

Nanotechnology: The Future of Drug Delivery?

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Within this paper, it will be discussed as to whether advances in Nanotechnology could be the new frontier in drug delivery that Medicine is looking for. Through exploring Nanobots and Nanotubes amongst other areas of research, it will be questioned to what extent Nanotechnology can enhance our current understanding of the human body and disease.

Nanotechnology can be defined as 'the branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules'. (Oxford Dictionary) Scientists have only just scratched the surface of the Nano World. When we take into consideration that the discovery of the Nanometre only occurred in the last century, (1902 Zsigmondy) our knowledge of this area of science, and how it can be sculpted to benefit our World and its developments is dramatically progressing. Whilst it is easy to assume our state of progression will only excel our current understanding of this relatively new science, it is only logical to bear in mind we cannot work with what we cannot see. Other extents of physics will need to develop ways of producing new apparatus which will enable us to not only influence individual atoms, but subparticles to fully harness this budding, upcoming part of research and technology.

Richard Feynman, a physicist at California Institute of Technology, in an after-dinner speech in 1959 titled, "There is plenty of room at the bottom", at the American Physical Society's Winter Meeting of the West 2,4, 6-30. Junk and Riess The first observation and size measurements of nanoparticles were carried out using an ultramicroscope by Richard Zsigmondy in 1902 The term nanotechnology was first used in 1974 by Norio Taniguchi Gerd Binnig invented scanning tunnelling microscopy (STM) while Henrich Rohrer invented atomic force microscopy. In 1985, Fullerene C60 was discovered by Kroto's and Smalley's research teams. In 1991, Saumio Iijima discovered carbon nanotubes and by 2000...

Drug delivery has developed drastically within the last century, from when it used to consist of homemade plasters with powdered mustard seed upon the surface. (1). It is now evolving into a new system which harnesses the use of all particles involved. Since disease starts at the subatomic level, is it not logical to being treatment at this stage? Drug delivery has now become so advanced that an alternative to ointments on the skin, isn't just simply tablet form, but insulin passed through the skin by nanotubes and miniature nanobots delivery drugs straight to the infected cells (2). Even intravenous drugs are fading out in place of nanotechnology as implantable delivery is becoming more and more common, making it more comfortable and pleasurable for the patient. If we can capture this opportunity to use the information nanotechnology gives us, we can truly change medicine completely. At this moment in time it is difficult to predict exactly how nanotechnology will enhance the future of medicine as it is such a young science, all we can know is that it has amazing possibilities for us as humans to harness. It could be quite possible for nanorobots to single out water contaminants therefore decreasing the chances of disease and infection. There could be evidently nothing that nanotechnology could not repair from a single cell to an entire organism, the atomic world has the power and the capability to be the answer to the world's problems.

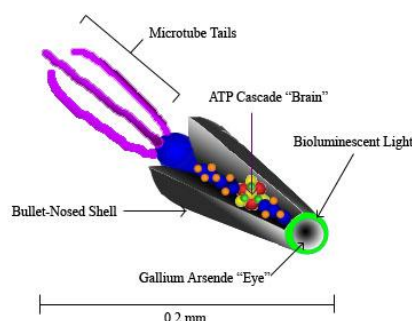
Cancer is a class of diseases in which a group of cells display uncontrolled growth, invasion that intrudes upon and destroys adjacent tissues, and sometimes metastasis, or spreading to other locations in the body via lymph or blood (3). Estimated cancer prevalence in the United States, 2007 states 126,000 people were

diagnosed with cancer of the brain or nervous system (4). At the present day Cancer is treated in a violent manner to match the disease's violent outbreak. The body is bombarded with harmful toxins such as those used within chemotherapy. These toxins do not just target the cancerous cells; they affect cells undergoing rapid division such as hair follicles and the epithelial cells lining the gut, which is a typical trait of cancer cells. This takes its toll on the entire body and just like a machine, without all the working parts, the body is just likely to fail and shut down. If this fails, then invasive surgery is the next port of call. With immunity and strength of the body decreased by chemotherapy, surgery is a risky alternative to undergo. Invasive surgery leaves the patient potentially prone to acquiring an infection which will dramatically increase recovery time, and takes up valuable hospital beds, time and money. If surgery is successful, which entirely depends on which region of the body the cancer has affected, the cancer treatment does not stop there. Frequent visits to hospitals and specialists to ensure the patient is on the road to recovery are required, and if cancer treatment is unsuccessful, the monitoring of the progression of the melanoma is vital to inform the patient of how long they have left.

Although this is an alternative, with the introduction of Nanotechnology many risk factors associated with disease treatment can be abolished. Using Nanotechnology to approach cancer treatment as opposed to methods which frequently do the entire body more harm than good, we see an innovation which fuses biology, technology and robotics. Imagine a world where it is possible to diagnose, locate and exterminate the diseases which reduce quality of life, and can be fatal, such as the afore mentioned, cancer.

Using nanobots, we can correctly diagnose the type of cell the cancer consists of, for example malignant or non-malignant. By taking a biopsy, we risk releasing cancerous cells into the body, where they can travel via the bloodstream to an area they may replicate in. The nanobots could encapsulate the desired cells and return them to the pathologist's laboratory where they can be scrutinised, diagnosed and a treatment can be selected or engineered according to what the cells result in being. The treatment is then carried by the nanobots to the site of disease where the drugs can be administered to the specific cells in question.

As afore mentioned, nanobots are the new major advancement in medicine in the 21st Century; they are small 'robots', only micrometres long, engineered with specific zones for moving, detecting and excreting the internal antibiotics, [figure 1]. These micro 'robots' have a very large surface area to volume ratio; this is so that their exterior can bind to the receptors on the infected cells, such as a tumour. The encapsulated treatment, which is specified for the tainted cells, is contained within their shell and released to the cells individually, as to not interfere with the living organelles that help function the human body.



[figure 1]

Mettin Sitti, the director of the Nanorobotic lab at Carnegie Mellon University, has been intrigued by the endless possibilities that nanobots have in helping in the on-going fight against diseases (5). He and his team have been building nanobots for drug delivery and using virtual experiments to test how well they are developing. One of the predicaments with nanobots is the question of how they can be controlled. One of Mr. Sitti's ideas is manipulating bacteria to help propel the nanobots in the right direction. One experiment included using optical and magnetic stimuli to coax bacteria into stopping and accelerating. These notions have not yet been specifically accepted, so the question of control is still a problem.

This problem therefore develops a difficult interpretation for a few individuals in the World. For the everyday 'man on the street' nanotechnology and nanorobotics are science-fiction and not a reality which could be a part of our World today. If the idea of small robots going into your body – which cannot fully be controlled – doesn't frighten people, then there isn't much which can. It is a fact that the relationship between scientists and the public is dwindling, if the community has no trust in science and technology then developments cannot take place, which could on the long run help phase out diseases, or even find a cure for cancer.

Dr. Anirban Bandyopadhyay believes he has the answer to this problematic situation. He has created a 'brain' that controls the nanobots which are sent into the body. (6). He and his team have created a chemical brain which has been recorded to control 256 operations simultaneously and he hopes to exceed this to 1024. If his work is promising there is no worry of how to influence the minute robots into carrying out the correct procedures (7). Another predicament that comes from the use of nanobots is what happens to them after they have done their job. The thought of these robots staying in your blood stream for weeks after the task is completed, can prevent many from ever going through with the procedure. This is why a 'biodegradable' nanobot has been conducted from nanoparticles, such as iron oxides, polymers, dendrimers and liposomes. Moreover, personalised medicine which is designed to target drug delivery is still possible but the nanobots will disintegrate after a few hours and leave the bodily system naturally.

If we can harness the power of nanobots effectively we can truly change the future of medicine. It is obvious that nanobots have many positive aspects within themselves, as they are the only way to fight against disease without invasive surgery. They can easily seek out and target certain types of cells. And now with the continual advancements of controlling the 'robots' there is less and less worry with how they will react in an actual human body. One of the main arguments against the use of them will be the ethical issues involved in many religions. Some will claim that it is not natural to insert supposedly controlled robots into the body. But on the other hand, is not simply capturing the true essence that is 'nature' to the very core which begins all of life, single atoms and molecules.

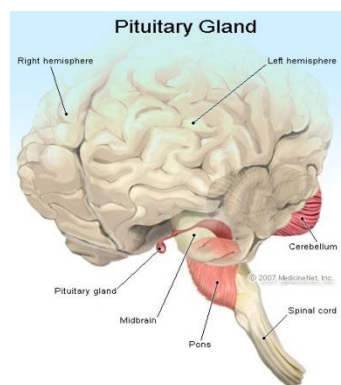
Nanoscience is modern day's witty comeback to the argument posed by patients: how can we have minimally invasive treatment?

Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1 (8). Part of the “fullerene family”, nanotubes have been reported to be made up to eighteen centimeters in length, as of 2010, and they have a width of just a few nanometers. A nanometer is approximately 1/50,000th of the width of a human hair (9).

Surgery is always the last resort when it comes to patient treatment. When we think about ‘undergoing the knife’, we often fail to take into account the added burdens that are heaved onto the shoulders of the NHS and the patient. If surgery is the only option left for a patient, we must consider what this entails to both parties: pre operation assessments by General Practitioners; pre-operation assessments by specialist consultants nurses, specialists, ward staff and anaesthetists to prepare the patient for theatre surgeons, theatre staff and anaesthetists for the procedure; a bed for recovery of the patient drugs to support the treatment and to prevent infection; post-operative care in the hospital and home, including prescribed drugs.

The patient, whose immunity to infection may be reduced by their illness and possibly by the drugs they are on, may become more susceptible to acquiring an infection after their operation and during their stay in hospitals. Bearing in mind hospitals generally hold the most ill members of society, there is going to be a high number of various diseases in a relatively small area. Combine this with the amount of strains there could potentially be of an illness, due to antibiotics provoking variation of the genetics of the bacteria which can lead to resistance. Lowered immunity mixed with high concentration of a variety of contagious illness could be fatal for someone recovering from surgery. By reducing the size of the incision made during surgery, we could potentially lessen the area through which pathogens can enter the body.

[figure 2]



We could let our mind wander, and consider a patient, diagnosed with a prolactinoma, which is a growth in a rather inaccessible region of the brain, on the pituitary gland [figure 2]. A prolactinoma is a noncancerous pituitary tumor that produces a hormone called prolactin. This results in too much prolactin in the blood. (10). We must consider the placement of the growth. Instead of invasive and risky surgery, we can, with nanotechnology, pose an alternative method of treatment,

which will have little impact and interference with the functionings of the unaffected body. A perfectly engineered nanobot could be delivered via a nanotube, entering the skin and penetrating the cranium and deliver drugs to the tumour which would terminate the benign cells. Advantages of such a procedure:

- little to no incision required so reduced risk of infection
- the cranium, protecting the vulnerable brain, isn't left too badly damaged, and the pathway of surgery through the brain to reach the pituitary gland is minor
- the nanotube, measuring mere nanometers across will be minimally invasive and can be selectively guided to the site of requirement
- the nanobot can be engineered to disintegrate after delivering drugs and its minuscule carcass will be passed into the blood stream and filtered out, later being excreted from the human body
- perfectly functioning regions of the body are not affected by the bombarding of toxic poisons to kill the tumour and there will be little to no side effects of treatment, with a high success rate.

The same would apply to cancerous cells. Cancer, as afore mentioned, is a violent disease and treatment with chemotherapy can result in many downfalls of the healthy human body. By limiting the region affected by effective treatment, we can raise the standards of quality of life during treatment for the disease. Likewise, we can combat risky surgery with the use of nanotechnology by reducing the amount of tissue damaged through invasive incisions. This would save the NHS money by limiting the amount of time required for recovery after surgery, and would let wards see an increase in the amount of beds available for seriously ill patients.

It is clear to see that nanotechnology provides new methods and understanding into how well it can truly enhance medicine in the 21st century. At the present moment virtual simulations are used to experiment how nanotechnology can be revised and refined. So that when they replace many of the old methods of drug delivery they can be 100% effective. Nanobots can be chosen to be used in specialised circumstances such as the fight against cancer cells or for personalised drug taking. Nanotubes can be adapted successfully to allow diabetic patients to take insulin through a small patch no bigger than a finger nail, instead of the daily injections which are used currently.

When analysing the pros and cons of constructing nanotechnology to assist in drug taking it is obvious that there are more positive aspects than negative. But there are always going to be problems that will be difficult to overcome. Problems such as: due to the fact that all of nanotechnology is experimented virtually how do we know that it all works effectively in the 'real' world? The majority of experiments are only 'thought experiments' to suggest how something could occur, there at the moment seems to be no definite within nanotechnology. If control is not fully succeeded in our world, this could easily lead to a frenzy involving nanobots throughout the body unable to regulate their movements.

There is a good side to all of this though, there are always answers to the problems that occur. As we have already seen control within the 'nano' world is becoming more and more achievable as 'brains' and 'remote controls' are being

manufactured. Although, at the moment, all experiments are virtual they will someday reach the point where the experiments are real so that when they are used in the medical field there will be no complications. If these problems are dealt with effectively the 'nano' world can be used to only improve, not hinder our future. The uses of nanobots and nanotubes can be applied to the medical world and put an end to invasive and unnecessary surgeries, and therefore decreasing the amount of recovery time; allowing more bed space, more available pharmaceuticals and happier patients. It is clearly apparent that nanotechnology can benefit our world and how we deal with drug providing in a clean and proficient method.

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