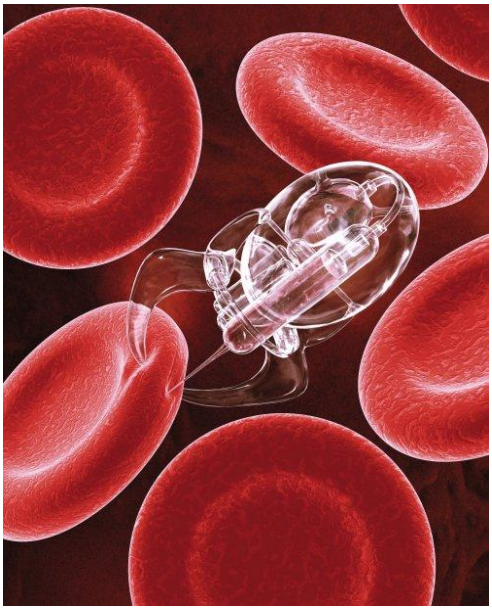
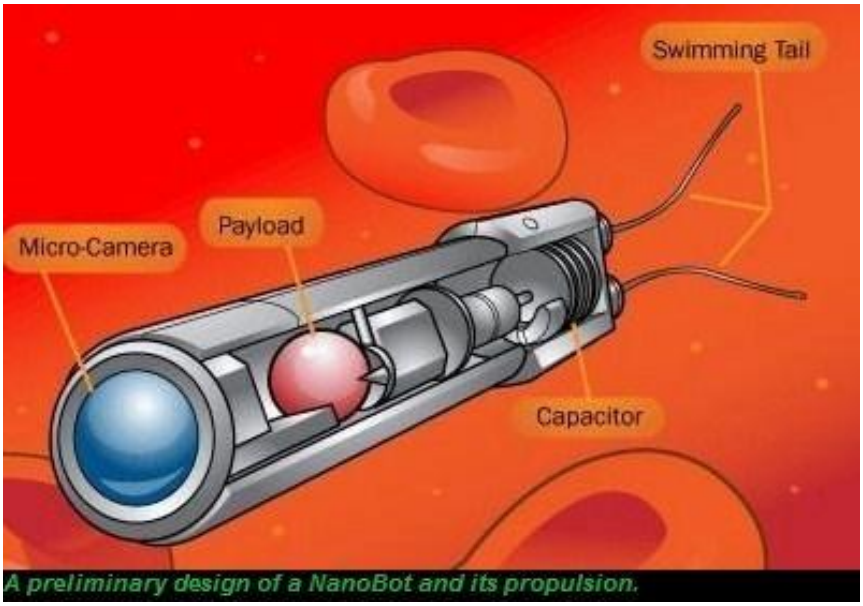
NANOTECHNOLOGY:
THE USE OF NANOBOTS IN THE DETECTION AND TREATMENT OF DISEASE





BY

EMMA LORMOR
HELEN CLOUGH

PASS

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Abstract
Nanotechnology is the application of engineering machines at a molecular level, using the "there's plenty of room at the bottom" speech given by Richard Feynman in 1952. Research and development in nanobots and nanotechnology, dating back to the last 15 years, has provided the background to this paper, such as Richard Errett Smalley's discovery of Buckyballs in 1996 and his further development of carbon nanotubes; this discovery has accelerated the production of nanotechnology in medicine. Our central idea for this paper was mainly based on nanobots in particular, as we felt they had the biggest potential to transform how we diagnose and treat diseases which have no cure at the moment, but may do in the near future thanks to their innovative design and their ability to remotely treat and diagnose illnesses. For example, doctors will be able to use nanobots to rebuild bone and bone marrow for trauma patients and leukaemia sufferers. Other techniques using nanobots such as quantum dots, drug delivery and gold nanoparticles are also discussed in detail. Ethical issues are examined and we will also consider the future of nanobots in medical applications and whether the general public is willing to accept them as part of the medical industry.

Introduction

The field of nanotechnology focuses on developing technology on the nano scale. Including the development of devices and machines that work on this small scale, nanobots are potentially small enough to penetrate inside a human cell. Nanotechnology is already used within the fields of electronics *(nano sized processors)* and cosmetics *(sunscreens)*. This same technology can be applied to the human body in sickness and in health. Nanotechnology is different from any other older technology because unusual physical, chemical and biological properties can emerge in materials at the nanoscale; many important functions of living organisms take place at the nanoscale. The human body uses many natural nanoscale materials, such as proteins, to control the systems and processes within. Haemoglobin for example is a protein which carries oxygen through the bloodstream within the red blood cells, haemoglobin is nanometres in diameter. This shows the size of the scale nanotechnology works on. [17]

There are two basic kinds of nanobots; assemblers and self-replicators. Assemblers are simple cell-shaped nanobots that are able to interpret molecules or atoms of different types, and are controlled by specific specialised programs. Self-replicators are fundamentally assemblers that are capable of duplicating themselves at a very large, fast rate; it is this sort of duplication that aids the construction of large-scale applications or deployment of nanobots for large-scale tasks. [18]

Richard Errett Smalley was a university professor who conducted extensive research in cluster chemistry and cold ion beam technology. In 1996 he was awarded the Nobel Prize in Chemistry along with his research partners Professor Robert Curl and Harold Kroto for their discovery of a new allotrope of carbons, it consisted of 60 carbon atoms in the shape of a football. They named the molecule the buckminsterfullerene and it was given the nickname 'Buckyball'. After discovering the Buckyball, Smalley focused his research on carbon nanotubes. [16] He was very passionate about both energy and education and therefore spent time not just doing his research but teaching politicians and major world leaders about the need for a solution to the worlds energy problem. His discovery of the Buckyball and research into nanotubes is helping the future of medicine as it is allowing the development and production of nanobots.

A lot of the damage that is caused through injury and disease happens on a cellular level. [1] Therefore, the development of nanobots is crucial, as they are able to handle repairing these damaged cells which could not be repaired otherwise without pain and trauma. Unfortunately the ideal nanobot is not yet fully complete, however, researchers know that they need to be agile enough to navigate through the human blood stream unnoticed. The human circularity system is made up of extremely complex veins, arteries and tiny capillaries. Nanobots don't just have to be small and agile, their purpose is to identify what is causing a disease and then, hopefully, treat it. This means that

nanobots need to be small, agile and able to carry a camera, medication and tools, as shown in Figure 1.

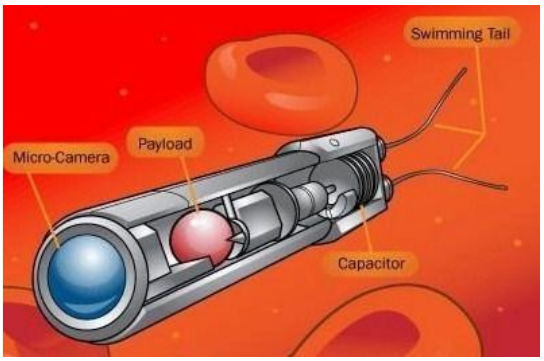

Figure 1 shows an ideal nanobot. It is this that scientists are aiming for and hope to achieve.

Discussion

Detection of Diseases

At present, current diagnostic techniques are limited in the way of accuracy and duration of time between the test and finding out the results. Nanotechnology will be able to revolutionise how we diagnose an illness, so that the patient will not just be able to instantly find out the results of the test, but can find out so early in advance that the disease will not have made any significant damage to the tissue and therefore can be treated or even cured much more quickly and efficiently.

Nanobots will be able to perform a range of diagnostic and testing functions, both in tissues and in the bloodstream. The nanobots would be able to continuously record variables, such as temperature, pressure, chemical composition and immune system activity all from different parts of the body, which could indicate the presence of a disease. In some cases, nanobots could be swallowed by a patient and be able to approach the surface of the stomach lining to search for signs of infection [1].

Cancer

Current imaging methods can only readily detect cancers once they have made a visible change to a tissue, by which time it may be extremely difficult to cure the cancer. Nanobots can be used to detect the disease at a very early stage, so the cancer can be cured quickly and efficiently. Currently research is focussed on introducing specially designed nanoparticles into the body. These particular nanoparticles are composed of tiny fluorescent quantum dots [13] that contain antibodies - which are coated on to the nanoparticles - which identify specific receptors that are found in large quantities in cancerous cells. These then produce a high contrast signal on Magnetic Resonance Images (MRI) or Computed Tomography (CT) scans [14]. In turn, these antibodies bind selectively to cancerous cells. When this occurs, the quantum dots fluoresce brightly. Experiments with mice bearing human breast tumours showed that the injected nanoparticles were easily detected in the cancerous tissue by MRI scanning within five hours after injection [12]. This fluorescence can be picked up by the scanners, enabling the accurate targeting of the disease even at a very early stage.

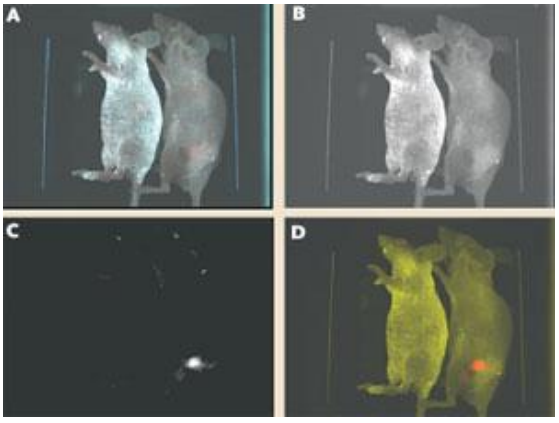

Figure 2 Using quantum dots in nanobots to show a prostate tumour present.

Another way of detecting malignant tissues is to inject nanoprobes in the human body to search for cancerous cells in blood and tissue samples. The nanoprobes that are injected contain a coating of molecules that bind themselves to specific reagents that are present in cancerous cells. When these nanoprobes bind themselves with a cancerous cell they release a dye agent. This dye agent is a mixture of colours and this provides the doctor with the information of the kind of cancer that is present and the treatment that should be used to cure it [11]. So a particular colour corresponds to a specific type of cancer. A similar type of approach is also being researched using gold nanoparticles, which are capable of identifying marker proteins on breast cancer cells. These nanoparticles, which can then be detected by ultrasound, are enabled with antibodies designed to bind to a specific marker on cell surfaces. Scientists will then be able to analyse these proteins on the cell's surface which will be able to confirm what type of cell the proteins belong to or in what condition that cell might be in. This will be useful in accurately diagnosing the type of cancer, as certain types of cancers have specific surface markers. Using gold nanoparticles is much more efficient than the conventional use of flow cytometry (counting and examining microscopic cells) as this requires hundreds of thousands of cells to diagnose cancer, where as the gold nanoparticles require only a few cells [4].

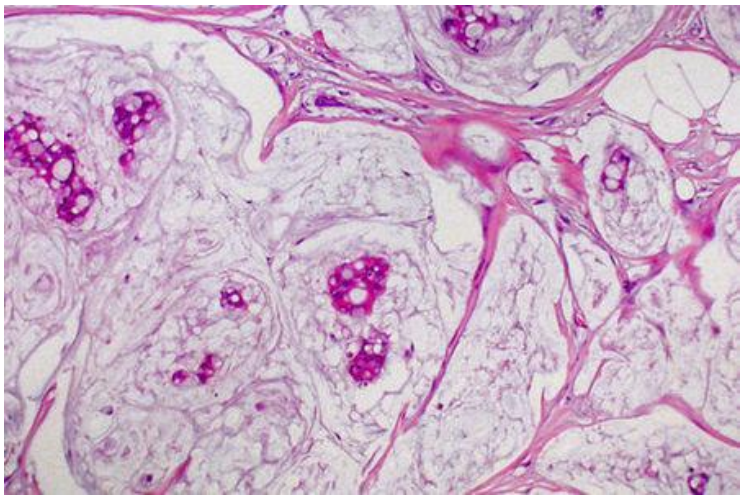

Figure 3 shows breast cancer cells stained with a dye agent released from a nanoprobe.

Furthermore, a nanoprobe is being designed to function as a screening test for ovarian cancer. As a result, an ovary will not have to be removed to determine if cancerous tissue is present. The nanoprobe will test the stiffness of the tissue, as cancer tissues are stiffer than most healthy tissues. A second area of research involves developing nanometre sized contrast agents with ultrasound to diagnose ovarian cancer. Such nano ultrasonographic contrast agents can pass through the smallest capillaries. These tiny bubbles will be able to light up on ultrasound and will be able to show the earliest vascular changes associated with ovarian malignancy [15].

Type 1 Diabetes

Nanotechnology can also be used to detect chronic illnesses such as Type 1 Diabetes. A breath sensor, composed of tungsten oxide and silicon nanoparticles, has been launched which can determine whether a person is suffering from the disease. The sensor is able to detect high amounts of acetone in the person's breath, which is an indicator that the person may be suffering from Type 1 Diabetes. When the sensor comes into contact with breath, the acetone molecules come into contact with the pores of the coating of the sensor and begin to react with the tungsten oxide nanoparticles. If the breath contains relatively high acetone concentrations, the electrical resistance of the material drops.

This causes more electricity to flow between the electrodes, generating a stronger signal from the nanosensor. The sensor will be able to reduce the time of diagnosis and reduce the costs of medical services compared to conventional diagnosis such as blood testing [8].

Alzheimer's disease

Nanotechnology has seen the development in diagnostic tools for neurodegenerative diseases such as Alzheimer's. Gold nanoparticles can be used to detect a biomarker associated with the condition, making it easier to detect Alzheimer's in the very early stages. The cerebrospinal fluid in patients suffering from Alzheimer's contains abnormally high levels of a highly phosphorylated protein known as tau, which is involved with microtubule stability. Large amounts of this protein are thought to cause inflammation of the brain, leading to the associated memory loss found in the disease [3]. The diagnostic technique involves using monoclonal anti-tau antibodies combined with gold nanoparticles to identify Alzheimer's tau proteins through antibody-antigen interactions. When the tau proteins are present, several nanoparticles can bind to each protein to produce nanoprotein aggregates. If the tau protein is present, the aggregates will change colour, which can be detected by analysing the change in intensity of two photon light scattering from the solution [5].

Treatment of Diseases

Currently a large number of the medical procedures used cause patients a great deal more pain and suffering, medical scientists want to be able to use nanobots to not only detect but to treat disease and repair damaged tissues without pain and trauma. Medical scientists also believe that nanobots will not only be able to repair damaged tissues but re-grow them by rebuilding individual molecules to create a new layer of tissue. Nanobots are believed to work quickly and neatly so this new layer of tissue would be made without leaving any nasty scarring.

Take a cancer patient for example, most cancer is treated with chemotherapy or radiotherapy, the treatment received by these patients often makes them feel much worse and causes them additional pain. This is because these treatments are unable to just distinguish and treat the cancerous cells. The chemotherapy and radiotherapy kills many healthy cells in the quest to kill off their malignant cancer cells. It is hoped that when the nanobot is complete doctors will be able to use them to inject into cancer patients, allow the nanobots to locate the cancer cells and kill them without causing too much, if any, harm to the body's healthy cells, this way the patient becomes free of cancer without needing surgery. [10]

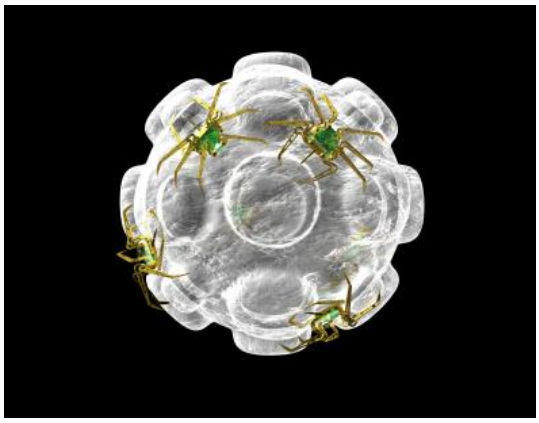

Figure 4 shows medical scientists prediction that nanobots will be able to locate and kill/treat specific cells

Nanobots will not only be used to repair damaged tissues but to also administer drugs. Drugs operate by the way of the circularity system, as the bloodstream is an indiscriminate cycle that delivers its contents to many parts of the body. Many drugs have side effects, side effects that can sometimes make the patient feel worse, this is because any drug that is administered will automatically effect cells within the body that are perfectly healthy. [2] This can result in some cells being worse off than before the patient took the medication. It is circumstances like this where nanobots will be useful and helpful in medicine as doctors will be able to inject nanobots into the bloodstream where they will be taken to the necessary cells in the body that require their attention and medication without causing unnecessary harm and damage to other healthy cells.

Research believe nanobots will be able to act as antibodies for patients with weak immune systems, they will be able to patrol the bloodstream searching for harmful bacteria and viruses and eliminating them before they cause the patient any harm. This will become extremely useful when tackling more common illnesses. Nanobots will not only be able to help doctors and surgeons fight life-threatening diseases but more common bacterial and viral cases. By potentially having an effective synthetic immune system within the body medical researchers believe that sufferers of HIV/AIDS will be able to fight and beat the virus. HIV (human immunodeficiency virus) is a virus that is transmitted from person to person, an advanced state of the HIV infection is AIDS (Acquired immune deficiency syndrome) In AIDS sufferers; the virus has progressed resulting in significant loss of white blood cells and infections that result from the damage the immune system has undergone. At present there is no cure for the HIV/AIDS virus, this results in so many lives being, in many cases, unnecessarily lost. If medical researchers were able to create special nanobots to help the body's immune system then nearly every case of HIV/AIDS would be expected to be cured. From this medical researchers will hope to completely wipe out the HIV/AIDS virus, which would make a complete difference to the world as in 2009 16,600,000 children were orphaned globally due to the loss of parents from the AIDS virus. If this technology is able to work consistently the impact made to so many lives in unthinkable. [6]

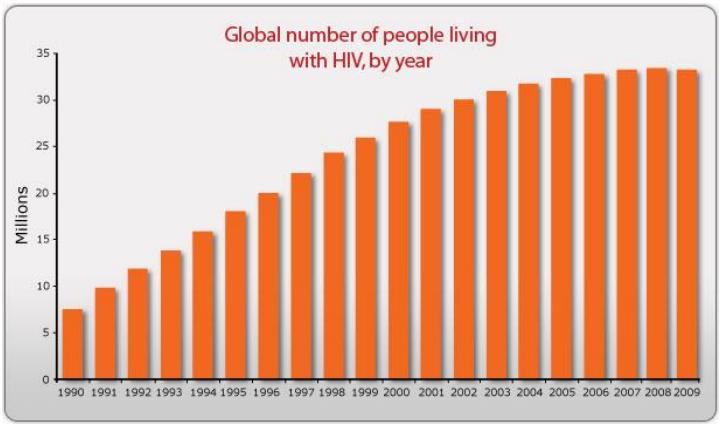

Figure 5 shows how the number of people living with HIV globally has risen each year since 1991.

Medical researchers have managed to create nanobone. Nanobone has all the natural properties of regular bone but it is much stronger and a lot more flexible. Nanobots would be used here to go into the area where the bone is broken or shattered and piece together what is there and where necessary use nanobone to help rebuild the missing and broken pieces of bone (as shown below in figure 3). This will reduce the recovery time and be extremely useful for accident victims. [7] From this medical scientists believe they will be able to not only repair or replace bone but bone marrow. This would allow medics and medical scientists to get extremely close to find a cure for leukaemia. Leukaemia is cancer of the blood and is the most common cancer in children. In leukaemia the normal control mechanisms in the blood break down, as a result the bone marrow starts to produce large

numbers of abnormal white blood cells and disrupts the production of the normal blood cells thus affecting the vital functions that these blood cells carry out. [9]

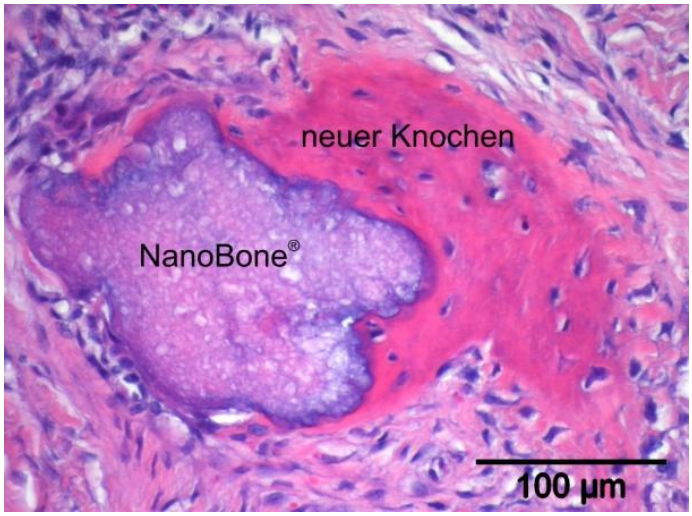

Figure 6 shows how nanobone will be used to bind to broken pieces of bone to help accelerate the recovery of bone breakages

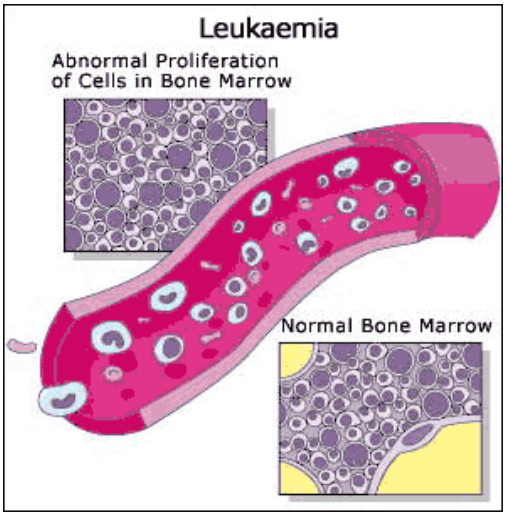

Figure 7 shows the difference between the blood cells in the bone marrow of a leukaemia sufferer and the blood cells in the bone marrow of a healthy person.

At present demand for surgery is extremely high and patients have to be prioritised. Sometimes organs break down due to age or are too damaged or diseased they cannot repair themselves this is where nanobots could be used to perform micro-surgery. This would mean that the patient does not require surgery and can be dealt with on the spot. Nanobots will also be extremely useful for very delicate surgery, for example stitching a split vein; this requires the work of an exceptional surgeon and would require a lot of time and consideration. However, with the use of a nanobot, a surgical procedure required on this small scale will become much easier and the success rate will increase. In the case of patients with allergies to anaesthetics using nanobots for treatment instead of surgery will allow these patients to be treated differently and make a huge difference to their lives. For sufferers of haemophilia, their blood cannot clot well enough to heal; this can sometimes result in patients bleeding to death. Medical scientists are working on nanobots that would produce a special synthetic clotting material for wound areas that stop the bleeding and would result in saving many more lives.

Conclusion

To conclude, nanotechnology is still relatively new in the medical world but things are moving forward. We are living in the Twenty First Century and people are dying because they cannot fight certain illnesses or medics cannot treat and cure their diseases. There is no question in saying that nanotechnology and nanobots will completely change how we diagnose, treat and control some of the most life-threatening diseases known today, replacing the more conventional, time-consuming and sometimes even painful of diagnostic tools.

The most important thing to medics is the treatment of their patients. With the advances in nanotechnology and the development of nanobots will help patient treatment become quicker, easier and less painful. Nanobots will hopefully be used to treat and cure patients who, at the moment, are losing their lives due to diseases medics cannot treat. Nanobots will be able to identify the diseased cells and destroy them without damaging other cells, which is unfortunately how many illnesses, such as cancer, are treated now.

However, although nanobots may be the answer to solving all our medical ailments, there are concerns about how they may impact society. Nanobots may encourage people to act irresponsibly as a result, by drinking excessively and smoking, and assuming that the nanobots will cure the consequent damage. I view this as exploiting the life-saving technology that is on offer and will cause people to be less cautious when it comes to taking alcohol and drugs. To avoid this, nanobots should only be offered to patients who have a chronic illness or if the prognosis is death. As for illnesses caused by lifestyle choice, it should be based on whether the patient is willing to change their lifestyle in order that the damage does not happen again. This can be compared to the organ transplant controversy. Although nanobots have the power to cure us, that power must be controlled so that we do not take this advancement in medicine for granted.

We must also take the time to ask ourselves this question: would we want nanobots to treat us? It is all very well saying that nanobots could potentially diagnose and cure every disease on the planet, without the need for surgery or serious side effects, but to some people the thought of using a machine which is invisible to the naked eye, seems rather frightening as we are unable to see what they are doing. What would happen if they were to get trapped in a capillary in the heart or brain? Issues such as this need to be addressed before nanobots are in mainstream use in the medical profession.

I have no doubt that nanotechnology will change many lives, and replace some of the relatively outdated medicines and diagnostic tools on offer to us at the moment. For example, using quantum dots to detect the presence of malignant tissue in the very early stages will drastically cut the number of unnecessary deaths and reduce the time needed to cure the disease. Although the thought of nanobots being present in our everyday lives seems distant, the technology and resources nowadays mean that a potential cure for many diseases will be available in the near future, and a new generation of treatments and diagnostic techniques is established.

There is argument to say that medical scientists are taking their research and discoveries too far and should allow some space for natural processes to occur. People are afraid that the use of nanotechnology will be giving surgeons “godlike” powers by interfering in the normal functioning of the body. A nanometre is one-billionth of a meter and people are anxious that because

nanotechnology is so small they do not know what is being put inside them. It is also a concern to some that with the progress in the research and development of nanotechnology and nanobots, the demand for surgeons or the number of students wanting to be surgeons will decrease. For the future of medicine this would be disastrous as even with the developments in nanotechnology surgeons are a necessity in all hospitals around the world.

Medical researchers are extremely excited about what the future holds. They believe that nanobots will be able to be used for research and discovery within the human body. Well-placed, highly trained nanobots could potentially journey to the brain stem in a completely painless manner. If this were to become possible, scientists will be able to observe the firing of synapses and other mental processes to provide a greater understanding and discovery of their functions and abilities.

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Figure 3 – All in One Nano Agent detects, target and disables tumour cells
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Figure 6 – How Nanobone Will Work
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Figure 4 – How Nanobots will be able to locate and kill cancerous cells
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Figure 1 – Ideal nanobot
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Figure 7 - Leukaemia
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Figure 5 – People Living with HIV Globally from 1991-2009
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Figure 2 – The Ups and Downs of Biotech
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