts of a patient's body. This will be because the original cells used for the graft will remain to be extracted from the patient and due to the protein receptors on the cell surface membrane they will not be identified as a "non-self" protein and attacked by the immune system when transplanted.

Professor Johannes Heitz, co-ordinator of the ModPolEUV project and his team of Austrian, Czech and Polish scientists are looking to generate a way to efficiently reconstruct human cells [(12)]. Progression in the research could lead to the reconstruction soft tissues, muscles and organs more accurately. The Polish partner at the Military University of Warsaw has emerged with a laser-based technology called Extreme Ultra Violet (EUV). It allows for the establishment of nano-structured surfaces and works by channelling a beam of EUV light formed with a unique mirror (developed by the Czech partner REFLEX S.R.O.) being directed at a surface, creating numerous kinds of new polymeric materials. Prior to this method the precision of traditional systems could only reach degrees of accuracy of 100μm, but EUV puts forward the potential of being within 10-20μm accuracy, once more expanding the prospects of cell manipulation. [(12)]

Accuracy is the fundamental part within the advancement of nanotechnology. Along side with the engineering of skin grafts, is the development of rapid prototyping. This future development, if successful, could dramatically change medicine as it theoretically has the capacity to achieve the scientists' dream of being able to regenerate or replace parts of the anatomy and their role whether having been injured, missing or damaged tissue. Rapid prototyping (also called 3D printing) [(10)] facilitates for tissue engineering that copies porous and arranged forms of the original tissues at a revolutionary level. A highly precise computer controls a laser that cures a tank of polymer resin and builds up a solid object layer by layer to produce what is known as a nanofibrous scaffold structure [(6)]. Nanofibrous scaffolds structures that equip scientists to grow cells in 3 dimensions would mean the creation of natural artificial organs was no longer just a dream. It would prove to be the future for regenerative medicine as whole organs could be cultivated in a laboratory, which consequentially would save thousands of lives.

The nanofibrous scaffolds must contain 2 imperative characteristics in order for them to be a success. Firstly they must be porous and have pores of the correct size to allow the diffusion and seeding throughout the entire structure. Secondly the scaffold must be biodegradable to enable the encompassing tissue to absorb it, disregarding the need for surgical extraction [(6)] - an attractive feature as the patient would not have to undergo numerous treatments, just one.

Despite having the limitations of not having entire control of the miniscule pores and architecture of the scaffold, rapid prototyping would defeat the many more restrictions of the pre-existing scaffold techniques [(10)]. Ordinary tissue engineering involves cells being taken from the donor/patient and then inserted in to their body. If amalgamated with the degradable scaffold structure in the laboratory, implants would not only be able to restore the impaired tissue but the scaffold would prompt the body to rebuild the tissue on its own – neo tissue. The neotissue then has the capacity to stimulate the body and take control for the restoration of the damaged tissue.

Using the method of stereo lithography scientists in Massachusetts have engineered an artificial vascular system [(11)] – an enormous break through in to the eventual goal of rebuilding whole organs. Not only has the system been developed but also tested and proved to have a 95% success rate [(11)] when tested in rats. The next phase would be to gradually extend the size and begin to work on bigger animals such as rabbits, pigs and eventually humans. The network of branching blood vessels built is capable of supplying oxygen and nutrients to tissues (due to the porosity), and holds the potential to bring the idea of building organs a step closer to reality. The lead researcher in this, Mohammad Kaazempur-Mofrad from the Massachusetts Institute of Technology (MIT) used 15cm wide silicon wafers and in to them inscribed the path of the modelled vessels as a mould to overlay a layer of biodegradable polymer, producing scaffolding very similar to that used in rapid prototyping. However the researchers at MIT have taken this procedure to the next level. Once the scaffolding is made 2 are secured to one another and have endothelial cells injected in to one half and then on the opposing side have the cells of, for example a kidney injected. The purpose of this is that the endothelial cells cover the polymer nano-tubes of the scaffolding, and because of the scaffolds biodegradable property it disintegrates to leave behind a shell of vessels replicating the natural vascular reticulum [(11)].

It is progress like this that is forming the pathway for regenerative medicine in the future. In order for this method to be applied to grow larger organs more layers need to be built up by the laser, and it is estimated that in order for the minimum requirement of a liver (1/3) to be made 30-50 stacked layers are needed [(11)].

The development of the creation of tissue scaffolds on the nano scale could become an expedient way to add new properties to materials that are not possible even on the macro-scale. Possibilities incorporate being able to make a material physically lighter, by introducing more pores; reducing their chemical reactivity - to give them a less corrosive nature (or vice versa: enhancing it to become more reactive); or making them mechanically stronger so they are able to withstand greater pressure [(14)]. However, the topic of intentional enhancement leads on to the ethical perspective of the uses of nanotechnology in medicine.

Nanotechnology not just opens up the window of opportunity to change medical science forever but also opens the doors to the concept of human enhancements, creating a sea of ethical issues that have to be dealt with. The delicate division that lies between medical and non-medical purposes: therapeutic, preventative or diagnostic [(8)], in the nanotechnolgy world is subject to much controversy as who is to say when enhancements have gone too far. Currently millions of people undergo cosmetic surgery with numbers increasing each year, in 2007 the USA conducted 12million cosmetic surgeries[(9)], with the most common reason for people (mainly women) to take on the surgery being because they are not happy with their physical appearance so were seeking personal enhancement. Restoration of organs too enters the category of personal enhancement, and it is feared that as science strives forward moral and ethical issues are left lagging behind [(8)].

Is it right to make intentional changes to the body? The ethical issues raised here are very similar to those involved in the debate regarding Pre-Implantation Genetic Diagnosis [(13)] as, by making enhancements and using the advancement of nanotechnology to make molecular changes in the DNA -whether it be screening embryos for genetic faults (as in PGD) or giving a marathon runner cardiac cells in his legs so they never fatigued – poses the ethical issues of discrimination. It evolves around the idea that people who seek medical enhancement are creating a prejudice against those who do not have the desirable characteristics [(13)], which would inevitably spiral viciously in to a clash of classes: those who can and those who can not afford the enhancements. What more, Dr Raja Bawa [(8)] points out that making changes on the nano scale by being able to discover and manipulate individual cells' DNA makes it difficult to distinguish between what is a "healthy person" and a "person who has a disease."[1] Diagnostic nanotechnologies that can stretch that far, require for the understanding of a disease to be reconsidered, for example as when do you decide if someone has cancer. Dr. Bawa asks: "How many cells from the body must be of a cancerous nature for it to be defined as cancer? 1? 50? 1000?" [8] The crucial factor would be to weigh up the amount of vast detailed information that can be processed against its advantages to society and an individual's health.

Leading on from this comes the argument over the transhuman debate. By being able to characterize cells derives the ability to produce purposely-enhanced body parts through the implantation of nanoscale medical devices and raises the ethical questions of transhumanism. The knowledge would have the potential to alter the human brain, which although could be a benefit to neuroscience, could be a catastrophe if it were treated disrespectfully, creating the topic of much controversy of: therapy vs enhancement [8]. By evolving nanomadicine to the point where it is possible to purposely magnify human intellectuality, physicality and psychological breadth [14] comes the potential of creating the "post human" and what more could perhaps lead to a form of genocide: Nietzsche formulated the image of the 'superman' with specific characteristics that encouraged Adolf Hitler's "Aryanisation" resulting in the holocaust.

As briefly explored nanotechnology has the capacity to be not purely a benefit, but also a risk to society and healthcare. Due to its comparably new arising, large quantities of knowledge are missing [8] with regards to the negative impacts on the activities of the human anatomy and the biochemical pathway, which in turn creates the ethical problem that long term follow up data concerning nanomedicines is not yet in existence. Although Dr. Bawa argues it is the same concept as cancer patients being open to the prolonged effects of chemotherapy and radiotherapy it remains an: "important risk factor that must be disclosed to patients". The uncertainty of secondary affects ties in with the issue of: toxic nanowaste disposal and polluting the environment from the construction of the nanomedical devices must all also be taken in to consideration, but for the moment remains in unknown territory.

Part of the Hippocratic Oath is "a solemn promise to: maintain confidentiality and never gossip." This flags up one last ethical concern for nanotechnology. Completely making sure the privacy and confidentiality of a patient is paramount in medicine and currently there are few health care institutions that have a substantial and reliable electronic method of storing records [8]. With patients medical files only increasing in size and detail, a system without safeguards is a major ethical problem as information leaking, or great amounts of medical information being collected and not being known how to be handled, create ethical problems.

Conclusion

To conclude, what nanotechnology could bring to society is a new era of medicine and medical techniques, all of which would be for the most part advantageous to man. Decreased: pain, scaring, rehabilitation, and the ability to artificially grow vital organs such as the liver and heart via the nano-tubes in the prosthetic vascular systems is the future of medicine and would save thousands of lives. However with regards to the immense power that nanotechnology is embedded with poses the serious ethical problem of how do you know when to stop? There has to be some restriction on the uses so as not to abuse the power that it brings, else aspects such as human enhancement could be taken to a dangerous and unhealthy level. Legislation must be passed to ensure the knowledge is not abused which could be done in the formation of contracts and oaths. What more is that for the system of growing organs to be effective the whole process needs to be relatively fast and efficient in order for the patient's outcome to actually be bettered. The whole system would be in essence, pointless if it could not be conducted fast enough to save an individuals life and reduce the recovery time from that of a traditional transplant.

Nano medicine will provide a pathway for a new field in health care as it provides the ability to take accuracy to a new level. On the contrary achieving levels of accuracy on the nanoscale (1x10^-9 m) can only be achieved by computers and machinery, which detracts from the "personal touch" of medicine. The danger that nanotechnology carries is because its focal point is miniscule interventions in the body it may develop so much so that it loses sight of the bigger picture – the whole person. Medicine is not solely about fixing people, more than just advanced machinery is required. A Christian exposition of empathy regards humans as more than just ill bodies, and that nanotechnology should not be allowed to dominate and redefine the human in the search for functional perfection. Although enhancements can be beneficial, they are also at risk of detracting from the huge attraction that medicine has – for people to help one another, not for machines to help. A balanced and synergetic approach is essential for the values of nanotechnology to work within society, this means without waste of resources, and a misguided vision of evolution as implied by transhumanists.

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