# 6 Social and ethical issues

## 6.1 Introduction: framing social and ethical issues

1 As recent debates in the UK and elsewhere demonstrate, developments in science and technology do not take place in a social and ethical vacuum. Widespread discussions of issues such as nuclear energy, agricultural biotechnology and embryonic stem cells illustrate this point only too clearly.

2 Given this backdrop, it seems highly likely that some nanotechnologies will raise significant social and ethical concerns. Such concerns seem most likely for developments envisaged for the medium (5–15 years) and much longer (more than 20 years) time horizons. However, such issues rarely become matters of concern merely as a result of the underlying science or engineering. More typically, they are associated with specific applications of a technology. For example, in Europe medical or 'red' uses of biotechnology have raised a very different set of concerns from those raised by agricultural or 'green' applications (Gaskell and Bauer 2001). As earlier chapters of this report illustrate, the term 'nanotechnologies' encompasses an even wider range of basic science, methods and engineering approaches than biotechnology, and so are likely to give rise to a highly diverse set of potential applications over very different time-scales. Predicting all but the near-market applications of such a diverse effort is a difficult enough task, as a recent report from the RAND Corporation points out (Anton et al 2001), but anticipating which applications are likely to raise significant long-term social or ethical issues sets an even bigger challenge. Some currently envisioned applications of nanotechnologies which are seen as technically feasible may never be realised on a significant scale, while unanticipated scientific breakthroughs may lead to rapid applications that are not currently foreseen.

3 Most of the social and ethical issues arising from applications of nanotechnologies will not be new or unique to nanotechnologies. However, throughout this chapter we take the view that effort will need to be spent whenever significant social and ethical issues arise, irrespective of whether they are genuinely new to nanotechnologies or not. Previous chapters have highlighted some of the possible short-term health and environmental implications of certain developments in nanotechnologies, each of which have their own social and ethical dimensions. Here we discuss some of the wider social and ethical issues that these new technologies raise. The list is not intended to be an exhaustive treatment but to highlight what seem to us to be significant issues. When discussing both the potential positive and negative impacts of nanotechnologies, we have tried to avoid an unbalanced discourse (present in some of the more speculative writings on the subject), which implies that major positive benefits for society always be accredited to the 'new science of nanotechnology', while any negative social and ethical issues are 'just a problem of technology' or alternatively that the very newness of a technology is itself evidence against it. Nanotechnologies, whether singly or in convergence with other technologies, are likely to hold a range of both positive and (however unintended) negative outcomes.

4 Widespread acceptance and use of nanotechnologies will depend upon a range of social factors including: specific technical and investment factors; consumer choice and wider public acceptability; the political and macro-economic decisions that contribute to the development of major technologies and outcomes that are viewed as desirable; and legal and regulatory frameworks. Equally, just as the knowledge-base underpinning science and technology can change rapidly and unpredictably, so can society. Forecasting people's needs and values 20 years or more into the future is fraught with uncertainty. Accordingly, it is difficult to state with any confidence how nanotechnologies are likely develop in the future, in interaction with a changing society and its shifting social and ethical concerns. It may also be important to look beyond the perspective of Western industrialised societies, to take account of the ways in which people in developing societies might respond to developments in nanotechnologies and their impacts.

5 Precisely which social and ethical issues become a focus of concern will hinge upon the actual trajectories of change in particular nanotechnologies. In their recent report for the ESRC on the social and economic challenges of nanotechnology, Wood et al (2003) point out that current evaluations of the impacts of nanotechnologies can be located on a continuum whose extreme poles are on the one hand incremental progress (the view that nanotechnologies merely represent a basic evolution from well-established principles and procedures), and on the other a radical disjunction from current science and technology (for example, as represented by the vision of nanobots outlined in Annex D). According to the authors of the ESRC report, most current commentary on social, economic and ethical impacts, which ranges from the highly optimistic to the almost apocalyptic, occupies the centre ground of this continuum. What does seem clear is that genuinely new and/or unanticipated social or ethical issues are likely to be associated with radical disjunctions if they occur. Equally, much of what passes for incremental nanotechnologies (for example, powerful computers networked with cheaper small sensors) may still prove transformative in social terms. This is because the role of nanotechnologies is likely to be an enabling one, often in convergence with other

new technologies, bringing to fruition applications such as pervasive sensing which have been anticipated by commentators for many years, but are only now becoming a practical possibility. Much of the commentary provided to the working group also suggests that many of the social and ethical issues raised by incremental developments are unlikely to prove entirely new. For example, many concerns about the overall impact of a rapidly changing science on society, and the governance and regulation of the technology, are likely to echo some of those raised previously about other developments in science and technology that have proved controversial, such as nuclear energy, reproductive technologies or biotechnology (Mosterín 2002). That does not make these concerns any the less significant or worthy of the attention of policy-makers; indeed, past experience with controversial technologies should predispose policy-makers to pay timely and applied attention to these concerns rather than dismissing them as 'nothing new'.

6 This chapter provides selective comments on the significant claims and arguments that have been presented to the working group, alongside others that are found in the published literature, to highlight some of the more difficult issues that might potentially emerge. Some of the issues covered here were also raised in the group workshops on nanotechnologies with members of the public that were conducted as part of this study; findings from these are discussed in detail in section 7.2. For the reasons outlined above, this chapter cannot pretend to be a full-scale horizon scanning exercise for social and ethical impacts. This is one of the reasons why we recommend here that at least some form of ongoing evaluation, and in section 7.6 that continuing dialogue and engagement, be extended well beyond the lifetime of the Working Group.

## 6.2 Economic impacts

7 There is some disagreement about how much of an economic impact nanotechnologies will have. A range of views has been heard in evidence. Overall, it seems that effects will be incremental in the short term but, given the fact that nanotechnologies are likely to enable a great many products and processes, they may well have significant economic impact in the long-term. As argued above, much will depend upon which particular applications eventually come to market, and the order in which they are developed. Judging by experience, seemingly insignificant technological advances could have profound long-term economic impacts. Some commentators appear to assume that the potential economic results of nanotechnologies – greater gross domestic product (GDP), greater efficiency and less wastage in industrial processing – will be entirely positive across society or across the range of developed and developing nations. However, in general the introduction of new technologies creates both 'winners' and 'losers'; for example, as employment is displaced from one sector to another.

8 At this stage, evidence does not suggest that nanotechnologies raise economic issues that differ significantly from other cases of technological innovation. However, it would contribute greatly to the wider societal debate and to decisions about the introduction of nanotechnologies if appropriate economic analysis of developments with widespread societal impacts, including an assessment of the advantages and disadvantages, is undertaken at an appropriate stage. Since this cannot be done on a systematic basis far ahead of the development of new technologies (for reasons given at the start of this chapter), such analysis would need to proceed on a case-by-case basis, as developments and applications come closer to market. Such analysis should also take full account of the uncertainties involved, of the case for relying on alternative technologies and of any economic shocks and surprises.

## 6.3 A 'nanodivide'?

9 Much of the 'visionary' literature at the radical disjunction end of the continuum described in the ESRC report (Wood et al 2003) contains repeated claims about the major long-term impacts of nanotechnologies upon global society: for example, that it will provide cheap sustainable energy, environmental remediation, radical advances in medical diagnosis and treatment, more powerful IT capabilities, and improved consumer products (see many of the contributions to two recent National Science Foundation (NSF) workshops (NSF 2001, 2003)). If even a few of these predictions prove true then the implications for global society and the economies of many nations are profound indeed. However, it is equally legitimate to ask who will benefit and, more crucially, who might lose out? The application of science, technology and engineering has undoubtedly improved life expectancy and quality of life for many in the long term. In the short-term, however, technological developments have not necessarily benefited all of humankind, and some have generated very definite 'winners' and 'losers'.

10 Concerns have been raised over the potential for nanotechnologies to intensify the gap between rich and poor countries because of their different capacities to develop and exploit nanotechnologies, leading to a so-called 'nanodivide'. If global economic progress in producing high-value products and services depends upon exploiting scientific knowledge, the high entry price for new procedures and skills (for example, in the medical domain) is very likely to exacerbate existing divisions between rich and poor (P Healey, written evidence). Equally, a parallel danger that could arise if the more radical 'visions' of the promise of nanotechnologies were realised, is that enthusiasm for developing a 'technical fix' to a range of global and

societal ills might obscure or divert investment from cheaper, more sustainable, or low-technology solutions to health and environmental problems.

11 A further concern that has been highlighted (ETC 2003a; GeneWatch UK written evidence) relates to patenting in the field of nanotechnologies. Appropriate ownership of intellectual property is generally considered advantageous. However, as experience in genetics shows (Nuffield 2002), patents that are too broad or that do not strictly meet the criteria of novelty and non-obviousness, can work against the public good. There is a concern that broad patents could be granted on nanotechnologies, for example on processes for manipulating or creating materials, which would stifle innovation and hinder access to information, not least by those in the developing world. As highlighted in the Royal Society report on intellectual property (Royal Society 2003), it is vital that patent offices monitor the complex and rapidly changing developments in science and technology so that any patents which are granted are appropriate and support rather than constrain research and innovation.

12 In evidence presented to the Working Group, Doug Parr of Greenpeace highlighted the potentially beneficial applications of nanotechnologies for the developing world and for the environment, for example by reducing carbon dioxide emissions through improving renewable energy technology, and expressed concern that nanotechnologies could become another 'opportunity lost' for developing countries. The Joint Centre for Bioethics (2004) also highlight applications such as using nanosized quantum dots for cheaper, quicker disease detection, and improved water purification technologies, which could have benefits for the poor. There have also been suggestions that nanotechnologies could offer new opportunities for some developing countries to participate more directly in global technology through their own initiatives – for example, through the development of plastic electronics facilities, which are one-hundredth of the cost of conventional silicon fabrication plants.

13 There are therefore significant risks that some short-term developments in nanotechnologies will be exclusive to those who already own wealth and power, to the detriment of wider society. Equally, opportunity to apply nanotechnologies in ways that will benefit the developing world should not be overlooked. Two fundamental questions arise in this context. First, can the future trajectories of nanotechnologies be steered towards wider social or environmental goals (for example, cheap sustainable energy generation and storage) rather than towards meeting short-term or developed world 'market' opportunities (for example, cosmetics)? Second, if a 'nanodivide' develops, what can governments do about it? For example, to the extent that the products of nanotechnologies become essential to normal participation in society, should public authorities try to rectify the divide in an appropriate way? Where the products are luxury goods, can their demand and supply reasonably be left to the market? The governance of nanotechnologies must in some way be designed to incorporate the perspectives and objectives of governments, the market and civil society.

## 6.4 Information collection and the implications for civil liberties

14 As we saw in Chapter 3, nanotechnologies promise considerable advances in developing small and cheap sensing devices, enabling a range of features that will make smaller, longer-lasting sensors possible. The convergence of nanotechnologies with IT could provide the basis for linking complex networks of remote sensing devices to significant computational power. Some nanodevices may be widely incorporated in other products. Such developments could be used to achieve greater safety, security and individualised healthcare, and could offer advantages to business (for example in tracking and other monitoring of materials and products). However, the same devices might be used in ways that limit individual or group privacy by covert surveillance, by collecting and distributing personal information (such as health or genetic profiles) without adequate consent, and by concentrating information in the hands of those with the resources to develop and control such networks. The ETC Group claim that 'biosensors and chips…could become ubiquitous in daily life – monitoring every aspect of the economy and society' (ETC 2003a).

15 These kinds of development might reinforce existing consumer concerns about the use of radio frequency identification (RFID) technology to replace bar codes, currently being trialled by supermarkets and clothing retailers. A recent briefing on RFID from the National Consumer Council (2004) highlights concerns such as: the potential to link personal information (for example, credit card number) to a particular product, which may then allow individuals to be profiled and tracked in store and marketed to on an individual basis; the increased collection of data on an individual; and whether there is abuse if the technically unequipped cannot detect sensing devices. The Government's Foresight programme recently completed a project on cyber trust and crime prevention, which explored the application and implications of next generation information technologies (including developments in nanotechnologies) in areas such as identity and authenticity, surveillance and information assurance. One of the science reviews that contributed to this project (Raab 2004) highlighted the increased use of surveillance, with implications for policing, profiling and 'social sorting', all of which 'continually seek to identify, classify and evaluate individuals according to ever more refined and discriminating forms of personal data. Sorting is a highly potent set of techniques with political and social-control

implications'. These themes were also explored in the Royal Society's public dialogue on cybertrust and information security in March and April 2004.

16 This issue is clearly one where nanotechnologies play an enabling role in promoting societal changes that have both positive and (if the technology is abused) negative consequences. It seems unlikely that the underlying legal and ethical issues raised by such developments will be any different in principle from those society has faced in the past across a whole range of healthcare and consumer issues. However, as new forms of surveillance and sensing are developed, further research and expert legal analysis might be necessary to establish whether current regulatory frameworks and institutions provide appropriate safeguards to individuals and groups in society. We touch on this again in section 8.5.

## 6.5 Human enhancement

17 As noted in section 3.5.3h, nanotechnologies are contributing to the development of some 'enhancement' applications; the closest to development being improved cochlear and retinal implants, to improve or restore hearing and eyesight.

18 A few disability rights groups have objected to proposed interventions that enhance human capacities, on the grounds that this might lead to stigmatisation of those without enhanced capacities (see, for example, Wolbring 2003). The general concern is difficult to grasp without a clear account of the difference between enhancements and other interventions. The issue of specific human enhancements is also likely to fall, initially at least, squarely within the medical domain, where there is an established history of considering emergent ethical issues and the societal acceptability of particular procedures.

19 The general issues about stigmatisation of those who are different in various ways is a serious one, but it has little connection with ways in which differences between people may be brought about. All successful medical treatment of illness, including treatment of illness with a genetic basis, enhances the functioning and capacities of those who are treated. Even where an intervention – a drug, a prosthesis, a medical device, surgery – is not effective for all sufferers, it can hardly be withheld from those who could benefit on the grounds that some others cannot. There is no general case for resisting technologies or interventions that enhance human capacities. It would be wrong to deny appropriate treatment to patients whose impaired sight can be improved by glasses or surgery simply because others have sight impairments that cannot be improved.

20 What is important to note is that a purely 'technical fix' view of disability is not unproblematic. In evidence presented to the Working Group, Richard Light, director of the DAART Centre for Disability and Human Rights, suggested that disabled people may prefer money to be allocated to, for example, anti-discrimination or human rights measures, rather than technology in general and nanotechnologies in specific as a cure. He also stated that medical technology is irrelevant unless people can afford and have access to it, and urged proper consideration of the claims that nanotechnologies will provide benefits to the disabled: 'any suggestion that nanotechnologies will have an impact on their lives must be assiduously tested; making such claims without a demonstrable basis in fact is immoral and does little to reassure those concerned by the commercialisation of science.'

21 However, certain types of enhancement may be more controversial, whether because those who lack them would be stigmatised or (more probably) for other reasons. For example, some have argued that all enhancement by gene therapy is an unacceptable form of eugenics, while others have argued that genetic enhancement of basic capacities such as intelligence or height would only be acceptable only if fairly distributed (Buchanan et al 2002). Yet others hold that if enhancement of capacities by education or training is acceptable, then enhancement of capacities by other means, such as cosmetic surgery or taking drugs with cognitive effects, is also acceptable. A parallel debate can be found between those who are concerned about the use of performance-enhancing drugs by athletes or others (usually on grounds of unfairness or risk to health)[1], and those who think that if it is acceptable to enhance performance by exercise, then it is acceptable to do so by taking drugs[2].

## 6.6 Convergence

22 Convergence refers to the multiple ways in which nanotechnologies will combine in the future with other developments in new technology (reflecting its genuinely interdisciplinary nature). Convergence probably presents some of the biggest uncertainties, with respect to what is genuinely plausible and when new technologies might actually come into use. We have noted above how convergence of nanotechnologies with information technologies could raise concerns about civil liberties. However, convergence is likely to generate a range of other social and ethical challenges, particularly in relation to longer-term applications within bio-nanotechnology that involve significant interface of material systems with, or internal modification of, the body. Some developments – although essentially physical interventions conducted primarily for medical benefits – might well raise a range of fundamental psychological and sociological questions centred around the issue of identity: that is, what we understand to be 'human', what is 'normal' and what is not. As stated in the recent report from the German Parliament Office of Technology Assessment (TAB 2004):

[1] *For more on the medical consequences of taking performance-enhancing drugs in sport, see http://www.bmjpg.com/chapters/0727916068_sample.pdf.*

[2] *For a bibliography of writing on human enhancement see http://www.ucl.ac.uk/~ucbtdag/bioethics/biblio.html.*

'In visions of nanotechnology, we repeatedly see aspects which dissolve the boundaries between what constitutes a human being, and what they can create with the help of technological achievements and applications. Such aspects relate for example to the penetration and modification of the human body by attempts to supplement or replace its biological components by nanotechnology components, and to network it with external machines or other bodies or body parts'. Developments that in some way invade or intervene with the body in the manner described above are also likely to raise issues of control and choice and to be particularly sensitive in relation to public perceptions and concern. In evidence presented to the working group, Stephen Wood and Richard Jones highlighted that although these very extreme visions of the potential outcomes of nanotechnologies – including the possibility of greatly expanding lifespans, or even of the separation of human consciousness from the body and its relocation in a computer – may seem too far-fetched for many scientists, these visions do form a background for discussions of the impact of nanotechnologies by informed non-scientists.

23 An example of proposals for radical human enhancement appears in a recent publication jointly sponsored by the US NSF and the Department of Commerce, which maps out a possible future convergence of nanotechnologies with biotechnology, information and cognitive sciences for enhancing human performance. The editors of this report suggest that 'the integration of the four technologies (nano–bio–info–cogno) originates from the nanoscale, where the building blocks of matter are established' (NSF 2003). Although it is not entirely clear what is being said here, it appears that convergence is being used in two senses. In addition to the definition of convergence as interdisciplinary research and development, convergence is used to refer to matter 'converging' at the atomic level – ie to the fact that all matter is made of atoms.

24 This volume provides a very good example of the difficulty some commentators find in drawing an appropriate line between hope and hype. The authors contributing to this report are almost universally optimistic about the potential of convergence for the human condition, and provide very little critical discussion of potential drawbacks. The report also makes strong assumptions about the social acceptability of some of its implications (see Baird 2004). The book also places some very concrete and beneficial developments that converging technologies will shortly bring (non-invasive diagnostics for example) alongside more fanciful visions of the future (for example, of human society as one single interconnected 'brain'). Many of the papers also advocate a highly mechanistic view of people and society, where machines and biological systems are intersubstitutable, with very little consideration of some of the ethical challenges that the more radical enhancement proposals (such as the development of direct neural-to-computer interfaces) might encounter. One would be forgiven, therefore, for dismissing many of the papers as being less about sound science and technology than they are about science fiction (for example, the volume talks extensively about the 'human cognome project' but contains little by way of mainstream neuroscience). However, the volume does pose the question of whether society has appropriate mechanisms for anticipating and deliberating some of the more radical enhancement proposals, currently thought possible through convergence, if and when they were ever to become practical realities.

## 6.7 Military uses

25 Nanotechnologies are predicted to offer significant advances and advantages in defence capability. According to the UK Ministry of Defence (MOD 2001), nanotechnologies will present both new opportunities for defence and new external threats. Echoing the points made above about the prospects for the development of pervasive sensing, the main initial defence impact is predicted to be in information systems using large numbers new and cheap sensors, as well as in information processing and communications. These developments might enable pervasive nanosensors to contribute to national defence capability through early detection of chemical or biological releases, and increased surveillance capability. In addition, 'a whole range of military equipment including clothing, armour, weapons, personal communications will, thanks to low cost but powerful sensing and processing, be able to optimise their characteristics, operation and performance to meet changing conditions automatically'.

26 A current military example is provided by the US Institute for Soldier Nanotechnologies at Massachusetts Institute of Technology, which has been awarded a $50 million budget from the US army to research new materials. Its ultimate goal is 'to create a 21st century battlesuit that combines high-tech capabilities with light weight and comfort', focusing on soldier protection, injury intervention and cure, and human performance improvement. Specific features of the battlesuit were described in section 3.2.3c. The Institute states that their research describes 'a long-range vision for how technology can make soldiers less vulnerable to enemy and environmental threats' but does not discuss a specific time-scale for realising that vision.

27 Military developments raise several obvious social and ethical issues, most of them once again not confined to nanotechnologies. Manipulation of biological and chemical agents using nanotechnologies could result in entirely new threats that might be hard to detect and counter. Some observers have suggested

that refinements of both existing and new weapons systems, through applications of nanotechnologies, might lead to a new form of arms race (see, for example, Gsponer 2002; Arnall 2003). One can also ask whether the use of arms control frameworks developed for existing categories of nuclear, chemical and biological weapon will be sufficient to control future developments involving nanotechnologies.

28 A related issue arises from the fact that much of the basic knowledge and technology needed to achieve military capabilities using applications of nanotechnologies will be produced within the civil sector, and hence is potentially available to a very wide range of parties, including non-state actors. Joy (2000) suggested that 'The 21st-century technologies – genetics, nanotechnology, and robotics (GNR) – are so powerful that they can spawn whole new classes of accidents and abuses. Most dangerously, for the first time, these accidents and abuses are widely within the reach of individuals or small groups. They will not require large facilities or rare raw materials. Knowledge alone will enable the use of them' . This factor also makes proliferation of weapons development programmes much harder to detect because the line between non-military and military industrial activity becomes blurred. In this way, nanotechnologies may increase the range of asymmetric power relations.

29 Those applications of nanotechnologies that attract military funding are likely to raise other concerns: for example considerations of secrecy will make the open peer review of findings in these areas much more difficult. An unintended consequence of secrecy in the development of some nanotechnologies could also be to fuel public distrust and concerns about non-military developments. This would be so particularly if the term 'nanotechnology' as a whole became to be closely associated with military ends (it is not currently: see the analysis of our research into public attitudes in section 7.2). The case of nuclear energy is instructive here. Flynn (2003) in the USA argues that one of the historical reasons for the stigmatisation of, and enduring hostile public attitudes towards, nuclear power was the inability of the civilian nuclear industry to separate itself from destructive uses of the atom. Government denials of this linkage – scarcely believed at the time – further served to undermine public trust in those regulating the technology. There seems to be a significant danger that public acceptance of a whole range of beneficial applications of nanotechnologies, particularly in the environmental domain, might be threatened by too close an association with military applications. However, individual perceptions of the role of the military will of course impact on the way that military development of nanotechnologies will be received.

## 6.8 Conclusions

30 Nanotechnologies will have an impact across many branches of science and technology and can be expected to influence a range of areas of human endeavour. Some applications of nanotechnologies are likely to raise significant social and ethical concerns, particularly those envisaged in the medium (5–15 years) and longer (longer than 20 years) time-scales. However, given the difficulty of predicting any but the most short-term applications of nanotechnologies, evaluating long-term social or ethical impacts is a huge challenge. Incremental advances in nanotechnologies may play a role in enabling a number of applications, often in convergence with other technologies, which may in the long term prove transformative to society.

31 In the near- to medium term, many of the social and ethical concerns that have been expressed in evidence are not unique to nanotechnologies. The fact that they are not necessarily unique does not make these concerns any less valid. Past experience with controversial technologies demonstrates that effort will need to be spent whenever significant social and ethical issues arise, irrespective of whether they are genuinely new to nanotechnologies or not. In this chapter we have identified a range of social and ethical issues relating to the development of nanotechnologies that would benefit from further study. These include concerns about who controls nanotechnologies and who will benefit from its exploitation in the short- and long term. The recent report to ESRC (Wood et al 2003) raised other relevant issues. Although not all these issues are necessarily research questions, some are and others may be in the future, presenting a unique opportunity for interdisciplinary research to be undertaken between scientists and social scientists. The cost would be small compared with the amount spent on research on nanotechnologies, the applications of which could have major social and ethical impacts. Therefore, **we recommend that the research councils and the Arts and Humanities Research Board (AHRB) fund an interdisciplinary research programme to investigate the social and ethical issues expected to arise from the development of some nanotechnologies**. This programme would include research grants and interdisciplinary research studentships, which would explicitly link normative and empirical inquiry. Research studentships could involve taught courses to familiarise students with the terms and approaches used by natural and social scientists, pooled or within institutions.

32 In the longer term we see civil liberties as a key ethical issue. The expected convergence between IT and nanotechnologies is likely to enable devices that can

increase personal security on the one hand but might be used in ways that limit individual or group privacy by covert surveillance, by collecting and distributing personal information (such as health or genetic profiles) without adequate consent, and by concentrating information in the hands of those with the resources to develop and control such networks. There is speculation that a possible future convergence of nanotechnologies with biotechnology, information and cognitive sciences could be used for the purposes of radical human enhancement. These currently fall into the far-future/science fiction category, but should they be realised are likely to raise fundamental and possibly unique social and ethical issues. There is a need to monitor future applications of nanotechnologies to determine whether they will raise social and ethical impacts that have not been anticipated in this report. Later in this report we consider how this might be facilitated for nanotechnologies (section 9.6) and for other new and emerging technologies (section 9.7).

33 On the whole, the scientists and engineers from whom we have collected evidence during this study indicated that they had considered, or were willing to consider, the ethical and social impacts of their work. Because nanotechnologies and other advanced technologies have the potential for significant and diverse impacts, which bring both benefits and risks, all researchers engaged in these fields should give thought to the wider implications of their work. We note that the Joint Statement of the Research Councils'/AHRB's Skills Training Requirements for Research Students does specify that research students should be able to demonstrate awareness of the ethical issues associated with their research. However, the Statement does not require formal training of students to raise awareness in these areas, which in the case of advanced technologies such as nanotechnologies may not always be obvious, nor does the Statement apply to staff. **We recommend that the consideration of ethical and social implications of advanced technologies (such as nanotechnologies) should form part of the formal training of all research students and staff working in these areas and, specifically, that this type of formal training should be listed in the Joint Statement of the Research Councils'/AHRB's Skills Training Requirements for Research Students.** The research councils/AHRB should support and expand the provision of short courses, bringing together junior researchers and doctoral students in science, engineering and social science to address the ethical and societal implications of technological developments.