

Using Nanotechnology to Create Body Tissues
and
Ethics Surrounding Medical Applications

By

Matthew Morfitt

PASS

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Abstract

In order to treat diseases and other medical issues, doctors are becoming aware that conventional medicine does not hold the answer to progress in all fields of combating illness in human beings. With some illnesses, current methods of treatment have a low success rate, sometimes due to factors that cannot be overcome by known practises at the current time. Therefore, research is being carried out into new forms of medicine that can overcome these barriers to deliver a more efficient and successful way of treating illness and improving patients' quality of life. The use of nanotechnology in medicine is a fairly recent development but one that boasts of achieving many outstanding goals. This paper will discuss the promises of the successful use of nanotechnology to create tissues to replace damaged parts of the body and to aid bone tissue growth in orthopaedic surgery. Research is currently being carried out into how nanostructures can treat injury and defects of the skeleton and tissue growth; problems that affect hundreds of thousands of people a year worldwide and also the ethics surrounding the use of nanotechnology in medicine.

Introduction

Nanotechnology is the science of creating structures on an atomic scale. Usually, the term nanotechnology refers to creating and making use of structures between 1 and 100 nanometres in size; as small as a single virus. These measurements are often difficult to imagine so it is sometimes useful to compare sizes of known objects. 1 nanometre is 1 billionth of a metre, the same as the diameter of a carbon nanotube. Put another way, a human hair has the diameter of around 25 000 nm and a cell membrane has a thickness of around 6-10 nm. This developing science is incredibly varied and ways to use these miniscule structures are being discussed in many areas varying from microprocessors and nanocomputers to methods of drug delivery in medicine. Current ideas are showing that nanotechnology could dramatically change the way we use science and how it can be used to achieve many great breakthroughs in all forms of science and even everyday life.

The medical application of nanotechnology is called nanomedicine. Scientists believe that nanotechnology could hold the key to treating illness because typically, disease and problems within the body are caused by factors smaller than the body cells themselves. In most illnesses, the cause of the problem is tiny; sometimes it is unable to see them with the most powerful of microscopes. An understanding of interactions, processes and structures of some of the smallest things known to science can help to combat the equally tiny things that cause the problems. For example, viruses could be dealt with more successfully if we could build minute particles which produced hormones or proteins to destroy them at an atomic level. Such nanoparticles could be injected into the body and then left to help cure the disease in a similar way to the methods white blood cells use to destroy pathogens.

Scientists have published information on the possible use of nanotechnology as far back as the 19th century: in 1867, James Clerk Maxwell expressed his view that individual molecules could be manipulated. Since then, many scientists have thought about how these individual atoms and molecules could be influenced and just as importantly, what sort of outcomes

science could produce from this new science. Huge advances in science's knowledge of nanotechnology mean that in the last 50 years, uses have not only been thought of but actually utilised to carry out tasks in real life.

Research in the 20th century showed what type of structures could be built from the atomic level. In the 1980s and 1990s, a molecule made up of 60 carbon atoms and with a unique 'football' shape called buckminsterfullerene or 'bucky balls' were discovered by scientists (see Figure 1). Research has taken place into the options of using buckyballs in medicine for many applications including drug treatments. Buckminsterfullerene allows other molecules to be attached to it to allow certain molecules to be targeted by the attached medicine. For example, a protease inhibitor has been created that can attach to the active site of a HIV virus far better than any molecule known to science.

Buckminsterfullerene molecules have large internal spaces which can be used to house atoms of different elements. These abilities lead to ideas of using bucky balls as 'cages' to carry medicines and also transport dangerous metals out of the body. To back up this hypothesis, it was found that buckminsterfullerene is resistant to laser beams of high energy, therefore it is very difficult to remove any molecules from inside; meaning that it could be safe to use in this application. In the diagnostic side of medicine, bucky balls are thought to have possible uses in improving MRI scanning in hospitals by taking the place of other molecules transporting toxic metals through the body to show contrasts in the scans. The unique shape allows the harmful metals to be safely encased inside buckminsterfullerene so they cannot harm the tissues of the body. On a similar note, one of the major drawbacks of the use of chemotherapy in treating cancer is that the drugs being delivered are not targeted accurately enough to the cancer cells, meaning that normal body cells are badly damaged. It has been found that by attaching nanoparticles full of drugs to RNA strands (that are attracted to cancer cells), an interaction takes place and the drug is released into the cancer cell without causing damage to surrounding cells.

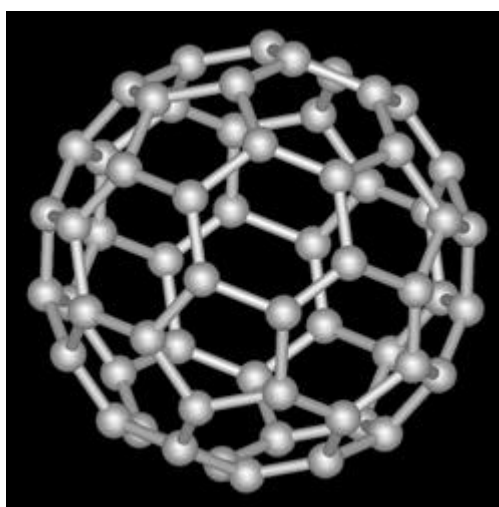


Figure 1

Other current research into nanomedicine includes using nanoparticles to help surgeons restitch arteries severed during organ transplants. Gold-coated nanoshells are applied to the seam of the cut artery before an infrared laser 'welds' the tissue together. This method has already been applied to fusing two pieces of meat into a single piece and in medicine would allow surgeons to seal arteries without the risk of leakages.

The field of nanotechnology is full of exciting prospects that has the potential to transform medicine in settings around the globe in the next few decades. Vast sums of money are being put into researching how minute structures can be formed and how they can be utilised in medicine to treat previously incurable diseases and improve the treatment of serious illness such as cancer and HIV. It is unlikely that nanotechnology is not going to be researched and used in a huge amount of situations over the course of the next century as its achievements could be astronomical; saving countless lives.

Discussion

In orthopaedic surgery, a prosthesis is an artificial device produced to replace a damaged part of the body's structure. For hundreds or possibly thousands of years, crude prostheses have been used to replace parts of limbs often lost in battle. An early example of a prosthesis being used to replace a missing body part was recorded by Pliny the Elder who noted that an iron arm was made for a Roman general in order for him to be able to hold a shield and return to the battlefields once more. In those days, such devices were solely for the use of the extremely wealthy, because of high production costs and limited knowledge. Unfortunately, these early prosthetic limbs were not very advanced in their design and could not be moved in a way to regain near normal body function. Over the coming centuries however, the designing of prosthetic limbs became more advanced and in 1500BC, devices were made that offered some limited movement. Iron hands were made that could allow the wearer to remove his hat and even sign his name. Improvements in prosthetics have been made and at the present time, amazing devices can be fitted by surgeons to give the user an almost normal life and body functions.

Although close to the general idea discussed in this paper, prosthetic limbs are not the main focus point of this thought experiment. In the 20th century, such huge progress has been made in replacing lost limbs in humans and even animals that scientists now also look to replace other parts of the body, mostly internally. This kind of treatment for patients is often more difficult than replacing limbs because of the smaller sizes that are required and the added difficulty of needing to reduce the influence of the implants on bodily functions. In hospitals around the globe, parts of the human body sometimes need to be replaced by surgeons in order for the patient to lead a normal, fulfilling life.

Bone Repair

If you went to your nearest hospital, it is very likely that many of the people waiting in the Accident and Emergency department would have suffered broken bones, from active children to the elderly with their more brittle skeletons. Of these patients, some will need an operation to allow their bones to heal and regain normal function and a few may need an implant of some description to help achieve this goal; some temporary and some permanent.

With small fractures, a surgeon may decide to fill the fracture space with bone cement and for a large fracture, titanium based metal implants could be used. The purpose of choosing to use an implant is usually so that the bone can be helped to support the strains put on it and to make it stable so that it can repair itself enough to function as before. The metal alloys normally used in this field of surgery are chosen because of their properties; light and strong whilst being inert to avoid scar tissue forming and so they do not affect the body's functions and biological balance in any way. The problem with using such materials that whilst being useful in some ways, they are not perfect and can lead to other problems. After ten to fifteen years, because the implants are not really part of the bone's structure, they often become loose from the bone and cause severe pain and a loss of function to the patient's body, often requiring further surgery and the difficulties that go with it. The main issue with the implants being loose, apart from pain to the patient, is that sometimes little bone growth is observed, meaning that the metal is not held securely in place for a lifetime and so it's usefulness is less.

It is in medical situations like these that nanotechnology can help to overcome medical problems which current methods and medicine cannot easily solve. As shown above, the issue with normal metal implants is that they don't join to the bone well enough for long enough. However, research is now being carried out into using nanotechnology to overcome these issues. Scientists studying nanotechnology recognise that the implant needs to 'interact' with the bone to stop the implant from becoming loose and breaking away from the bone. It is now the intention of scientists to try and form methods of helping the implant to bond with the bone. Building from research done in the past few years, scientists can create implants that use surface-chemistry to interact with bone-forming cells to promote new bone growth. This has had some success in that bone growth has increased in some examples, but often the actual implant structure is not suited to its role in joint replacements due to its weaker properties. Nanotechnology is hoped to further improve this work on understanding surface chemistry and cell-implant interaction. It is thought that by adding a surface layer of proteins built at the nanoscale, the strong materials can still be used as the backbone of the implant but will promote bone growth and therefore the implant will not become loose. The nano features on the surface should absorb to the bone

almost as soon as the implant is fitted and will stimulate the osteoblasts (bone-forming cells).



Figure 2. Hip Implant with nano-textured surface to encourage bone tissue to bond to it.

If this research is successful, in the next few years materials could be made that will allow artificial structures similar to the metal implants used today to bind to the bone and promote growth to reinforce this bond so that the patient can enjoy normal body functions such as joint movement for a lifetime without the need to return to hospital for more operations and treatment. It could even lead to temporary implants that promote bone growth and then when sufficient strength has been regained, can be removed with no after effects. If doctors are able to stimulate body cells into growth, then it may be possible to use nanoparticles in a similar fashion to start cell growth in other areas, such as to replace damaged tissue due to attack by cancer or to tackle the issue of brittle bones in the elderly; could nanotechnology be used to help 'regrow' bone material weakened by osteoporosis to reduce breakages when people grow old? The skeleton is one of the most important structures of the body and if nanotechnology can help to rebuild damaged parts of it or strength weakened bones, people around the world could live independently for longer and reduce the suffering many elderly people undergo due to broken bones.

Tissue and Organ Engineering

When tissues and organs are damaged, tissue replacements can be made to help fix the problem of decreased organ function. These early substitutes are scaffolds with cells attached and can provide mechanical support and some even instruct the cells in their development, but this is fairly limited at the moment. Scientists now want to create artificial tissues that have the same functions and capabilities as our own tissue cells. This goal is one that research has already begun into achieving, with the help of nanotechnology, but it is

hoped that much more progress will be made in the years to come as nanotechnology improves.

To make artificial tissue, cells of some sort must first be made or cultivated in some way. These cells need to then be arranged into a structure that mimics structural and physiological features of tissues in the body. To do this, scientists will use nanotechnology; building up from molecules of special polymers or proteins such as collagen to build a scaffold called an extracellular matrix. This matrix holds the key to cell function. Scientists can already make interconnected, porous scaffolds made from fibres to do this job using 'building' blocks of a billionth of a metre. To help the cells function correctly, nanotechnology can be used; the surfaces of the structures contain artificially obtained proteins to promote growth and by embedding more nanoparticles into the structure, can add electrical conductivity properties which are vital for cell function. Nanomaterials can control the cells' shape and structure by adding different proteins and nanodevices can be used to test the tissue before it is transplanted into the body to test if it is working correctly. The main use of nanotechnology in this field is using nanoparticles to create a structure suitable to house cells and these miniscule structures work because they are built up from materials even smaller than the cells themselves.

Once these techniques of creating tissues are sufficiently advanced, I believe that nanotechnology will be used to create structures to produce the large amounts of tissue necessary for building organs and also be able to have surface nanoparticles to help control the growth and function of these cells. Building on current research, scaffolds will have more capabilities in that they will allow communication to reach cells from the brain so they can carry out different functions by means of electrical pulses. There are suggestions of using devices that can receive information from the nano scaffold so they know when to release growth hormones and perhaps other nanoparticles to influence how the cells work. This kind of goal is probably a long way off and cannot yet be put into practise but is a possibility for the future. If scientists can use nanotechnology to help make tissues and possibly simple organs then it is conceivable that other parts of the body could be manufactured. For example research is looking at how it could be possible to grow facial features such as the ear to replace damaged tissue. It is easy to delve into science fiction when thinking of the limits of nanotechnology, for example the widespread talk of creating nanobots to directly mend cells has been discarded by many scientists as ridiculous but I believe that current research has shown the possibilities of using nanotechnology to help create tissue and later organs such as the small intestine, not impossible.

Imagine a scenario where scientists can use a few of the patient's body cells (to avoid rejection) to build a new part of intestine, cornea or kidney. According to organ donation statistics for the UK, there are over ten thousand people currently waiting for an organ donation and of those, it is estimated that one thousand of these ill people will die a year. I would not claim that complete hearts and lungs are likely to be created using nanoparticle

backbones in the near future, but if amounts of specific tissue could be created to replace damaged tissues in kidneys or livers for example, the number of people dying each year would drop. An advantage of using nanotechnology to build tissue from the bottom up is that specific shapes and types of structure could be made to mirror nature almost exactly; the very thing nanotechnology is all about achieving.

Medical Ethics and Nanotechnology

Nanotechnology appears to be an incredibly exciting and useful science which is said to have what it takes to change the way medicine works in the future. However, some scientists and some of the general public have some doubts and issues with some ideas being discussed. The use of nanoparticles is still a relatively new concept therefore any dangers have not yet been made clear as not enough research has been done to deem the use of nanotechnology in medicine completely safe.

There is always a danger when adding foreign bodies to the body, for example the human body can reject organ transplants even with an excellent tissue match. It is not known whether adding nanoparticles to humans can cause more harm than good if things go wrong, moreover, even less is known about what could actually go wrong. It could be that nanomedicine would interfere with processes in the body and the dangers that would cause to the lives of patients. Some people would argue that building structures from the bare molecules is getting too close to the commonly heard phrase “acting God” and are uncomfortable with the idea of artificially copying nature’s methods.

As well as curing disease and damage to the body, there is discussion surrounding nanomedicine enhancement: creating or improving body parts and their functions that were not damaged in the first place, using nano devices. This would be a form of transhumanism, condemned by religion and much of the public. Many people believe that it is wrong to try and improve human capabilities in this artificial manner as they worry where it will stop as science is advancing at such a rate.

Scientists are concerned about whether nanoparticles can be toxic to the body over a lifetime, as long term experiment have not yet been carried out. When nanotechnology is more advanced and experiments have been carried out it will be easier to say whether nanomedicine will be safe to use on patients in the long term. I think that before nanomedicine is used prolifically, doctors should first wait to see if studies show that it is safe over a longer period of time in case dangers have been overlooked or missed in order to reduce risk to patients and avoid a major disaster; as is the danger with unfamiliar science.

Another major concern of critics of nanotechnology in medicine is the possible effects that nanomaterials could have on the environment. We have seen that nanoparticles could alter

the actions of proteins or cells and this could be very dangerous if some nanoparticle waste was accidentally or even deliberately let into ecosystems as its effects on animal and plant life is so far unknown. I also think that in a similar way to nuclear energy, nanotechnology could one day become of interest to terrorist or criminal groups who would use the advancing technology to threaten human life or damage property.

Conclusion

When scientists first started to explore the possibilities of manipulating atoms at the nanoscale to create structures they unlocked a whole new package of ideas, uses and possibilities. Nanotechnology could solve many problems in a huge variety or continually growing areas including medicine. At the moment it seems like there is an infinite amount of applications that nanotechnology could influence and rule and it's likely that scientists have only scraped the surface of this modern form of scientific research.

In the field of medicine it is already starting to have important and successful uses in settings such as directing medicines to the cells that need them and in detecting disease at an early stage. It has been seen that nanoparticles can be manipulated into complex and useful structures that can act as a base to create artificial tissues to repair the bodies of patients damaged by accidents or disease. This application is one of the most interesting and exciting as it could, with further research, lead to whole organs or at least sections of organs being created by scientists in a laboratory and then transplanted into a patient to function correctly for the rest of the patient's life. It looks likely that the use of nanotechnology in medicine would be a massive leap forward in the abilities of doctors in treating patients all around the world.

However, it is easy to be lulled into a false sense of security when reading of the almost magical properties and possibilities that nanotechnology could hold for medicine in the coming years and decades. It could be that because of the excitement surrounding nanotechnology, its usefulness has been vastly exaggerated and some of the ideas that scientists have claimed may be classed as mere science fiction in fifty years time. Furthermore, as indication of possible dangers of using nanotechnology, especially on human health is not well known, I believe that although much research needs to go into nanotechnology and how its capabilities can change medicine, much more research needs to go into the possible negative effects on health and the environment on a much longer scale in order for scientists and the public to feel that it is safe for treatment. If nanotechnology in medicine is found to be as safe and useful as is currently hoped, then doctors will have a massive source of knowledge and devices capable of treating even the most difficult diseases and problems of the human body.

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