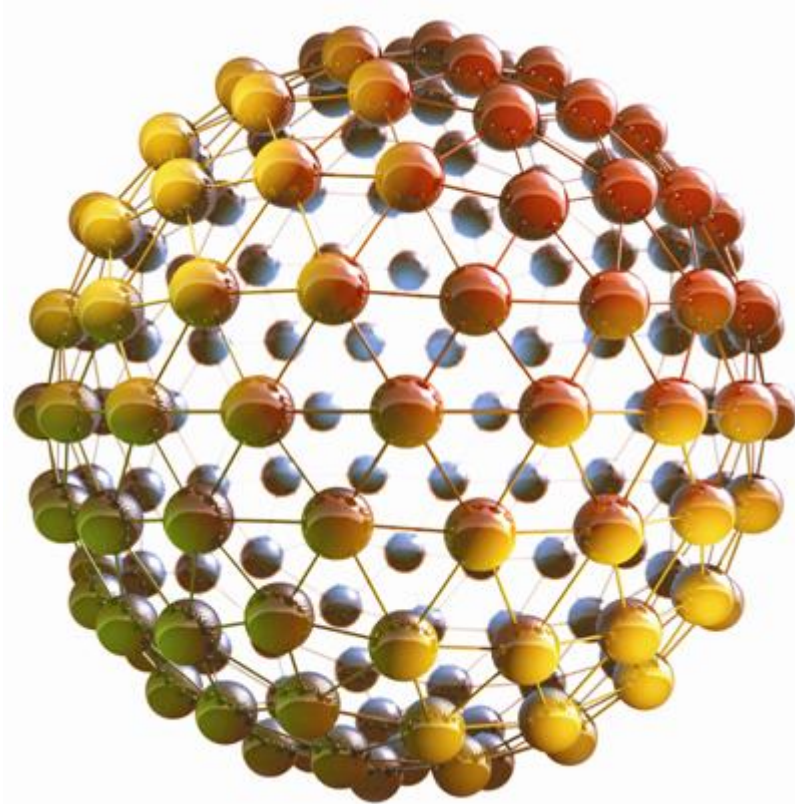


**Preparing for the advent of nanotechnology in medicine:
Are our health care systems ready?**



By

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PASS

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Abstract

The unrelenting pace in the development of nanotechnology means it has transformed into a truly wide-ranging field of research. It is no longer adequate to simply use “nanotechnology” for the various applications of nanotechnology and the huge amount of accompanying research - this paper will focus on the medical applications drawing on the basic principles underpinning most research into nanotechnology. In the past, references to research in this field have always been made in the belief that advances made in nanotechnology will have a huge impact on our lives- with many branches now showing progress, this assumption is no less correct than before. However, most analysis of the impact of nanotechnology on our world looks at the short-term feasibility, cost-effectiveness, and impact on the environment- I intend to look at long-term effects on society, and highlight potential pitfalls for healthcare governing bodies to consider, as nanotechnology is introduced as a potential method of treatment, whether publicly or privately.

Introduction

Nanotechnology is the field of study concerning science at a molecular level. Typically, this means at a scale of 0.1 to 100 nm. Research at this level is fraught with difficulty, as a need for extreme precision and accuracy is required to safely and effectively complete objectives. Unusually, we find that the properties of materials can have dramatic changes- gold is one example. Although gold is relatively inert in common usage, at a molecular level, gold becomes more reactive as a catalyst, and useful in encapsulating chemicals. Another example is silver, which exhibits anti-bacterial qualities at a nano scale and so is being pursued for use in wound dressings. These unusual qualities found in what were thought to be useless materials in terms of medical applications, indicates a need to investigate a wide range of materials for their potential benefits. However, their properties are not completely changed- gold is unlikely to have a place in future medicine due to its toxicity to the liver, which can build up as inert gold compounds are deposited.

We must appreciate that working at the nano scale gives other advantages apart from differing properties of materials. At a nano scale, weight is no longer a significant consideration; in addition the ability to interact with extremely small substances that are not necessarily nano, but are too small to be controlled using surgical equipment, becomes possible. We have also found that nano-particles can form long chains in a biological setting, which could offer potential uses in other areas of treatment.

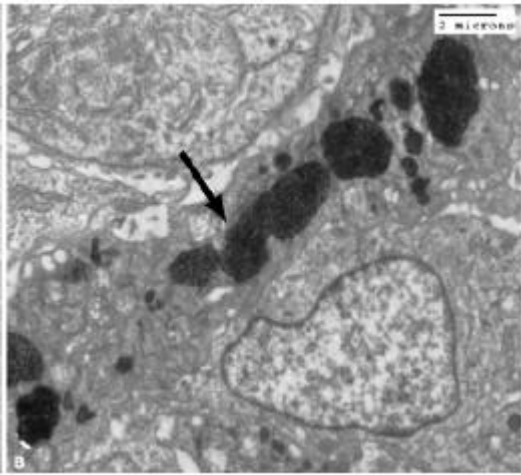


Figure 1 An example of nano-particles clustering together. Nanoparticles are pointed out by the black arrow.

In actually creating these nano-materials for medical use, chemists and engineers each have their own way of approaching this task, of which there are two. The first is the “bottoms-up” approach, favoured by chemists, where materials such as “bucky-balls” are “persuaded” to build together under the right conditions from simple molecules. Bucky-balls, formally known as “Buckminsterfullerenes”, are spherical molecules consisting of 60 Carbon atoms, and have the ability to conduct electricity and so are useful in the construction of finished nanomaterials.

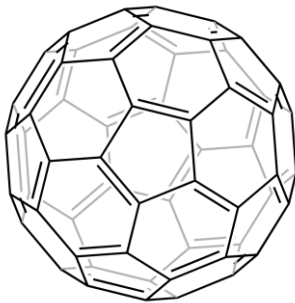


Figure 2 A Buckminsterfullerene (or "Bucky-Ball")

The second approach is the “Top-down” approach, where large materials are cut down and shaped to form consistent nano-structures, such as silicon in Microarrays. Microarrays, also known as a “lab on a chip”, are able to analyse the properties of multiples of biological substances at once, through the use of nanoelectromechanical systems (NEMS). This allows for rapid diagnosis of a wide range of possible afflictions, leading to quicker and more stringent assessments of identification of a problem, and therefore treatment.

The intricate ways of developing nanotechnology treatment at this time indicate the current level of development. Although yet to appear in a healthcare setting, we gain an

understanding of how future treatment will attempt to cure afflictions, although such techniques may also point to the amount of work that has to go into such research. It is reasonable to infer that further developments will cost much more time and money, and assessments of quality.

Nanotechnology has already begun to play a role in society. In a bottle of Coca-Cola for instance, the graphite structure of the small white disc in the bottle top prevents bacterial growth. In modern LCD TVs, the liquid crystal is interspersed with nanomaterials to facilitate current flow. Most modern applications are based on their research into the properties of graphite, more specifically Graphene. Graphene has the same structure of graphite, except sheets of graphene are one atom thick. Such material also allows electricity to conduct on a very small scale.

In medicine, the applications of nanotechnology have huge scope for usage. In the treatment of diabetics, insulin could be ingested rather than given intravenously. Nano-capsules containing insulin can be ingested without being broken down, until they reach the intestinal tract where a “lock and key” method is used to break the capsules open.

Another idea of nano-capsule application is the treatment of cancer. At present, chemotherapy used to kill cancer cells is destructive to healthy tissue as well as cancerous tissue. In an effort to prevent the carpet-bombing of affected areas, Dr Cave and his research team at Nottingham Trent University have been investigating how capsules containing chemotherapy can be used to target specific areas. Nano-capsules can bind with anti-bodies created by the body to target cancerous tissue, allowing chemotherapy drugs to be directed to only cancerous tissue, thus minimising damage to healthy cells and associated unpleasant side-effects.

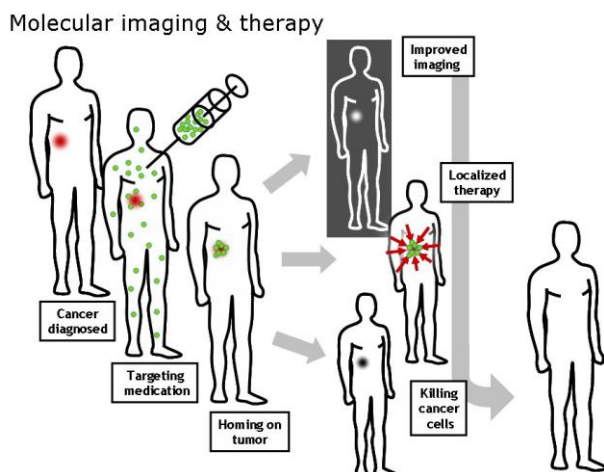


Figure 3 A simple guide displaying the ways in which cancer can be treated

Another way to treat cancer is being investigated by Dr Cindy Dennis at the National Institute of Standards and Technology (NIST). Her team is looking into using nanoparticles to

cause necrosis of cancerous tissue, leading to a regression of the tumour. Nanoparticles are injected directly into the tumour. By using an Alterable Magnetic Field, and MRI scanners to accurately control a specific area of tissue, the nanoparticles can be heated up through various physical phenomena to destroy the cancerous tissue.

A popular advancement associated with the general idea of nanotechnology is the idea of nanorobotics, which are robots on the nano scale that can be programmed or controlled to carry out specific and multiple functions. However, this technology is very speculative and current research is very limited, simply due to the difficulty of building mechanical parts on a molecular scale- parts may have to be constructed out of individual atoms or molecules, which would be extremely expensive and time-consuming if such technology even became possible. Developers would also have to contend with heat-dissipation issues at the molecular level, and determine how robotic functions would be controlled.

At time of writing, nanomedicine is fairly primitive, compared to advancements made in imaging and drug therapy, although it must be stated that major advances are being made. Most treatments are still in their research stage, and as such are currently not used in general healthcare. One reason for this is the cost of treatment- nanomaterials are difficult to manufacture, and difficult to put to use. This renders nanomedicine unrealistic for organisations such as the National Health Service (and to a large extent private healthcare companies), and so such treatment is not widespread.

However, recent developments may lead to a reduction in costs of finished nanomaterials. The first nanomaterial commodity exchange, the “Integrated Nano-Science & Commodity Exchange” (INSCX) was recently set up to provide easier access to nanomaterials. This development is indicative of a trend towards more common usage, and will likely make it easier for a full-scale global industry to develop around the production of finished nanotechnology, thus lowering general costs of treatment. According to their press release, with regard to nanomaterials, “large volumes will be available to producers, and the nanomaterials purchased will be of assured quality and will be more competitively priced.” The exchange will result in “access to large amounts of inexpensive raw materials to facilitate research, development and mass production.” How far the exchange will go to realising this is to be seen, although such a step shows that propagation of raw materials is moving in the right direction.

As basic nanotechnology advances, its role in medical treatment will expand, and as this treatment becomes cheaper, it is likely that nanotechnology will become more common throughout health-care. However, we must consider the effect of cost on the direction of research, and its effects on diffusion. As treatment becomes more diffuse, its impact on society will become larger and larger, and social attitudes towards health are likely to change dramatically. We shall now explore possible scenarios in social impact.

Discussion

We have seen how current research into medical applications of nanotechnology is starting to lead to effective treatment. The focus of many researchers now is to look at giving a more personalised form of treatment- indeed, this is the next objective of Dr Cave's team at Nottingham Trent University. They hope to discover a way of allowing cancer-targeting capsules to identify the specific antigens of the patient, and adapt to their structure. As the use of antigens is the body's way of identifying familiar and foreign cellular tissue in the body, such a step would allow a more effective way of targeting cancerous cells that exhibit a mutation in their antigen structure.

Much attention is given to the role of nanorobotics in medicine. Research in this aspect of nanotechnology is certainly in its infancy, and is unlikely to have an impact in the near future. It can be easy to use nanorobotics as a grounding for many claims of complete human augmentation in terms of biological structure and ability, or on removing the effects of aging on humans, as posited by Ray Kurzweil and others. It is unscientific to make extreme speculation on the future impacts of nanorobotics, as it must first be established as to what extent nanorobotics will be able to function.

A serious point raised by a number of researchers and in papers is the environmental effect of nanoparticles. Urgent empirical evidence is required to determine whether nanoparticles have an impact, in accordance with the US Food and Drug Administration protocols regarding new medical treatment. Concerns have been raised that as nanoparticles are more complex to control at a molecular level than normal-sized molecules, it is not enough to give theoretical assumptions of any dangers posed by nanoparticles. Questions such as "how is waste nanotechnology cleaned up?" and "How is nano-material disposed of?" are questions still lacking answers, and there is a serious possibility that nano-materials could become the "asbestos of the 21st century" if their effects on the environment and workplace safety are not fully comprehended. Other problems highlighted by Dennis et al. are the effects of treatment involving nanomaterials on other biological functions in the body, and whether treatment found to be effective on mice translates to human application. In addition, the discovery that nanoparticles have a tendency to join together to form chains is one aspect of unexpected properties of nano-particles that have the potential to help or hinder- it is possible that a use for this property could be found in medical treatment, but it is also feasible that a build-up of nano-particles in the environment or in the body could lead to unintended consequences.

Retel et al. propose that an urgent Constructive Technology Assessment (CTA) is carried out as soon as possible. This means making periodic assessments of the effects of nanomaterials on the environment at different stages of development to highlight problems encountered along the way. Not only would this establish sooner the dangers posed by the introduction of nanomedicine, it would take less time than carrying out a Health Technology Assessment,

which would be carried out after the treatment is ready for application. This would also reduce the danger of whole years of development being scrapped due to unforeseen derogatory effects.

It is clear that the long-term objective of some of the research mentioned is the extreme decrease in mortality rate from cancer. Success in this would be hugely significant- 7.6 million people died from cancer in 2008, and the effective detection and treatment of cancer poses many difficulties for medical researchers, and also significantly burdens healthcare budgets. If the number of people dying from cancer were to reduce significantly, the first problem to consider would be over-population. Fewer people dying from cancer would increase average life spans, and potentially cause more strain on governments already struggling to cope with overpopulation. However, successful implementation of nanomedicine would reduce the cost of cancer treatment, as intended by the research in the first place. This may have the effect of shifting the medical and financial strain of problems regarding cancer care to problems regarding overpopulation. Whilst it may be unethical to deny treatment on these grounds to cancer patients if nanotechnology were developed enough to do so, the time-scale of this treatment being available should be looked at carefully, in order that health services can prepare for the eventual out-come of greatly increased success in cancer treatment due to the implementation of nanotechnology-based treatments. Sufficient analysis must be carried out to determine how future healthcare bodies will adapt to this shift in focus, in order that we are not caught unaware, which could potentially lead to personal hardship and budgetary dislocation.

Another problem that must be considered is social attitudes to activities that would increase the chances of developing cancer. If it became less-likely to die from cancer, then leading contributors to cancer development would become much more acceptable as dangers would be reduced- smoking would pose less of a danger to an individual's health, and excessive consumption of alcohol would have less of an effect on the liver. In the past we have seen how the availability of statins led to people believing that it would effectively reduce the cholesterol intake from junk food. Though doctors stress that the use of drugs to combat the dangers of an unhealthy lifestyle will not work completely, their use is often adopted by people willing to make lifestyle choices previously deemed unhealthy, despite an incomplete knowledge of the complete effects of such a lifestyle. This problem would be further compounded by the adoption of more effective nanotechnology-based treatments. In such a case, it would indeed be true that smoking, drinking and eating junk food would be safe to do so for an individual, allowing individuals more freedom of choice. However, if other individuals who passively suffer from their actions would require treatment, this could put more strain on health service budgets.

These are just some of the ways individual lifestyles will affect a community, and not enough has been done to research just how social attitudes will change: will society see

these lifestyles as irresponsible and invoke sanctions, or will they become accepted, and if so, how society will deal with associated problems? This question may be harder to answer from current perspectives.

The distribution of nanotechnology funding must be carefully considered. If unfair financial distribution exists or restrictions on treatment diffusion are apparent, a scenario could arise where more and more money is used to fund improvements of existing nanotechnology, and not enough in ensuring that present nanotechnology medical treatment becomes widely available. This means that only those with enough money and previous access to nanomedicine would benefit from the research going into new forms of such treatment, whilst those without enough money to pay for basic nanomedicine would be unable to take advantage of any future developments. In a worst-case scenario, this could lead to two strands of humanity forming: one strand where their access to nanotechnology greatly improves their lives leading to a much better quality of life and functional ability, and a second strand that is unable to afford even the most basic nanotechnology as the pace of improvements leaves them behind, with a lower quality of life and less functional ability.

This scenario could also arise as a result of greater social disparity. It is likely that nanotechnology would be more available in the private sector of health care (especially in countries such as the US and Singapore where the private sector is more dominant), as new developments are likely to be expensive, or else take more time to be widely distributed under the National Health Service. Accelerated development of nanomedicine may exacerbate social divides, as only those able to afford private health care will have access to such treatment, and therefore a better quality of life. For example, in the treatment of organs that are failing; where nanomedicine may fix the problem quickly and not require an extended care period, someone who is unable to afford private treatment may be faced with an organ transplant and extensive check-ups for the rest of their life (thus impacting their careers and making access to treatment more difficult). However, if the nanotechnology treatment costs remain high, even private healthcare companies will find it difficult to implement widespread availability- it may be wise to consider pooling private and public healthcare resources to ensure effective diffusion. With regard to public healthcare, organisations such as the NHS may find that nanomedicine will cost less in the long run, as current treatment of patients may require many years of treatment and drug therapy.

Such a scenario where the nanotech-poor strand of humanity becomes relatively more prone to health problems and lower incomes as nanotechnology leads to body augmentation of the nanotech-rich strand, could lead to a defunct and doomed class. It is conceivable that nanotechnology treatment may become so developed that it is possible that people who have not been able to enjoy the benefits of nanomedicine in the past, will be barred from the possibility of ever doing so, as new treatments become focused on

improving the lives of those already enjoying the benefits of nanotechnology. It is possible that such a scenario could possibly be avoided if the research into nanotechnology is not allowed to grow exponentially, which adds to the argument that more research must be done into the social and environmental impacts of nanotechnology. However, forcing nanotechnology research to halt may only lead to less control over further developments, and therefore increased social disparity.

Another way to ensure an equal distribution of nanotechnology treatment, and therefore avoid the scenario, is to encourage treatment diffusion. Medical treatment becomes diffuse throughout a healthcare system when the treatment becomes cheaper, allowing more medical centres to invest in the treatment for a wider population of patients. Nanotechnology-based medical treatment may struggle to become widely available if it continues to be expensive, and therefore less diffuse. If nanomedicine were to continue to be expensive, only those with enough money would be able to pay for such private healthcare, leading to the aforementioned scenario. However, institutions such as INCSX work towards increasing the availability of cheap, high-standard nano-materials, leading to cheaper finished nanotech products, allowing treatment to become cheaper. Future research bodies may wish to consider new ways to reduce the cost of nanomedicine development, such as ensuring minimum expenditure in acquiring new materials, and encouraging medical centres to take advantage of new treatment.

We must also consider which ends non-treatment based advancements in nanotechnology will lead to. Should our manipulation of nanomaterials lead to the ability to protect the human body from hazards such as toxins, this technology could lead to more advanced versions of hazmat suits. Whilst this would be ideal for harsh environments, it is feasible that such technology could be deployed in warfare- soldiers equipped with advanced protection would be able to utilise much more dangerous weapons without any harm to themselves, and potentially threatening innocent lives who may be affected by biological warfare. It is therefore clear that even basic applications of nanotechnology to augment the human body would very quickly lead to highly sophisticated warfare, which is not in keeping with medical ethos as explained by the Hippocratic Oath. Governments must take the possible catastrophic effects on civilian populations into account when planning violent engagements and budgeting for new forms of warfare. Organisations such as the American Centers for Disease Control must be ready for the impact of nanomedicine, and such preparation will only come as a result of further studies.

Conclusion

According to INCXS, the “age of cheap, ubiquitous nanotechnology is now at hand”. It is clear that the scope and future applications of nanotechnology are enormous and have the potential to change our lives fundamentally. But it is also clear that we are in danger of rushing head-long into discovering ways to apply nanotechnology to medicine without fully appreciating all possible side-effects. The lack of CTAs or comprehensive studies into the environmental impacts of nanotechnology is one indication that we are unprepared and ignorant of just how nanomedicine will change our approach to medicine and society itself. It has also been indicated that whilst nanotechnology is starting to grow past infancy, it is constructive to form impact scenarios on our society- although such scenarios may never come to pass, a careful and logical approach to nanotechnology application is essential to ensure that only treatment will come out of medical research in this field, and no harm. Careful managing of how nanotechnology treatment will be introduced is imperative to the protection of all individuals of society, with appropriate safe-guards and precautions taken to account for the likely social trends created by the introduction of treatment that could revolutionise our attitudes to the body. It is highly likely that the commodification of the raw materials used in the development of medical nanotechnology will affect the diffusion of such treatment to the wider population. Greater availability of cheap, high-quality materials will lead to greater availability of nanomedicine. Such a diffusion will require an increase in safe-guarding research to establish the effects of nanotechnology on the environment and biologically. However, greater diffusion is likely to also lead to overpopulation, and insufficient preparation for the likely changes in society will lead to massive dangers, as changes occurring without sufficient preparation usually lead to unintentional collateral damage. It is vital that the introduction of nanomedicine is handled carefully, and that governments will have to deal with the problem of overpopulation- any attempt to minimize nanomedicine may result in less control over its availability, with some states and non-state actors pushing ahead with development regardless of ethical considerations.

It is all too easy to become complacent regarding the dangers posed by nanomedicine to society in general, and medical treatment without any focus will only lead to more social disparity, as only those with enough finance will have access to nanomedicine. Failing to realise the immensity of the dangers from inconsiderate preparation and lack of understanding have the potential to threaten the advantages offered by nanotechnology. Without further studies however, we are in danger of doing just that.

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