Nanos in the human body – Medical perspectives and ethical concerns

Healthcare is a priority focus of nanotechnology research, where the convergence of nanosciences, molecular and cell biology, and medicine can act to deliver improvements in human health and quality of life. It is an appealing prospect; but as with any new technology, there are both ethical and health and safety issues to be addressed, especially where applications in human bodies are concerned.

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Nanotechnologies can be seen as a "tool-kit" that enables different life sciences to work together to produce new tools for diagnosis and treatments.

Advances in nanotechnology harbour many potential uses in medicine. They will help increase our understanding of the human body, its mechanisms and diseases, and how to restore it to health.

One possible application will be to customise medical treatment through personalised medicine delivery, where patients will be given the precise, controlled dose of their specific medication at the right time. Nanotechnologies will enable the development of nanostructures to deliver drug molecules directly into the cells. Nanoparticles can act as *drug-carriers* or Trojan horses by encapsulating the medication, travelling around the body indiscriminately and delivering the medication to the patient at the molecule level at the required dose when it is needed[1].

Nanotechnology could also help in the fight against cancer, by developing nanomaterial systems to attack and destroy tumours.

Other developments are the generation of nanomaterials that could be applied to improve tissue regeneration, like restoring cartilage function to overcome arthritis, *in vitro* engineered organ patches or biomaterials for *in situ* regeneration of bones. Nanotechnology could also help in the fight against cancer, by developing nanomaterial systems to attack and destroy tumours.

Their multiple properties give nanomaterials a wide spectrum of medical uses; some have a biocidal activity used in self-cleaning surfaces. Recent research has investigated the properties of fullerene compounds[2] as antiviral agents to eliminate pathogens and bacteria in place of long-term antibiotic treatments[3].

Nano-tool kits are also being developed that will use nano-robots to monitor health inside a patient or to act at the sub-cellular level where a disease occurs. Nano-robots could be introduced through the vascular system, and could be programmed and guided by a surgeon to identify the molecular origins of severe diseases like Alzheimer's or Parkinson's, or to perform intra-cellular surgery[4].

Behind this ostensibly rosy prospect, however, loom ethical and health and safety issues that any new technology raises, and which must be addressed to make a reasoned assessment of what is in view.

On ethical aspects, there is a wide-ranging discussion of the potential risks of nanomaterials and nanotechnologies for humans, as little is still known about how they interact with the human body in terms of toxicity and carcinogenicity. This lack of knowledge is one reason why specific regulations are needed to control the use of nanotechnologies.

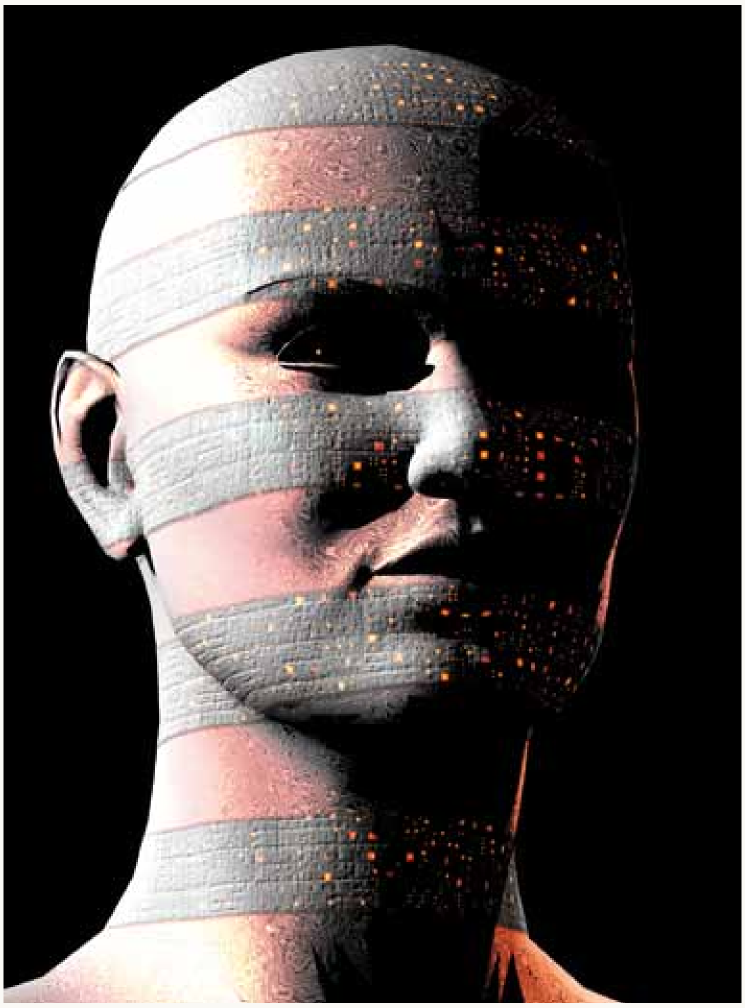
1. National Nanotechnology Initiative 2003, *Workshop Report on Nanobiotechnology,* Virginia, p. 39. Liposomes for drug delivery in some cases of cancer therapy; nano-magnetic particles for magnetic resonance imaging and nanomaterials for void filler and dental restoration have been recently approved in the USA. Engineering and Physical Sciences Research Council 2008, *Nanotechnology for Healthcare*, p. 3.

2. Fullerene is one of the four types of naturally-occurring forms of carbon. Its architectural structure resembles a football, or the geodesic domes designed by the architect and philosopher R. Buckminster Fuller; C60 is the most common, and consists of 60 carbon atoms. Fullerenes were discovered as recently as 1985, and their most striking properties high symmetry, stability and versatility give them a wide range of applications.

What is a nano-device?

Very tiny objects could be manufactured and inserted in the organs of the body for a specific purpose. They are small enough to enter the body, travel around, enter the cells and interact with DNA and proteins. Some examples of nano-devices or nano-implants are the so-called *smart pills*, organ replacements, neural interfaces, and brain implants. They would offer a good way to treat neurological dysfunctions, cancers and other diseases and disabilities.

Nano-devices might help to cure some diseases or deliver treatments; they could provide drug delivery, photodynamic therapy, or read the genetic code and detect errors. Other examples are titanium-bases micro-needles to control drug delivery, carbon nanotubes that trace the shape of the DNA and make a map, and quantum dots as sensors.



Nanomedicine opens up untold prospects, but at what price for the integrity of humankind, personal free agency and respect for privacy?
Image: © Belga, NSP

Nano-applications in humans should deliver a better quality of life and health, but there are inherent risks in the development of any new technology. The ethical issues must be considered to gain a more rounded view of what the consequences might be, and how society can respond to them. Ethical concerns have been raised in the sphere of health care in relation to implanting nano-devices and the possibility for human enhancement offered by the use of nanotechnologies.

Nano-implants in the human body

Nanotechnology could change the face of medical implants by allowing miniature devices to be further reduced in size and inserted in the human body to cure and repair damaged cells using nano-materials that have improved biocompatibility and physiological integration with human tissue.

Their ability to penetrate cell membranes allows some nanoparticles to enter the human body, travel easily through the bloodstream and deposit in organs. Skin, lungs and the intestine are likely to be the first entry route for such nanomaterials into the human body.

Nano-applications, by contrast, are tiny devices deliberately inserted into the human body as a tool for tracking, diagnosis or treatment delivery without handling or exposure of the patient.

A big aim is to develop a single, multipurpose nano-device that will be able to assist in imaging inside the body, recognize precancerous or cancerous cells, release a drug that targets only those cells, and report back on the effectiveness of the treatment.

There are two key considerations when implementing nano-devices. One relates to the individual or patient who must specifically consent to having the device implanted in their body. The other is how the nano-device itself reacts once in the organism, its effects and safety.

For the individual, the risks and adverse outcomes of agreeing to a nano-implant raise issues of autonomy – control over one's body – privacy, data protection, and informed consent. It also has wider societal implications, raising questions of prudence and distributive justice.

On the technical side, the small size and complexity of nano-devices means that their behaviour inside the human body may be unpredictable and uncontrollable, having unknown effects that could cause a health problem. Future nanomaterials used in biomedical applications must be biologically compatible,

3. Freitas, RA 2005, What is nanomedicine? *Nanomedicine: Nanotech. Biol. Med. 1*, p. 2-9.

4. Freitas, RA 2005, Nanotechnology, nanomedicine and nanosurgery, *International Journal of Surgery*, Vol. 3, Issue 4, p. 243-246.

Lab-on-a-chip inside battle suits

Battlefield hospitals are not easily come by, so the Institute for Soldiers Technologies based in Massachusetts, USA, is researching ways of improving the survival of soldiers in combat. Its exploration of the use of nanomaterials, has led it to develop laboratories on chips that will be fitted into battle suits.

This lab-on-a-chip consists of nano-devices that carry out rapid, real-time medical monitoring of soldiers exposed to toxic agents and biological hazards by sampling one of their cells. The results can be available within 10 minutes.

Another battle suit project is nano-enabled material and devices to far-forward medical treatment and drug delivery, like splinting wounds or preventing adverse movements after head or neck injury, and materials and devices to enable controlled release of medication.

5. Harris, J 2007, *Enhancing Evolution. The ethical case of making better people*, Oxfordshire, Princeton University Press. Professor John Harris, British philosopher at the University of Manchester, defends a libertarian position on bioethical issues.

as well as functional within biological fluids and tissues, mainly because some cannot be detected by the immune system, making it essential that they behave safely.

The implementation of nanotechnologies in healthcare systems will be fairly complex and costly, mainly because this technology requires expertise and precise biomedical equipment that may not be easily available. The question is, therefore, if nano-based treatments do become available for curing or treating diseases, how many people would be able to benefit from them? Will they be available to everyone? How many countries will be willing to implement this new technology in their health systems and medical centres?

These technologies will have far-reaching therapeutic uses of genuine potential benefit, but it will be a small step to go far beyond treatment of disease or disability towards an end that faces society with another scenario – that of enhancement.

Human enhancement

Human enhancement – the idea of improving human characteristics and capacities – is a vast topic that embraces ethical considerations about health, life and humanness. New technologies that can act within the human body make it possible to alter and eventually transform it in different ways.

Transcending the limitations of humanness to become a super-being has moved from the realm of science to that of literature and films. Modern writers like Mary Shelley with *Frankenstein* (1818); Aldous Huxley with *Brave New World* (1932); George Orwell with *1984* (1949) and Isaac Asimov's *Robot* series, have brought ideas of perfect societies or improved individuals into the popular consciousness. On the big screen, films like *The Boys from Brazil* (1978); *Gattaca* (1997) and *The Island* (2005) have also excited the public imagination with issues about communitarian eugenics.

Enhancing the body or mind could be seen as the ultimate goal for humans. A major proponent of human enhancement, the controversial British philosopher John Harris, argues that the idea of improving humans is not just promising but should be seen as a duty. He argues that humans have the capacity to decide what enhancing techniques are best for themselves, and emphasises that "there is no moral case for delaying access to any treatment or any technology with health benefits until we are in the position to provide equitable and universal access. The more beneficial the technology, whether it be therapeutic or enhancing, the greater moral imperative for wide and equitable access"[5]. The complexity of the issue, however, lies in ensuring safety (of treatments and effects) and universal access, among other matters that must be addressed in order to justify enhancements.

Human enhancement means the augmentation, improvement, enrichment or addition of human functions, sensorial performances (physical and performance excellence); the modification of physical appearance (beauty perfection), the augmentation of memory or intelligence (cognitive enrichment), or the improvement in mood and personality (greater contentment).

It may also involve the insertion of devices or human-machine interfaces and the extension of life, prolonging productive life and delaying the decline in faculties that accompanies old age.

If the right technique is applied and the complex scientific issues are overcome, human enhancement can be a real possibility. The best example is therapy. Generally speaking, the aim of a therapy is to cure or treat a condition, while the aim of human enhancement is to improve the – generally, healthy – organism above its normal capacities. A therapy may go further than its purposes of just curing a disease to become an enhancement by increasing the individual's general capabilities and health. For instance, it might be possible to go from correcting eyesight to enhancing vision outside of the normal parameters.

Current thinking is around prospects for enhancing memory, attention, muscle strength, speed and sight. Other possible scenarios include boosting physical abilities to achieve perfect performances in competitive sports, or endowing people with new capabilities by adding new genes to the DNA code or eliminating "wrong" ones.

One fear about nanotechnology-based enhancement is its scope for altering human DNA through a modification to the genetic code or gene expression which could remain in the DNA and be passed on down the generations. These changes could have an impact on the genetic variability of human evolution.

It is still too soon to tell for sure what the effects of such interventions may be, but it is not unfeasible that over the long term, a DNA modification could be handed down the generations, with no certainty as to whether it could be inherited safely or with errors of some kind. Whatever the outcome of the intervention, could the unwanted effects be controlled, or the mistakes corrected? The concern is about the risk of modifying human traits and even human nature – a step to be taken with caution.

Also, altering parameters in human beings could change our understanding of what it is to be human – in sum, creating a new conception of the human body, of health and physical condition, and of the meaning of life. The end result could be a progressive redesigning of the human condition. New social parameters will most probably require changes to social organisation, laws, culture and values, which would involve a complex re-organisation of society.

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In a scenario where some individuals were changed while others remained "natural", unchanged, society might become subdivided into classes of human: the enhanced *vs.* the unenhanced; or the controllers and the controlled. So enhancement raises the issue of power, of the balance between the new technologies, individual choices and genetic tendencies.

For planned design to take over from the genetic lottery or natural traits could subjugate certain human values that should be preserved – strengthening the sense of responsibility, of what humans are, solidarity with others, and fostering society.

A nanowalker robot built with DNA

New York University and China's Nanjing University have developed a nanorobot made of strands of DNA that walks on two legs each of ten nanometres long. The robot reportedly has the ability to alter and exchange pieces of genetic code, because it is small enough to work on a molecular scale.

It measures approximately 150 x 50 x 8 nanometres; its legs are each 36 bases long and are linked to each other by DNA. To make the foot take hold of the sidewalk, researchers added a "set strand" — complementary to both strands — that zips the foot to the foothold. To make the robot walk, they then added an "unset strand" to unzip the foot. The released foot then grabs another set strand to move forward and zip up to its next hold on the track. A new set strand unzips the foot to allow it to step backwards.

The legs, called cassettes, store different pieces of information; while DNA has previously filled that niche, other species such as proteins and chemical components could theoretically be placed in them. The niche could potentially serve as a factory for assembling the building blocks of new materials. With this capability, it has the potential to develop new synthetic fibres, advance the encryption of information, and improve DNA-scaffolded computer assembly. But first, the researchers have to figure out how to make their tiny robot carry something, like a single atom.

The ethical debate

The issue of ethics in nanotechnology is not about future-gazing. The point of an ethical discussion is to develop a responsible attitude towards the future of society and humanity as a whole, enabling future generations to inherit a better environment in a holistic sense.

The idea of a responsible future has been widely developed by Hans Jonas, a German philosopher, in his critical theory of ethical responsibility for including new technologies in society, and the relationship of man to modern technology, trying to anticipate the consequences of the technological choices that society makes: "ethics of the future"[6].

This article has offered some examples of possible nanotechnology applications in health care. The power and complexity of these technologies means that the potential consequences need to be assessed to avoid harm and misuse.

Application of those techniques may involve many ethical issues, and the funding for nanotechnology projects must give weight to the health and ethical aspects. Safety is certainly a major one. Are the risks measurable? The general concern is whether the technologies will be safe in use, whether there are potential risks or unwanted effects, and what steps would be taken to avoid misuse.

It is not only patient awareness that needs to be raised – there is also concern about nurses and hospital staff who carry out various procedures involving high exposure to radiation and hospital waste, for example. Some hospital personnel are routinely exposed to radiation on a daily basis. Specific exposure measures, information and adequate training need to be provided for newly-developed nano-related therapies.

There is also a lack of knowledge about chemical risks, because the physical phenomena at nano-level are not yet fully understood. Research into nano-developments and techniques must address the need for nanomaterials to be introduced safely into the human body, explore the interactions of biocompatibility and possible toxicity.

The body of research publications on the possibility that some nanoparticles might penetrate the organs has led some scientists to propose that a database of health risks be

6. Jonas, H 1984, *The Imperative of responsibility. In search of an ethics for the technological age*, Chicago, The University of Chicago.

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compiled, linking the different nanomaterials to their interaction, impact and possible consequences on different cells, tissues or organs.

If these technologies are to be applied in health systems, there should be structural reforms of healthcare programmes to make them available to the community. Nanotechnologies should enable the delivery of better healthcare; the cost of nano-applications, public and private research funding and risk assessment are issues here.

Developing countries or regions that are not benefiting from nanotechnology might even need to be given help, in order to further the common good of humanity. But some regulation of this would be a wise precaution.

One ethical issue under debate overlaying the economic impact is the possibility of a widening social and economic divide caused by access to these technologies. The hypothesis of two species of humans was mentioned earlier, differentiating the technological "haves" and "have-nots".

Questions of distributive justice, fairness and autonomy must be seriously addressed. Individual selfhood is a complex concept, embracing protection of the identity, self-determination, belonging and relationships, which are fundamental human rights.

Where human identity is concerned, each human being has the right to have their own characteristics, signifying that no-one should have the power to determine how others should be, what traits they should have. Irreversible interventions that modify human traits actually diminish human freedom[7] – the freedom that every human being has to be themselves and not be dependent on others' decisions.

The preservation of humankind obviously raises considerations of the authenticity and dignity of individuals and the perpetuation of the species. The question is what right we have to interfere with natural evolution, and to what extent can it be done – what are humans capable of?

All our actions and omissions have consequences for the future. Many international declarations and agreements recognize the need to safeguard future generations. Our actions may not be primarily directed towards harming successor generations, but they have the potential to affect them. This means taking responsibility for what we do today, and not leaving others to pick up the cost.

An ethical assessment of issues around nanotechnology applications will provide society with information, knowledge and tools to respond to possible perils. It will also help to construct a framework for assessing nanotechnologies and nanosciences.

But preventive action may help people to manage their health and enhance their quality of life by themselves. An individual's best chance of leading a healthy life comes from the sense of responsibility of their own well-being and lifestyle education. Nanotechnology development and the education of the public need to go hand in hand.

The purpose of analysing ethical aspects of nanotechnologies is to develop awareness and a critical approach to the possible benefits and risks of potential applications. One key issue is providing people with the knowledge to give fully-informed consent to the nano-applications that might affect their health. Society must be able to have a holistic vision of the meaning of the human body, and make choices about health and life. ●

7. Habermas, J 2003, *The future of human nature*, Cambridge.

Read more

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