Nanoneurons: A possible cure for paralysis

BY

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PASS WITH DISTINCTION

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Abstract

Nerve damage is a problem that has many detrimental effects upon a person's life. It can lead to loss of movement, feeling or even chronic pain. Therefore, it is vital that such a severe problem that affects many lives be resolved. I have developed, following current research, a theory to develop artificial neurons using nanotechnology. This is a Gedanken experiment however the research shows that it is highly possible. After much research and thought, I have concluded that such a theory is entirely plausible and will undoubtedly be developed in the near future.

Introduction

Nanotechnology is defined as "*the design, characterization, production, and application of structures, devices, and systems by controlled manipulation of size and shape at the nanometre scale (atomic, molecular, and macromolecular scale) that produces structures, devices, and systems with at least one novel/superior characteristic or property.*"[1] In simpler terms, nanotechnology is engineering on a very small scale in order to produce structures or devices that have a unique property. The nanometre scale, to which nanotechnology is associated, comes from the Greek word "nano" meaning dwarf as one nanometre equates to one billionth of a metre which is approximately the length of 10 hydrogen atoms[2]. The concept of nanotechnology was first introduced by Nobel Prize Winner, Richard Feynan, in 1959.

The application of nanotechnology is normally done by manipulation of nanomaterials to form more intricate and specialised structures. Nanomaterials are materials that have unique properties due to their extremely small size. There are two reasons as to why nanomaterials exhibit these properties. Firstly, nanomaterials have a very large surface area when compared to their volume therefore there is a larger area over which molecules can bond thus making nanomaterials much more chemically reactive when compared to normal materials. Their large surface area to volume ratio occurs because as an object decreases in size there are a greater proportion of atoms on its surface than those present within the object. Also, at such a small scale, the quantum effects that dictate the properties of the material, more specifically the optical, magnetic and electrical behaviours, changes as the size of the material decreases. This is because, generally, the properties of any material is the average of the quantum effects acting upon it. However as the size of the material decreases to the nanometre scale this average is no longer applicable[3].

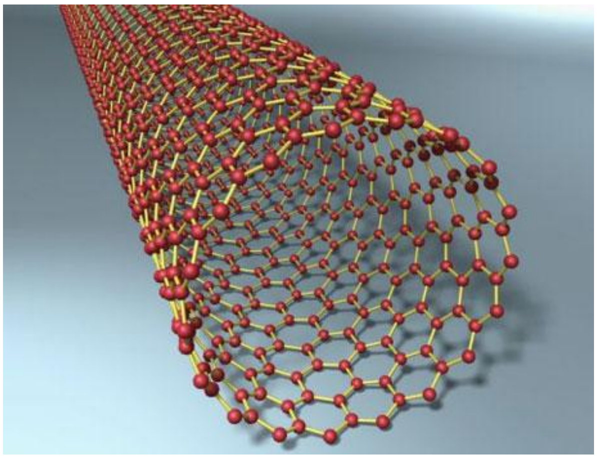
Figure 1 Example of a carbon nanotube

There are many nanomaterials currently in existence. For example, the carbon nanotube is one of the most significant discoveries of the 21st century. The carbon nanotube has three distinct properties: it is highly conductive of electricity and heat (conducts electricity as well as copper and has a thermal conductivity as high as diamond[4]; 100 times stronger than steel despite being one sixth of the weight; and is flexible about its axis[5]. These properties give carbon nanotubes the potential to be used in many areas such as plastics and textiles to produce light-weight bulletproof vests.

Nanotechnology is currently applied in many fields and products including commercially sold products such as sunscreen lotions and tennis balls. Nanosized zinc oxide particles are used in sunscreen to absorb and reflect UV rays. Because the zinc oxide is so small, the lotion is transparent and smooth which is a contrast to its former state of being white and sticky. This makes the product much more appealing to the consumer. In tennis balls, the balls are coated in a nanosized material which acts as a molecular barrier and traps air thus making the balls bouncier[6].

Nanotechnology is also used widely in medicine and this field of nanotechnology is known as nanomedicine. Nanomedicine is defined as the "*process of diagnosing, treating, and preventing disease and traumatic injury, of relieving pain, and of preserving and improving human health, using molecular tools and molecular knowledge of the human body*"[7]. One of the main applications of nanotechnology in the field of medicine is the controlled release of a drug or the targeted release of a drug. This is done in order to reduce the side effects that many medications have. By slowly releasing small doses of the drug or by targeting the drug at a specific area, this reduces the number and intensity of side effects thus making the patient more comfortable.

This can be done in a variety of ways. One method of gradual release of a drug is by encapsulating the drug in layers of lipids[8]. More clearly, this would consist of layers of lipids with doses of the drug between each layer. Because there are several layers, the enzymes and acids within the digestive system would corrode each layer and release the drug in small doses. This will therefore reduce the number and intensity of side effects as there will be less of the drug circulating in the body in a given time.

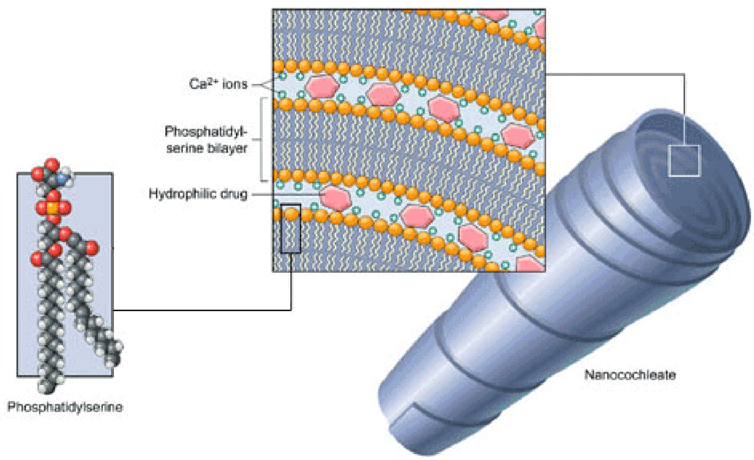

Figure 2 An example of a drug release system

Targeting drugs at a specific area is done in a different manner. The precise targeting of drugs is achieved via the use of specially designed drug-carrying nanoparticles. These particles circulate through the body and the drug is inactive while contained within the nanoparticle. The drugs are then activated at the site of the disease, for example a tumour, by an external source such as light or radiation. Because the light or radiation is only targeted on the specific site of the disease, only the drugs that are present in that area will activate. Thus only that area is affected by the effects of the drug. This allows much smaller quantities of the drug to be introduced into the body thus reducing the toxicity of the body as well as reduce any adverse side effects that the drug may have. Also, because the drug is activated by an external source, this method can be used in tandem with treatments such as photodensity therapy and chemotherapy.

Nanotechnology is also used in antibacterial dressings. Here, the dressing is made of a special nanomaterial known as nanocrystals. This is useful in a number of ways. Firstly, the nanocrystals have a wide antimicrobial spectrum and kill rate[9] therefore destroying any pathogen that may approach the wound. This would significantly reduce the risk of infection as there would be no pathogens to infect the wound. Also, the nanocrystals allow the dressing to have different degrees of absorbancy so that it may deal with the exudate from the wound while still maintaining a level of moisture which is optimum for healing thus speeding up the recovery process.

There is a great deal of research that is currently being conducted in the field of nanomedicine across the world. One of the most recent research studies was commenced by Cornell University in January 2011. The study aims to test the use of “Cornell Dots” in diagnosing and treating cancer. The Cornell Dots or C dots are silica spheres with a diameter of about 8 nanometers and they contain within them several dye molecules. The silica shell is chemically inert and the spheres are small enough to pass through the body and out through the urine. To allow the C dots to stick to tumour cells, organic molecules which bind to tumour surfaces are attached to the spheres. When near infrared light is shone upon them, the encased dye molecules will fluoresce much more brightly than non-encapsulated dye thus showing the location of the tumour. The C dots can also be altered to deliver radioactivity or cytotoxic drugs to the tumour[10].

Research is also being done on the use of nanoparticles in vaccination. Here, concentric fatty spheres are used to carry synthetic versions of proteins, that are normally produced by viruses, to cells. This is similar to the concept of immunisation where a weakened or dead virus is introduced into the body in order to stimulate the production of antibodies. This method is advantageous as it allows a strong immune response to synthetic proteins that are normally produced by extremely dangerous viruses such as malaria or HIV. Viruses such as these cannot be used in vaccines because they cannot be rendered harmless and the use of synthetic proteins without the use of nanoparticles does not create a strong enough immune response because they are unstable in the body fluid which causes them to degrade quickly. However, the fatty spheres are stable enough that they do not degrade when injected into the blood but break down once they enter the cell. This allows it to stimulate a strong immune response[11].

Discussion

With the view of current developments in nanotechnology, I foresee the replacement of damaged neurons in the body with synthetic neurons which comprise of a combination of several different nanodevices and nanomaterials. These “nanoneurons” could be used to cure paralysis or blindness if applied at the correct areas. The majority of nervous conditions are due to the malfunction of part of the nervous system due to externally caused damage. This normally results a lack of function in the area to which the nerve is connected. For example, damage to the optic nerve can cause blindness because the visual impulses cannot be conducted to the brain. Therefore, I intend to bridge the gap between the functioning neurons using nanoneurons to conduct the nervous impulses that would normally be lost due to the damaged neurons being unable to carry theses impulses. In paralysis of the body, nervous impulses could be carried to areas that were unreachable beforehand and in blindness, malfunctioning or damaged optic nerves could be replaced thus allowing visual impulses to be relayed to the brain. With this, control over paralysed body parts and vision can be regained. To achieve this, a combination of nanosensors, carbon nanotubes and nanopores would have to be used.

Nanosensors are nanowires that have been treated so that they can very sensitively detect viruses and pathogens. Nanowires are nanostructures, made of silica, that have a diameter which is limited to tens of nanometers but have an unconstrained length. To make nanowire detectors (or more commonly known as nanosensors) the nanowires are coated with molecules which enable them to bind to specific organic molecules such as bacteria. This is important as depending on the molecule that it is coated with, the nanosensor can be altered so that it may detect different substances. When the desired molecule attaches itself onto the coating of the nanosensor, the nanowire’s conductivity changes. The change in conductivity causes an electrical signal which can be detected thus showing that a certain substance is present.

Carbon nanotubes, as mentioned earlier, are nanomaterials that are made of carbon atoms which have been arranged in a cylindrical shape. It can be more easily imagined as a layer of graphite (grapheene) which has been rolled into a tube. Due to its unique shape and the bonds that hold the atoms together carbon nanotubes have unique properties such as extreme strength and being an electrical superconductor. The bonds within the atoms are covalent bonds, more specifically sp2 bonds. Sp2 bonds are bonds where the electrons in the bonded pairs have come from both the s orbital and the p orbital in order to form a hybrid bond; this is similar to the arrangement of electrons within a π bond where two p orbitals overlap to form a shared pair of electrons. The capacity for it to conduct electricity well is imperative as it will allow electrical signals to be carried along it, similar to the process found in nerve cells. Its strong conductivity is due to the number of free electrons that it has. This is because a carbon atom has four electrons with which it can form bonds however each carbon only forms three bonds. Hence, each carbon atom has a free outer shell electron which allows it to carry a charge when a current is passed through it.

Nanopores are tiny cell-containing chambers made of silica which react with the surrounding biological environment through a polycrystalline silicon membrane[14]. These are combined in large quantities and together they form a uniform nanopore. These pores are large enough to allow small molecules such as oxygen and glucose to enter but small enough that it impedes the entry of much larger molecules such as immunoglobulins (antibodies). This artificial silicon barrier protects the cells which are encased within it and the sizes of the pores allow the cells to receive nutrients so that they can continue living while simultaneously protecting them from the immune system by concealing them. This allows foreign cells to be inserted into the body and because they are concealed they are not detected as non-self material by the body's immune system as so will not be attacked by white blood cells.

These nanomaterials, when used in conjunction, hold the potential to become nanoneurons. To achieve this, the nanomaterials must be connected together in a specific order where the nanosensor is placed at one end and attached to the carbon nanotube. The other end of the carbon nanotube should be bonded to the nanopore. When all three nanomaterials are connected together, they will act as a single neuron. The carbon nanotube acts as the axon, with the nanosensor acting as the axon terminal. The nanopore acts as the dendrite and will contain neurons which have been obtained from an external source. In this model, certain parts of a typical neuron will no longer be required. For example, a myelin sheath will no longer be needed as previously the myelin sheath was used to protect the axon from damage but because the axon has been replaced with a carbon nanotube, which is much stronger than steel, a protective layer will no longer be necessary.

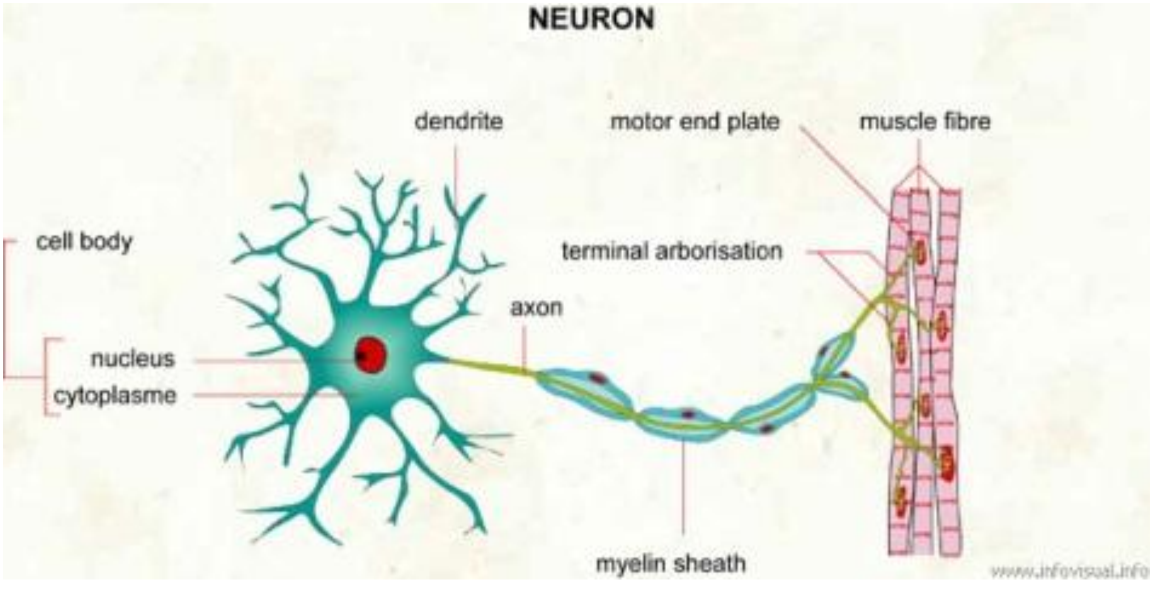

Figure 3 A typcial nerve cell

The nanoneuron will function as if it were a typical nerve cell. In a typical neuron, nervous impulses are detected when a neurotransmitter (a chemical that carries nervous impulses) binds to a receptor at the terminal arborisation of the neuron. This nervous impulse is then carried through the axon of the neuron in the form of electrochemical waves to the cell body of the neuron. There, the nervous impulse triggers the release of a neurotransmitter across the synapse. The neurotransmitter will be carried in vesicles that will travel across the synapse and trigger a nervous impulse in the next neuron.

The nanosensor will be coated with a molecule to detect neurotransmitters, such as acetycholine, thus acting like the terminal aborisation. When the acetycholine molecule binds to the nanopore, the electrical conductivity of the nanowire will change thus producing an electrical signal. Due to the carbon nanotubes high electrical conductivity, the electrical signal produced will be conducted down the nanotube to the nanopore. The electric signal will stimulate the neurons encapsulated within the nanopore. The neurons will then release another neurotransmitter which will further carry the nervous impulse which was earlier detected. The neurotransmitter molecules will carry the nervous impulse chemically across a synapse to any neighbouring neurons. In this way, the original nervous impulse would be continually carried towards its intended destination. Thus, with this design, it is possible replace non-functioning neurons with synthetic ones that could effectively carry out the same function that the original neurons did. This would allow areas of non-functioning nerves to be replaced thus allowing a person to regain control of a part of the body which he or she had previously lost control over.

One of the main advantages of this treatment would that it presents little risk to the host as since the majority of the nanoneuron is made of silica, the body is unlikely to reject it because silica is chemically inert and so will not trigger an immune response. The foreign neurons within the nanopore will also not trigger an immune response because, as mentioned earlier, the artificial barrier of the nanopore will prevent the neurons from stimulating an immune response. In addition, the neurons will survive for a long time as the pores will allow oxygen and glucose to be supplied to the neurons for respiration by surrounding blood vessels. Another major advantage is that the process of conducting nervous impulses in the nanoneurons is very similar to the conduction of nervous impulses in actual neurons. This is helpful as no external chemicals are needed to stimulate a response. This will reduce the risk of any side effects as the neurotransmitters required to carry the impulse to the nanoneuron will be produced by the body itself and so is completely natural.

Another advantageous feature of this system would be that neurotransmitters are not people specific. Neurotransmitters are the same in all people. A benefit of this would be that the neurotransmitters created by the neurons which are contained within the nanopores will not be detected as non-self. Therefore, they will not be destroyed by T lymphocytes and so will successfully transport the nervous impulse across the synapse. In addition, the receptors on normal neurons will also easily identify the neurotransmitters and allow a nervous impulse to be stimulated as it will be unable to interpret any difference between the neurotransmitter produced by the neurons in the nanopore and neurotransmitters created by the body naturally.

However, there are several important factors that must be considered when attempting to place this within the body. The first is, following Dale's principle, the existence of several different types of neurotransmitter receptors as the type of reaction that occurs depends on the receptor that is stimulated. If the nanosensor were able to detect only one kind of nervous impulse then the reactions produced could be terribly destructive. The treatment could easily cause more harm than good. To troubleshoot such a problem, it is most likely that more than one nanosensor will be attached to each carbon nanotube. Each nanosensor will represent a specific receptor thus different muscular reactions can take place. Therefore, when the patient's brain creates a nervous impulse for a specific reaction that reaction will take place as the correct receptors will be stimulated.

There are also several ethical conundrums that surround this theory. Firstly, it is the introduction of foreign material into a body. Despite the benefits that the nanoneurons could provide, it must be kept in mind that the insertion of nanoneurons into a living human being involves an alteration in the normal state of his or her body. On the one hand, the nanoneurons can be compared to a prosthetic limb as it allows a person to regain control of part of the body. This is similar to prosthetics where an artificial substitute is attached to the body, much like replacing non-functioning neurons within the body with nanoneurons. However, there is also the argument that replacing a limb only replaces the external characteristics of the body and so is not too severe. Using nanoneurons however will change part of the body on a cellular level. If it were to be used, there would be part of the body that would be fundamentally different from the rest. This raises the question as to whether it is right to alter something that Nature had created. Therefore, when deciding on this use of treatment there must be a balance between the intentions to significantly help someone and the right of doctors to meddle with Nature's work.

Similarly, the neurons that will be encased within the nanopore can be obtained from only two sources. The first is to culture neurons using animals and then inserting it into the body. This is similar to the production of monoclonal antibodies however it does bear the risk that the neurons might produce neurotransmitters that could have an adverse effect within the patient. Also, it involves the misuse of animals as the animals will mostly likely die or become very ill due to having their neurons removed. Another option would be to remove the neurons from another person and use that as the source of neurotransmitters within the nanopores. This raises less moral questions as it can be likened to organ transplants or blood transfusions. All of these processes are similar in the sense that it involves the introduction of foreign cells from into a patient from another person as a form of treatment.

Another moral dilemma is the regulation of this treatment on people. This treatment is likely to be extremely expensive. Therefore should this treatment be solely aimed to those who can afford it or should the treatment be available free of charge to all members of a community. Both the rich and the poor will have nerve damage as it does not discriminate between its victims based on their income and so a decision must be made as to whether or not a patient should receive the treatment despite the fact that he or she cannot afford it. If it is agreed that those who cannot fund the treatment themselves should still be treated, on what criteria should the severity of a person's condition be judged? Is inability to move one's legs more important than blindness or is being paralysed from the neck down worth more than being unable to move one side of the body? In addition, who should be given the right to decide who is worthy of receiving such a life altering treatment. The person or people who might be given this right would have to the power condemn or better someone's life and that is a responsibility that cannot be bestowed lightly upon someone's shoulders.

Conclusion

Nearly all aspects of the theory have already been developed leaving only minor problems to be taken care of. The main problem that this theory would probably face is the production of enzymes that would hydrolyse the neurotransmitters produced. If these neurotransmitters were not broken down by the enzymes, they would cause constant nervous impulses which would cause that part of the body to constantly spasm. However, the development of microscale biological robots could solve this. Microscale biological robots are artificial biological devices that mimic the functions of actual cells. Here, engineered bacterial robots could be developed to release the enzyme needed upon detecting the neurotransmitter[15]. This will prevent any excess nervous impulses from occurring thus avoiding any adverse effects of the treatment.

In conclusion, I believe that the possibility of nanoneurons becoming more than just theory is very likely. Considering the current research and developments that are occurring everyday it is only a matter of time before such an idea is made into reality. Carbon nanotubes, nanopores and nanosensors provide the perfect combination to produce nanoneurons. Their unique features and common chemical inertia provide the perfect platform for the remodelling of the nervous system. I have no doubt that this will produce many ethical questions but I strongly believe that the benefits will far outweigh the disadvantages as with this medicine could drastically improve the quality of life for many.

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