PUBLIC ADVICE ON THE DEVELOPMENT OF NANO*BIO*TECHNOLOGY

FINAL REPORT OF FOUR EUROPEAN CONVERGENCE SEMINARS

WORKPACKAGE 3, NanoBio-RAISE

ROYAL INSTITUTE
OF TECHNOLOGY

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November, 2007

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Acknowledgements

First of all the authors wish to thank all the participants who engaged in the convergence seminars. Needless to say, this report is a sheer product of the interest and careful deliberation that they devoted to the seminars. Nor would this project have been possible without the outstanding group of people and organisations who in various ways helped administer contacts, organise, facilitate and structure the seminars: NanoBio-RAISE Steering Group committee; Dr David Bennett; Daan Schuurbiers; TU Delft; Mikael Karlsson, The Swedish Society for Natural Conservation; University of Gotland; Nicola Godman; Guy Thompson; Dr Robert Doubleday; Sheffield Institute for Biotechnological Law and Ethics; Dr Misse Wester Herber; Susanne Sleenhoff; Dr Radoslaw Janicki; Nanotechnology Centre, Maria Curie – Sklodowska University; Institute for Molecular and Cell Biology (IBMC). As the main organisers at respective seminars we would like to especially thank Dr Karin Bengtsson, AnnCatrin Hjernquist, Dr Mike Adcock, Professor Karol Izydor Wysokinski, Dr Anna Olsson, Ana Paula Pêgo and João Diogo Silva.

We would also like to thank the group of advanced ethics students at KTH with whom we ran a trial session of the NanoBio-RAISE seminar in April 2006. For necessary input on the scenarios used in seminars, we are indebted to the insights and advice of our colleagues in NanoBio-RAISE, Daan Schuurbiers, Dr David Bennett, as well as Dr Henrik Carlsen and Erik Göransson. Finally for the help with final report we are again very grateful for extensive comments made by our NanoBioRAISE colleagues at TU Delft. Finally the report profited from the suggestions made by participants at the ethics graduate seminar at KTH in April and at the NanoBioRAISE Steering group meeting in Delft in November, 2007.

NanoBio-RAISE is a 6th Framework Programme Science & Society Co-ordination Action funded by the European Commission. We gratefully acknowledge the support.

1. Summary

In order to explore public views on nanobiotechnology (NBT) and clarify the potential ethical issues emerging from their development, convergence seminars were performed in four places in Europe; namely in Visby (Sweden), Sheffield (UK), Lublin (Poland), and Porto (Portugal). A convergence seminar is a new form of public participatory activity that involves structured decision-guiding discussions. The initial discussion was arranged to ensure serious consideration of several possible future developments, followed by a comparative discussion about what could be learnt from each of these possibilities.

The seminars took between 2 ½ and 3 hours, and consisted of three phases. In the first phase, the participants were divided into three "scenario groups", each of which was assigned the task of discussing a scenario of developments up to the year 2020. One of the groups was assigned a scenario that focused on the competitive disadvantages for Europe if the development of NBT were to be severely restricted (while major non-European countries reap great economic advantages of NBT). The second group had a scenario that focused on potential medical uses of nanotechnology together with the accompanying equity issues, side effects and misuses. The third group's scenario focused on the use of NBT in diagnostics and surveillance with potential infringements on privacy and freedom of choice. Based on their respective scenarios, the participants were asked to discuss what decisions should be made in the near future about NBT.

In the second phase, the participants were regrouped into three "convergence groups", each of which contained representatives from each of the three groups from the first phase. To begin with, they told each other about their respective scenarios and the conclusions drawn in their scenario group. After that, they discussed what could be learned from comparing the scenarios and what advice they would like to give decision-makers.

In the third phase, all participants met. Each convergence group gave a brief summary of their discussions and recommendations, and then the recommendations were discussed in the whole group. Contrary to the two previous phases, the third phase was audio-recorded. The documentation from the seminars consisted in these recordings and a questionnaire filled in at the end of the third phase by all participants.

1.1 Participants' policy recommendations

The following list summarizes the recommendations where there was a close to complete agreement amongst the participants when asked what advice they wished to give policy-makers deciding on the development NBT. See section 5 and 6 for a complete account of the advice given at the four convergence seminars.

- Decide on research priorities that target crucial needs in society. For instance, socially useful applications that target global environmental problems and benefit human health should be prioritised over novel consumer products and military applications.

- Research should generate applications that truly benefit the developing world, thereby contributing to decreasing rather than increasing the gap between countries.

- Research should be directed toward finding solutions for the less privileged part of the population within wealthy countries.

- Create a variety of forums for debate and discussion of NBT in order to promote the curiosity of the public.

- Encourage different actors (researchers, policy-makers, industry, media) to take responsibility for public engagement *at all stages* of the development, but ensure that the public receives unbiased information.

- Develop programmes for international cooperation across both research and regulation of NBT. Focus the international cooperation on mutually important problems, such as combating global climate change.

- Involve a range of researchers from different scientific disciplines in the NBT development. Do not conceive of NBT as a strictly technological or industrial venture.

- Prepare for a debate on arising controversial issues of privacy, freedom of choice, enhancement and distributive justice in medical applications of NBT.

1.2 Key findings

- Facing an emerging and uncertain technology such as NBT a major consideration is the existing level of trust the public has in institutions, industry and policy-makers. Participants made comparisons with recent experiences with other technological and commercial developments where they felt that the objectives to create a cheap and accessible technology had not been realised.

- Many important ethical issues are not necessarily ones that arise in the mid- to long-term stages of the NBT development. The discussions in fact showed that the participants' chief concerns lay rather in the earlier stages of the development, for instance in deciding on research priorities and regulation.

- Further public participation on social and ethical issues of NBT was unanimously encouraged. A broader public influence over the technological development was supported in its own right, but it was also advocated as a necessary step in avoiding (additional) public alienation or backlashes, and in enabling NBT to be beneficial to different members of society.

- Views were divided on how much regulation is needed to curb unwanted developments. Some participants believed that early regulation is necessary as it deters unwanted applications. Others argued that regulation (and bureaucracy) is important as it at least delays the development, thereby allowing for more insight into long-term impacts and side effects. In contrast some said that over-regulation and excessive precaution were a problem because it implied a loss of potential benefits and would also generate (economic) unbalances if certain countries went ahead with less regulation. A common feature in all responses was the recommendation to make the regulatory bodies robust to meet the demands of novel technologies.

- As a methodology for facilitating a forum for decision-making under uncertainty the convergence seminars were by and large successful. The responses the participants gave in the discussions and questionnaires indicated that their advice on what decisions should be made about the NBT development was influenced both by different possible future developments and also the point of view of different individuals.

2. Background to the project

Nanobiotechnology (NBT) is an emerging field of research where nanoscience and biotechnology play the principal roles. Most of this research is considered to be still in an embryonic phase but in the mid- to long-term perspective NBT is expected to have major consequences not only for medicine and diagnostics, but also for ICT, agriculture, food production, energy production, and environmental remediation.

We arranged these convergence seminars as part of a European research project, Nanobiotechnology: Responsible Action on Issues in Society and Ethics, (NanoBio-RAISE), funded as a 6th Framework Programme Science & Society Co-ordination Action. NanoBio-RAISE recognises the need to address the social and ethical issues emerging from the development of NBT through organising a wide range of activities such as an expert working group, horizon-scanning workshops, briefing papers and lectures as well as ethics and public communication courses for nanobiotechnologists.

A central aim of the project is to engage the broader public in discussing and clarifying the potential ethical and societal issues of NBT. To this effect, the Philosophy Division at the Royal Institute of Technology (KTH) in Stockholm conducted four public opinion focus group seminars in 2006. Although many public engagement activities on nanotechnology have been arranged in the past few years[1], our project was one of the first that explicitly focused on nano*bio*technology and its potential applications. Moreover, while most other public engagement exercises have been confined to a specific country or region, our seminars were held at four different venues in four distinct cultural regions of Europe: in Visby (Sweden), Sheffield (UK), Lublin (Poland), and Porto (Portugal). For our focus groups we chose to use a new model for public participatory activities called *Convergence Seminars* that is under ongoing development at the Royal Institute of Technology.

[1] Some of the most recent projects include the Nanodialogue (an Italian EC-project), Nanodialogues (from DEMOS), Nanologue (EU, 2005-06); Nanojury (UK, 2005); Global Dialogue on Nanotechnology and the Poor, GDNP, (U.S., 2004-05); Citizens' Attitudes Towards Nanotechnology Survey (Denmark, 2005); Melbourne Citizens' Panel on Nanotechnologies, (Australia, 2004); Deepening Ethical Engagement and Participation in Emerging Nanotechnologies, DEEPEN, (EU, 2006-09). For a recent valuable publication that summarises public engagement initiatives on nanotechnology see Karin Gavelin, Richard Wilson, and Robert Doubleday, *Democratic Technologies? The final report of the Nanotechnology Engagement Group (NEG),* June 2007. Available at: http://www.involve.org.uk/negreport

3. Theoretical background to the methodology

Convergence seminars are based on a theoretical approach to rational decision-making under risk and uncertainty, which has been described more in detail in a recent article by one of the authors.[2] Like many other philosophical ideas, it consists in the refinement and systematic application of a pattern of argumentation that is prevalent in non-philosophical discussions. One of the most common types of arguments about future possibilities consists in referring to how one might in the future come to evaluate the actions one takes now. These arguments are often stated in terms of predicted regret: "Do not do that. You may come to regret it." This is basically a sound type of argument. Decision-stability, in the sense that we continue to consider a decision correct after we have made it, is clearly a desideratum. Decision-making under risk and uncertainty will be improved if we seriously consider possible future developments. Therefore, such *hypothetical retrospection* can be used as a means to achieve more well-considered social decisions under uncertainty. Just as we can improve our moral decisions by considering them from the perspective of other concerned individuals, we can also improve them by considering alternative future perspectives.

However, hypothetical retrospection cannot be adequately accounted for in terms of regret-avoidance. Regret is often unavoidable for the simple reason that it may arise in response to information that was not available at the time of decision. In a systematized application of hypothetical retrospection, regret-avoidance has to be replaced by more carefully carved-out criteria.

In cases of risk and uncertainty there are, at each point in time, several alternative "branches" of future development. Each of them can be referred to in a valid moral argument about what one should do today. As a first approximation, we wish to ensure that whichever branch materializes, a posterior evaluation should not lead to the conclusion that one did (morally) wrong. In the article referred to above, it was proposed that an ideal procedure involving hypothetical retrospection should have the following characteristics:

- Each evaluation of a possible future development should refer to that branch of future development in its full length, up to the moment at which the retrospection is enacted. This means that the evaluation should not be restricted to the outcome but also cover

[2] Sven Ove Hansson, "Hypothetical retrospection" Ethical Theory and Moral Practice 10:145-157, 2007.

the *process* leading up to it. This is necessary to ensure that moral considerations that pertain to the rights and responsibilities of different parties are not programmatically excluded.

- Each such evaluation should refer to the decision in relation to the information (actually) available at the time when the decision was made, not the information (hypothetically) available at the time of the retrospection. This is because the decision-relevant moral argument is not of the form "Given what I now know I should then have..." but rather "Given what I then knew, I should then have..."

- Each such evaluation may refer to the need to be prepared for other branches of possible development. We do not today consider the decision to buy a fire extinguisher for our department five years ago to have been a wrongful decision, although we have had no use for it. For the same reason we should not have considered it wrong if, five years ago, we had evaluated it in a hypothetical retrospection of a scenario of five coming years without fire.

- Hypothetical retrospection should be performed with the moral values one has at the time when the actual deliberation takes place, not the values one predicts that one will have at the time at which the hypothetical retrospection is staged.

- Since it is not possible to investigate all possible branches of future development, a selection is necessary. The major criterion in that selection should be to identify for each alternative course of action, as far as possible, the branches in which the choice of this alternative will be most difficult to defend in hypothetical retrospection.

In a certain respect, hypothetical retrospection goes in the opposite direction of much current moral theory: it adds concreteness instead of abstracting from concrete detail. The concreteness gained through hypothetical retrospection has the advantage that our moral deliberations will be based on "the full story" rather than on curtailed versions of it. More specifically, this procedure brings to our attention interpersonal relations that should be essential in a moral appraisal of risk and uncertainty, such as who exposes whom to a risk or a danger, who receives the benefits from a risk exposure etc. It is only by staying off from such concreteness that standard utility-maximizing risk analysis can remain on the detached and depersonalized level of statistical lives and free-floating risks and benefits.

Discussions on the social effects of future nanotechnology are characterized by a generally very low level of knowledge and understanding among the broader public and a high degree of uncertainty both about the technology itself and about the ways social decisions on it are or might be structured. Hence, opportunities to apply quantitative analysis are rare in this area.[3] However, it does not follow from this that discussions on the effects of nanotechnology have to be reduced to a debate between technology optimism and technology pessimism. A more nuanced discussion can be achieved with the help of a reasonably balanced selection of scenarios. Therefore, nanotechnology is a subject-area in which scenario-based reasoning is particularly useful. This makes it an excellent testing-ground for the development of a systematic argumentation methodology that employs hypothetical retrospection.

[3] Sven Ove Hansson, "Great Uncertainty about Small Things", Techné 8(2), 2004.

4. Methods

4.1 The basic idea of convergence seminars

Convergence seminars have been constructed as a decision-aiding method that employs hypothetical retrospection. For that purpose, it is necessary to achieve the following two criteria:

(i) Several scenarios should be seriously discussed, each of which explores possible future consequences of decisions that we take now.

(ii) A comparative and concluding discussion takes place in which each of these scenarios is taken into account.

Furthermore, the methodology should be practically useful, so that it can be used for instance in evening meetings in voluntary organizations. This amounts to a third criterion:

(iii) The procedure should be easy to apply, and performable in a few hours.

In order to satisfy criterion (i), a set of concrete scenarios has to be developed for the discussions. These scenarios should be constructed in accordance with the requirements for hypothetical retrospection summarized above. Hence, they should bring us to some future point in time, but each scenario should lead us to a different "branch" of future development. Each scenario should describe in outline the respective branch in its full length, not only the "final" state at the point in time at which the hypothetical retrospection is enacted. The focus should be on some decision in the present or near-present time that the participants are asked to evaluate from the viewpoint of their scenario. Furthermore, the different scenarios should be selected so that they represent, for different alternative decisions, branches in which these decisions give rise to problems that make them difficult to defend in hypothetical retrospection.

Ideally a large number of scenarios should be included in the procedure. However, in order to satisfy criterion (iii), the standard procedure proposed and tried out for NanoBio-RAISE employs only three scenarios. For the same reason, participants are divided into groups and each scenario is discussed in detail by one group only. In order to satisfy criterion (ii), i.e. comparative analysis, this first phase of one-scenario discussions has to be followed by procedures in which participants from the different groups in the first phase exchange experiences. This is initially done in small groups that are formed by regrouping the participants

so that each new “convergence” group includes a representative from each of the scenario groups. In the third and final phase the participants are assembled for a concluding discussion about what advice the participants would like to give decision-makers who will decide on the development of NBT. The term “convergence” thus refers to the converging structure of this seminar model – not necessarily to convergence of opinion amongst the participants.

4.2 Schedule

The following schedule describes the procedure for the convergence seminar as used for NanoBio-RAISE. Apart from a relatively brief introduction, the convergence seminar consists of three phases of group discussions. The total time for this convergence seminar is 2,5 – 3 hours.

Introduction (10 min)
To start off, the seminar moderator gives a brief presentation of the NanoBio-RAISE project, the idea behind the convergence seminars, the structure of the seminar, as well as the topic for discussion (nanobiotechnology). The participants are then divided into three groups. These “scenario groups” (A, B, and C) are directed to separate rooms for their discussions.

Phase 1 (30-40 min)
All scenario groups begin by reading a two-part scenario. The first part of the scenario is the same for all three variants and briefly describes the "current state of affairs" and what kind of decision is to be made. It is designed in such a way that the participants can place themselves in the role of the decision-makers.

The second part of the scenario is different for each of the three groups. While all three scenarios skip ahead 10 - 20 years into the future, they represent different courses of development. Having read their group-specific scenario, each group discusses three general questions that ask for their opinions on what happens in, and what they can learn from, the scenario. In order to allow for a free discussion this phase is neither moderated nor recorded.

Phase 2 (40 min)
In the next phase, the participants are rearranged into “convergence groups” where each group consists of at least one representative from each of the previous scenario groups. This phase

begins with one person from each scenario group briefly recapitulating their scenario and their subsequent discussion (they may also bring a copy of their scenarios with them to the convergence group.) The group then discusses questions similar to those in Phase 1, but here the discussion and evaluation is intended to work by explicitly comparing the different scenarios with each other. Just as in Phase 1 this phase is neither moderated nor recorded.

Pause with refreshments (10-15 min)

Phase 3 (30-40 min)

All the participants meet up for the final convergence. To begin with each convergence group gives a short account of their discussion and any conclusions drawn within their group. After these presentations there is a joint discussion led by the seminar moderator. The moderator's role is to ensure that the most central and controversial issues in the previous discussions are brought to the table as well as to encourage all participants' contribution to the discussion. This section is audio-recorded.

Following the discussion all the participants are required to fill in a questionnaire that allows them to express their advice individually, outside the group. This questionnaire also gives them a chance to give feedback on the seminar itself. Finally, the participants receive a letter of thanks that includes a list of links for further information on NBT and its ethical/societal issues, as well as an email address to the seminar instructor in case of additional comments.

4.3 Group size

The discussions in phases 1 and 2 should take place in groups that are small enough to ensure, as far as possible, that all participants actively take part in the discussion. Therefore the total number of participants should not be higher than fifteen. Since we considered groups of four persons (a total twelve persons) to be the ideal size, this was the number aimed for in the recruitment of participants. In cases when this number of participants could not be recruited, or when some did not turn up, the convergence seminar can be conducted with as few as six participants. Conversely the convergence seminar can be arranged to accommodate a group exceeding twelve participants. The following table illustrates the variations in group-size determined by numbers of participants.

Table 1

Participants	***Phase 1***	***Phase 2***
6-8 persons	3 groups of 2-3 persons	2 groups of 3-4 persons
9-11 persons	3 groups of 3-4 persons	3 groups of 3-4 persons
12-14 persons	3 groups of 4-5 persons	3 groups of 4-5 persons
15 persons (maximum)	3 groups of 5 persons	3 groups of 5 persons

4.4 The three scenarios

Since the principle applications of NBT will likely be in medicine and diagnostics, these areas were naturally given a central role in the scenarios for the convergence seminars. However we also found it important to cover potential applications in areas such as ICT (information and communication technology), energy production and conservation, and water purification.[4] The scenario narratives were based on material taken from scientific articles and reports on nano- and biotechnology[5] and fellow researchers in these areas and in ethics. We also consulted researchers experienced in working with scenario workshops. Because many of the more crucial applications of NBT are anticipated only in the mid- to long-term time frame, the hypothetical decision making situation was placed in the short-term future in year 2010; and the three scenarios, each representing a different course of development, were placed in year 2020.

An essential part of the planning of the convergence seminars was to construct scenarios that would expose potential issues of risk and ethical controversies in the future advance of NBT research and applications. One of the scenarios focused primarily on the distributed risks and benefits of medical applications and the potential misuses of these applications. Another scenario focused on the use of NBT in diagnostics and surveillance with concomitant issues of

[4] Other potentially important areas of application that we might have chosen are food production and agriculture; however these were excluded from the scenarios – though not necessarily from the discussions – due to time restrictions compelling us to make some selection of topics.
[5] Some of the reports that formed our main references for the scenarios were: Davis Baird, Alfred Nordmann & Joachim Schummer (ed.), *Discovering the Nanoscale*. Amsterdam: IOS Press, 2004; The Royal Society and Royal Academy of Engineering, *Nanoscience and nanotechnologies: opportunities and uncertainties*, 2004, available at: http://www.nanotec.org.uk/finalReport.htm; Economic and Social Research Council (ESRC), *The Social and Economic Challenges of Nanotechnology*, 2006, available at: http://www.esrcsocietytoday.ac.uk/ESRCInfoCentre/Images/Nanotechnology_tcm6-5506.pdf. Please contact the authors for a full list of references for the scenarios.

infringements of privacy and freedom of choice. Nevertheless, considering our theoretical point of departure, in our third scenario the controversy lay rather in the *restriction* of NBT research. This precautionary scenario, Scenario A, focused on the competitive disadvantages which Europe might face by severely restricting the development of NBT while major non-European countries were the ones reaping the economic advantages from NBT. The three scenarios thus contained diverging approaches to technological development, i.e. either more regulation and restrictive use of NBT or less regulation and more promotion and use of NBT. They also involved different key ethical themes. The main themes of the scenarios are summarized in Table 2. For the complete scenarios as given to the participants at the seminar, see Appendix 1.

Table 2

Scenario	***Line of development***	***Ethical themes***
Scenario A	Restrictive	Environment, economical risks and international competitiveness, scientific environment
Scenario B	Promoting	Health risks, misuse, enhancement, distributive justice, and longevity
Scenario C	Promoting	Freedom of choice, privacy, control of biological and genetic information

4.5 Practical arrangements

One of the central objectives with the NanoBio-RAISE focus groups for public opinion was to include as broad a span of the European public as possible. This was accomplished in part by hosting the seminar in four geographically distinct regions in Europe: in the town of Visby, on the Swedish island of Gotland in the Baltic Sea; in the city of Sheffield, central England; in the city of Lublin, eastern Poland; and finally in the city of Porto, northern Portugal. In addition, we aimed towards including people of different age, gender, social and cultural background at each location.

For the organization of the seminars we were very fortunate to be able to rely on good contacts at each location that co-hosted the convergence seminars with us. The convergence seminar was advertised through various channels, providing us with a group of 7-13 voluntary participants at each location. The local organizers were responsible for coordinating the time and venue for the seminar. Marion Godman attended all of the seminars and was also the moderator at all of them, with the exception of the Porto seminar that was held in Portuguese and moderated by João Diogo Silva. No monetary compensation was offered to the participants but coffee and a light meal was provided at the end of each seminar. Although we explicitly tried to encourage participants with a limited background within, or knowledge of, scientific research, there were a few (1-4) participants with some background in technology or natural science at all of the seminars.

In terms of age and gender we managed to achieve a fairly good balance between the seminar participants, with the exception of Visby and Porto where women were in the majority. Nor were we able to get as many participants to attend these two seminars as we did in Sheffield and Porto. In terms of socio-cultural background, students were an over-represented group at all of the seminars. This might be explained by their prior interest in the topic, or the fact that the main organizers in all cases were universities or research centres and that the seminar itself was held within university settings.

Since the scope of the exercise only included an extremely small section of each country's (or city's) population at large, we would like to emphasise that the comments should not be interpreted as representative of the general public in each region. Similarly, although we do offer some comparisons between the views at the different seminars in the discussion, we would not claim that the variations represents, or should be explained by, significant cultural, social or regional differences. However, it is our view that the advice given at the seminars and included in this report can be taken as advice given by a reasonable variety of the public in Europe.

4.6 Overview of the four seminars

The first seminar was held at the University of Gotland in Visby, Sweden, on 4 May 2006. The eight participants in the group were members of local branches of the Swedish Society for

Nature Conservation and "Fältbiologerna", a youth environmental organization. The seminar was organized with the help of Dr Karin Bengtsson (Gotland University), AnnCatrin Hjernquist (Swedish Society for Nature Conservation), and Nicola Godman (Fältbiologerna). The seminar was held in Swedish and the scenarios and seminar discussions were translated to and from English by the authors of this report.

The second seminar was held at the School of Law at the University of Sheffield, UK on 28 July 2006. The seminar was hosted in cooperation with the Sheffield Institute for Biotechnological Law and Ethics where Dr Mike Adcock played a key role in organizing the seminar. The group of twelve participants consisted of students and members of a science discussion club.[6]

Lublin

Lublin

[6] The photos from the seminars were taken by Marion Godman and a participant at the Lublin seminar.

The third seminar was held at the Maria Curie – Sklodowska University, Lublin, Poland on 25 November 2006. The seminar was held in close cooperation with the Nanotechnology Centre at the same University. Several people at the Nanotechnology Centre were involved in organizing the seminar, especially the Head of the Centre, Prof Karol Izydor Wysokinski. The group of thirteen participants consisted principally of students in linguistics, architecture, and chemistry. There were also two senior researchers from nanotechnology-related fields participating.

Porto

Porto

The fourth and final seminar was held at the Institute for Molecular and Cell Biology in Porto, Portugal on 6 December 2006. The seminar was hosted in close cooperation with the Institute for Molecular and Cell Biology (IBMC). The group of seven participants consisted of students and non-academic staff such as administrators at IBMC. The entire seminar was held in Portuguese. The scenarios were translated in advance by João Diogo Silva at IBMC who also moderated the concluding seminar discussion and translated the participants' questionnaires

and the recorded transcript of the final discussion into English. In organizing the seminar we are also grateful to Dr Anna Olsson, Laboratory of Animal Science (IBMC), Ana Paula Pêgo, Instituto de Engenharia Biomédical (INEB), Universidade do Porto. As a trained nanotechnologist, Ana Paula Pêgo also contributed with an instructive presentation of nanotechnology for the participants *after* the seminar exercises were finished.

5. Results from the four Convergence Seminars

5.1 The documentation of the seminars

The participants' comments were documented in two ways: the first was a tape recording of the final discussion at the end of the seminar and the second was the questionnaire that the participants were asked to fill in following those discussions. The first section of each of the following seminar reports is based on the responses given in the questionnaire while the second section is based on the recorded discussion.

The participants' advice and arguments have been classified into four broad categories**.** The first two categories concern recommended guidelines: for research and development of NBT and for the regulation of NBT, respectively. The third category includes arguments concerning democratic values and transparency. The fourth category pertains to the emerging ethical issues in potential applications of NBT. These categories and sub-categories were chosen on the basis of a preliminary study of the outcomes of the seminars and are employed in our analysis of the participants' views and advice in the following sections.

5.2 Results from Seminar 1 (Visby, Sweden, May 4th, 2006)

5.2.1 Questionnaire responses

The participants in this seminar were divided into three scenario groups as follows:

Scenario A participants, designated as: A_1, A_2, A_3

Scenario B participants, designated as: B_1, B_2, B_3

Scenario C participants, designated as: C_1, C_2

1. Guidelines for the research and development of NBT

1.1 Research priorities

1.1.1 Focus on applications that will benefit the environment.

- Strongly emphasise the environmental aspects of NBT research and application. (A_1)
- Technology must be used for environmental remediation, cleaner water etc. (A_2)
- Concentrate on "positive" fields such as energy production, water purification etc. (B_1)
- Invest in solutions for global problems like energy, water supply, food industry and population increase. (C_1)

1.1.2 Medical applications should not replace preventative health care.

- Apply this technology to medicine at a later stage, and prioritise preventive health care rather than medication. (A_1)
- Be very careful with this technology. We must keep in mind that people will get weaker. As more medication is developed one becomes increasingly dependent on it. (A_2)

1.2 Scientists from a range of different disciplines should steer the development of NBT.

- Create a broad line of research – all areas of science should be involved. (C_1)

1.3 Critical reflection on the underlying values in technological development.

- Think carefully about which needs NBT should fulfil. Does it create more problems than it solves? (B_2)

1.3.1 Economic interests should not be the main drive behind technological development.

- Don't be hypnotised by one particular benefit of this technology, for instance the economical one. Look at NBT from a broader perspective. (C_2)

2. Guidelines for regulation of NBT

2.1 International regulation or agencies should be in place to monitor research and control potential products.

- Control on a global level! (A_3)
- Advanced technology demands centralization and regulation. (B_2)
- Strict international control and legislation. (C_1)
- Introduce an international agency such as the IAEA [International Atomic Energy Agency]. (B_1)

2.2 The precautionary principle should be considered for risks and illegitimate use.

- Use the precautionary principle - don't let anything out on the market before there really is evidence that it isn't dangerous. (B_1)
- Wait. Use the precautionary principle and examine the ways in which it [NBT] can be put to illegitimate use (war, terror, etc.). (B_2)

3. Democratic principles and transparency should guide the development.

- Let the development take time. People must be allowed to keep up. (B_1)
- Create an open dialogue so that everyone is able to have knowledge and influence! (B_2)
- Use transparent decision structures. (C_1)
- The aspects that have to do with ethics, human rights, and democracy are very important: they are the most important. (C_1)

5.2.2 Final Discussion

1. Guidelines for the research and development of NBT

1.1 Research priorities

1.1.1 Focus on applications that will benefit the environment.

"In the scenarios one had chosen to focus mainly on medicine, which has a direct impact on humans, but one did not choose an equally strong focus on environmental aspects, though, according to us, these might have had the most positive impact."

1.1.2 Medical applications should not replace preventative health care.

"We'd be more and more dependent on medication and technology."

"We need to find out what causes our disease, if we really want to treat it."

1.1.3 Focus on applications that will benefit developing countries.

"What happens to the developing countries? What if they are merely used as guinea-pigs or hostages in testing out new products?"

1.2 Commit to the goal of developing a (globally) affordable and accessible technology.

"There are often promises of an inexpensive and available technology, but as in the case with GMOs, one might not keep one's promises."

"One should not invest in an expensive technology but rather a cheaper smaller-scale reasonable technology that can be used by and is available to everyone."

2. Guidelines for regulation of NBT

2.1 International regulation or agencies should be in place to monitor research and control potential products.

"There is a need for international control as for instance, the IAEA that checks if certain restrictions are followed. All research in NBT should lie under international control."

…

"We need an independent controller like the IAEA that can perform inspections without warning."

2.2 Regulation is required to avoid fallibility and uncertainty in the development of technology.

"Another good thing with global regulation is that it slows things down and we are not able to take any great leaps forward."

…

"The problem with the let's-just-try-it-idea is that it might be that the recurrent long-term use that will prove to be the most dangerous. How are we to know the really long-term problems?"

…

"Perhaps, during a transitory period, we should have specialised hospitals for NBT. We have a high control over these institutions and know that the information here won't be spread."

2.3 The precautionary principle should be considered for risks and illegitimate use.

"Being restrictive with our applications through legislation is not enough. There will always be industrial espionage, how do we control that? How can we trust people's good intentions?"

…

"You just have to look at the nuclear bombs – there are never any guarantees that we will not use technology in the wrong manner. [But with those opinions] one is called a reactionary."

3. Democratic principles and transparency should guide the development.

"Of course it may prove to be a useful technology but it is important that we have a chance to choose *not* to have it."

4. Pay attention to the emerging ethical issues in applications of NBT:

4.1 Privacy

"Much focus was on control. This may be a good thing, but in most cases we thought if was negative. We'd have such a control over what happens in people's bodies and their brains. These are large risks, almost like a robot-society – this scares us."

4.2 Human enhancement and diversity

"If it is used to design or create super-humans – perhaps that's where we should put our restrictions. We can use the technology to cure Alzheimer's disease but one cannot receive similar treatment to enhance the memory."

…

"Of course there are beauty ideals right now too but with this kind of technology they might be used to enhance these ideals even further."

4.3 Longevity and overpopulation

"There aren't enough natural resources to handle such overpopulation that occurs when people start to live much longer and there are less fatal diseases. We're wasteful enough as it is."

5.3 Results from Seminar 2 (Sheffield, UK, July 28th, 2006)

5.3.1 Questionnaire responses

The participants in this seminar were divided into three scenario groups as follows:

Scenario A participants, designated as: A_1, A_2, A_3, A_4,

Scenario B participants, designated as: B_1, B_2, B_3, B_4

Scenario C participants, designated as: C_1, C_2, C_3, C_4

1. Guidelines for the research and development of NBT

1.1 Critical reflection on the underlying values in technological development.

- Avoid the quest for perfection or "progress" at the expense of psychological and personal well-being. How will we be as conscious beings if we are controlling our bodies and environment with technology just to get something we want? (A_2)
- We need to consider the wider impacts on humans as a species and in society. (C_3)

1.2 Engage industry in research and development but hold them accountable.

- Engage industry in early stages. (B_1)
- Regulators should have strong powers – companies must be open. (A_3)
- Make companies accountable to public and government. (B_3)

1.3 Encourage further research.

- Research should be done! (A_3)
- Funding NBT is a good idea and it's a strategic decision. It will benefit various fields such as medicine, ICT and energy production. (C_2)

1.4 Cooperation in research is needed on the international, European and national levels.

- In order to prevent economic disadvantages to some a certain amount of homology should be attained with other countries if possible. (A_4)
- Global co-operation in regulation, research and development. (C_3)

2. Guidelines for regulation of NBT

2.1 Regulation is required to avoid fallibility and uncertainty in the development of technology.

- Regulation is necessary for monitoring the applications in this field, for the safety, health and privacy of the public. (C_2)
- Regulation is the key, erring on the side of caution. A new technology, which we don't know the future consequences of, should be treated cautiously. (A_4)
- Foresight into potential side effects of other unintended applications. (B_4)
- Issue regulation for drugs and new treatments. (B_3)

2.2 International regulation or agencies should be in place to monitor research and control potential products.

2.2.1 National and local powers should be in place first.

- There should be regulatory powers at the national, European and international levels. One needs to take local variations, such as cultural considerations, into account, but ultimately regulation should be governed internationally. This monitoring should take moral and ethical considerations into account as well as health and business. (B_2)
- Regulatory bodies at the national level should be put in place as early as possible. (A_3)

2.3 Scientists from a range of different disciplines should steer the regulation of NBT.

- We need cross-disciplinary groups to look at regulating applications of new technology while keeping research open. (B_3)
- Establish monitoring with members from all disciplines connected with NBT, plus business and politicians. An independent power that has the power to regulate, unbiased by any particular area. (B_2)

2.4 Choose a regulatory framework that is consistent with regulation of other technologies.

- Ensure that regulation of nanotechnology is part of the regular regulation entity, not a separate part. (C_3)
- A unified risk strategy. Clinical trials should have side effects reported. (A_1)

2.4.1 Acknowledge that there may be specific aspects of NBT where current regulation may not be sufficient as it stands.

- A new technology ought to be regulated in line with defensible general principles. You should not assume, however, that the principles currently ensured within the law that regulates other technologies are themselves defensible. (C_a)
- Choose between specific/non-specific legislation. NBT covers so many areas that it may be impossible but R&D [research and development] should be regulated along with the commercial applications. (A_1)

3. Democratic principles and transparency should guide the development and regulation of technology.

- Encourage finding political support whilst formulating a framework of policy and legislation regarding: research and development; trials and applications (not just commercial) (B_4)
- Keep it open and democratic. (C_3)
- Open public debate early in the development of policies and regulation. (B_1)
- We can't leave decisions to one group; we need to include scientists, business, the public and politicians. (C_3)

3.1 The public should receive unbiased information.

- The public should be informed and consulted in as unbiased way as possible (A_3)
- Promote as many sources of information to the public as possible. (B_1)

4. Pay attention to the emerging ethical issues in applications of NBT:

4.1 Privacy

- Privacy concerns about surveillance also in criminal monitoring, CCTV and Internet. (A_1)
- Respect privacy. (A_2)
- People need to be given control of their biological data. (C_3)

4.2 Human enhancement and diversity

- Respect the integrity of human beings in their natural form – respect diversity. (A_2)
- Technologies are double-edged: one person's cure is another person's enhancement. (A_4)

4.3 Equality

- There may be a rich and poor divide, as in any technology, especially concerning health. (A_1)

4.4 Freedom of choice

- We need regulation for protecting individuals from undue influence. But it's very difficult without being paternalistic. (A_1)

5.3.2 Final Discussion

1. Guidelines for the research and development of NBT

1.1 Research priorities

1.1.1 Focus on applications that will benefit the environment

"Something that we all agreed should be promoted were the environmental aspects of research, such as energy production and water cleanliness. We thought that they would benefit everyone in society and the world on a whole."

1.1.2 Focus on medical applications, e.g. Tissue engineering

"Tissue engineering was important. At present there is a real problem when you need a new organ; you have to wait for someone else to die for organs to be available. It's a lottery in terms of being somewhere where you can get that level of care. There needs to be a realistic option for people that doesn't involve waiting for years and years on an organ waiting list."

1.1.3 Invest in solutions for those areas that answer to a crucial need rather than technological novelties.

"We should invest in areas that clearly will benefit society such as energy, medicine, ICT. It is possible that applications in cosmetics and athletics shouldn't be promoted."

1.1.4 Focus on applications that will benefit developing countries.

"If this technology is easy and cheap to move, it will help not only individuals in Europe but in other places where one can't afford to take care of issues such as global warming."

1.2 Scientists from a range of different disciplines should steer the development of NBT.

"When you claim to bring in an expert, that 'expert' should have to cover a whole range of issues in society, different fields of medicine and technical, but also social issues."

1.3 International cooperation in research is needed.

"There is a lot of talk about international control and regulation, but there is also a need for international framework of cooperation; of an exchange of ideas in science and building a body of knowledge together. The issues are going to be the same wherever you are."

…

"If you want global regulation you need to be in the frontline of research. If you are not and you still want the same regulation as countries like the US, it will be quite difficult to negotiate your views with them; you will just be left behind."

2. Guidelines for regulation of NBT

2.1 International regulation or agencies should be in place to monitor research and control potential products.

"Regulation cannot be confined to one area but we should try to get an international regime. But we realised it wouldn't be the easiest thing, considering stem cells and GMOs."

2.1.1 National and local powers should be in place first.

"Apart from an international regime you need a more detailed and tighter regime on the European level and also on the national level, since not each country will be willing to participate in the same way."

…

"Shouldn't regulation agree with what is evident in society? And different cultures and societies will have different standards of what is acceptable to them which other societies won't."

…

"It is very difficult to have international regulation. There is always going to be one country that deliberately decides not to go with the regulation since it can make a financial gain by people leaving to come to their region where there are no restrictions."

2.2 Regulation is required to avoid fallibility and uncertainty in the development of technology.

"Of course we'll end up with a lot of bureaucracy. That however is not necessarily a bad thing because inertia in these technological developments gives time for a system to take a close look at research and make sure that it's the right thing."

…

"There is a need for constant monitoring and reviewing of both the development and the applications of NBT; potentially there is a lot of good and a lot of bad, but the big thing is that potentially there is a lot of unknown. Regulation is the key to this."

…

"Individuals should be able to opt out of this technology. But if there were airborne NBT particles in the water would people be able to avoid them? As these substances might be alien to us, we need regulation before we get to that stage; we need to think more long-term."

2.3 Regulation should be moderate and follow the technological development

"The focus of the policy should be on the applications rather than on the research. To justify regulation early is tricky since we don't know what products will be available."

2.4 Choose a regulatory framework that is consistent with regulation of other technologies.

"Many of the issues that arose from our discussion were very similar to the concerns of other technologies. So probably the same regulatory framework can be used, but with some adaptations."

…

"A lot of the problems of NBT are not new as such; they are just caused a lot faster. The best thing to do is to extend current safety regimes."

…

"There is a lot of development going on that isn't using nanotechnology. Nanotechnology is in itself not a separate technology; it is jut the way much technology is currently going. I don't think setting up regulation specifically aimed at nanotechnology makes any kind of sense."

2.5 One should be restrictive toward commercial influence over regulation.

"It's extremely important to have a regulatory body that is independent of the industry, probably through the government so that they can restrict the influence of companies."

3. Democratic principles and transparency should guide the regulation and development of technology.

"Some people want to stay in the village and some want to leave. People that don't want to leave shouldn't be forced to; they should have a choice. We shouldn't get to the stage where it's a blanket decision to accept technological progress."

…

"Keep democratic control over regulation was vital. It can't just be business, experts, politicians, or people. We can't know everything about everything, and everyone has their own agenda, so we must try to keep this as open as possible."

3.1 Public should receive unbiased information.

"Public participation is to be promoted but only where there is balanced information. Otherwise it could be counter-productive. Politicians are not to base their decision on biased public opinion."

3.2 Public input is especially important for medical applications.

"Say you have a memory chip implanted, would it be inevitable to keep a subscription going and is that a good thing? The public may have valuable points to make on these issues. Especially in medical issues it's good to have lay members present for advice."

…

"The medical applications were a lot more controversial [than the environmental applications]."

4. Pay attention to the emerging ethical issues in applications of NBT:

4.1 Privacy

"I find the evasion of privacy very disturbing. Instead of having your bio-medical information held in a central database, it could be held within you. So when you went to the doctor you could provide it, giving you a 'key' maybe. Maybe the emergency services could have one as well but you still have to make the decision of who can have instant access to the information."

…

[Reply to above statement] "I like the 'key' example. Perhaps this technology can be used to improve on people's privacy. Maybe there could be funding specifically to this kind of applications so that people can regain control over their biomedical information."

4.2 Human enhancement and diversity

"The psychological effects of this quest for perfection in terms of genetics and in terms of health and environment might iron out the good things about diversity."

…

"There was a consensus that memory enhancement shouldn't be encouraged, although we couldn't agree on whether to forbid it or to introduce some other control on to the market."

…

"If you're changing a person's intellectual abilities, you are changing the persons themselves in a way. Still there is a need for these applications for people that have neurological conditions. Using a treatment to recover from an illness is one thing whereas a treatment for enhancement is quite different."

…

"We'd have to know that a superior memory doesn't have some other limitations. Does it perhaps make you emotionally less empathetic; you're so busy processing intellectual information that you can't relate to each other? Also forgetting things is not necessarily a bad thing: there is a reason why we don't remember every car we see in the morning."

…

"We didn't feel that the possible effect on humans as a species is being looked at. This could have a massive psychological impact. Things haven't changed in over a hundred years and now, in these scenarios, within a decade we may be radically altered. What kind of impact is that going to have on us?"

4.3 Equality

"When you go to university you get benefits in life; you get a better job, become richer and so on. But when you use a chip to become smarter it brings in the whole issue of the rich getting richer. If you are poor you might still get out of it through education, whereas the already wealthy can

afford new implants and chips. Suddenly it doesn't matter how smart you are; if you're not rich you can only get so far."

…

"The government could provide chips to a selection of poor people. That would be one way to keep a balance. This technology could be made available to those who have the social disadvantages."

…

[Reply to above statement] "But that's not the way it works. The people that have the money and the interest are not going to make that kind of decision."

4.4 Freedom of choice

"Some valuable [biological or genetic] information could come out of this but who has control of this information? If there is a danger of you having a disease but you know that getting tested could impact on your employment decision; this shouldn't stop you from finding out what is happening. You have the right to your data; you should have control over who has access to it."

…

"The main problem with the enhancement of the intellectual capabilities is that an employer could do it. We have to look at how the relationship of power between the employer and the employee would affect the individual's decision."

…

There might be a societal pressure to have memory enhancement that perhaps should be regulated early on because the level of pressure would not marry with individual choice."

…

"Legislation might hinder individual choice related to autonomy. If an individual wants to use medical research, allowing potentially harmful particles to enter the body, they should be able to choose this treatment. Perhaps there should be a categorisation of different levels of risk."

…

"I don't see a huge difference between NBT and new drugs since new drugs can have repercussions. If you think of the treatment for cancer, they're extremely toxic and no one would ever say they were good for you. But, if you're the person with cancer, it's your life; your choice."

5.4 Results from Seminar 3 (Lublin, Poland, November 25th, 2006)

5.4.1 Questionnaire responses

The participants in this seminar were divided into three scenario groups as follows:

Scenario A participants, designated as: A_1, A_2, A_3, A_4,

Scenario B participants, designated as: B_1, B_2, B_3, B_4, B_5

Scenario C participants, designated as: C_1, C_2, C_3, C_4

1. Guidelines for the research and development of NBT

1.1 Research priorities

1.1.1 Focus on applications that will benefit the environment

- Since many of our natural resources will be finished one day, one should think about inventing new sources of energy rather than how to lead a more comfortable life. (B_5)
- The environmental aspects are the most important and need more attention than the medical ones, which in the end are only "upgrades" for humans. (B_2)
- First environment, second society, third finances. (A_1)
- First and foremost it should be a question of the environment and the future of the Earth. (B_4)

1.1.2 Invest in solutions for those areas that answer to a crucial need rather than technological novelties.

- NBT should be applied especially in the areas of medicine and environmental conservation. (B_4)
- Set nature and health as your priority. Military applications are not necessary since weapons, as a rule, are considered to be something that should not be used and which will shift the balance; so skip it! Do we really need a machine that will control our thoughts? It is humans that should control technology, not the other way around. (C_1)
- The efforts should be toward tackling already existing problems rather than looking at those aspects of life that, while they still could be improved, currently are on a level that satisfies our needs. (B_5)
- Technology should be the tool and not the target of development. (C_3)
- Decide which invention would have the greatest positive influence on humanity as a whole. Remember that technology should be safe for humans and environment alike. (C_4)
- One should take into account the environment and the basic needs of people. If we develop only ICT for example we might even destroy our natural environment in the process. (C_2)

1.1.3 Focus on applications that will benefit developing countries.

- They should not forget about the "Africa problem"; it is imperative to minimize the gap between Africa and other continents. (A_3)
- The most powerful countries should stop thinking about profit and focus on third world problems and the problems of those who are left behind. (B_4)

1.2 Commit to the goal of developing an (globally) affordable and accessible technology

- The technology should be safe and cheap so as to be widely distributed. (B_1)

1.3 Critical reflection on the underlying values in technological development.

1.3.1 Economic interests should not be the main drive behind technological development.

- Weigh pros and cons; not costs and benefits. Don't be too short-sighted and focused on getting financial profits. (C_4)
- Stay focused on the human being. Don't put economical or political issues before it. (A_3)

2. Guidelines for regulation of NBT

2.1 International regulation or agencies should be in place to monitor research and control potential products.

- An international organization should be founded to make some global decisions. (B_1)
- Be aware of threats; measures must be set to minimize the potential threats of military applications. An international treaty and some body of control will do. (A_2)
- The agreement should be made as internationally as possible. Choose wisely who is in control: if it is to be an independent organ, governments, UN, EU. (C_1)
- Improper use should be avoided and forbidden by international agreements. (C_3)
- An international system of control is needed for worldwide applications; flow of information; humanity; ethics; cheap technologies; helping developing countries. (A_1)
- Think globally – whatever is done, should be done on an international scale with the participation of all willing sides. (A_2)

2.2 Regulation should not be too rigid but carefully controlled and put in responsible hands.

- The control of the regulation should be strict; otherwise what is illegal will be over-extensive. (C_1)
- Set soft regulation and control it strictly. (B_2)

3. Democratic principles and transparency should guide the development and regulation of technology.

- Organize these kinds of meetings where people are able to get information on what is going in such field like NBT, and where the conclusions can be gathered and discussed at a greater scale. People may be conducting research on very crucial matters but so far society isn't informed or has no opinion of it. My advice is: inform society and make them a part of your activity. In this way it will be more beneficial for all of society. (A_4)

4. Pay attention to the emerging ethical issues in applications of NBT:

4.1 Human enhancement and diversity

- Think about all the consequences of your decisions. People can make good things as well as bad things with new NBTs. The example of Alzheimer's' disease (memory treatment or enhancement) shows two aspects of developments in medicine. (B_3)
- Intelligence enhancements should be banned because a "hyper-race" would appear and would surely upset the balance. (C_1)

4.2 Freedom of choice

- If applied to an individual, NBT should be non-obligatory. (C_1)

5.4.2 Final Discussion

1. Guidelines for the research and development of NBT

1.1 Research priorities

1.1.1 Focus on applications that will benefit the environment.

"Our group considered the environmental aspects the most important, such as developing technology for energy production such as solar cells."

1.1.2 Focus on applications that will benefit developing countries.

"This technology should be cheap enough for most of society. If it is the richest countries that develop it, they will also choose things that are only attractive to a certain part of the population. This will create a social and economical gap as we can already see between the developing countries and the countries in the West. In this way conflicts will arise."

…

"We would focus on the medical aspects of helping people. We should focus on people in developing countries not only people in the rich countries."

…

"We have the problem of aids or pneumonia in developing countries and we should focus on developing vaccinations, medicines, and drug-delivery systems to assist people with these

problems. Otherwise we will have a technology for an American, or someone who has a lot of money, who wants to exchange his skin because he doesn't like the colour of it."

…

"Another socioeconomic problem is food: how do we feed all the people? So we came up with the idea that we can, with the help of nanotechnology invent food that is very small, but which hold enzymes, vitamins and all the nutritional supplements you need. Normally we waste a lot of that which has nutritional value so perhaps with the help of new delivery-technology we wouldn't have to eat so much, since everything we ate would be exploited. This could help developing countries as well."

1.2 Commit to the goal of developing an (globally) affordable and accessible technology.

"We have to consider the wellness of the *whole* country's population because we are not equal economically."

…

"Technology should be made accessible to everyone and we should take measures such as special subsidies, especially if it comes to medical applications so that we don't create a bigger gap between the rich and the poor; those who can afford modern technology and those who cannot."

1.3 Critical reflection on the underlying values in technological development.

1.3.1 Economic interests should not be the main drive behind technological development.

"Politics should be involved. Since people usually think in terms of financial rewards anyway, the economical aspects of nanotechnology should be the last priority."

1.3.2 Acknowledge that there are problems and potentials of having multiple objectives in technology development.

"We divided the decision into four aspects: societal, economical, global, and environmental. Taking all these aspects into account it is difficult to figure out what the best option for the future would be."

…

"During our discussion it was mentioned that research on new technology generates money and money is needed for the general development of a country. This refers to the development in many different domains, not just the progress of technology and technological applications per se. That's also why we prefer a softer regulation to a stricter one."

1.4 Encourage further research.

"Scientists should be allowed to work on solving a problem to the very end. If you leave something behind then much more serious problems may arise. One should concentrate on issues like: 'What should we do with the waste?', or as in the technology that kills cancer cells: 'Is it biodegradable or not?'. We don't want technology that is more serious than the disease, so research should be conducted with a focus on the basic problem."

1.5 Cooperation in research is needed on the international, European and national levels.

"In many countries the starting-point is: if we don't discover it, they will. Instead, in order to promote the wellness of the country, we should think about what we can do to support the flow of information between Europe, Asia and the U.S., thereby spreading the knowledge of new technologies and artefacts."

…

"Nanotechnology should not be used as a military tool; we should work together within Europe and even outside Europe for mutual benefits and progress within medicine and energy etc. Not with the view of war but of a better world."

1.5.1 Choose specific fields for international cooperation and agendas.

"It would be better to focus on specific fields for international cooperation. If we are trying to achieve compromise on the use of energy resources, we must take into account that each country is already using foreign energy resources. If we can negotiate an agreement on a global scale we would probably be closer to the solution where most countries would use these novel technologies to make the whole planet a bit healthier. This also goes for the medical technologies."

2. Guidelines for regulation of NBT

2.1 International regulation or agencies should be in place to monitor research and control potential products.

"There should be some kind of international treaty that decides on the purposes and the limits of new technologies – especially concerning NBT, which can be quite dangerous if used improperly."

…

"Take the development of nuclear energy. Now we have an organization whose job is to control technologies on such a level that it is really hard to do the same thing in your workshop, your garage, or whatever. So the point is that technology should be developed in safe surroundings."

2.2 Regulation should not be too rigid but carefully controlled and put in responsible hands.

"We came up with the idea that regulation shouldn't be too strict. It is widely known that what is forbidden is the most attractive. People will find a way to overcome these regulations and then we will have no way to monitor the activity. We should ban only what is utterly 'bad'; that which we cannot control and which we should not work on."

…

"If we for example implement very strict regulations in Poland then people that are interested in the particular technology or scientists might emigrate or will do it illegally. In such a case we won't keep up with the rest of the world."

…

"If we put technology into responsible hands it is OK. We can view it as some sort of a basic agreement between people in society – a society that today means a global village. There is a sort of agreement that this technology exists since we all agreed that it should exist. If someone breaks the rules they basically break the agreement. That will surely result in some sort of conflict."

2.3 Be restrictive on military use of NBT.

"We should invest in medicine, and in environmental applications and not in the military. Still, we need to be aware of these applications, systems for spying etc. to be able to detect if others are using these applications against us."

…

"Technology should first of all be safe, both for the environment and for humans. Safety also means that technology should not be developed for military purposes."

3. Pay attention to the emerging ethical issues in applications of NBT:

3.1 Human enhancement and diversity/Freedom of Choice[7]

"The limits [of people's right to choose an enhancing technology] should be set so that the attributes of human life are prioritised. This means preserving the right to a natural life span: to be born, come of age, grow old, and finally to die. If this balance is upset, we have a problem."

"Some people do wish to have their life prolonged. In 100 years there will be people that will have minds that are greater than ours and will also think of things that we can't think of. So we can't control it."

"Still, there should be rules. There will be people who want to do such things as prolong their lives forever, but we don't have to agree with it. I think that it is wrong for people to enhance their mental capacities since it's against nature. I think nature will revenge, finally."

[7] In this section we have included a full section of the participants' debate over enhancement and freedom of choice.

"*But do we have the right to tell an individual what he would like to do with his own body, especially if he doesn't interfere with others? Perhaps he acquires certain super powers, such as an incredible strength. Then he could, I don't know, pick up trees or something, and he wouldn't do any harm to anyone. Or let's say, I want to be super-intelligent and learn fifteen foreign languages and I can afford to buy myself an implant, a chip that helps me – do we have the right to ban such a procedure? And say: 'No, no, you can't be more intelligent than I am' or, 'You can't be stronger than me'?*"

> "No, the reason for banning it is that you might be dangerous to others or that it has a negative influence on your own brain."

"But can we pass such judgements and apply something like a precautionary principle just in case something 'might' happen but before we know that it will. People are usually allowed to buy knives even if they might kill someone with the knife. Of course if the person commits a crime we have the right to punish him or her afterwards. But as long as person moves within the boundaries of the law do we have the right to tell him: 'No you can't be more intelligent'."

> "The risk is that we create a hyper race of people."

> "We have to focus on basic human needs."

"It is rather like a 'nanoevolution'. If you can afford to buy a chip, you are, say, a better 'hunter'. It is sad but true, you are better prepared and in a way it is quite natural: the strongest survives. If it is wrong then biology will take care of itself."

> "But these developments are much faster than evolution."

3.2 Longevity and overpopulation

> "We saw in the scenarios that there were problems with only focusing on medicine since we have the problem of a growing population and the issues that it introduces."

5.5 Results from Seminar 4 (Porto, Portugal, December 6th, 2006)

5.5.1 Questionnaire responses

The participants in this seminar were divided into three scenario groups as follows:

Scenario A participants, designated as: A_1, A_2

Scenario B participants, designated as: B_1, B_2, B_3

Scenario C participants, designated as: C_1, C_2

1. Guidelines for the research and development of NBT

1.1 Establish or use governmental commissions to deal with the ethical issues of a technology

- Establish commissions and ethical guidelines for dealing this subject (C_2)
- Search for a balance between advancing NBT and keeping an awareness of ethical issues. (B_3)

2. Guidelines for regulation of NBT

2.1 Regulation should be moderate and follow the technological development.

- In spite of the negative aspects, NBT has plenty of positive effects. One just has to control the negative effects. Regulation must always accompany the advance of NBT to avoid abusive use. (B_1)
- There can be too many restrictions… (A_1)

3. Democratic principles and transparency should guide the development and regulation of technology.

- Do not decide on your own. Inform the public and continuously define priorities: what is good and bad; what are the costs versus benefits; and what are the risks versus benefits. Abide by the principle that people have "the right to choose". (A_2)
- Assess the impact that these scientific discoveries will bring in the future. NBT can bring immediate benefits but is it still beneficial for the generations to come? (B_2)
- Keep in touch with the public, technology commissions etc. in order to avoid a (further) rift between these issues and the public. (B_3)

3.1 Focus on creating forums for public debate and engagement

- After informing the general public in the best possible way, one should organize public discussions, starting with schools, universities, etc. Promote curiosity and interest on this topic through practical examples. (C_1)
- Organize public seminars for discussing the advantages, disadvantages, and applications of NBT. (C_2)

5.5.2 Final Discussion

1. Guidelines for the research and development of NBT

1.1 Research priorities

1.1.1 Focus on applications that will benefit the environment.

"Energy production and water treatment; those two fields were considered priorities."

1.1.2 Focus on medical applications.

"We also considered that health is the most important field for new applications."

1.1.3 Allow for more novel applications.

"Indeed, the advancements of NBT may have fantastic consequences: economically, socially, and in terms of welfare. Not just in medicine, in predicting diseases and fighting starvation, but generally speaking; for the quality of life. It can be used for things that are essential for developing a more advanced society."

1.2 Commit to the goal of developing a (globally) affordable and accessible technology.

"Equal access to this technology is fundamental, no matter what the application is."

"I totally agree. Just look at the developments of the pharmaceutical industry: sometimes a drug is developed with state support, but as many people can't afford it on their own, an injustice is created."

1.3 Scientists from a range of different disciplines should steer the development and regulation of NBT.

"We suggest the formation of international committees that contain experts in different fields of research, but also with the presence of the public."

1.4 Cooperation in research is needed on the international, European and national levels.

1.4.1 International cooperation in research enables each country to focus on their research strength.

"Cooperation is important. In the Portuguese case, it's a little ridiculous to invest in fields that one lacks knowledge of and where other countries are very strong. Perhaps it isn't very logical to do state of the art research in countries where those fields are not that developed. It would be more important to invest where there already is a basic structure, rather than to re-organize things."

2. Guidelines for regulation of NBT

2.1 International regulation or agencies should be in place to monitor research and control potential products.

"To prevent or at least limit abuses within scientific progress, regulation can't be set just for one country. It has to cover as many countries as possible. They should all get together and talk about it – sometimes they are so focused on their own progress."

…

"Control should be performed together with other countries, for instance through international conventions or agreements. There are many ways of harmonizing policies concerning technologies without necessarily having a universal law."

2.1.2 Cooperation in policy and regulation should first be achieved within the EU and then outside the EU.

"Even in Europe it is difficult to reach a consensus about these things. First we should aspire to have an agreement within the European Union and then for an agreement with other countries. "

…

"The more international [regulation] the better; if it is done only within the European Union it is not enough. We might have the scenario where each country chooses their own path, as was the case with China and Japan."

2.2 Regulation should be moderate and follow the technological development.

"We have agreed that technological development cannot and should not be restricted. Technological development should be regulated moderately. We also considered that the evolution of new technologies must be accompanied by ethical principles and ethical discussion."

…

"The evolution of technology should come hand in hand with legislation. "

…

”In terms of economical effects it would be a disaster [to apply the precautionary principle] and I think that right now we should have an eye on economical advantages, although mostly on the social advantages. The first scenario is too preventive in all aspects; it limits economical benefits but also social evolution, medical evolution and all existing technology. One doesn’t know what can be developed since legislation is constantly constraining.”

2.3 Be restrictive toward commercial influence over regulation.

“Naturally private companies will be interested in investing in these areas. This investment is very important but if it is not properly regulated and monitored it can have many negative impacts.”

3. Democratic principles and transparency should guide the development and regulation of technology.

“Because there is a great amount of uncertainty; one has to be very cautious in advancing without having for instance focus group interviews with the public, which I consider to be the most important. For example, we didn’t know what nanotechnology was: now we have opinions about it. Perhaps if we were invited to discuss it in the city hall tomorrow, we could learn even more. I think that is what’s missing.”

…

“These [public] procedures might not be enough in our country but as members of the European Union we benefit from these discussions on an international level.”

3.1 Focus on creating forums for public debate and engagement.

“I think it all starts with information that in my opinion doesn’t exist. All of us gathered here come from different backgrounds, some even with a technological background, and still we don’t know about the applications of this technology. It has benefits – we’ve seen lots of examples of benefits – but people haven’t heard of them.”

…

“People’s curiosity isn’t properly encouraged: they will only talk about nanotechnology if the subject knocks at their doors. That’s how things work around here and in many other places.”

…

“I think that there are already ways of enlightening the common citizen; for instance in Northern European countries there are science shops. In situations like the debate on abortion there could be a place with experts on the topic, which could clear up the doubts of those who dropped by to ask some questions. I heard on TV that the government is going to invest in nanotechnologies, what if I could go to a science shop and ask some questions?”

3.2 Engage different actors for informing the public.

3.2.1 Scientists and universities

> "It has to start with the experts. Those who work with science are more inclined to talk about."
>
> …
>
> "But the problem is it can't be too "scientific". There is plenty of information but sometimes it has to be decoded into a language that everyone understands. It is one thing to speak of NBT with people who at least vaguely know what it is – it is quite another thing to talk about it with people who have never heard about it. This could be done with the help of universities."

3.2.2 *National governments, commissions, and the EU*

> "I think that science communication should be inside a larger project of science and technology ministry, because one can't leave it all in the hands of science institutes."

3.2.3 *Industry and private companies*

> "Private companies working in this field could also give a hand by promoting information and initiating action."

3.2.4 Individual citizens

> "I think people themselves are able to get information. When issues like abortion or euthanasia are debated, most people don't spend enough time thinking about it. I still believe that each one of us must take the first step and start searching for information on our own."

4. Pay attention to the emerging ethical issues in applications of NBT:

4.1 Privacy[8]

> "It's just a matter of enhancing existing techniques, for instance surveillance cameras already exist"

"I think it is a little different. Currently they aren't watching you in particular; in a shopping mall the purpose of surveillance is not to watch you specifically but to detect possible problems."

> "On the other hand, that kind of technology has many advantages. Imagine you have a missing child or someone who is mentally impaired – NBT could help you find them. With this technology it won't be possible to kidnap a child; you will always know his or her whereabouts."

"One must know who controls the use of the technology, who defines the priorities? Someone might think it's a good idea to control everyone, who defines the problem?"

[8] In this section we have included a full section of the participants' debate over privacy.

"Medical data should always be confidential. And a person must have the right to choose whether or not they want to learn about their diseases."

…

"In both groups we discussed the issue of privacy. It is very important to protect people's privacy and freedom in all areas, not only in medicine. In a case such as in scenario C where it would be possible to predict what diseases we would have in the future, we believe this may have negative impact when it comes to hiring people."

4.2 Longevity and overpopulation

"Knowing to what extent something is good at an individual level – for instance curing Alzheimer's disease is good – does not necessarily mean it is good at a broader societal level. We'll have even more elderly people in our society than now. This could cause some social imbalances."

4.3 Freedom of choice

"I think that NBT is a risk when it puts acquired human rights at stake – such as the right to health and the right to work. This is what regulation should focus upon. When someone can find out what disease he or she is going to have ten years from now, they must have the right to choose this kind of diagnostics."

6. Discussion

The central issue of the four convergence seminars was what advice the participants would give to decision-makers that would decide on the development and future use of NBT. This issue was reflected in the different phases of group discussions, the final discussion, as well as in the questionnaire responses obtained at the end of the seminar. The purpose of having such a broad focus on NBT was to avoid prematurely delimiting whatever concerns the participants might have on the technology. In this way, rather than promoting a close investigation of one particular topic in the field we encouraged a wider exploration into the ethical and societal aspects of NBT. Hence the participants were assigned both the task of selecting the relevant issues and that of giving advice on those issues.

Although our objective was to grant the participants greater latitude in discussing the ethical issues and possibilities within the NBT development, the scenarios inevitably steered the participants' attention to what is given within the scenarios. A correspondence between the narrative of the scenarios and the participants' comments can thus be discerned. Still, the impact of the scenario content on the participants' opinions should not be exaggerated. First of all the scenarios consisted of descriptive rather than evaluative accounts of possible NBT developments and applications. More importantly, the theoretical base of presenting the participants with three divergent future scenarios, quite explicitly encouraged the participants to take their own stance on NBT in regard to the technological development and the ethical issues. We also encouraged the participants to bring to the table whatever issues they as a group or as individuals felt were relevant.

In what follows we highlight the topics that attracted most attention at all seminars. Often these issues coincided with those where there was the most consensus of opinion, but at other times they might rather represent topics where there was considerable divergence of opinion. These disagreements can be debates or controversies at a particular seminar. Since our aim with the seminars was not the convergence of participants' opinions, if there was a disagreement on a particular issue we encouraged the groups to bring these issues forward in the final discussion (these controversies can also be established in the individual seminar reports). In what follows we also discuss divergences of opinion that can be shown by a comparison of participants' views at the different seminars. We conclude by offering some reflections on the methodology of the seminar.

Research Priorities

One of the key recommendations was that governments and research institutes set research priorities that correspond to vital global needs. Environmental applications, such as energy production, environmental soil remediation, and water desalination were unanimously encouraged. Another area that received strong support was applications that would benefit developing countries. This was particularly emphasised in Lublin where participants were concerned that the richest and politically most powerful countries were the ones defining the areas of priority without giving much attention to medical applications that might benefit African countries. They saw it as problematic that already wealthy countries perform the majority of the research and subsequently reap the social and economic benefits.

Medicine was also encouraged as an area of priority, and applications such as drug delivery and tissue engineering were emphasised as important applications. In Visby, however, it was cautioned that advanced medical applications may become a pretext for not dealing with the root of the problem or may even replace preventative health care. Also in Sheffield several medical applications were considered quite controversial and were pointed out as an area where it would be particularly important to have lay persons present for consultation.

In general the participants advocated that research priorities be aligned with crucial needs, i.e. environment and medicine, rather than with what were considered to be technological novelties i.e. military applications, applications for bodily or cognitive enhancement, and, to a somewhat less extent, ICT. One notable exception was an opinion expressed in Porto that advanced novel applications are essential for developing a more advanced society.

Access, distribution, and equality

In the reports there are several categories of comments that encompass the concern that NBT might be developed to serve the needs of a fortunate few. Although it was believed that researchers and industry often express the best intentions to create a cheap and accessible technology, it was also believed that those promises often have fallen through in other areas such as in the genetic technologies (Visby) and in the pharmaceutical industry (Porto). In Visby participants doubted that NBT applications would help developing countries and feared that these countries might in fact be used as guinea pigs for testing out new products. All seminars advised that the advance of NBT should be accompanied by a commitment to the goal of

developing applications that would truly benefit the developing world. While it was on one hand argued that technological development should not increase the gap *between* different countries, it was also argued that certain parts of a country's population should not be left behind in the development. Participants in Lublin suggested particular subsidies for certain treatments in order to make them generally affordable. In Sheffield there was a debate on whether the future use of advanced chips and sensors would give unjust advantages to the already rich and powerful.

Commercial interests

Economic interests were recognised as an important drive in the technological development. Participants judged that research generates further economic growth and is an essential criterion for social welfare. Nevertheless, in both Lublin and Visby it was argued that economic interests should not be the *main* drive of the NBT development since they were too narrow and short-sighted motivations. It was also felt that there is a need to set political priorities separately from economic interests, as the latter would be incorporated into the development at any rate.

The role of industry and private companies in research and regulation was also debated. In Sheffield it was claimed that as much as industry should be engaged in research they must also be held accountable for the products they develop or put to market. In Porto it was proposed that industry should be assigned a role in informing the public of research and product development. In terms of regulation, in both Porto and Sheffield it was stressed that the regulatory body should be as independent as possible from the influence of industry.

Encouraging public debate and deliberation

Public participation in the development of NBT was strongly encouraged at all of the seminars. Among the arguments brought forward for involving the public were principled democratic arguments, such as "people have the right to choose" (Visby, Porto); the need to avoid a further rift between science and the public (Porto); and that public participation would be instrumental for securing that NBT would be beneficial to different members of society (Lublin).

In Sheffield it was seen as important to have democratic control over the regulation by including as many actors as possible, thereby avoiding a regulation that would only fit a particular actor's agenda. However it was also emphasised in Sheffield that while the public should be involved in the debate over policy and regulation, it was equally important that the scientific information they receive should be as unbiased as possible. One feared it might be counter-productive for democracy to include potentially biased public opinions.

The discussion in Porto highlighted the need to create various forums for debate so as to promote the curiosity and participation of the public. At several points in the discussion a comparison was made with an appreciated concurrent debate and referendum about abortion. The group however was divided on who should be responsible for initiating the flow of information and public engagement. Amongst the suggestions were scientists and universities, national governments (and commissions), the EU, industry, and individual citizens themselves.

Research and the risks of regulation

At all seminars further NBT research was encouraged in one way or another, with the possible exception of Visby where further research did not receive any explicit support. In Visby the participants were in fact inclined to evoke the precautionary principle for several areas of research. In contrast, participants in Lublin claimed that scientists must always be able to work on their basic research question to the end, or else researchers might end up with a greater problem than they had started with.

Over-regulation was also acknowledged as a potential problem; not simply because of missing out on the benefits of potential applications, but also because certain countries with strong regulation might be (economically) left behind by those whose regulation was less rigid. In Lublin the solution was to have a softer regulation and to leave it in responsible hands. In Porto it was believed that regulation should be adapted to the NBT development rather than becoming an impediment. The participants there expressed concern about the economical risks one would take with premature regulation.

International regulation

Although the participants at the seminars thought that it was important to attain some homogeny between the levels of NBT regulation (use of nanoparticles etc.), they also recognised that there were significant obstacles to enforcing a global regulation. Several participants, particularly in Sheffield, expressed scepticism toward the possibility of international regulation. The GMO debate was referred to as an example of how international regulation had been hindered due to differences in cultural and scientific traditions. Therefore it was emphasised that national and local powers should be in place before one attempted to reach a consensus internationally. In Porto the EU was emphasised as an important intermediate step between national and global regulation.

In Sheffield an argued prerequisite for international regulation was to extend the amount of international cooperation in research. A similar view was expressed in Lublin where it was also proposed that particular *areas* of research be chosen for international cooperation. Areas suggested were those that would solve problems of global warming and pollution – which the participants then claimed would assist the achievement of common standards in regulation. Just as in Sheffield, participants in Lublin recognised that cultural differences might become an obstacle for international cooperation although here the relevance of such differences seemed a lot more controversial.

The advice in Lublin and Visby was extended from cooperating across borders, to establishing an international *agency* for monitoring nanotechnology, modelled on the IAEA. Another suggestion from Visby was that medical applications of nanotechnology be confined to be used within certain hospitals, which then would receive closer monitoring and control.

Uncertainty in NBT development

In the seminars in Sheffield and Visby it was recognised that there is a high degree of uncertainty regarding both future societal trends and technological progress, and that predictions made by researchers, decision-makers and public alike are fallible. In Sheffield for instance, it was suggested that regulation and bureaucracy are important as they create inertia in funding and in the technological development, thus allowing for foresight into long-term applications and side effects. Participants in Visby also encouraged inertia in the NBT

development, as it would allow the public to keep up. With respect to the uncertainty of military application the precautionary principle was strongly advocated in Visby.

The participants of the seminars generally agreed that any NBT regulation should not be independent of policy used for other technology but rather reflect such policy. However, it was equally emphasised that as certain aspects of NBT are still uncertain, they might possibly fall outside current regulatory regimes.

Emerging ethical issues

The emerging ethical issues of potential NBT applications and products received considerable attention and debate at all seminars, perhaps especially at the seminars in Sheffield and Lublin. The participants generally recommended that the public be engaged in the ethical debate over the possible effects of technology at all stages of the development. Other recommendations for addressing the ethical concerns were to involve a range of researchers from different scientific disciplines in the NBT development (Visby, Sheffield) along with establishing governmental scientific commissions (Porto). Perhaps one of the main outcomes of these discussions was that they directly addressed the question of which might be the controversial ethical issues. They also illustrated how the debate over these issues might run once more NBT applications are available.

The main issues that were discussed were *privacy, human enhancement, freedom of choice*, and *longevity/overpopulation*. These issues all had in common that they inspired particular controversy. Certain participants advocated strong regulation for applications that might lead to cognitive enhancement or would infringe on people's privacy, whereas others took a far more liberal stance. However even those participants who were positive toward certain NBT applications being used for controversial purposes, they thought it was important that it be up to individual choice and not be forced upon the individual by an employer etc.

The concern for privacy referred to potential applications in both medicine – such as the opportunity for early diagnosis and sensor monitoring – and in surveillance technologies. In Porto there was a debate on whether NBT really would imply any greater infringements on privacy; some felt that it would be a natural and improved development of already existing techniques where as others claimed that the smaller-scale surveillance would be a greater threat to the individual integrity. In Sheffield there was a suggestion that each patient would be

provided with the equivalent to a "key" to their biological or genetic data, which would be given to medical staff only in emergency cases or following the consent of the patient. It was argued that this might even improve the integrity of the patient.

Several participants were troubled by the fact that many medical treatments would also be developed to enhance different human abilities and create a "robot-society" (Visby) or a race of super-humans (Lublin). The problem with such a development was not only that it might imply a radical departure from "natural" abilities, but that it might iron out the good things about diversity (Sheffield). The long-term opportunities for cognitive or intellectual enhancement was the greatest worry. In Sheffield participants feared that the negative implications of having a superior memory would not be properly investigated, i.e. what happens if certain tragic (or trivial) information cannot be forgotten? While participants in Sheffield also expressed concern about nanomedicine simply becoming luxury treatment for the wealthy and the educated, in Lublin participants were instead concerned that enforcing heavy restrictions would not be defensible due to the individual's right to choose.

The value of freedom of choice entered into the ethical debate at several points, both in relation to the issues of privacy, enhancement and the general recommendation public participation. A key concern was that the development might be forced upon people without allowing any real opportunity for individuals to opt out. On the other hand it was recognised that too heavy regulation might be an obstacle to individual risk-taking in connection with novel treatments. Another ethical issue, which participants felt had to be considered in advance, was the socio-economic consequences of individuals living longer due to advanced medical treatment.

Methodological conclusions

Apart from the advice given in the seminars, we would like to briefly comment on some conclusions in regard to our theoretical objectives. As mentioned, we tried to ensure that although participants were asked to discuss different possible effects of NBT, the ethical reasoning would not be confined to a consequentialist agenda. The scenarios were thus constructed in a way that disclosed the *process* leading up to the given scenario. Another means for ensuring considerations of process was through structuring the seminar in different phases. This encouraged the participants to imagine what kind of decisions might have led up

to their particular scenario. As a result we found that the focus of many discussions was on procedural guidelines for decision-making, regulation, public engagement etc. For instance the discussion on regulation was not restricted to its potential harms and benefits of regulation, but also referred to how the regulatory body should be constituted and whether the regulation should be set at national or international levels.

Another central idea with the seminars was to achieve decision-stability through considering different future possibilities. One sign that such considerations had indeed achieved such an impact was given in the participants' responses in the final questionnaire. A vast majority of the participants indicated that taking alternative developments into account had influenced their opinion of NBT (see appendix 3). After completing phase two many claimed to have become aware of new aspects of NBT and its interplay with society, thereby becoming more positive, negative, or balanced in their over-all view. The responses in the questionnaire also indicate another positive outcome of the different phases of discussion; namely that the participants felt that their decision-capacity had been improved by repeatedly taking into account the perspective of other participants. Some of the scientists participating in the seminar expressed that they found this aspect particularly rewarding as they were given a direct account of the values and priorities of non-scientists.

7. Conclusions

This was the first use of convergence seminars. The method functioned well, both logistically and more importantly, by giving rise to the type of discussions that we aimed for, namely discussions on how today's decisions should be influenced by different possible future developments. As expected, the methodology was well suited for discussions on the future of nanobiotechnology, with its many uncertainties.

In spite of the wide differences between the participants in geographical, demographic and professional terms, some standpoints seemed to receive unanimous or near unanimous support. Participants wanted nanotechnological developments to be aimed at socially useful technology. They mentioned in particular technological solutions to environmental problems, improved medical technology, and technology that meets the needs of developing countries. Military applications were often mentioned as undesirable. Equality concerns were raised by many participants. The need for public participation and deliberation in NBT issues seemed to be acknowledged by all participants. Views on the means by which NBT should be steered into socially useful directions were more divided. In particular, different views were expressed on how much regulation of company activities is needed to curb unwanted developments.

Appendix 1

Scenarios and questions for phase 1

Scenario 2011 (common to all groups)

We are at the beginning of year 2011. Politicians and policy-makers in Europe are facing crucial decisions on whether or not to promote the development of nanobiotechnology. (As a reminder, here is the definition given to you earlier: *Nanotechnology* is about investigating, manipulating and engineering matter that is roughly situated at the level of molecules and atoms. *Nanobiotechnology* is the branch that concerns the biological or biochemical application of nanotechnology, as well as the creation of biological nanostructures. It also covers the tools and devices developed for working with these extremely small units.)

In 2011, this technology has left the labs and is increasingly being applied to various fields such as medicine, ICT (information and communication technology) and energy production. The supporters of nanobiotechnology are calling for more funding and for liberal policy and legislation concerning its commercial applications. They believe that with further economical and political support, we now are able to develop the most sophisticated systems of communication and, more importantly, cure a long list of previously incurable diseases.

On the other hand, an increasing amount of concern and protest is being raised against nanobiotechnology. Critics believe that the application of nanobiotechnology will have reverse impacts on our health and well-being: exposing people to new health risks, infringing on our freedom and privacy. Again, many believe that such worries are futile, since any withdrawal or restrictions on funding will only force Europe to lag behind countries such as the US and China in the development of nanobiotechnology.

Scenario A

We are at the beginning of year 2020. In general, since 2011, European politicians have taken a very precautionary stance towards nanotechnology. Certain areas have received a lot of support, such as the development of energy- storage and production. This support has helped advance successful methods for energy production such as nano-coated solar cells and nano-catalysts that are used for hydrogen generation. Nanobiotechnology has also been developed for water treatment and purification. The combination of these methods has had a great positive impact on the environment, not only in Europe but also in many developing countries.

Even so, European politicians have made a joint decision to generally restrict financial support to further research in nanobiotechnology. In a similar line, they have also restrained application of nanobiotechnology in ICT and medicine. Many European countries have adopted considerable legislation in order to stop any chance of uncontrollable and potentially harmful nanoparticles entering the body and causing damage. Much of nanobiotechnology aiming for diagnostics and treatment (such as drug-delivery, nanosensors and nano-engineered tissue) is affected by this legislation and, if not illegal, these methods are very rarely applied in medicine.

Meanwhile countries outside Europe have chosen a completely different path. The United States and Canada are putting a huge amount of funding toward medicine enhanced by nanobiotechnology. Although there are a few reports of serious side effects, even death incidents, related to the use of nanoparticles; on balance medical treatment has been substantially improved thanks to the new methods of nanobiotechnology. Many Europeans have also chosen to go overseas to get nano-engineered tissue implants that are forbidden in Europe.

Other countries such as China and Japan take the lead in nano-related ICT-research that has provided great economic benefits. Also from a purely economical standpoint, Europe is lagging far behind these countries. Unemployment, especially in the technological areas, is much higher in the European countries than what it was ten years ago and most young researchers have little choice but to find work outside Europe. It is generally recognised that the restrictions put on nanobiotechnology ten years ago, is a major reason why Europe so rapidly has lost, and continues to lose, ground to many countries.

Some international collaborations and partnerships have all the same been set up between Europe and other countries; especially in the nanotechnological research that concerns sustainability and energy production. On the whole, however, the countries that put nanotechnology development high up on the agenda tend to cooperate with each other rather than with Europe. The decision not to further nanbiotechnology development has created a role for Europe as the old-fashioned sceptics.

You have read a possible scenario of how the development and application of nanobiotechnology has affected life in 2020. The scenario also describes the results of certain decisions made in 2011. Our questions to you are:

1. What do you think of the scenario? Which are the positive and negative aspects?

2. What can we learn from the scenario?

3. Should different decisions have been made in 2011?

Scenario B

We are at the beginning of year 2020. Thanks to the support toward nanobiotechnological research in Europe, since 2011, some major breakthroughs have taken place in medicine. Medical applications now

dominate the field of nanotechnology and a lot of new jobs have been created in this area. One important novelty is the use of nanoparticles in selective treatment of neurological diseases and brain-tumours. A kind of nano-carrier is used to carry therapeutic agents (medicine) across the blood–brain barrier where they target the diseased cells. Although a lot of people are being cured using this method of "drug-delivery", there are some severe health risks that were not foreseen ten years ago. Since nanoparticles aren't easily degraded they tend to stay on once their "work is done". As a result there is a risk that they may end up harming healthy parts of the brain. A tragedy recently occurred in a large city hospital when 20 patients received severe brain inflammation and 5 died from this kind of treatment. Many blame the incident on the hospital for their careless application of the method, while others claim that one already should have stopped this kind of treatment to avoid the potential of serious side effects.

In another area of medicine one, nowadays, no longer has to rely on organ donors for replacement of malfunctioning organs. Instead one can engineer a biodegradable scaffold that allows for the regeneration of damaged tissue or the growth of donor cells. Not only can one now grow new skin, bone, muscles but also some organs such as kidneys. Aside from the method being used to repair damage and cure various diseases, it is becoming increasingly popular in other areas. For instance, these implants are also used for cosmetic purposes and muscle tissue implants have become accepted amongst athletes. Although some governments are considering prohibiting such "non-therapeutic" treatment, there is currently no legal restriction in this area.

Similarly neurological implants has proven efficient for patients with Alzheimer's disease. Another possibility is the through nanobiotechnology improved biochip that works as an artificial hippocampus. As the hippocampus plays a key role in creating new memories, with this new technique one is able to restore the memory capacity of Alzheimer's patients. Since this technique seems to boost the memory in general, people with normally functioning memory are also beginning to have these implants inserted into their brain. Although the use is still not widespread, several cases are known where employers have paid for implants for those employees whose work tasks set high demands on intelligence and performance. One of the main worries is that because the treatment is so expensive, it will give rise to a new and serious inequality, namely between those who can afford this kind of "enhancing" treatment and those who cannot.

Thanks to nano-engineered biosensors we are now able to diagnose many diseases much earlier and more accurately than we could ten years ago. Along with the development of drug-delivery and tissue implants, the average life span has increased with ten years; going from around 80 years to 90 years! While many cherish the opportunity to live a longer life, there are problems on the socioeconomic level.

It is hard to pay for the needs of the large part of the population that is over 75. At the same time the overpopulation in urban areas is becoming increasingly difficult to deal with.

You have read a possible scenario of how the development and application of nanobiotechnology has affected life in 2020. The scenario also describes the results of certain decisions made in 2011. Our questions to you are:

1. What do you think of the scenarios? Which are the positive and negative aspects?

2. What can we learn from the scenario?

3. Should different decisions have been made in 2011?

Scenario C

We are at the beginning of year 2020 and Europe has since 2011 gone ahead and given top-priority to research in nanobiotechnology. Since there has been a special focus on the commercial application of nanobiotechnology, some of the main rewards have been in the area of ICT. Nanobio-sensors have created smooth and exact means for people to communicate with computers and with each other. It is now possible to connect our nervous system with external communication systems. This technique has provided paralyzed persons with highly functional artificial limbs. Similar sensors are also being used by the military where a new weapons system directly read off the electrical impulses from the soldier's brain. So far this novel brain-computer interface system is restricted to these specialized areas, but the push is on for the technique to be used in other commercial areas. We may very soon be able to administer kitchen equipment, stereo systems, machines at our workplace and all kinds of devices "directly with our thoughts".

Other kinds of nanobio-sensors are being used in medicine. These sensors are implants that collect information in otherwise inaccessible parts of the body while at the same time being "online" with an external computer. They can be used for monitoring blood pressure and glucose levels in people with diabetes etc. These sensors are also able to detect new diseases, for instance by tracing cancer cells. In fact, they have proven so efficient that one country has decided to implant them in all one-year-olds. The motive for doing this is of course individual health and health-care economy. However, since these devices function without our conscious awareness, many feel that they are an intrusion to our privacy. They're concerned that those supervising the output often know more about the patient's state of health than the patient may be willing to let them know!

Another kind of diagnostics that is dependent on nanotechnology is the so-called "Lab-on-a-chip". It combines a sensitive chemical analysis with an interfacing computer that simultaneously evaluates the results. As a result, more and more information can be extracted from very small quantities of material. The method has been advanced to the level that it allows for a disclosure of genetic and other biological information, thereby supplying a catalogue of the diseases one is likely to develop. Although it is not

required for patients to be informed of all details, many feel the social pressure (and responsibility) to find out about all conditions that will affect their future state of health. The common use of this technology in screening job applicants, has given rise to heated debate in several European countries.

Nanobiotechnology has also allowed for a new kind of surveillance since the tracking devices can be made at such a scale that they are impossible to detect. Military secret service has succeeded in attaching nanoscale GPS-tracking devices to different individuals, thereby locating the exact position of potential terrorists. There have also been several stories recently in the news about private persons who use this technique to track the whereabouts of their partner. The simple fact that these devices are so extremely small and discrete makes it impossible for someone to find out if he or she is under surveillance.

You have read a possible scenario of how the development and application of nanobiotechnology has affected life in 2020. The scenario also describes the results of certain decisions made in 2011. Our questions to you are:

1. What do you think of the scenario?
2. Which are the positive and negative aspects?
3. What can we learn from the scenario? Should different decisions have been made in 2011?

Appendix 2

Exercise and questions for phase 2

Exercise

During phase 1 all of you were given the same situation that was described in year 2011. Then the different groups followed different courses of development until year 2020. Each of you should give a brief account of the discussion and the conclusions that were drawn in your former groups.

Now we ask you to discuss two questions, similar to the ones you were given in phase 1. This time we would like you to jot down your answers for the final phase where you will give a brief presentation of your conclusions.

1. What can we learn from the scenarios?

2. What decisions should have been made in 2011?

Appendix 3

Questionnaire

The questionnaire was handed out to the participants following the final discussion. For answers to question 1 see each individual seminar report in section 5. For answers to questions 3 and 4, see the following appendices 4 and 5.

Questionnaire

1. What advice would you like to give to decision-makers who in the near future will decide about the future of nanobiotechnology?

2. Which scenario group did you take part in? A B C

3. What, if any, impact did the discussion in the second group (phase 2) have on your opinion of nanobiotechnology?

4. What is your opinion about these seminars as a means to facilitate decisions about future technological developments?

Appendix 4

Answers to question 3 of questionnaire

The following is a list of the responses we received for what kind of impact the participants thought the discussion in Phase 2 had on their opinion of NBT. All letters within the parenthesis indicates the scenario group that the participant belonged to, so that A indicates a participant in group A and so forth.

Visby

1. More negative opinion of NBT

- The environmental aspects were neglected. This can become a political conflict. (A)
- Realised that if this technology exists it may also be used in war and in cosmetic surgery. (A)
- Strengthened my fears! (B)
- Got more insight into what kind of control NBT would have over people if it ended up in the wrong hands. (B)

2. More balanced opinion of NBT

- Became aware of risks but also opportunities. (A)
- Realised the danger of NBT but also of the possibilities with this technology. (B)

3. More positive opinion of NBT

- That there were more things that could be positive with this technology. (C)

4. No effect (C)

Sheffield

1. More negative opinion of NBT

- There is a need for regulation to avoid any unpleasant scenarios. I was concerned over the lack of control. There is a need for long-term studies. (C)
- It is very clear that lack of regulation may have catastrophic results on public health, safety and policy. (C)
- It emphasised the dangerous aspects of NBT. (B)
- The other scenarios highlighted the potential problems that could arise from NBT, particularly the privacy issues and interference with peoples' autonomy. (A)

- I became more fearful of the applications; more convinced that just because things are possible, it doesn't mean that that they should become acceptable. Each application will have ramifications that should be properly assessed by ethical and well-informed people. (A)

2. More balanced opinion of NBT

- The difficulty of suggesting an appropriate regulatory regime. The potential for using NBT to usurp free will and self-determination. (B)
- Aware that too much regulation could be bad. I hadn't considered the privacy issues. (B)
- I became aware that it is very difficult to predict the outcome of research with accuracy. I became aware of the possibility of NBT increasing divisions in society. (A)

3. More positive opinion of NBT

- That it should take place, despite previously being warned about it. (A)

4. New perception of NBT

- That nanotechnology is not a unique technology, not a separate one. (C)

5. More informed of the views of other participants

- I was impressed that most people were quite supportive (liberal) of the technology and controversial applications, but at the same time called for regulation. (B)

6. No effect

- It didn't really have an impact (C)

Lublin

1. More negative opinion of NBT

- What is currently conceived as a "good" idea can cause serious problems in the future. (B)

2. More balanced opinion of NBT

- I do not share the enthusiastic attitude of those who are wildly for the development of NBT. However I am convinced that with people who are conscious and responsible we may avoid the negative aspects of developing NBT. (A)
- It made me more open to problems in this field of studies which I haven't noticed before. It also made me think about the benefits of nanotechnology on the environmental level; not only individual benefits but for the entire planet. (B)

3. More Positive opinion of NBT

- It showed my some positive aspects of NT. Even if I might have thought of some myself there were some that surprised me. In other words, it simply broadened my view. (A)

4. New perception of NBT

- We have to think of the entire planet. I didn't think of certain aspects before, although I work in nanotechnology. (A)

- I learned that the question of NBT is still very broad and still unknown. There should be a special law defining the development of such technologies and people should look more globally at what changes science and our lives. (B)
- It showed me that there are many issues with NBT that should be closely examined closely and carefully, not only in terms of technical aspects. (C)
- With or without our permission this branch of science will be developing and we should do our best to keep up with others. (A)
- I learned more about the inventions in the field of NBT. I was able to predict threats and benefits as well as share my view on different aspects of NBT with other members of the group. (C)

5. More informed of the views of other participants

- I could exchange my ideas with others and verify whether those views were only my own or in fact shared by others. However, I have the feeling that we can discuss these things but in the end the powerful and wealthy will decide… (B)
- We all had similar doubts and saw similar risks, though we didn't reach consensus on artificial intelligence – should it be left to individual choice or not. (C)
- It had an impact on my opinion because I understood the point of view of other groups in society. (C)

Porto

1. More negative opinion of NBT

- It strengthened the impression that this is an area with many uncertainties and that one must use the Precautionary Principle as a guide to our actions. (A)

2. More balanced opinion of NBT

- I concluded that the right way is to find a balance. In other words, research mustn't be stopped. Though it should be totally controlled – not only nationwide but worldwide. (B)
- One realised that NBT carries many benefits, though this technology must be used moderately. We should focus not only on the economical development but also on the social development. (B)
- Like all science and technology it must be regulated, evaluated, and accompanied by experts in different fields and international ethics commissions. But the advances in knowledge must never be stopped but rather monitored. (C)

3. New perception of NBT

- Medicine is the field with most impact (A)
- It was important to have an awareness of other possible scenarios for the development of NBT and the actions of European organizations about it. (C)

4. More informed of the views of others

- It allowed for exchanging ideas and opinions with different people. (C)

Appendix 5

Answers to question 4 of questionnaire

The following section lists the participants' opinion of the convergence seminars as a means to facilitate decisions about future technological developments.

Visby

- It gives an opportunity to reflect in advance! Also it's an opportunity to think about what we want to use technology for and in what kind of abusive ways it may be used.
- A very good idea!
- Good as a way to gain information. Good as prevention.
- Good as it brings out the important questions that must be discussed.
- It is good to discuss the aim and meaning of a technology before it enters into "reality". That way one doesn't simply foist a bunch of stuff on people without them having considering if they need it or if it's good or bad. But this seminar was perhaps a bit small. It should be the start of, or a part of, a general discussion in society. It is very important that everyone receives information and the opportunity to take a stand.
- I missed the facts. What is the state of the art in research, how far has one come? Where does the law and the politicians stand? The seminar is not really a tool but something that is interesting for the individual. I don't think that us as grassroots can influence the development.
- Interesting for me on a personal level, but for a better discussion the groups should have been put together in a more thorough fashion.
- Seminars are good, but all the participants had the same kind of interests (”save the environment”). Everybody was in unanimous agreement; there should have been people with different opinions.

Sheffield

- Good way to not only get opinions but to inform people. Should be regular as the technology is developing all the time.
- It's a good way to express the opinions about a lot of issues related to future technological developments.
- They include a wide range of issues. This does make it difficult to get to the bottom of any one question.

- A good forum to gather a range of opinions from a diverse social group. Perhaps it should not be used as the sole means to facilitate decisions on future technological developments, but it is useful as a first step to gauge reactions and gather ideas.

- Good! Enjoyed it. Would have liked a longer discussion at the end. Perhaps a quick intro to some technologies would have been handy.

- Very interesting, we could have talked a lot more. Perhaps having a nano-expert would have been good. Enjoyed it.

- Try to stop them from getting too philosophical and speculative.

- A good thing!

- These seminars are a good idea. It tends to attract people of certain intelligence but who have no specialist knowledge of the field. This leads to an informed debate that should reflect people's true beliefs.

- They are useful for, in a structured manner, gathering concerns of people, which can then be used for other exercises.

- Very interesting and a good experience to discuss these issues. Thank you!

- Interesting – how far does the feedback go? How representative of the "general public" are they?

Porto

- They are very important because they're an efficient way of informing the general public about the subject. In the future there should be more of these seminars.

- They are very important. Not only for their informative side; the seminars should also be part of the decision process for public policies that concern technological developments.

- These seminars allow society to decide the future of not only the technological development but also the social and economical development.

- I consider the seminar not only positive but also fundamental.

- These seminars are very important since people normally don't know what's going on scientifically. Education and information are very important for these kinds of decisions.

- I consider it a fantastic idea for society in general; for the help I'm giving as a common citizen but also for personal enrichment. It helps me be a little more informed about fundamental matters for our future.

- I found it refreshing and very interesting to promote public participation on technical issues and it should be open to larger groups. For me it was a good experience to participate in this forum of discussion as a citizen concerned with technological issues.

Lublin

- Such a seminar can be helpful in understanding general needs and in understanding different points of views.

- People's opinions, like those who participated in this seminar, should be taken into account by those in power. All of society should decide on things like these – not just the government.

- It is hard to say. This kind of seminar can raise people's awareness of problems but I'm not sure whether it's enough to affect future decisions.

- It's great, do more such things. I wasn't convinced of whether to come here yesterday (and if I hadn't I'd probably have slept to 10 am and watched TV until noon). The things we discussed seemed obvious at first, but eventually turned out to be crucial. People are not aware of the importance of research and this situation should change. These seminars are helpful and should be held more often.

- It was an academic discussion between young people that can provide a fresh point of view in political discussions. Those that make the decisions are usually skilled in a specific field and these seminars can help broaden the discussion.

- The seminars gather valuable information about how people view certain issues. These meetings should take place more often and various fields should be discussed.

- It is a very good idea since it makes us think about future issues, which are not very far away. For instance, during our discussion, we tried to think of possibilities of how to prevent technology being used to create a race of super-humans.

- The seminars are useful because ordinary people, who are not involved in the actual development, can express their opinions and share their views with each other. This may contribute to future decisions made by experts.

- People off the street can often have a more fresh view or idea to a given problem than scientists. We should ask people that live ordinary lives what their everyday problems are. Despite their lack of scientific knowledge, they can still "switch on the light" in the darkness.

- A very good idea. It encouraged us to think about the benefits and the risks of the development that is taking place and will affect us in the future. I hope this seminar raised some doubts that will be considered by those who actually work in the field, either in the production phase or with the decision-making, and will make them think twice before implementing this technology.

- These seminars are a good way to understand what others think of nanobiotechnology. For me, as a scientist, other people's opinions are very important because I can prepare my research in a way that serves the community.

- Interdisciplinary seminars are a very good way to look at different aspects of the development, such as what influence the technological development has on society, in terms of ethical, political and economical aspects.

- I am very positive: they allow for the exchange of different views and for exploring matters further. They gather the opinions of people whose lives will be affected by decisions taken,

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