Tiny Technologies Raise Big Ethical Issues

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Nanotechnology shows potential for improving the health, social and environmental well-being of many people around the world. However, it may have unintended consequences, particularly for vulnerable populations.

Nanotechnology is literally the "science of small things". It is a term for a range of technologies, techniques and processes that involve the manipulation of matter at the smallest scale, from 1 to 100 nanometres (1/10,000th the thickness of a human hair). What is interesting about nanotechnology is that when materials are manipulated at this small scale, they exhibit different properties that are not evident at a larger scale. For example, when silver is turned into very small particles it develops antimicrobial properties, while gold particles can become any colour we choose. By manipulating materials at the molecular level, new products and materials can be created.

A number of products contain nanostructured materials, such as polymer films that cover glass, making the glass able to conduct electricity or improving its strength, insulating properties or ability to filter light. Another example is the use of carbon nanotubes in fibres to make very strong materials that can also be used to conduct electricity. A third area that is considered particularly promising is the use of very small devices to send electrical signals to the brain.

Nanotechnology is making a significant impact in the field of health and medicine. In the field of medical bionics, researchers study the human body to design and develop artificial limbs, organs and other prosthetic devices. This is the emerging field of nanobionics – the merging of biology, mechanics and electronics using recent advancements in nanotechnology and neuroscience – and it shows enormous potential in improving the health and well-being of people who suffer from loss of hearing or sight, illnesses such as cancer, or nerve damage. As Gordon Wallace and Geoffrey Spinks point out (*Soft Matter*, 2007), materials that can conduct electricity, such as carbon nanotubes and conducting polymers (tiny molecules formed into long repeated chains), are increasingly being used in the design and development of bionic devices to achieve better communication between the human body and bionic devices (see box, p.18). By improving communication, nanotechnologies can help the bionic device work more effectively, meaning that the people using the device experience improvements in their ability to hear, see or move their body.

Pressing Ethical Issues

One set of questions that arises for the ethicist concerns the place of technological developments in the wider social context, and the possible ethical consequences of pursuing technological developments. In this section we draw on the World Health Organisation's

(WHO) Millennium Development Goals (see box opposite) to illustrate three aspects of the ethical significance of nanotechnologies. We use them because they are specifically concerned with the health, social well-being and environment of those who are most vulnerable around the world.

In 2000, WHO developed a number of goals, to be reached by 2015, that represented its commitment to improving the health of people all around the world. These Millennium Development Goals include the commitment to eradicate extreme poverty and hunger; to reduce child mortality; and to combat HIV/AIDS, malaria and other infectious diseases, among other goals. The significance of these goals is particularly apparent when we consider the kinds of health problems that the majority of the world's population face.

According to WHO's *Top Ten Killers Fact Sheet* (2008), infectious diseases are the predominant cause of death in low-income countries such as Ghana and Papua New Guinea. These diseases include lung infections, diarrhoeal diseases, HIV/AIDS, tuberculosis and malaria. Lack of access to clean water, lack of food, extreme poverty, lack of healthcare facilities and lack of access to medicine are just some of the contributing factors to the prevalence of such diseases.

Considering the Millennium Development Goals, we can ask whether the use of the funding for nanobionics is appropriate or fair given competing demands. The *Nanotech Report* by Lux Research (2007) states that in 2006 the US government alone invested $1.78 billion in nanotechnology research and development, while Japan invested $975 million. A range of existing health conditions dramatically affect the well-being of millions of people around the world, in particular people in developing nations, and it may be the case that research and targeted healthcare interventions would address significant health problems if resources were devoted to them rather than to bionic device research.

In considering the ethics of funding specific research programs in health and medicine, such as bionics research, it is important to note that some of the infectious diseases that kill millions of people in developing nations are of less significance in developed nations. For example, over 90% of the world's population infected with HIV/AIDS live in developing nations, according to the *AIDS Epidemic Update: Special Report on HIV/AIDS* (UNAIDS, 2006).

WHO Millennium Development Goals

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empower women
- Reduce child mortality
- Improve maternal health
- Combat HIV/AIDS, malaria and other diseases
- Ensure environmental sustainability
- Develop a global partnership for development

Child Health

Even in developed nations there are discrepancies in health outcomes between different groups. If we think that some of the benefits from bionics arise from their ability to compensate for hearing loss, then it is worth asking whether it would be better to concentrate on the prevention of the loss of hearing rather than a more expensive and less available treatment that works to restore some hearing for a small proportion of the population.

In Australia, Aboriginal people generally suffer from poorer health in comparison with non-Aboriginal people. According to the Australian Bureau of Statistics report *Deaths Australia, 2006* (2007), Aboriginal children in particular suffer from poor health. Otitis media, an inflammation of the middle ear, is very uncommon in developed nations, and is considered a disease of poverty. By WHO standards it is a significant indicator of a major public health problem requiring urgent attention. Among Aboriginal children in Australia the rate of incidence is particularly high, as found by Sophia Couzos and colleagues (Systematic review of existing evidence and primary care guidelines on the management of otitis media in Aboriginal and Torres Strait Islander populations, 2001). Is the use of resources for the development of bionics justified if it were possible to use those resources to help prevent hearing loss in those children?

This can be seen as an application of the principle of justice in healthcare resource

How Bionic Devices Work

Bionic Ear

The cochlear implant, commonly known as the bionic ear, is an artificial device that provides simulation of sounds to people who are deaf or hearing-impaired. The cochlear implant uses an external microphone, speech processor and a transmitter to pick up sounds and send signals to a device implanted in the person's cochlea (which is inside their ear). The device then stimulates the auditory nerves, sending a signal to the person's brain, which is interpreted as meaningful sound.

Bionic Spine

At the Bionic Ear Institute in Australia (as well as other laboratories), polymers are being used to create intelligent scaffolds that can deliver "helper molecules" to aid the repair of damaged nerves, including damaged spinal cord nerves. Gaining insight into how nerves regenerate with these intelligent polymer scaffolds may lead to the development of a bionic spine (*Bionic Ear Institute 22nd Annual Report 2007-2008*, 2007). The upshot of this technology is that the bionic spine may enable those people with limited mobility to regain movement and function in their legs.

Bionic Eye

The bionic eye is being developed with the intention of restoring reading vision to people suffering from a range of eye diseases or injuries. Like the cochlear implant, the bionic eye consists of both internal (electronic chip) and external (video camera, processor) components.

A collection of electrodes is implanted on the surface of the retina to stimulate the optic nerve in the eye. These electrodes act as a substitute for the photoreceptors that have been badly damaged or have degenerated and no longer function effectively. The visual image is then captured on a miniature video camera and is processed, then transmitted wirelessly to the bionic eye through an ultra-high frequency radio, after processing to select for the target image (e.g. human faces or large objects). By electrically stimulating the appropriate electrodes, the optic nerve is activated and it transmits the signal to the brain, which it interprets as an object.

allocation. It requires us to compare the potential benefits and costs of using resources or funding in specific areas, such as research, basic health care provision and education.

Environmental Sustainability

Another important concern for the ethicist is the potential effects of nanotechnologies on the health and safety of people and the environment. Carbon nanotubes – cylinders made up of pure carbon molecules – are being used in a number of technologies and products. These products, such as stronger and lighter building materials and fibres that can conduct electricity, may have huge benefits for the environment in terms of reducing the cost of building, manufacturing and maintaining structures (e.g. by requiring less steel, thereby reducing carbon emissions).

However, little is known about the toxicity of the materials used in these products. Carbon nanotubes are, chemically, the same as bulk (or large-scale) carbon. However, they have different properties to large-scale carbon, and the risks posed by these materials for human health and the environment are unclear according to Brian Priestley and colleagues (*Medical Journal of Australia*, 2007). What happens to these nanotubes when they are in the body or the air? Do they simply disappear? Can we inhale them unknowingly?

Many people may be unaware that nanoparticles have already been integrated in a number of cosmetic products that are commonly used, such as sunscreen. Various groups are seeking better regulation, including labelling of products that contain nanoproducts, but as yet there are no consistent requirements.

Ethicists advocate close monitoring and increased public awareness of both the risks and benefits of these new products and technologies.

Poverty and Hunger

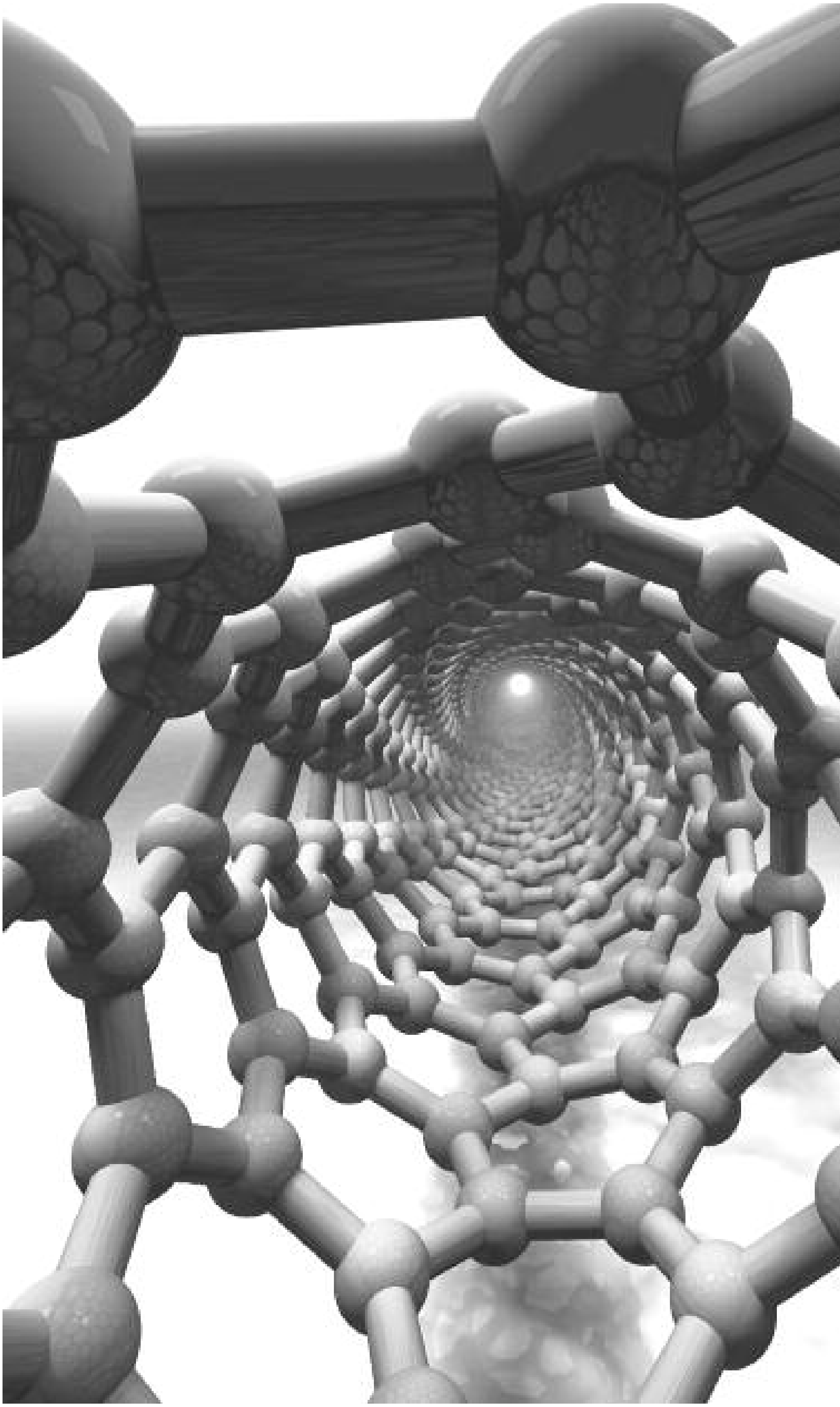
Some ethicists are particularly concerned about the potential for investment in nanotechnologies to increase what they call the "nanodivide". This refers to a situation where the benefits of the development of nanotechnology go to those who already enjoy a higher standard of living and can afford to purchase such technologies, while those people with few material resources, poor access to clean water and health services and high vulnerability to poverty and disease are unlikely to see any benefits. Thus people in wealthier countries are likely to disproportionately benefit, and those in poorer countries are more likely to bear burdens (for the environment, social well-being and health).

Nanotechnology is often portrayed as promising cleaner, greener and cheaper products and manufacturing processes. Prashant Jain and T. Pradeep are researching the use of nanotechnology for water purification and for small-scale energy generation (*Biotechnology and Bioengineering*, 2005). This could have a significant impact on poverty and hunger for the world's poorest people.

Even if successful, this research can only lead to real improvements in the quality of life for poor communities if governments and industry together decide to make the development of the technology and its availability an international aid priority. Of course, this needs to be done in a way that protects the environment from further damage.

Conclusion

Rapid developments are occurring internationally in nanotechnology, and these may have both positive and negative effects. Ethicists identify, evaluate and consider the unintended consequences of these developments for all people, including those who live in poverty, suffer ill health and who are frequently excluded from technological debates.



Are nanotubes as dangerous as asbestos? Image: iStockphoto