What can nanotechnology learn from the ethical and societal implications of biotechnology?

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Introduction

The leading industrialised countries consider the mastering of nanotechnology to be vital to the economic and technological competitiveness in the 21st century, and it is often said that nanotechnology may lead to the next industrial revolution. Therefore, research into nanotechnology has advanced rapidly in recent years, the funding of nanotechnology has increased dramatically and nanotechnology has become a buzz word and is currently highly profiled compared to many other fields of research. Several researchers, including Canadian researchers at the University of Toronto Joint Centre for Bioethics, however, warn that there is a paucity of research into the ethical, legal and social implications of nanotechnology and they caution that ethical reflections on nanotechnology lag behind the fast developing science.

The present article questions their conclusion, pointing out that the predicted concrete ethical issues related to the field of nanotechnology are rather similar to the ethical considerations related to the field of biotechnology and biology. Furthermore, the ethical challenges of these fields have been considered by researchers within the area of ethics and by ethical boards since the establishment of the academic discipline of bioethics during the 1970s and 1980s. Hence, the fact that only few articles dealing specifically with the ethical issues of nanotechnology have been published so far, does not imply that the discussion of concrete ethical issues in the field has to start from scratch. A knowledge base has already been acquired from the ethical reflections on biotechnology and biology, which may be a good starting point and foundation for a discussion of ethical reflections on nanotechnology.

In addition, it is argued in this article that a promising approach to the ethics of nanotechnology is so-called ›principlism‹, i.e. the claim that a limited number of basic ethical principles is generally accepted. By considering the use of nanorobots (nanobots) for detection of early disease and the delivery of therapeutic agents, it is shown how the bioethical theory of principles by the two American ethicists Tom L. Beauchamp and James F. Childress can be applied to ethical issues of nanotechnology.

The last part of this article focuses on the societal implication of nanotechnology. A large number of reports on strategies for research into nanotechnology stress the importance of perceiving nanotechnology research in relation to the society in which it is to be implemented. It appears from European and American reports that particular effort is devoted to integrating the humanities and the social sciences into the interdisciplinary approach to nanotechnology. The overall objective is to gain the general public's acceptance of nanotechnology in order not to provoke a consumer boycott, as it happened with genetically modified (GM) food products. It is stated implicitly in the reports that this accept depends on the public's confidence in the technology and that the confidence is created on the basis of information, education, openness and debate. However, researchers and empirical studies point out that information and education are not the only factors influencing the public attitudes towards new technology. In the public mind, risk also involves moral considerations, democratic considerations and uncertainties. Several of these aspects belong to the research areas of the humanities and the social sciences.

This article objects that it is a narrow apprehension of the role of the humanities and the social sciences to focus exclusively on creating trust in and acceptance of nanotechnology in the general public. The humanities and the social sciences have a critical function making a critical assessment of new technology so that the public may make an *informed judgement*. Moreover, the motive for integrating the humanities and social sciences may be to establish interdisciplinary research environments enabling a daily dialogue between for instance ethicists and nanotechnologists facilitating ethical reflection as an integral part of the research process.

Ethics in nanotechnology

Must the ethical discussion of nanotechnology start from scratch?

The Canadian research group at the University of Toronto Joint Centre for Bioethics is undoubtedly right in their claim that few articles have been published so far specifically on ethical issues of nanotechnology (Mnyusiwalla et al., 2003). However, in those published the ethical issues of nanotechnology fall into three groups (Table 1): *Risk problems* (a–d), *privacy problems* (e–f) and *problems of transhumanism* (g–h). None of these can be regarded as unknown hitherto. Risk and privacy problems are addressed within a number of areas. Transhumanism, indicating a transgression of the limits of the human, is a rather new concept, but it is not totally unknown either. In order to show that the potential ethical problems of nanotechnology are not new and unique, this article points to parallels within the fields of biotechnology and biology that have been widely analysed.

Parallels drawn to currently considered ethical issues:		The literature mainly focuses on the hypothesis that the introduction of nanotechnology could lead to:
Uncontrolled spread of GM crops and toxicity of asbestos	a)	Prospects of runaway proliferation of self-replicating nanosystems *Ethical issues: Risk-benefit analysis, beneficence, nonmaleficence*
	b)	Uncontrolled function of nanorobots (nanobots) *Ethical issues: Risk-benefit analysis, beneficence, nonmaleficence*
	c)	Possible toxic nature of nanoparticles dispersed in the environment *Ethical issues: Risk-benefit analysis, beneficence, nonmaleficence*
Terrorist attack September 11th (anthrax powders)	d)	Biological warfare and terrorism *Ethical issues: Risk-benefit analysis, beneficence, nonmaleficence*
Cell phones and internet 24 hours a day	e)	Invasion of privacy as a result of improved communication capabilities *Ethical issues: Respect for autonomy and integrity*
	f)	Invasion of privacy as a result of dispersed nano-sensing structures (e.g. microphones) in the environment *Ethical issues: Respect for autonomy and integrity*
Genetic enhancement (gene therapy)	g)	Enhancement of human capabilities *Ethical issues: What is a human being?*
	h)	Transhumans caused by the incorporation of nanostructures and nanomachines in the human body. How many nano-prosthesis will make you non-human? *Ethical issues: What is a human being?*

Table 1. Parallels drawn between currently analysed ethical issues and ethical issues of nanotechnology pointed out in the literature (Rickerby, 2004; Robison, 2004; NSF, 2001; Gorman, 2004; Satava, 2002; Drexler, 1986).

As to *risk problems* one can draw parallels between the fear of the uncontrolled spread of GM crops and the prospects of runaway proliferation of self-replicating nanosystems (a) and the uncontrolled function of nanorobots (b). The discussion of the possible toxic nature of nanoparticles (c) can be compared with the discussion of the toxicity of asbestos which has run for years. The fear of biological warfare and terrorism caused by nanotechnology (d) is not only a future issue but of current interest, especially since the terrorist attack on the US September 11th 2001 and the subsequent mail deliveries of anthrax powders.

On the matter of *privacy problems*, the fact that nanotechnology could lead to an invasion of privacy as a result of improved communication capabilities (e) is a currently discussed issue, as people can be reached by cell phones and internet connections 24 hours a day. But, of course, the ethical problem of invasion of privacy could grow if nanotechnology leads to the spread of spying nanomicrophones in the environment (f).

As to *problems of transhumanism*, one can draw a parallel between the ethical issues of the enhancement of human capabilities and *transhumans* caused by nanotechnology (g, h) and the issue of genetic enhancement. Since the first experiments of gene therapy in cell cultures during the 1980s, ethicists have warned that gene therapy may lead to the enhancement of normal characteristics in contrast to treatment of disease.

In light of the parallels drawn between ethical issues of nanotechnology and ethical issues of biotechnology and biology, a survey of three scientific databases was made – ›ISI Web of Science‹, ›PubMed‹ and ›Philosopher's Index‹. The data demonstrates a general pattern of an average increase during the last 20 years in the number of publications on ethical aspects of genetics, biotechnology and environment which parallel ethical issues of nanotechnology. This means that a reasonably sound knowledge base has already been acquired in the field of bioethics that can be extended to nanotechnology. There is no reason the ethical discussion of nanotechnology should not gain from this knowledge base acquired from previous ethical reflection on biotechnology and biology.

In short, this section concludes that the fact that only a few articles dealing specifically with ethical reflections of nanotechnology have been published so far does not imply that the ethical discussion of nanotechnology needs to start from scratch. Nanotechnology can draw on matters already considered by researchers within the area of ethics and by ethical boards since the establishment of the academic discipline of bioethics during the 1970s and 1980s.

General ethical principles at stake

In this section it is argued that a promising approach to the ethics of nanotechnology is so-called ›principlism‹, i.e. the claim that a limited number of basic ethical principles is generally accepted. It is shown that regarding the ethically relevant features of nanotechnology mentioned above (*risk problems, privacy problems,* and *problems of transhumanism*) the general ethical principles about respect for autonomy and integrity and beneficence, nonmaleficence and justice are at stake (Table 1). Several examples will illustrate this.

The first example is the fear that the dispersion of nano-sensing structures (e.g. microphones) in the environment may lead to an invasion of privacy (Table 1, f). Behind the ethical issue of respect for privacy is a general ethical principle that the autonomy and integrity of humans ought to be respected. Autonomy means self-determination, and, as an ethical principle, the respect for autonomy means that in questions concerning his/her own life each individual has the right to make his/her own decisions. The ethical principle of respect for integrity is closely related to respect for autonomy and means a person's sphere of experiences, of information, and of self-disclosure, etc. should not be intruded upon under normal circumstances. It makes sense to speak of respect for integrity especially in the case of human beings who are not able to exercise autonomy. This could be the case for toddlers, drug-dependent patients, persons who are senile or mentally troubled, etc. The principle of respect for integrity means, then, that prima facie no-one has the right to access information that is intimately linked to the life and identity of a human being.

Another illustration is the prospect of runaway proliferation of self-replicating nanosystems (Table 1, a) and the spread of possible toxic nanoparticles in the environment (Table 1, c). In light of such a prospect one ought to perform a risk assessment. On this matter, the American bioethicists Tom L. Beauchamp and James F. Childress show that the moral evaluation of risk in relation to probable outcomes can have the character of *risk-benefit analysis.* They use the definition of ›risk‹ as possible future harm, where ›harm‹ is defined as a setback to interests, particularly in life, health and welfare (Beauchamp & Childress, 2001: 195, 199). In the field of biomedicine, the term ›benefit‹ commonly refers to something of positive value, such as life or health. Risk-benefit relations may be conceived in terms of a ratio between the probability and magnitude of an anticipated benefit and the probability and magnitude of an anticipated harm (Beauchamp & Childress, 2001: 195). The terms ›harm‹ and ›benefit‹, as defined above, are ethically relevant to nanotechnology since ethical obligations or principles are generally accepted against inflicting harm (nonmaleficence) and promoting good (beneficence) (Beauchamp & Childress, 2001: 4).

It should be evident, also, that there are societal implications at stake in relation to nanotechnology. These include issues such as the prioritising and commercialisation of science, public trust and transparency and the question of who should gain from nanotechnology. For instance, do we have a responsibility for sharing this technology with developing countries? Clearly, the ethical principle of justice is at stake.

As most ethicists will recognize, these general principles – respect for autonomy (and integrity), beneficence, nonmaleficence, and justice – are part of the bioethical theory developed by Beauchamp and Childress. They published their theory for the first time in 1979 in the work *Principles of Biomedical Ethics*. The general ethical principles mentioned above have been used for years for analysing ethical issues in the field of biomedicine. Thus even though only a few specific articles have been published on ethical issues of nanotechnology, it does not mean that we need to start from scratch with the ethical discussion of nanotechnology. The analysis above shows that nanotechnology does not demand a new kind of ethics and we don't need new ethical principles such as ›nanobeneficence‹, old-fashioned beneficence should suffice as one general ethical principle among others. In short, the problems nanotechnology raises seem, so far, to be analogous to well-known problems raised by biotechnology and biomedicine, so that the problems of ›nanoethics‹ can be dealt with in the framework of bioethics.

The use of Beauchamp and Childress' bioethical theory of principles to analyse ethical issues of nanotechnology

As mentioned above, Beauchamp and Childress have formulated a theory based on four basic principles. These principles are respect for autonomy, beneficence, nonmaleficence and justice. According to Beauchamp and Childress, no principles rank higher than others. It is context-dependent which principles are set-aside in the actual situation. Beauchamp and Childress consider these principles *prima facie binding*, i.e. they must be fulfilled unless they conflict on a particular occasion with an equal or stronger principle. This type of principles is always binding unless a competing moral obligation overrides or outweighs it in a particular circumstance. According to Beauchamp and Childress: »Some acts are at once prima facie wrong and prima facie right, because two or more norms conflict in the circumstances. Agents must then determine what they ought to do by finding an actual or overriding (in contrast to prima facie) obligation« (Beauchamp & Childress, 2001: 14). Thus, the agents must locate the greatest balance of right and wrong.

In the fifth edition of their book *Principles of Biomedical Ethics* (2001), Beauchamp and Childress describe how to specify the principles (Beauchamp & Childress, 2001: 15–19). Furthermore, Ben Mepham (1996) has developed a practical way of applying Beauchamp & Childress' theory termed an ›ethical matrix‹. This approach describes how to move from the general level of the principles to the level of practical questions (Kaiser, 2005).

However, Beauchamp and Childress have been criticised for the lack of a concrete rule on how to balance the principles if they conflict (DeGrazia, 1992). Soeren Holm (1995) claims that Beauchamp and Childress' method is unable to give solid answers to problems of morality. He states that by the method of principles we can get precisely the answer we want. Holm accuses the balancing method of being intuitive and subjective (Holm, 1995). In the third edition of their book *Principles of Biomedical Ethics* (1989), Beauchamp and Childress are aware of the problem of balancing and they specify conditions that should be fulfilled in order to allow one prima facie principle to weigh more than another. They write:

»The following are all requirements for justified infringements of a prima facie principle or rule:

1 the moral objective justifying the infringement must have a realistic prospect of achievement;
2 infringement of a prima facie principle must be necessary in the circumstances, in the sense that there are no morally preferable alternative actions that could be substituted;
3 the form of infringement selected must constitute the least infringement possible, commensurate with achieving the primary goal of the action; and
4 the agent must seek to minimize the effects of the infringement« (Beauchamp & Childress, 1989: 53).

To follow these directions purely by intuition would hardly be possible. In the fifth edition of *Principles of Biomedical Ethics* (2001), Beauchamp and Childress sharpen the conditions that must be fulfilled in order for one prima facie principle to outweigh another. Among others, they add the following premise: »The agent must act impartially in regard to all affected parties; that is, the agent's decision must not be influenced by morally irrelevant information about any party« (Beauchamp and Childress, 2001: 20).

An example of the application of Beauchamp and Childress' ethical principles to analyse ethical issues of nanotechnology could be an ethical assessment of the use of nanobots for detection of early disease and the delivery of therapeutic agents. The visions are that nanobots may be able to seek out a target within the body (for instance a cancer cell) and perform treatment. The treatment delivered by the nanobots may be that of releasing a drug in a localized area, thus minimizing the potential systemic side effects of generalised drug therapy as for instance chemotherapy (Satava & Wolf, 2003; Satava, 2002; Haberzettl, 2002). Although some of these nanosystems may be manufactured, many may need to be created by self-assembly, analogous to the manner in which the human body ›self-assembles‹, i.e. puts itself together in prescribed architecture in a naturally driven process (e.g. cells self-assemble into organs). The scientific challenge will then be to control these processes (Satava & Wolf, 2003; Satava, 2002). Since many macromolecules do not diffuse readily through tissues, delivery systems have to be designed to shuttle the therapeutic agents to the target sites. Some of the target sites such as the brain and solid tumors have unique physiologic barriers to drug delivery which have to be overcome before the therapeutic agents can reach their targets (Li et al., 2004). Thus targeting mechanisms must be incorporated into the nanobot. These targeting mechanisms may include the potential of detection of physiological changes in environment of the nanobot which triggers the desired action (the treatment). Such mechanisms are likely to include the use of nanoscale biosensors and other sensing or detection mechanisms which may also be used as diagnostic tools (Haberzettl, 2002). A nanosensor used as diagnostic tool or drug deliverer could for instance be a sensor being able to detect biological changes due to tumour development and metastasis indicated by increased production of proteolytic enzymes or loss of expression of for example the epithelial cell-cell adhesion molecule E-cadherin. Thus rather than indiscriminate destruction in a large area or systemically as is done in chemotherapy, the results of targeted drug delivery may be the delivering of drugs with ultrahigh precision to specific organs, tissues and cells (Satava & Wolf, 2003). However, drug delivery in general is not trivial and much research needs to be performed in this field.

Haberzettl (2002) points out that nanobots used in drug delivery may get ›out of control‹ in the absence of feedback mechanisms to control their function. To take this into account, it may be a possibility to develop nanobots, which are biodegradable or composed of naturally occurring substances which can be eliminated from the body through natural mechanisms of metabolism and excretion. Alternatively, nanobots could have ›homing‹ devices, which would allow them to be collected and removed after performing the desired function (Haberzettl, 2002).

If nanobots are going to be used in the future for the detection of early disease and the delivery of therapeutic agents, one ought to balance the risks of maleficence caused by the nanobots getting ›out of control‹, the possible beneficence obtained by the treatment of serious disease and the respect for the autonomy of the patient. As an ethical principle, the respect for autonomy means that in questions concerning his/her own life each individual has the right to make his/her own decisions. Hence the ethical considerations of nonmaleficence, beneficence and respect for autonomy are in conflict and the agents most consciously determine which considerations should have more weight. It should be noted, however, that in addition to the ethical principles pointed out above, the ethical principle of justice plays a role at the level of health policy formation.

Societal implications of nanotechnology

The humanities and social sciences as a means of gaining public acceptance

It appears from European as well as American reports that particular effort is devoted to integrating the humanities and the social sciences into the interdisciplinary approach to nanotechnology. The overall objective is to gain the general public's acceptance of nanotechnology in order not to provoke a consumer boycott, as it happened with GM foods (NSF, 2001: 63; Royal Netherlands Academy of Arts and Sciences, 2004: 27). It is stated implicitly that this accept depends on the public's confidence in the technology and that the confidence is created on the basis of information, education, openness and debate. Thus, in a European report it says:

»Without a serious communication effort, nanotechnology innovations could face an unjust negative public reception. An effective two-way dialogue is indispensable, whereby the general public's views are taken into account and may be seen to influence decisions concerning R&D[1] policy. The public trust and acceptance of nanotechnology will

1 Research and Development (R&D).

be crucial for its long-term development and allow us to profit from its potential benefits. It is evident that the scientific community will have to improve its communication skills« (European Commission, 2004b: 19).

An American report states that the integration of researchers within the humanities and social sciences can establish a dialogue between nanotechnologists and the public. According to the report, this dialogue will assist in maximising the social benefits of the technology and in minimising the risk of debilitating public controversies:

»The inclusion of social scientists and humanistic scholars, such as philosophers of ethics, in the social process of setting visions for nanotechnology is an important step for the NNI[2]. As scientists or dedicated scholars in their own right, they can respect the professional integrity of nanoscientists and nanotechnologists, while contributing a fresh perspective. Given appropriate support, they could inform themselves deeply enough about a particular nanotechnology to have a well-grounded evaluation. At the same time, they are professionally trained representatives of the public interest and capable of functioning as communicators between nanotechnologists and the public or government officials. Their input may help maximize the societal benefits of the technology while reducing the possibility of debilitating public controversies« (NSF, 2001: 15).

In the American report, it is mentioned that informing the public is not enough; the public have to be educated to perceive the advantages of nanotechnology (NSF, 2001: 100–101). Thus, it is assumed that informing and educating the public will create trust and consequently an acceptance of nanotechnology. In that way, according to the American report, research into the societal implications of nanotechnology will boost the success of nanotechnology, and hence it will be possible to take advantage of the benefits of nanotechnology sooner, more effectively and with greater confidence (NSF, 2001: 2). Hence, it is not assumed that information about nanotechnology may lead to scepticism. The public must perceive and be convinced of the benefits of the introduction of nanotechnology. No importance is attached on the public's informed judgment. However, a few EU reports assume the citizen's right to informed judgement. But in these reports it is also stressed that educating people in science and technology must be prioritised in order to obtain this informed judgement:

»The Commission's strategy: Promote scientific and education cul-

2 National Nanotechnology Initiative (NNI).

ture in Europe. First of all, people must become more familiar with science and technology […]. The Commission is committed to improving transparency and consultation between administrations and civil society […]. If citizens and civil society are to become partners in the debate on science, technology and innovation in general […] it is not enough simply to keep them informed. They must also be given the opportunity to express their views in the appropriate bodies […]. They aim to provide a space for scrutiny and informed debate on important issues of public concern, bringing together the public, interest groups and policy makers […]. The Commission will organise regular events enabling civil society to participate (in the form of public hearings, consensus conferences or interactive online forums)« (European Commission, 2004a: 7–18).

However, researchers point out that information and education are not the only factors influencing the public attitudes towards new technology. Returning to the Europeans' sceptical attitude towards GM foods, there is disagreement whether the scepticism is exclusively due to lack of information and education. If we first look at the results of the so-called Eurobarometer survey on the European's attitudes towards GM crops and GM foods, it shows an increasing scepticism from 1996–1999 about GM crops (a rise from 20% to 32%) and about GM foods (a rise from 39% to 52%), respectively. In contrast, the figures were relatively stable from 1999 to 2002. However, regarding the application of biotechnology in medical science, the Europeans' attitudes were very positive in 2002: E.g. only 9% were opposed to genetic testing and 17% to cloning of human cells (European Commission, 2003). Hence, the general public's attitudes varied according to the specific biotechnological application. Applications within the plant and food area were assessed considerably more negatively than applications in the field of medicine. The ethicist *Bryn Williams-Jones* from the University of Cambridge writes:

»Indeed, there tends to be widespread positive public regard for technologies that appear to have a clear benefit and minimal or at least well understood risks (e.g. biotechnologies that improve health care, such as genetic diagnostics or bio-pharmaceuticals). But when the benefits are dubious and the risks are potentially very serious and not well understood, as in the case of GM foods, then the public as consumer of new technologies may be very wary. The lesson for a nascent filed such as nanotechnology – in which there are as yet few applications, but which is receiving billions of dollars of public monies – is that there must be broad and genuine public engagement in determining the scope and possible futures for this field« (Williams-Jones, 2004).

The Eurobarometer surveys, which are based on responses from app. 1000 individuals in each EU country, depict how different perceptions of biotechnology are distributed among the population on EU level and within the individual countries. However, these quantitative investigations are not sufficient to explain *why* the general public responds the way it does. As mentioned, the reports on research into nanotechnology blame the general public's lack of knowledge of new technology for the boycott of GM food products (Royal Netherlands Academy of Arts and Sciences, 2004: 27). Taking the studies on the Europeans' knowledge of GM crops and GM foods into consideration, it is fair to point out the lack of knowledge, for instance 64% of the European population believed that GM tomatoes contain genes as opposed to ordinary tomatoes (European Commission, 2003). However, science sociologist *Claire Marris* emphasises that studies have shown that a greater insight into GM organisms does not necessarily lead to a more positive attitude; on the contrary, it makes the public more sceptical and polarised (Marris, 2001; Sjoeberg, 2004). Marris (2001) dismisses it as a myth that persons who are against GM foods are irrational, and that they would accept GM foods if they knew more about biotechnology. In the debate on GM crops there has been much focus on the public's confidence in the experts. The argument goes that without confidence in the experts the public will misunderstand risks and uncertainties. The public will then be persuaded by the opposing organisations using eye-catching headlines. Consequently, risk communications by trusted experts has long been offered as the solution to public scepticism (Gaskell et al., 2003). A Swedish study shows that confidence in experts only plays a small role regarding the public perception of risk. Topics like ›intervention in nature‹ and moral considerations generally mean a lot more (Sjoeberg, 2004). Researchers claim that the European population's perception of risk in connection with GM foods is much broader than the technical-scientific perception communicated by experts. In the public mind, risk also involves moral considerations (is it right doing this?), democratic considerations (who is funding and controlling biotechnology?) and uncertainties (will there be as yet unknown adverse consequences?) (Gaskell et al., 2003). This is also the conclusion of a Danish qualitative investigation made in year 2000 based on focus group interviews. The overall picture shows that the arguments advanced in the discussion on biotechnology primarily relate to two types of utility: Utility in terms of society and utility in terms of economy. Utility in terms of society concerns solving problems like famine and environmental problems, curing diseases and relieving pain. The economic utility arguments concern business economic motives and biotechnology as a source of increased material wealth. Most often, the societal utility was considered a legitimate argument for the application of biotechnology, whereas business economic motives were used as arguments against the application of biotechnology. As mentioned, risk has often been limited to dealing with harmful effects on human health or the environment. The interviewees assessed the risk more broadly, including considerations on the possible violation of the order of nature, violation of the eigenvalue of nature and of God's creation. The respondents also mentioned power relations, democratic rights and the possible application of biotechnology to prevent poverty in developing countries (Lassen & Jamison, 2006; Tveit et al., 2003: 9–14). The referred studies indicate that viewed from a traditional (technical-scientific) risk assessment perspective, the use of new technology may be unproblematic. However, the application of the new technology may yet still be rejected by the public due to social, economic, ethical and political aspects.

European and American reports on research into nanotechnology focus on educating the public in the scientific and technical aspects of nanotechnology (European Commission, 2004a: 7–18; Royal Netherlands Academy of Arts and Sciences, 2004: 27; NSF, 2001: 142). However, the studies referred to above on the public attitude in Europe towards GM foods and biotechnology in general indicate that social, economical, ethical and political dimensions of implementation of new technology are important to the public. A lesson to be learned from the introduction of GM foods in regard to the implementation of nanotechnology may hence be that information to the public on nanotechnology should encompass more aspects than specific technical-scientific facts. It should deal with political, sociological and ethical aspects of nanotechnology.

The critical function of the humanities and social sciences

As described above, it appears from reports on nanotechnology that the role of the humanities and social sciences is to maximise the societal advantages of nanotechnology, boost nanotechnology and reduce the possibility of debilitating public controversies. This entails e.g. that ethics is reduced to a tool or a means to an instrumental end, which can be expressed as a reduction of ethics to a PR agent for the laboratory. I object that this is a narrow apprehension of the role of the humanities and the social sciences to focus on creating trust in and acceptance of nanotechnology in the general public. The humanities and the social sciences have a critical function. To illustrate this viewpoint one can argue that the function of philosophy and ethics regarding the implementation of any kind of new technology is to ask the fundamental questions such as: What impact will this new technology have on humanity? What is a good life? Will this new technology bring a realisation of a good life? What kind of society do we want? How does this new technology relate to that kind of society? The aim of posing these questions is not to build trust and acceptance in the public, but to make a critical assessment of new technology so that the public may make an informed judgement. This critical assessment does not have to be a negative one. Ethics is not only a demarcator saying thus far and no further. Instead, ethics may be viewed as a co-player firstly discussing the needs and goals of the public and society, and secondly serving as a framework to guide society towards these goals. As for nanotechnology, it should be contemplated which goals we wish to obtain by means of technology. Is it the goals stated in the reports on nanotechnology research strategies? Or is it totally different goals? To mention a specific example, some reports state that the aim of research into nanotechnology is to improve human quality of life (European Commission, 2004b: 1). But what does it mean to improve human quality of life? An American report claims that the answer lies in the improvement of human capabilities and performance while at the same time respecting fundamental values:

»At this moment in the evolution of technological achievement, improvement of human performance through integration of technologies becomes possible. Examples of payoffs may include improving work efficiency and learning, enhancing individual sensory and cognitive capabilities, revolutionary changes in healthcare, improving both individual and group creativity, highly effective communication techniques including brain-to-brain interaction, perfecting human-machine interfaces including neuromorphic engineering, sustainable and ›intelligent‹ environments including neuro-ergonomics, enhancing human capabilities for defence purposes, reaching sustainable development using NBIC[3] tools, and ameliorating the physical cognitive decline that is common to the aging mind […] The aim is to offer individuals and groups an increased range of attractive choices while preserving such fundamental values as

3 Nanotechnology, Biotechnology, Information Technology and Cognitive Science (NBIC).

privacy, safety, and moral responsibility« (NSF/DOC, 2002: ix-x).

Ethics could contribute to a reflection on whether improving human quality of life really equals improving its capabilities and performance, and in the first place whether it is possible to improve human subjects without compromising fundamental ethical values.

The above may be an idealisation of the role of ethics regarding the introduction of nanotechnology. Maybe in reality, nanotechnologists are most likely to include an ethical dimension in their research projects, since it is required in their applications for research funding. However, ethics should take advantage of the fact that there is a market for ethics regarding the current research into nanotechnology; ethics should take advantage of the fact that it can be voiced and heard. The ethicist must then retain his or her critical sense and provide the society with impartial information on nanotechnology.

The overall motive for integrating the humanities and social sciences in the interdisciplinary co-operation on nanotechnology is not necessarily restricted to gaining public trust and acceptance of nanotechnology in order to prevent a boycott of the technology as it happened with GM foods. The motive may also be to reflect on fundamental questions such as: What is the objective of introducing the application of nanotechnology and how are these objectives met in an ethically responsible way. Moreover, the motive for integrating the humanities and social sciences may be to establish interdisciplinary research environments enabling a daily dialogue between ethicists and nanotechnologists. This may facilitate ethical reflection as an integral part of the research process.

Conclusion

By considering predicted concrete ethical problems of nanotechnology this article points out that the ethical challenges of nanotechnology are very similar to the ethical challenges of biotechnology and biology, and that the ethical problems of these fields have been analysed by researchers within the area of ethics and by ethical boards since the establishment of the academic discipline of bioethics during the 1970s and 1980s. The reflections in the article suggest that even though only few articles dealing specifically with the ethical issues of nanotechnology have been published so far, it does not imply that the discussion of concrete ethical issues has to start from scratch since a knowledge base has already been acquired from the ethical reflections on biotechnology and biology. This knowledgebase may be a good starting point and foundation for a discussion of ethical reflections on nanotechnology.

Furthermore, it is argued that a promising approach to the ethics of nanotechnology is so-called ›principlism‹, i.e. the claim that a limited number of basic ethical principles are generally accepted. It is shown how the bioethical theory of principles by Beauchamp and Childress can be applied to ethical issues of nanotechnology by considering the use of nanobots for detection of early disease and the delivery of therapeutic agents.

The last part of the article focuses on the societal implications of nanotechnology. By considering American and European reports on strategies for research into nanotechnology the article points out that the overall objective to integrate the humanities and the social sciences into the interdisciplinary approach to nanotechnology is to gain the general public's acceptance of nanotechnology in order not to provoke a consumer boycott, as it happened with GM foods products. However, this article objects that it is a narrow apprehension of the role of the humanities and the social sciences to focus on creating trust in and acceptance of nanotechnology in the general public. The humanities and the social sciences have a critical function regarding the implementation of new technologies which for instance encompasses asking fundamental questions such as: What impact will this new technology have on humanity? What is a good life? Will this new technology impact the realisation of a good life? The aim of posing these questions is not to build trust and acceptance in the public, but to make a critical assessment of new technology so that the public may make an informed judgement.

Ethics may be viewed as a co-player firstly discussing the needs and goals of the public and society, and secondly serving as a framework to guide society towards these goals. The motive for integrating the humanities and the social sciences may also be to create interdisciplinary environments, where for instance ethicists and nanotechnologists are in daily dialogue facilitating ethical reflection as an integral part of the research process of nanotechnology.

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