The Future with Nanotechnology

Abstract

Nanotechnology is a new discipline that has opens the door to many fields. This report is to identifies the uses of nanotechnology in the following areas; Telecommunications, Bio-Engineering, Medical Electronics and Robotics. These are the four main areas that there is potential to offer business opportunities in the future. Also in this report there will be analysis of these areas eventually leading to a recommendation of the sector that we feel has the biggest potential for businesses in the future. This analysis will also look at the feasibility of the selected sector weighing the potential risks against potential gains.

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Introduction

Nanotechnology is a modern technical knowledge which implies the engineering concept at atomic scale. It involves the manipulation of the atomic structure at nanometre level (10^{-9} of a meter), to create new material that can be used at a very small scale. For example, in Israel, the scientists had created a silicon chip which is $1/1000^{th}$ inch square tinier than a pinhead and they printed the entire Old Testament in its memory [1].

So far in 2006, about €8.1 billion has been invested in the R&D on nanotechnology in the world and it is expected that the world market for nano-products may reach €1 trillion by 2015. [2] With so much money being thrown into nanotechnology you can only see more breakthroughs being made using nanotechnology and all the next wave of innovations made by companies" worldwide using nanotechnology. There are many different ways that nanotechnology can be either used to complement or to replace existing technologies. When these are realised and released to the market, depending on the usefulness and/or novelty of the innovation the potential for breaking into the market could be unlimited and now we shall look at some of the ways that nanotechnology can be implemented in different areas of technology.

Telecommunication

Telecommunications is an example of a field with which nanotechnology is making a significant impact in. This particular field involves the transmission of information through a certain media which spans a certain distance. The media could either be a cable, telegraph, telephone or any means of broadcasting information. [3][4] Improvements to telecommunications and information processing can be realised due to increasing research taking place using nanotechnology. The use of traditional electronic devices can be replaced with optoelectronic devices with are based on the effects that has light on semiconducting materials due to quantum mechanics. Examples of such devices include Photonic Crystals and quantum dots. [5] Nanotechnology has a wide range of applications and has impacted the telecommunications industry in several ways.

<u>Fibre Optics</u>
One of the categories that the telecommunications industry has been impacted upon by the introduction of nanotechnology is fibre optic communication. Fibre optics is mainly concerned with transmitting information between two locations through pulses of light waves which travel through the core of a wire. The light forms an electrical carrier wave that modulates a signal. The light travels through the cable using the principle of total internal reflection. [6] As the complexity of telecommunication networks are always increasing, the need for power control and regulation also increases. Power control is achieved through the use of optical devices that are based on nanostructures. Nanostructure based optical devices have already been introduced to the field; this includes optical fuses and optical limiters. Optical fuses are devices that operate as a normal fuse whilst the input power is lower than a specified threshold point. Once the threshold is reached the power drops irreversibly. [7] Optical limiters are devices that transmit power as normal provided that the input power is lower than the limit power, when the input power exceeds the limit power, the output power remains constant. These devices act in a similar fashion to circuit breakers and Zener diodes, which are electronic counterparts of optical fuses and limiters. The fundamental principle of these particular optical devices is nonlinear interaction with transmitted optical power. Optical devices can provide an effective means of power regulation and protection within optical networks. Other applications that are currently being researched include the use of nanostructures for fibre splicing. Fibre splicing describes the joining of multiple optical fibres together using an electrical arc. [8] The idea of using thin nanostructures for absorbing properties that can be melted provided from within the fibre itself thus enabling fusion splicing between fibres [9].

<u>Use of Nanotubes</u>
Carbon nanotubes are cylindrical based nanostructures that consist of sheets of graphite rolled up to make a tube. They have been demonstrated to exhibit unique electrical properties, robustness and act as efficient conductors of heat. Due to their remarkable set of properties, the application of carbon nanotubes are not only limited to telecommunications, they are a potentially useful across a wide spectrum of industries. Research on nanotubes has demonstrated that the resistivity of nanotubes is dependent on the properties of the nanotube itself and that the resistance between a nanotube and a graphite surface is increased by a factor of six if the nanotube is rotated by 360 degrees, this is caused by the atomic layout within the structure. This highlights the potential to build extremely small circuits as nanotubes can be introduced to provide the required resistive properties of the circuit. Another possibility which is being explored is light-emitting nanotubes. [10] The use of nanotubes to emit light at the same wavelength used in the telecommunications industry

currently exists and can be designed to provide a certain frequency by altering the diameter of the nanotube. Notable research has been carried out by IBM as they have fabricated a nanotube transistor capable of emitting a 1.5 micron infrared light wave which is commonly used in telecommunications. IBM have also reported to have successfully fabricated nanotube transistors that are 1000 times more efficient at emitting light in comparison to its predecessors. The application of nanotubes is not only restricted to tuneable resistors and fibre optic transistors.

Nanotube radios are of great interest to this particular industry. This is built using a single carbon nanotube molecule which is capable of providing all of the essential components of a radio and can be easily tuned after production. Successful reception of voice and music has been demonstrated and due to its simplicity, nanotube radios can be easily produced on a mass scale. This could reshape existing technology by making extremely small radio receivers and also be integrated into wireless communication systems. It is clear that carbon nanotubes has attracted and will continue to be the cause of extreme interest from the industry as well as researchers due to their unique set of properties and wide range of applications. [11][12][13]

A further area of nanotechnology that has also been linked with the telecommunications industry is the area of nanophotonics. This area is concerned with the "interaction of light with matter on extremely small length scales". [14] At present, it is only used as a replacement for copper in order to receive high bandwidth and high speed communication. However, research seems to offer an improved solution with regards to intra-chip and chip to chip communications by introducing nanophotonic switch architecture as it seems to be capable of providing low latency and high bandwidth and maintain minimal power dissipation at the same time [15]. This encourages the integrations of photonics with electronics in order to be able to meet the requirements created by future computer systems and support optical networks. Optical networks are networks within which the transmission of information takes place in the form of infrared pulses. They have currently been imposed on-chip. Nanophotonic switches play a role in this type of network and arranged in an array. This layout allows traffic to be routed effectively on chip as well as off chip, as shown in Fig. 1. Continuing along this direction will minimise the actual hardware required in order to provide certain functionality as routing can take place on a single chip rather than amongst multiple chips, thus increasing traffic flow and bandwidth requirements.

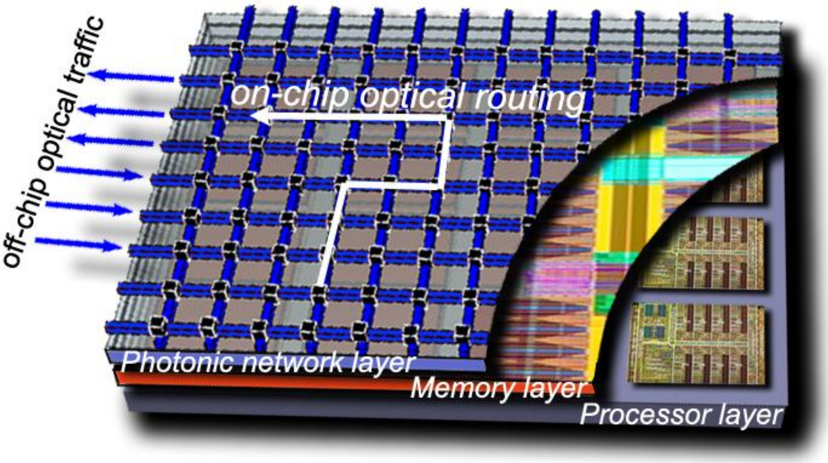

Fig. 1 Example of a nanophotonic switch [17]

Based on some of the developments made in the field of telecommunications, it seems that nanotechnology offers significant improvements to the way that existing technologies are made as electronic devices are being replaced or merged with photonic devices in order to minimise the amount of physical space required for hardware and providing the same technical capabilities within that space. This allows manufacturers to maximise performance and minimise physical requirements allowing devices to be able to meet the demands set by newer technologies with ease. [17] The creation of optical devices capable of manipulating light through the use of nanostructures can help increase bandwidth and break cost performance barriers for future generations. This has the potential to allow the telecommunications industry to reach new parts of the globe which may have not been possible before allowing for communications to take place across physical borders and cultural domains. [18] The concept of miniaturisation would allow for faster rates of data transfer, increased storage space and data transmission occurring in real time whilst exerting a smaller carbon footprint.

Despite the many benefits that are offered by nanotechnology, there also exist some causes for concern which need to be addressed. An example of this is the fact nanotechnology has no official regulatory body to represent it, therefore commercialisation of nanotechnology products are not overseen and have no need to meet the requirements or standards. This causes for increased scepticism of such products and could hinder any market opportunities. Any hazards imposed by the application of nanotechnology are not well understood yet and is a major cause for concern as particles on the nanoscale can easily enter the human body and alter the human state of well-being by potentially invading the blood stream. These nanoparticles could possibly have poisonous coatings and could cross over into the brain. [19]

Bio-engineering

People often think that biomedical engineering and bio-engineering are the same discipline but there are not the same in fact.

Biomedical engineering is the study of engineering principle and design concept in the medical field. It involves mostly the invention and creation of equipment that are used in hospital or private clinic for medical purpose such as the electrocardiogram, the x-ray scanner or the ultra-sound sensor.
Bio-engineering, also known as biological engineering or biotechnological engineering is the study of the electronic system, computer science and mathematics which will be used in the medical environment to develop devices that will look after the functionality of the human living system. [20]
Both disciplines look after the cost and practicality of the solutions that is going to be developed because there is no point in developing a device that will be too expensive to put in the market or a device that is too complicated to be used in the medical field.

Bio-engineering has many different sub-categories which are biomimetics, genetic engineering and tissue engineering. Biomimetics is the study of evolution of living system to be used to solve problems in artificial systems. Genetic engineering is the modification of DNA structure of an organism to improve it, for example by modifying the DNA structure of an apple you can make the fruit taste better or prevent it from over ripening for a longer period of time. [22] Tissue engineering is involved in the repairing or replacing of part or whole tissues, and much more. [23]

The fields where bio-engineering is used mostly at the moment are in the food industry, drugs industry and the army (biological weapons). In the food industry the bio-engineering concepts are used to create genetically modified foods (GM foods). GM foods have their genes modified in order to improve their consumption, by making the food last longer or giving properties which will make the food taste better.

Fig. 2 An example of a GM food; the genetic information containing the colour of this strawberry has been changed so that it looks blue [28]

Drug industries focus more on developing medicines that are used to reinforce the antibodies in our immune system. The army is spending vast amounts of money in this field to develop drug that can make their soldiers stronger and aiming for super human abilities. But it is also spending on research for new kinds of weapons that can be used in the case of war. [29]

One of the concepts of nanotechnology in bio-engineering is the development tiny particles combining inorganic and biological materials for the same purpose. These tiny particles, which will be developed at the atomic scale and will be small enough to be implanted inside the nucleus of any cell inside our body, would be able to replicated their selves in a small numbers just enough to be located in all major part of our body once inserted. The reason why these particles will also have biological features is to avoid any contact with the white blood cells inside the body, as the white blood cells will attack any living organism or non-organism inside your body that doesn"t belong there. The information that the biological feature will hold will be a DNA sample of the human where the particle will be inserted. Therefore each particle developed for each human will be different from each other.

For example in Singapore, Pr Jackie Yi-Ru Ying"s team of the Institute of bio-engineering and nanotechnology works on the intelligent insulin. Insulin is a chemical released by a cell to control carbohydrate and fat metabolism in the body [25]. Insulin is given to diabetes patients to reduce the amount of sugar in their blood level because if the concentration of sugar is higher than the recommended level, it can be lethal for their vital organs. The main aim of this intelligent insulin is to avoid the practice of self-monitoring the blood"s glucose levels. The insulin is enclosed inside a capsule which will be very sensitive to the concentration of glucose in the blood. The capsule would release insulin once degraded under the influence of high glucose concentration. [24]

Another example is that there are bacteria that are very resistant to antibiotics, which make them very hard to treat unlike other infections. These bacteria, that are called “superbugs” by the media, became very resistant because some of the patients that were given a course of antibiotics to eliminate them didn"t complete the course which allowed the bacteria to survive, mutate and increase its resistance to the antibiotics. These types of bacteria are commonly known as MRSAs and they thrive on surfaces that patients have touched, their clothes and the medical equipment used on them. This can be very dangerous in hospital, where patients have a lower immune system resistance to bacteria due to illness and accidents. To combat the MRSA IBM researchers and scientists from the Institute of Bioengineering and Nanotechnology have found a way to increase the power of normal antibiotics. They will be able to create antibiotics that will find the cells containing the bacteria after they have been inserted in our body in a small concentrations and then they will be physically attracted to them until the bacteria is annihilated. Once used, these particles will be disposed naturally from our bodies. It is thought that this new technology will be administered by simple water spray across the skin as the antibiotics will be in a very small dose as it will only need a small amount when injected in our body. [26]

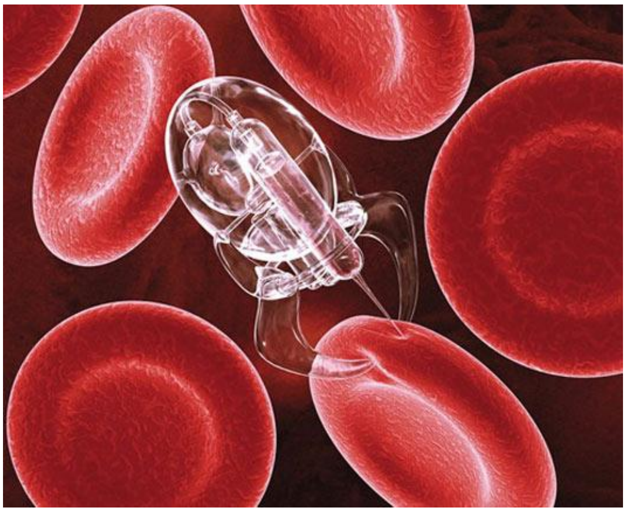

Fig. 3 A capsule injecting the antibiotics to a cell that contain the bacteria [27]

Nanotechnology in bio-engineering opens doors to many fields which it can be applied, from the human health system to the study of evolution for the improvement of artificial systems. There are many uses for nanotechnology in medical purposes; the government is actively spending money on R&D in these areas. Also other organisations such as banks and financial companies are investing money in it foreseeing that the future in this field will be very profitable.

Medical Electronics

In medical electronics there are many different uses for nanotechnology. This ranges from creating molecular structures to attach to specific antigens, to wound dressings that heal infection as and when they occur in wounds, to its uses in surgery. Given such a diverse range of uses you can already tell that there have been billions of pounds of research done throughout the years since nanotechnology came to the forefront. Many of these technologies have already been developed but haven‟t yet reached the human trial testing. The reason behind this is that while much testing has been done on lab mice and during simulations there hasn‟t been much money spent on researching the ethical and social aspects of introducing nanotechnology medically to the public. [30] There are also concerns regarding the use of carbon nanotubes, in particular, in the environment as some researchers are led to believe that it will be the new asbestos issue of this generation eventually. [30]

Buckyballs

Buckyballs, or Buckminsterfullerene by their molecular name, are used in medical research to deliver drugs specifically to a particular molecule within the body. The way that they function is that they have only hexagonal and pentagonal faces, which easier to hydrogenate than benzene which has previously been used to do targeted drug delivery. [31] Also another reason for the replacement of benzene is the discovery that it is a carcinogen and that it‟s unstable nature makes it highly unpredictable. [32]

There are other uses of Buckminsterfullerene as it can also be used to treat cancer. If the molecules have a very powerful light shone on them as they go around the tumour through the blood they will wrap themselves around the localised area where the tumour is and then destroy the cancer. This is a much more specific means to attack cancer than current chemotherapy offers, which is why a lot of research is being spent to perfect the method. [31]

Currently in MRI scans gadolinium is used but the Buckminsterfullerene molecules offer a safer option to patients as it can stay in the body longer without the threat of toxic poisoning to the patient. [32] Another alternate using gadolinium in MRI scans, another nanomolecule which does a very similar job is the ultrasmall superparamagnetic iron oxide nanoparticle. [34] This could be another option to see the contrasting results and find which better targets tumours. In Fig. 4 you will see the difference in results between the gadolinium and the iron oxide nanoparticle.

In terms of the business aspect of the price of buckyballs is falling all the time. In 1990 the price of an ounce of buckyballs was in the region of $35,000 yet this decreased to around $225 an ounce by late 2000. Experts have since predicted that the price will decrease further to $3 an ounce. [35] This will be when the use of buckyballs will be widespread so the quantities involved will be vastly greater. The social cost of buckyballs in future will be exceptional if trials are successful and the medical uses of buckyballs are cleared. It would be a great image for any company to be associated with the cure of cancer and targeted delivery of other drugs to the body.

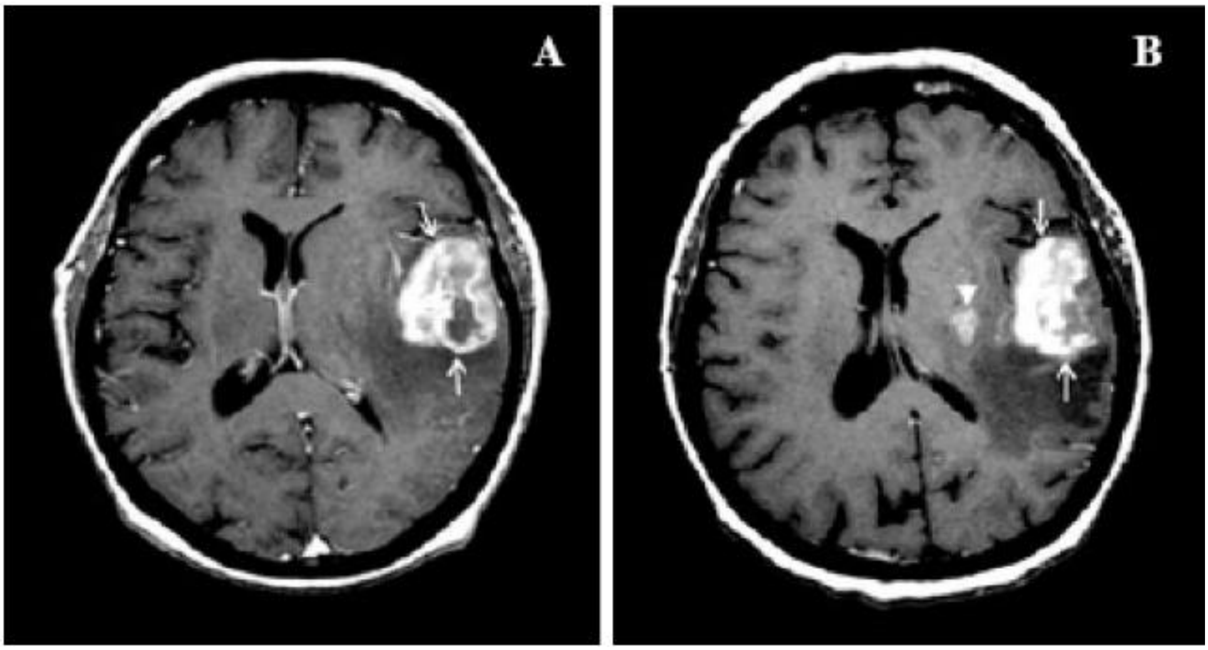

Fig. 4 A) – MRI using gadolinium. B) – MRI result using iron oxide. Below the full arrow head is an area of the tumour that only shows up in the iron oxide MRI [34]

Nanocrystalline silver wound dressings

With nanocrystaline silver wound dressings infections from wounds can be greatly reduced in future. This is due to the fact that the dressing has three or five layered dressing constructs of a silver mesh containing silver nanocrystals applied to either side of a rayon/polyester core. [33] The silver nanocrystals then release themselves into the wound, which occurs for over 30 days if necessary. [32]
Silver has natural antiseptic and anti-inflammatory properties that are hen spread across the surface area of the wound and released directly into it and as the silver particles are so small they are able to spread across all areas of the wound more effectively. Another property of silver is it is antimicrobial and this in turn maintains a moist environment that is desired in order to help the healing process. As bacterium is killed as soon as it develops in the wound this means that the resistance wouldn"t be able to build up thus reducing the risk of MRSA in hospitals, which would benefit not just the wound victim but also all the other patients in the hospital.

There has yet to be any research into the toxicity of the nanocrystalline silver, which will need to be investigated to ensure there are no long term health issues surrounding the technology. With regards to the retail price of the dressings, currently Smith&Nephew produce a range of different dressings, Fig. 5, with prices ranging £25.65 up to £263.58. [36] If a company producing such a product could get a contract with the NHS or other hospitals worldwide for their product they will have a great demand line and be able to compete with Smith&Nephew and potentially lead the market.

Fig. 5 – Acticoat's range of products currently [36]

Surgical Solutions

As more research is being done in nanotechnology, researchers are testing different ways to treat patients that require surgery. These include the use of nanoparticles to highlight tumours in MRI scans, the use of minimally invasive surgery for patients that are considered to have a high morbidity rating and the use of nanorobots to act as sensors to check the levels of critical compounds before during and after the surgery.

Minimally invasive surgery reduces the likeliness of complications during surgical procedures. It is aimed at patients currently that have high morbidity rates, obese and old patients [37], but in future it should become the standard procedure the more the technology is developed and the techniques trained on a global level. There are many benefits to the minimally invasive procedure as it results in just a small wound, which means plastic surgery wouldn‟t be as necessary and largely decreases the possibility of infection, and also an earlier discharge for the patient due to the lack of a significant wound. [38] While there are these advantages with minimally invasive surgery there are problems with the expense of retraining surgeons with the technique and the procedure typically takes longer to do than conventional surgical procedures.

Nanorobots are currently being developed that will be implanted inside a patient and then the robot will either remain in the body as an early detection device or be controlled and target specific areas of interest to check chemical compound levels. An example of the targeted nanorobot is the PillCam^{TM} capsule endoscope produced by Given Imaging Ltd and the Gutbot that is currently under development at Carnegie-Mellon University in Pittsburgh. [34] The difference between the two is that the Gutbot expands on the PillCam by allowing control over the direction and positioning of the camera as the PillCam currently only offers a 50% success rate and it is thought that this will greatly improve in time. With nanobot technology most of the testing is done using simulation currently as it is a very new field of technology. Each different nanorobot will only complete its pre-programmed tasks although in future with the use of artificial intelligence it should be possible to further their capabilities to respond to any abnormalities that are outside of its knowledge base. [39] It should also be possible in future to use these nanobots to perform surgery or even aid organ reparation the more that this technology is developed. Before all this is possible, there will be the need to be extensive research into the effects that having a nanorobot inside a human to ensure it is ethically and physically safe to do this as there are some concerns about the long term effects that nanoparticles may have on the body, not only in the targeted areas but all over the body if it is implemented into the blood stream.

Robotics

Robotics in nanotechnology is the creation of fully mechanical consciousness machine with its physical or its components size very close to the nanometre range. This kind of discipline is commonly known as nanorobotics. [40]

To this day there has not been any nanorobot created, there is only concepts about it. For example, if you look at the Nokia new concept of the futuristic mobile that it called "Morph", it has built in sensor type nanorobots that can detect if the food will be safe to eat by checking if there are any impurities. [41]

Robotics are generally used in the fields of communication, transportation, army, commerce and medicine. If you applied this same technique at a nanometre level then you can come up with different types of ideas by combining all the fields in some cases. But most of the use of nanorobotics will focus in the medical field.

Let‟s say as an example that you want to create a device that will be inserted inside your body to kill a virus that gave you a cold. You will need to create a robot small enough to travel through your veins and arteries. The robot will require a sensor to detect the virus, another sensor to know its location in the body, and it will also have some travelling mechanism to get to the virus as fast as possible before the virus mutates and expands. Finally it needs to have some kind of storage room to stock the medicine. As you can see in Fig. 6, the robot which was initially planned for medical purpose has now a means for transportation and a sensing feature.

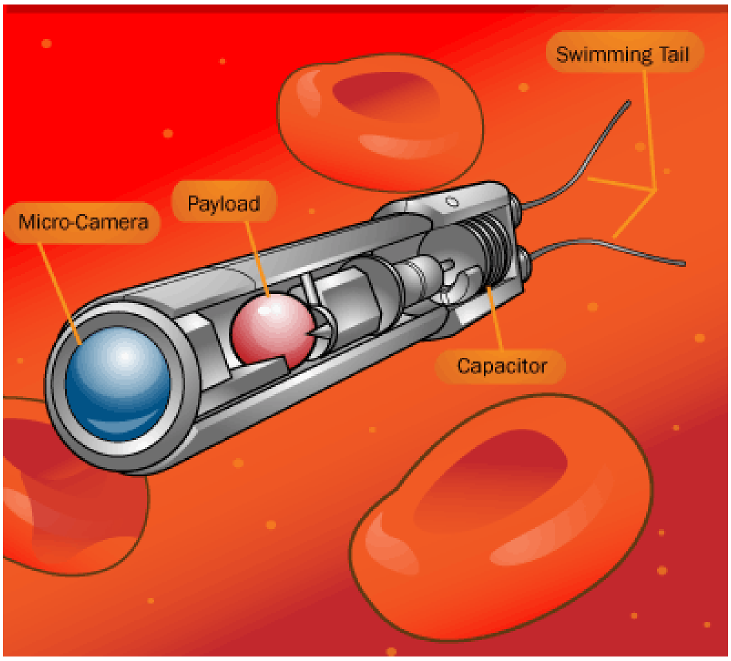

Fig. 6 A concept of a nanorobot capable of transportation [42]

Fig. 6 is a concept about a nanorobot that delivers the medicine, the payload in the image, straight to the place where the virus is located. It has got swimming tail to travel faster or to change the direction from the blood stream. The capacitor will hold the energy require for the robot to function. The micro camera will be used if you want to control the device movement otherwise it will use its built in sensor to get to the virus.

The other use of nanorobotics will still be in the medical field but the scale will be even smaller, it is going to deal at DNA level. Cancer is a term used for a large number of different diseases and it accounted for 13% of human death worldwide in 2007. Most of the cancers are formed because of a malformation of genetic structure. The creation of nanorobots that will fix this issue will help to combat cancer and save a lot of lives. There has been many concepts for this field but unfortunately it will take a lot more time as it deals at an incredibly smaller scale than any other nanodevices imagined so far. [43]

In robotic surgery there are two different types of robot available, one of them being a robot that a surgeon controls but instead of the surgeon using his own hand he uses a joystick that affects a robotic arm. With this method it transforms large joystick movements by the surgeon on the joystick to precise small movements on the operating table. [37] This gives the surgeon more control over the operation and greatly decreases the possibility of an excessive incision that could cause a problem during the surgery. The other way of operating using surgical robotics is that the robot fully completes the surgery without any human aid. This method relies on the robots artificial intelligence to complete the surgery and to act upon any unexpected problems that arise. With this method there would be huge concerns about the knowledge base of the robot as if a scenario that has never occurred before and wasn‟t in the knowledge base then patients could die as a result. Another ethical problem with the use of robotics in surgery is that it‟s not socially diverse enough to be implemented as the equipment would be too expensive for some levels of society. This will only further expand the gap in social classes where normally it is the poorer people in society that have the greatest health risks. [44] The tools that these robot surgeons will use will be nanoneedles, nanotweezers, nanoscalpels and also they will be capable of using precision lasers. The precision lasers will be able to destroy a specific organelle in a single cell and not damage any other part of the cell when it does so. [45]

Discussion

Due to the wide range of advantages provided by nanotechnology, it is highly likely that the number of products containing nanomaterial will rise. However, there exists uncertainty with regards to any potential risks caused by human contact with nanomaterials as they could potentially be dangerous. This emphasizes the need for regulation of this particular field and in order to be able to ensure successful commercialisation as potential consumers will feel confident when investing into something they know has been approved by a regulatory body.

Nanotechnology has the potential to disrupt the flow of the economy if it is to be introduced into a worldwide market as the effort required in manufacturing, transporting and storage of products will be minimised becoming more cost effective for manufacturers. The value of many materials and human resources could be reduced as a result leading to mass job displacement. This in turn could lead to cheaper products and potentially gain an edge in leading a market as it will be able to offer something that is unique and not seen in current products. This implies that products without nanotechnology will not be able to keep up with the new developments offered by nanotechnology. Another rising concern is that the monopoly could arise in the earlier stages of introduction as nanotechnology based products will be of extreme interest and will be valuable. A monopoly would cause an organisation to charge high rates for products and make high profits as a result, as there is no other entity to compete with, although the company with the monopoly will in turn be subject to fair trade regulations and face the possibility of huge fines if they aren‟t fair to the competition. The initial high cost requirements used for development will narrow out the amount of existing projects in the sector and would begin to encourage some form of monopoly. If an organisation manages to get a lead in this market then the profit generated as a result would allow it to deter any rivals by introducing patents to protect their products.

Criminals and terrorists could be further motivated to cause destruction the ease of installing compact devices would be much simpler and harder to detect, thus tempting attacks over a wide scale. Defence from such an attack will be extremely difficult as the variety of different types of attacks increases therefore designers of security systems will need to consider a wide range of imaginable scenarios in order to be able be robust against nanoterrorism. Disruption of society is amongst another cause of concern as new innovations and lifestyles may be introduced due to people becoming reliant on such products.

After comparing all the 4 main sections, it appears that bio-engineering in nanotechnology will have the biggest impact on nanoproduct development. This is because when analysing all the major parts, the application of nanotechnology always comes back to the medical field. When researching about the other topics the use of any product that will be developed would be in the medical field. For example, the development of nanorobot will help medically more than any other area. Therefore a SWOT and PESTEL analysis has been performed to identify all the important aspects of this field, to launch any product that will come up from this area in the future, to see how it will survive in the product market.

SWOT analysis for bio-engineering in nanotechnology

Strengths

- More and more people are interested in this new technology and most world government don‟t mind to invest money in this area
- It has many different fields that can be investigated for the invention of new product so there is less likely to have competition for a particular product when it is just launched in the market

Weaknesses

- It will take a lot of time and money to research and develop products in this field
- Today‟s technology does not provide enough resources to build these products
- As it is a new technology and it involves a lot of gene manipulation, some people may think that it may cause more harm to the human health system, at a later period of the human life cycle, by using these products
- Until it has been confirmed that it is 100% safe to use not everybody will try the product

Opportunities

- It is a new field so it opens the door to many new ideas and therefore potentially many new products
- If these products come to the market, because of it direct effect in a short period of time people would be impressed by this product which will increase the global image of the company

Threats

- Many countries are spending vast amounts on the R&D of this new field, therefore there would be a lot of competition in the future and potentially some patent issues as well
- Due to the fact that there is no current regulation there‟s the potential the products could be impacted hugely by regulation in the future

PESTEL analysis for bio-engineering in nanotechnology

Political

Governments worldwide are using billions of pounds of their annual budgets for research into science and technology. Of this money much of it is currently being spent on nanotechnology as people are viewing it as the industrial revolution of our time. With this money being spent, researchers in the field will have grants made available to them if needed for a portion of their profits on commercialisation. Governments will also want to have their country as the ones to produce a breakthrough in the cure for any disease to enhance the global reputation of the country.

Environmental

There is currently a lack of research into the effects of nanotechnology in general on the environment. Some people believe that the nanoparticles could have a very damaging effect to the environment and living beings to the extent that asbestos has affected it. The Environmental Protection Agency is currently looking into this. [45]

Social

There is the potential that bio-engineering will have a huge impact on the social divide worldwide unless governments ensure that it is accessible on a worldwide scale before the technology is cleared for medical use.

Technological

The equipment involved in making the nanoparticles is very expensive so there are only specific research facilities with the equipment available. This restricts the global availability of the technology although as the industry starts making money commercially, as it is predicted to be a €1 trillion industry in 2015 [2], there should be an increase in the availability of the required technology.

Economic

Currently the money in the industry is available through government grants and R&D allocations through big companies with not much being recouped commercially, although this shall begin to stop being the case sooner rather than later once products are cleared to be available to the market.

Legislative

Currently nanotechnology in bio-engineering is being evaluated under the Critical Path Initiative, which speeds up the processes surrounding getting new technologies from the labs to the patients. There is currently not much legislation for nanotechnology as research into the implications is being done. Patents on certain technologies will need to be investigated before products are released commercially to ensure that we are covered legally and not open to any lawsuits.

Conclusion

After identifying each major sector in nanotechnology, a deep research has been carried out for each one of them. During the research it has been established that the medical sector was at the forefront very often. It seems that most of the new ideas converge to the health sector as well. Therefore it has been concluded that the biggest impact in the future of nanotechnology will be in bio-engineering however before commercialisation any product that has been made out of nanotechnology will need to have gone through regulation. Therefore a regulatory body will need to be set up or established in order to oversee the global operations that are taking place at nanoscale. In the future healthcare will prosper as it goes hand in hand with nanotechnology and some diseases will be eradicated in time if the technology is spread on a global scale and not just to those that can afford it. There also comes the potential that, as a race, humans will become over reliant on nanotechnology and bio-engineering that natural immune systems become obsolete, this could lead to other opportunistic bacteria creating a whole new range of diseases to eradicate. If that is the case then it has yet to be seen if there is an answer to disease or whether we should allow nature to do its work and accept disease as part of being human.

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