Nanotechnology – the science of very small things

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PASS

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Abstract

The world of nanotechnology is one of the many exciting forefronts of science, a topic defined as being an interdisciplinary field. Having already shown benefits in our modern world, the promising future of nanotechnology, in all aspects, chemistry, biology and physics, shows great potential. I am going to explore the applications of nanotechnology, paying particular attention to the influence and possible future developments in relation to medicine. I will also discuss the future of tissue engineering and the ethics involved and whether we should eventually incorporate it with medicine.

Introduction to nanotechnology

The key point about nanotechnology is that it deals with matter and structures at atomic and molecular levels. This has brought to our modern world many uses such as self-cleaning glass, antimicrobial silver nanocrystals and sunscreen consisting of nanoparticles of titanium oxide or zinc oxide. The sheer size at which particles are being dealt at allows risk reducing and potentially lifesaving uses within the human body.

Some possible uses of nanotechnology in the human body:

- Nanocapsules containing antibiotics are being used in burn dressings to hasten the response to an infection. The antibiotics are released from the capsules by the presence of bacteria.

- Nanoparticles containing nitric oxide gas used in a cream has been proven to substantially reduce staph infections when it is applied to the site of the infection.

- Alternative methods of the delivery of insulin into the bloodstream of type 1 diabetes sufferers has been explored, one particular method researched by Chandra Sharma in 2009, involves the use of nanoparticles as a drug delivery method, whereby the insulin is stored within the nanoparticles and is not destroyed by acids in the stomach before it reaches the blood stream.

- Nanoviricides are designed to trap viruses and dismantle its protein coat, preventing it from binding to a cell. This technology could be used to effectively combat viral infections such as swine flu, bird flu, and seasonal influenzas. Nanoviricides which are virus specific could be used to combat HIV

- Tissue engineering using carbon nano-materials to replace or repair organs and regenerate bone tissue. The ethics of both will be explored in the 'Discussion' section of this paper.

In this section I will highlight the currently accepted applications of nanotechnology. Some of which are already being used, others are still at the research and development stage.

Hastening blood clot

Nanotechnology has already shown some benefits in medicine in the military. In various ways, military situations can prove to be more lethal than civilian situations, however, in both situations, preventing death after serious damage has been done requires immediate attention. The swift recovery of an open wound may seem like science-fiction for example, 'Heroes', however scientists recently developed medical gauze which greatly increases the rate of blood clotting therefore reducing the amount of blood lost so that patients do not bleed to death while they are rushed to a hospital. The QuickClot Combat Gauze contains aluminosilicate nanoparticles and is currently being manufactured by Z-Medica and used by Special Forces operators and emergency-room doctors. Replacing or repairing an organ, tissue or bone in the human body is one of the many aims of nanotechnology. It is hoped that nanotechnology could bring about the growth and repair of various parts of the human body, parts which cannot be replaced today. The arrival of this could completely replace wheelchairs, crutches and other means of disabled mobility.

Cancer treatments

Cancer kills a significant 7.5 million each year, taking the lives of 135,000 people in the UK, making it the number one killer both in the UK and in the world, which is why the use of nanotechnology in medicine is heavily stressed on finding a cure for cancer. One of the main problems of cancer is the elimination of cancer without damaging healthy cells. The chances of successfully achieving this is decreased the more developed the cancer is. It may seem like the simple solution is to diagnose and destroy it early by seeking advice from a doctor as soon as the victim notices any symptoms of cancer. However cancers may not produce symptoms until it is too late and early signs of cancer can be vague. Colorectal cancers usually start off as noncancerous polyps which then develop into cancer. What may seem to be a migraine headache may turn out to be a cancer of the brain, in the same way that what might seem to be bronchitis may be cancer of the lungs.

Chemotherapy is a treatment used to combat cancer. However there are concerns about the side effects of this process. Chemotherapy involves killing cancer cells using radiation however, the problem is that the radiation could harm healthy cells and damage internal organs which lead to loss of hair, loss of eyebrows, fatigue, vomiting, mental fogginess and many other side effects. Tumours could be surgically detached from the body however this is not always possible since there may be major arteries running through them which could prove fatal if damaged during surgery. Research is

currently being carried out in the field of nanotechnology to increase the chances of cancer victims surviving by safely eliminating cancer cells without causing damage to other parts of the body.

The introduction of nanotechnology into cancer is being heavily considered and explored, simply because the size of the nanoparticles allows it to enter and travel through the blood stream. In addition to this, the use of magnetic nanoparticles would allow it to be guided through the body and concentrated at the site of the cancer.

From inside the body, cancer killing substances or nanoparticles, in this case could reach the site of the cancer tumours via the blood stream through leaking blood vessels and one such nanoparticle, called the AuroShell takes advantage of this. The AuroShell is a nanoparticle designed to absorb and concentrate infrared light to produce heat which then incinerates the cancer cells. Once the AuroShell is inserted into a patient's bloodstream, it should travel to the site of the cancer cells. Once in place, infrared light is shined at the tumour which should travel through the skin reaching the AuroShell causing it to heat up and destroy the cancer cells, dealing minimal damage to the surrounding healthy cells. Figure 1 shows an illustrated explanation of the treatment. This treatment has been developed by Nanospectra Biosciences, and is currently approved for trial with human patients.

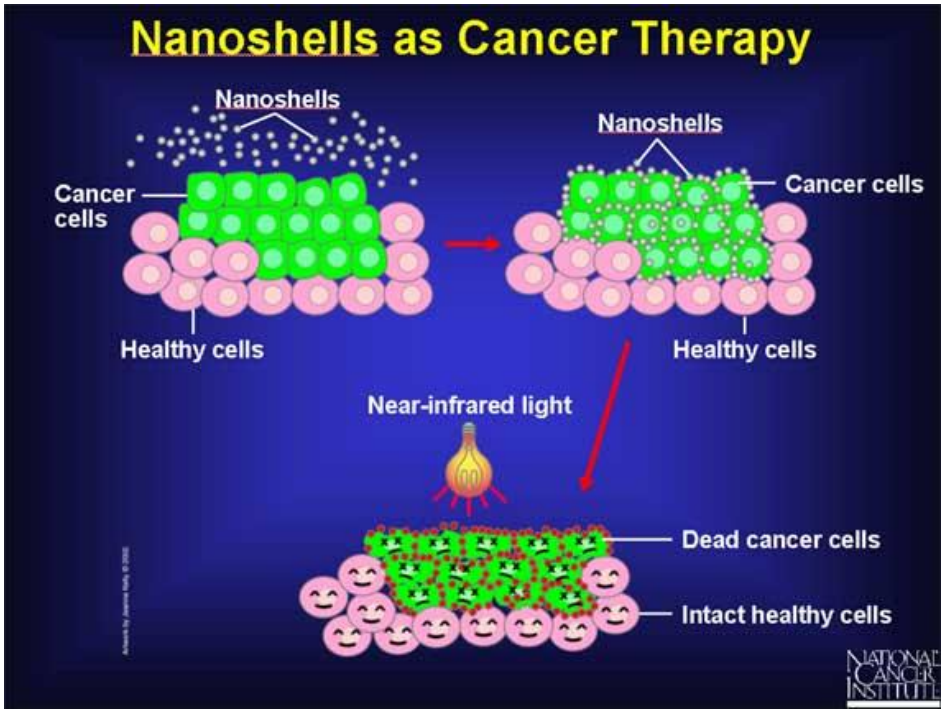

Figure 1

Another treatment utilises x-ray to kill cancer cells. A nanoparticle called NBTXR3, developed and is currently being tested by Nanobiotix, uses x-rays to generate electrons, destroying cancer cells. The nanoparticle is made up of crystalline hafnium oxide suspended in a coating designed for injection (figure 2). It is not considered a drug as the whole particle is inert and therefore will not react with any cell or tissue in the body. This feature allows it to be used in an 'on – off' status, because it only functions when in contact with x-ray emissions. It can be left safely in the body to be reactivated several times. It is injected into the tumour itself, and when excited by a beam of x-ray, it generates electrons which create free radicals in the tumour (figure 3). This causes heavy damage to membranes and DNA in the cancer cells which cannot be repaired and as a result, the cells are forced to kill themselves. The size of the nanoparticles is in its own right, a feature, because it improves the dispersion and diffusion of the effect within the cell, to ensure that it is spread evenly across the tumour.

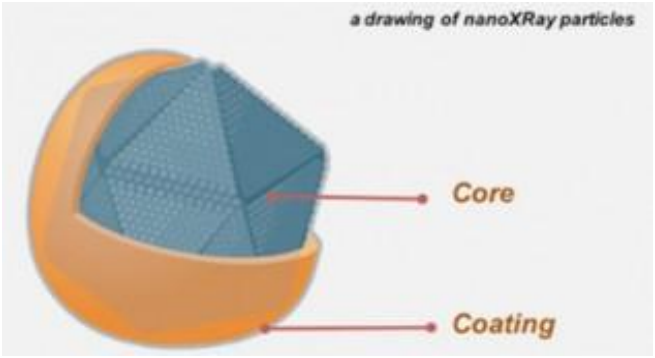

Figure 2

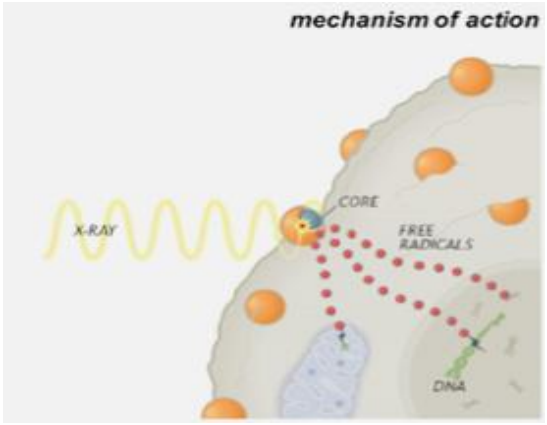

Figure 3

It is expected that clinical trials start between 2009 and 2010.

Discussion

Another possible application of nanotechnology in medicine is tissue engineering. Research is underway to produce carbon nano-materials that would be a suitable replacement to damaged tissue and possibly even bones. At present, there are surgeries available for hip replacements using a titanium bone implant. The only problem is it needs to be replaced after a decade or so since the muscles do not stick to the smooth titanium implant and therefore stops functioning properly. With the assistance of nanowires coated on the surface of the smooth titanium implant, muscle fibres attach to the implant more successfully. The future of tissue engineering looks promising, as we are able to foresee the day that synthetic organs can be ordered and implanted at will; however, do humans have the right to manipulate this ability? There is a fine line between nature and technology, and the development of nanotechnology is beginning to look like the manipulation of nature using technology, as we approach the possibility of tissue engineering. In this section of my research paper I will explore the problems and responsibilities involving the ethics of progress in nanotechnology and I will attempt to find a possible yet reasonable solution to the stated problems.

Tissue engineering - ethics

Mankind has been fighting a never-ending battle against the invasion of microbes for thousands of years. It is hoped that one day mankind could bring an end to this battle by incorporating regenerative abilities into the world of medicine, abilities which are demonstrated in other members of the animal kingdom, namely lizards, crabs flatworms and insects. Many disagree with the development of tissue engineering, for many reasons, one of which is because it is going against God.

Tissue engineering is being considered for the benefit, to save and possibly to prolong the lives of humans, by developing ways of replacing vital organs which a human cannot survive without. However, if we were to eventually be dependent on manufactured tissue, would we eventually be born without fully functional organs of our own?

According to the concept of evolution, useful traits, which stem from random mutations in an organism's DNA, usually allow the organism to survive and hence, pass on the beneficial gene, and a trait which is not useful is eventually bred out of a species through evolution. Many animals have tails for the purpose of balance, to swat flies, to show emotion and to communicate. Humans are capable of all of these in the absence of a tail. The remnants of a tail is the coccyx or tailbone which is present in the human body, indicating that humans, as a species, once had tails however have lost the use of it, and hence the whole structure.

I believe that if scientists achieved the goal of synthetically manufacturing tissue, we could lose the need of our own natural form, because there is no doubt that if we were to manufacture tissue, we would aim to produce one which is superior to what nature

has already provided us with, in the same way that nature has provided us with vegetation and fruits packed with the vitamins we need, yet we manufacture vitamin supplements to increase our vitamin intake. We pioneer the use of electricity despite having the perfect natural source of light and heat, fire. Similarly, nature has given us legs, an extremely energy efficient means of transport, yet we build extremely inefficient cars which we now almost cannot survive without. I have provided these examples not to express my hatred for technology, but merely to fuel my argument that if we were to create something new, to replace the natural, it would be in many ways, superior to the natural and hence we would see much less of it. Would we eventually lose our dependency on our own body to manipulate our surroundings and for mobility, so much so that future generations are born with such weak bodies that they need synthetic tissue in order to move or to carry out a process as simple as breathing?

If we were to manufacture tissue, it may behave the same way as normal human tissue, in particular, muscle tissue. It may not. We may lose the basic rule of physical development, training, because we could we replace weak, untrained muscles for much stronger, bigger muscles. The possibility of this should be strongly considered before we storm forward into the vast realms of nanotechnology. I think that the birth of tissue engineering for commercial uses would come packaged with the death of sports, sportsmanship and discipline. It would be a case of who has the most technologically advanced synthetic tissue instead of who has the strongest will to achieve their personal best and the most discipline to rigorously train to reach their full potential. Drug tests are carried out to ensure that competitors do not have an unfair advantage because they are under the effects of an enhancement drug, which ensures fairness in competitions but how would we judge a race if all the competitors had synthetic tissue in their legs, all manufactured by different companies?

I totally agree with channelling the power of nanotechnology into saving lives, however I do not entirely agree with the abuse of this power by producing synthetic tissue unnecessarily, to make an athlete stronger or faster, for example. If we were to give one person the ability to run faster, to lift heavier things, by means of synthetic tissue which was far more superior to human tissue, we would have to give it to society as a whole. Selectively giving it to a few humans could pose a risk of corruption of the selected humans. Furthermore, tissue engineering could create an economy of its own, in the sense that it would not only be available for use in the public sector, but also the private sector. This, I believe, could bring about the division of the human race, one fraction being the wealthy, who are able to afford better, stronger synthetic tissue and others either only able to afford weaker synthetic tissue or not being able to afford any at all.

Future Developments

My suggestion on the matter is that we work towards preserving the natural, instead of replacing it, and cancer makes a good example for how this method should be used when approaching the applications of nanotechnology in medicine. Instead of removing the affected body part and replacing it with a synthetically manufactured one, steps should be taken to swiftly identify and eliminate the cancer at an early stage by destroying cancer cells at the same time, doing minimal damage to healthy cells. If this could be achieved, the patient could recover possibly without the need of surgery.

A method of detecting cancer at an early stage using nanotechnology was proposed by Professor Igor Sokolov, director of Nano Bio Laboratory, and his team. It involves fluorescent silica beads and their adhesion to cancer cells and normal cells. Cancer cells and normal cells have a brush layer in which to interact with its environment. The difference between the two brush layers is the length and the densities hence, the fluorescent silica beads proposed would adhere differently to each cell. The light emitted from the fluorescence in a particular area could be measured using a high sensitivity spectrometer.

The National Cancer Institute (NCI) has been coordinating research in the field of cancer nanotechnology since September 2004 and has proposed the use of antibodies which bind selectively to cancerous cells. By attaching nanoparticles which produce a high contrast signal on Magnetic Resonance Images, the position of the antibodies in the body, and therefore the cancer cells at the site, could be detected.

Cancer detection to date involves biopsies to identify a cancer cell. The use of nanotechnology would no doubt, be significantly quicker and more accurate than the current methods for diagnosis for the detection of cancer. According to research carried out by the NCI, nanoparticles could possibly be used to detect biomarkers of cancer to determine the type of cancer present. Cancers which do not show any symptoms could still be safely detected and removed at an early stage using nanotechnology.

As mentioned in the introduction part of this paper, there are ways to safely eliminate cancer, once identified. Encapsulating anti-cancer drugs is one method, and is known as the "Trojan Horse" technology for cancer treatment. This method was tested in mice by Himanshu Brahmbatt, an Australian researcher at a biotechnology company, EnGenIC, based in Sydney. The drugs would target only cancer cells and hence do not damage healthy tissue. The drugs were packaged in nanoparticles and delivered directly to the cancer cells. This was done repeatedly in waves, so that the first wave would disable the resistance mechanism of the cancer cell and following waves would kill the cancer cell. The test proved effective on mice. One advantage is the cost

effectiveness of the treatment, because very little medication was used and this is cheaper compared to chemotherapy.

One successful leap in medicine is the invention of vaccinations. Taking advantage of the body's immune system, we familiarise the body with a weak or dead form of an otherwise deadly infection or disease. This is why we vaccinate to prevent, instead of having to treat it at a later date. This is, in my opinion, a successful leap because it is extremely effective yet it does not replace what evolution has perfected, but merely enhancing it.

Conclusion

Nanotechnology offers a range of possible ways to tackle problems in the field of medicine. I have described how nanoparticles can be used as a method of delivery, as a method of detection and as a method of destruction. All this is possible thanks to the size of the nanoparticles. We have found a means of dealing with viruses and bacteria at an atomic and molecular level, and theoretically, it is showing much more success than failures. However there is still a barrier between the laboratory and the hospital and clinics, and this may include questions such as 'will nanoparticles pass through biological membranes?' or 'will certain nanoparticles cause long term problems if not removed from the body?'.

Replacing human tissue with synthetic tissue would most definitely require surgical procedures. There is always a risk to the patient's health when it comes to surgery; complications during the surgery itself, or post-surgical complications. The patient's body may be too old or too weak to effectively recover from an operation. Furthermore, it is a fact that providing medication is a much cheaper option surgical procedures and hence, I predict that the cost of providing a patient with a new organ would be drastically more expensive than injecting nanoparticles to treat cancer.

The idea of 'preserve the natural instead of replace' is, in my opinion, the direction we should be heading in terms of nanotechnology in medicine and I have shown, using cancer as an example, how we can work towards achieving this. Instead of replacing full organs because irreparable damage has been done by cancer, we should aim to prevent early forms of cancer from becoming a real danger in the first place, we should aim to save the organ, not replace it.

"Better safe than sorry".

Despite the progress in nanotechnology so far, we are still a long way from realising the full potential of nanotechnology, and integrating it into our everyday lives. It is a growing field with a bright future that should be approached with caution.

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