The nanotech R&D situation in Japan and ethics of nanotechnology

Yutaka KATO*

SUMMARY

The aim of this paper is to introduce some characteristics of the historical as well as current situation of nanotech research and development in Japan in particular, including regulations, and to discuss how ethical issues of nanotechnology should be addressed or how the ethics of nanotechnology should be constructed to fit the situation. The first part will center around the strength and weakness of Japan's nanotech R&D (research and development) and new circumstances which nanotechnology has prompted in Japan and alongside which nanotechnology has arrived (especially interdisciplinarity). The following prescriptive argument will, based on the descriptive account, question how to address ethical issues of nanotechnology, taking into consideration the nature of nanotech R&D, namely continuity, uniqueness, international dimension and political intervention, citing the example of the pharmaceutical industry. I will argue that international cooperation in the form of mutual reference to, replication of and the integration of guidelines and regulations, can enhance cost-effectiveness to ensure the comprehensiveness of regulatory measures.

Key-words: Nanotechnology, Japan, Science, Technology, Research policy, Drug industry, Government financing, Health hazards, International aspects.

RÉSUMÉ

LA SITUATION R&D NANOTECH AU JAPON ET L'ÉTHIQUE DE LA NANOTECHNOLOGIE

L'objectif de cet article est de présenter quelques-unes des caractéristiques de la situation historique et actuelle de la recherche et du développement en nanotech au Japon en particulier, y compris la réglementation, et de discuter de comment les questions éthiques de la nanotechnologie doivent être abordées ou comment l'éthique de la nanotechnologie doit être construite pour s'adapter à la situation. La première partie sera centrée sur la force et la faiblesse du R&D (recherche et développement) nanotech au Japon et sur les nouvelles circonstances provoquées par la nanotechnologie au Japon et à côté desquelles est arrivée la nanotechnologie (surtout l'interdisciplinarité). L'argument prescriptif qui suit, basé sur le récit descriptif, examinera la façon d'aborder les questions éthiques de la nanotechnologie. Il prendra en considération la nature du R&D nanotech, à savoir la continuité, la singularité, la dimension internationale et l'intervention politique, citant l'exemple de l'industrie pharmaceutique. Je soutiendrai que la coopération internationale sous la forme d'une référence mutuelle aux directives et à la réglementation, ainsi que leur duplication et leur intégration, peut améliorer la rentabilité afin d'assurer que les mesures de contrôle soient complètes.

Mots-clés : *Nanotechnologie, Japon, Science, Technologie, Politique de la recherche, Industrie pharmaceutique, Financement par le gouvernement, Risque pour la santé, Aspect international.*

* Graduate School of Medicine, Osaka University.

INTRODUCTION

I attempted elsewhere to enumerate and elaborate the ethical implications of nanotechnology, focusing on the current circumstances in Japan, so that they can be discussed and addressed effectively (Kato 2009). In this paper, I will introduce several traits of the historical as well as current circumstances of nanotech research and development, in Japan in particular, including regulations, and discuss how ethical issues of nanotechnology should be addressed or how the ethics of nanotechnology should be constructed to fit the situation of Japan. The first part will mainly describe the strength and weakness of Japan's nanotech R&D (research and development) and new circumstances prompted by nanotechnology in Japan and alongside which nanotechnology has arrived. The following prescriptive argument will, based on the descriptive account, question how to address ethical issues of nanotechnology, taking into consideration the nature of nanotech R&D, namely continuity, uniqueness, international dimension and political intervention, citing the example of the pharmaceutical industry. In so doing, I intend to supplement my previous argument.

THE NANOTECH R&D SITUATION IN JAPAN

To understand the R&D situation of nanotechnology in Japan, I will outline the fields in which Japan has led, those in which it remains behind and the new circumstances which nanotechnology has prompted in Japan and alongside which it has arrived. It is well-known that Japan was leading in several fields that were later re-labeled nanotechnology prior to the National Nanotechnology Initiative (NNI) of the Clinton Administration. This is one reason, compared to the US, "The Japanese nanotech R&D strategy has the characteristics to strengthen existing technology and advances towards a nanotech level" (Islam and Miyazaki, p. 26). Islam and Miyazaki indicate this tendency when they note that "The analysis addressed the fact that chemistry, material science and physics have played important roles in the rapid growth of nanotech research in comparison with the biology discipline" (p. 34). Not to mention the significance of nanoscale machining technology in semiconductors, as early as the 1980s, Shiseido, Japan's largest cosmetic firm, for example, started research into the downsizing of cosmetic particles. To achieve higher semiconductor integration, and enhance absorption of chemical substances through the skin, the quest for miniaturization was a continuous and logical consequence from past R&D in these fields, though powder technology is anything but straightforward and it was considered difficult to break the 3-micrometer barrier in the early 1990s (One micrometer is one thousandth of one millimeter). Besides, the Ministry of International Trade and Industry (MITI) of Japan started a decade-long national project on the "micro machine" in 1991. Instead of a nanomachine, a micromachine, which is referred to as a MEMS (microelectromechanical system), is already common and used as such devices as an actuator or a sensor. Some have discussed the fear of a "gray goo scenario," in which the earth is covered by self-replicating nanomachines. As of September 2009, no self-replicating artificial assemblers had been fabricated, nor even any 1mm artificial machine capable of moving independently at present.[1]

Meanwhile, Japan remains behind in several aspects. The current nanotech R&D of Japan is said to be weak, especially, in biological and medical research of nanotechnology. Also, countermeasures against ELSI (ethical, legal and social issues or implications) related to nanotechnology were delayed. I wrote formerly that in Japan, the ELSI of nanotechnology seemingly "has gathered very little attention from ethicists outside some research institutions" to date (Kato 2009). The initiative in research on ethical issues of nanotechnology by research institutes is one manifestation of the absence of interests among ethicists in academia. The lack of focus on ELSI of nanotechnology is also conspicuous among the younger generations. Take for example the research fellowship for young scientists awarded by the Japan Society for the Promotion of Science (an independent administrative agency), which is considered important because Japanese universities do not usually provide a stipend for doctoral students. Among the applications adopted in the last five years, none of the 1,758 doctoral-course applicants in humanities and social sciences included the word

1. A nano-car developed by researchers at Rice University, with four buckyballs as wheels, can move back and forth. However, as the movement is random, it is null on average and no different from random heat movement. For practical use, movement in one direction needs to be materialized. It is true that a motor molecule activated by light is available. However, the researchers have not succeeded in loading an engine onto the car (Tour and Shirai pp. 71-75).

"nano" in the title of their applications (0%). Also, "nano" has never appeared in the titles of adopted applications for post-doctoral researchers (called PD, SPD or RPD). This indifference contrasts starkly with natural sciences. In chemistry, the word "nano" appeared in 112 out of 987 doctor-course applications (11.3%), and likewise in engineering, 142 of 1410 doctor-course applications (10.1%) over the last four years (the classification changed in 2005).[2]

Cosmetics, as previously mentioned, is a field in which nanotech products are already commercially available and go unchecked in this age of the greater independence or autonomy of patients or consumers of OTC (over-the-counter) drugs. Some question the safety of platinum nano colloid and fullerene used as cosmetics. A Google search (www.google.co.jp) for "fullerene" in Japanese shows advertisements for cosmetics at the top of the screen, some of which state that fullerene removes radical oxygen much more effectively (for example, 125 times) than vitamin C. Others even mention the Nobel Prize awarded for fullerene, though it is completely unrelated to the safety or effectiveness of substances used as cosmetics, while other surveys point to its oxidative stress.

Amongst the new circumstances nanotechnology has prompted in Japan are the interdisciplinary research, the resulting need for enormous investment and the possibility that Japan could be defeated in its forte. In Japan, nanotechnology has undeniably functioned as a catalyst for interdisciplinary research. This can entail problems stemming from different cultures among academic fields, different attitudes toward clinical applications,[3] vying for hegemony, the difficulty of assessing research projects through peer review, and the cost-effectiveness of interdisciplinary research. Also, as nanotech research spreads internationally, it becomes increasingly difficult for Japan to remain in front in its forte. It is true that there is the potential that nanotech R&D will widen the gap between developed and developing countries. However, this is not necessarily the case with countries such as China and South Korea, which Court and others categorize as developing countries (pp. 162f.), though South Korea is less commonly referred to as a developing country. The conventional dichotomy between developed and developing countries is of limited use. In terms of patent applications to the JPO (Japan Patent Office) from research and education institutions, Nagoya University (Japan) tops the list in high-functional materials, while the Korean Advanced Institute of Science & Technology (KAIST) ranks second followed by Tsinghua University (China) and two American universities.[4] In the ranking of private enterprises in the same area, Samsung SDI and Samsung Electronics of Samsung Group rank 6th and 7th respectively. However, in combination, the number of applications is nearly twice that of the top-ranked Sony Corporation (Japan). In emerging fields, it is possible that the last will be first, and the first will be last. In addition to the investment, assuming the pace of development of a particular technology to be positively correlated with the number of interactions among researchers per unit time, unless they are targeting something impossible in principle, it should be effective to integrate research bases. In Japan, research bases are scattered across the Japanese archipelago, as is the case for the United States. By this, Japan seems to place itself at a disadvantage. Nevertheless, any governmental intervention can be regarded as contradictory to free competition, benefiting only the few. On the other hand, in less developed countries, concentration by national policy may be possible.

The new circumstances are also apparent in the cooperation among different fields for countermeasures. It is said that "it is particularly noteworthy that, for the first time, a cooperative framework was established among the AIST, the National Institute for Materials Science (NIMS), the National Institute for

2. As a matter of fact, nanotech-related terminologies such as MEMS, fullerene, CNT (carbon nanotube) and titanium oxide appear as often. Thus, the percentage of applications dealing with nanotechology is higher. Considering the fact that objects in biology, semi-conductors etc. are often nano-sized and that DNA is also currently regarded as a typical nanotech material, strict demarcation is unreachable. In other fields of natural sciences (biology, agriculture, mathematics, physics, medicine, dentistry and pharmacology), 92 out of 4030 applications used the word "nano" in their titles (2.28%). Only the data for the last five years are available on-line (http://www.jsps.go.jp/j-pd/index.html). It is also true that each applicant's qualification matters. As I see it, this reflects what most evaluated applicants and referees prioritize or what applicants think the academic communities prioritize.

3. Personally I attended a course on biomaterials offered at the Graduate School of Engineering Science, through biomaterial course (the Center For Advanced Medical Engineering and Informatics, Osaka University http://www.mei.osaka-u.ac.jp/r02/index.html). The prospectus of the program states that the interdisciplinary nature of nanotechnology has facilitated the fusion of medicine and engineering. One of the things that surprised me, a former pharmacy student, is the difference in attitudes toward clinical application, as the group did not have future clinical application in mind at that time.

4. Ata p. 64 The table on the page categorizes KAIST as a public research institute. In effect, it is a university.

Environmental Studies and the National Institute of Health Sciences (NIHS), which are under the jurisdiction of different government ministries" (Takemura, p. 20 Translated by the author from Japanese into English).

THE NATURE OF ETHICS OF NANO-TECHNOLOGY

Based on the above descriptive account of the current situation mainly in Japan, this section is intended as a prescriptive account of the nature of ethical issues relating to nanotechnology. I point out continuity (of objects, infrastructure), uniqueness (in its entirety) and international dimension (widespread research, risk, vast investment and dilemmas, political intervention and possible impact on a particular industry).

CONTINUITY

In the previous section I mentioned the continuity of R&D in some fields. Continuity can exist among micro-, nano- and pico-scale. A news release publicized successful pico-scale processing by Institute for Molecular Science (National Institutes of Natural Sciences of Japan).[5] However, at present, the continuity between micro- and nano-level is of greater significance. The word "micro-nano" yields approximately 59,300 search results on Google as of September 2009. A book on the above-mentioned micromachine adopts a broad definition of the micromachine and includes nano-level (Micromachine Center, Preface). Another form of continuity is that among sub- and bordering fields, which I refer to as interdisciplinarity. Robert Freitas at the Institute for Molecular Manufacturing, for instance, lists as many as 95 subfields even within nanomedicine (Table 1 "A partial nanomedicine technologies taxonomy"). Moreover, each field is not entirely independent from the others. The continuity with other fields seems self-explanatory, partly because I think, in general, any academic field advances, redefining itself incessantly. For example, biology has changed its domain significantly during the previous century, which probably also applies to nanotechnology. The global move towards standardization, which is currently underway, is important particularly for risk assessment. Nevertheless, these considerations aside, I find scarcely any need to fix the definition and domain of nanotechnology immaturely, considering its current embryonic state.

Continuity can exist between nanotech and existing technologies. The development of ethics of nanotechnology can sometimes remind society of existing problems in other related fields.[6] Alternatively, nanotech can provide good opportunities to tackle long-ignored issues in some cases. What used to be called ultramicro particles in atmospheric environment research are nanoparticles with diameters of less than 100nm (Hirano, p. 37). Greater awareness of ELSI of nanotechnology seems to have facilitated the move toward more effective regulations, for example, of nano-particles in emissions from automobiles especially in Europe (Hirano, p. 37).

It is true that some think most objects have a nanostructure unless they are purely bulk matter (Hirano, p. 40). One symbolic substance is graphene, which is a mono-layer planar sheet of carbon atoms, only having become available in the year 2004 after fullerene and carbon nanotubes. Before then, mono-layer could not be isolated. The piled-up multi-layer graphene is called graphite, a frequently occurring carbon allotrope.

Concerning continuity, some insist that nanotechnology should target specifically nano-scale phenomena that are not continuous from those on a larger scale in order for public investment to be truly meaningful. On a nano-scale, gravity becomes increasingly ignorable, whereas the quantum effect, which is essential in semiconductors, and van der Waals attraction less ignorable. Also, as I see it, the importance of size is correlated with bodily structure, for example, the size of neurons or the nano-sized openings in the blood vessel walls. In case of the brain-machine interface, it is said that "Still more precise hookups might be furnished by nanoscale fibers, measuring 100 nanometers or less in diameter, which could easily tap into neurons" (Stix, pp. 58f.). Thus, miniaturization can be of significance for the practical use of nanotech applications. Change in size can lead to substantive,

5. Nikkan Kogyo Shimbun, February 2009.
6. One example is the fact that gas emissions from diesel-powered automobiles have been releasing nano-sized particles into the atmosphere. Also, according to Hirose and Hirano, it has been well-known among industrial health researchers that manganese battery workers sometimes suffer from Parkinson-like symptoms, and some have cited the possibility of health damage caused by nano-sized particles (p. 740).

discontinuous development. In this context, in Japan, the term "true nano" was used in the Basic Plan for Science and Technology (third stage) in 2006 by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in order to indicate the drastic and discontinuous progress enabled by nanotechnology.[7]

I emphasized the continuity of nanotech and existing technologies. However, continuity does not necessarily mean the absence of problems. I do not dismiss or underrate the urgency of the ethical issues concerning nanotechnology. Instead, I argue for the possibility of utilizing the accumulation of knowledge in related fields, which I think can minimize the time lag required for detecting and addressing such issues. To build up ethical regulations for nanotech research and applications bottom-up is simply impractical. "Bricolage" seems to be a realistic solution.

Such continuity can mean that the problems are already present. For one thing, it can pose the question of the unknown risks of nanomaterials currently used in experiments. Today, students or researchers may harbor anxiety about the safety of the substances they use in experiments, even if they are regarded safe in bulk. The fear may be greater for those with any underlying disease or pregnant. Alternatively, they may consider it disadvantageous for their future careers to question safety in the laboratory. Similar misgivings may be experienced by many others in various places. To remain competitive, it must be sometimes difficult for a researcher, enterprise or state to err on the side of caution. Moreover, it is also true that, just as other pharmaceutical agents, it is, in principle, impossible to know fully in advance what needs to be known. If one wishes to take into consideration the risk or threat to the entire environment, including natural circumstances, endemic diseases, nutritive conditions (malnutrition, starvation), and underlying pollution in a particular area, it is simply intractable. Long-term side effects are often impossible to predict through short-term clinical tests or experiments on animals with short lifetimes. Therefore, it is necessary to recognize the limits of our knowledge. Many physiological phenomena remain black box. Even today, many diseases known to humankind are incurable (even if symptomatic treatments are sometimes available). We do not even know, for instance, the exact location of adult stem cells. Nanoparticles are far smaller than biological molecules such as antibodies. We can be more certain about the metabolic disposition of molecules much larger than nano particles (e.g., antibody drugs). We know little about the (metabolic) disposition of nano-particles.

UNIQUENESS

Although I do not believe that each ethical issue known to us is unique (Kato 2009), they can be considered such collectively. I argue for the importance of recognizing the uniqueness of the ethical issues of nanotechnology. Moreover, as I see it, the uniqueness of nanotechnology is both prescriptive and descriptive.

First of all, if the government chooses to allocate a certain portion of its nano-labeled funding to ELSI, the scope must be specified and effectively covered. In that case, it is necessary to examine the entirety of the ELSI of nanotechnology for better or worse.

What is immanent in the term nanotechnology is merely information on size (i.e. nanoscale). ELSI deriving from the compactness of objects are necessarily limited. On the other hand, nanotechnology is one of the few fields possibly defined by size. Richard Feynman said, "There's plenty of room at the bottom." Yet it is probably not infinite.

The continuity mentioned in the previous section is simultaneously the uniqueness of (ELSI of) nanotechnology. If a nanotech application is isolated from other technologies, such as biotechnology and ICT (infocommunication technology), which can be used in combination with nanotechnology, it is difficult to address the ELSI effectively. It is usually reasonable to distinguish feasibility of particular intended technological applications, for it is not advisable to waste public resources for consideration of ethical implications of merely visionary applications. But, the continuity in the form of interdisciplinarity and potential (unexpected) interaction with other fields, together with secrecy prevailing in R&D especially after the Bayh-Dole Act, can undermine the predictability of the feasibility.

The reason Japanese ethicists are indifferent to nanotechnology seems to have much to do with the background and nature of the academic field and community of ethics in Japan itself. Japanese ethicists are interested in extracting some new perspective for

7. The MEXT website available at http://www.mext.go.jp/english/mext_2007_e.pdf (Downloaded 31 December 2008).

ethics as a field of academic study. Very few are interested in how rightly and effectively they can cope with real ethical issues. Such lack of attention is partly because evaluating the risks of nanoparticles, which are currently the main topic of discussion, is not so much ethical as technical per se. One negative effect of this tendency is the partiality of the discussion on ELSI of nanotechnology I discussed previously (Kato 2009), which needs to be addressed. If one does not regard the ethical issues of nanotechnology as a mere springboard for some purely philosophical argument, they can be seen as unique rather than generic.

INTERNATIONAL DIMENSION AND POLITICAL INTERVENTION

As a consequence of the lack of attention from ethicists in Japan, it is difficult to expect pioneering, fundamental and comprehensive contributions from domestic scholars to ELSI of nanotechnology. Also, new nanotech applications can enter Japan from overseas while the Japanese are unprepared. As I wrote previously, "Approximately 80% of the 83 applications for the JPO in the Official Gazette in the year 2008 containing the terms "nano" and "iryo (medical care or medical treatment)" either in summaries or claims are from overseas. This contrasts starkly with the overall tendency; only around 20% of the applications to the JPO are from overseas" (Kato 2009). Taking into consideration the fact that funding for ELSI of nanotechnology is a social cost and that little attention from domestic ethicists is paid to nanotechnology, international cooperation in the form of mutual reference to, replication of and the integration of the guidelines and regulations, can enhance cost-effectiveness and ensure the comprehensiveness of the regulatory measures, despite the possibility of free riding.

I mentioned above the possibility that Japan could be defeated in its forte. In simplistic terms, the current nanotech R&D situation can be described as follows. Many countries and enterprises jumped in unexploited areas with a view to monopolizing undiscovered nanotech applications and a few succeeded in monopolizing/privatizing only a tiny estate in a vast area. Failure to jump in appears to be a loss of easy profit; too many have jumped in the nanotech R&D. Nanotech research spread too hastily – probably unjustifiably – with little end product to show for the vast investment. There must be an enormous glut of redundant investment and research internationally. Furthermore, the vast investment already made can sometimes further hamper withdrawal.

The ethical divide, which usually refers to domestic circumstances, can also be considerable internationally in terms of ethical regulations regarding nanotechnology. Whereas an ethical divide exists internationally, products can transcend boundaries, especially if problems concerning intellectual property rights are resolved. More specifically, for example, a nanotech application, which does not evoke any ethical concern in a country with a particular social system or a social infrastructure, can cause ethical problems when imported to another country with different social milieu.

As for the potential impact of nanotechnology on industry and political intervention, I cite the example of the pharmaceutical industry, which Mulhall predicts will be the world's largest enterprises in the age of nanotechnology. As I will describe below, at least in Japan, such prediction will only apply for those surviving the structural change of the industry and securing fundamental/infrastructure technologies for themselves. The pharmaceutical industry in Japan is conspicuous in that, due to past regulations, as many as 1,000 or more pharmaceutical companies exist in Japan. Moreover, with the adoption rate of generic drugs remaining low, Japan's largest pharmaceutical firms rely heavily on off-patent products. Also, the industry has been subject to both Pharmaceutical Affairs Act and political pressure in the form of revised pharmaceutical prices. New technologies can trigger drastic industry change, with potential influence on stable supply of conventional small-molecule drugs. In addition to the depletion of lead compounds and the resulting increase in R&D cost, a major trend in the pharmaceutical industry in recent years is the growth in antibody drugs. In conventional chemical synthesis, larger molecules were much more difficult. Antibiotic agent penicillin, the total synthesis of which succeeded in 1957, is approximately 1nm in size. With a completely new mechanism, it is said that Remicade (or Infliximab, anti-TNF antibody) was so effective that double blind studies were useless. To compensate the weakness in antibody drugs, Takeda Pharmaceutical Company, the largest in Japan and Asia, acquired Millennium Pharmaceuticals for $8.8 billion. In Japan, the current trend toward larger molecules is boosting several middle-scale firms, but nanotechnology could shake up the industry in future. A pharmaceutical agent produced by nanotechnology could be totally different. It might be a cross or intermediate of medical machinery and pharmaceutical products. A pharmaceutical agent has been free from the "patent thicket," which is common in the case of automobiles or home electronics, where a single product uses hundreds or thousands of patents. A pharmaceutical agent usually consists of a single patent. However, this might change in future.

The decision on the balance between promotion and regulation is basically political in nature.[8] Governmental funding, meanwhile, is itself a form of intervention.[9] For example, according to an interview by Islam and Miyazaki, some scientists and researchers are championing the fairer distribution/allocation of the funds (pp. 32f.). In some cases, an industry hopes for governmental assistance in global competition, one example of which is the battle for resources overseas (cf. Schummer pp. 89f.).[10]

In the (near) future, a political decision on allocation would be made under circumstances where the general public know more about their own genetics and the probability of suffering from a particular fatal disease. For example, if the morbidity rate of a particular disease is around 25% and the prediction in advance is impossible, the majority of the general public are highly likely to be in favor of investing in research into the disease. However, when the more accurate prediction enabled by nanotech applications becomes available for many, the investment for that disease would be less likely to be endorsed by the majority. An improved prediction could make more people indifferent to a particular disease.

Despite the possibility that nanotech R&D can widen the gap, either domestic or international, due to the differences in scientific and technological capabilities, it is neither likely nor reasonable that the possibility of widening international gap can somehow deter nanotech researchers, institutions or enterprises from their endeavors. This issue is unsolvable on the level of research ethics, but should instead be addressed at governmental and international levels. If R&D by developed countries or multi-national enterprises were to be suffocated, only low-level equality would be achievable. Even if the so-called trickle-down theory cannot be entirely endorsed, nanotechnology can benefit developing countries, despite possibly widening the gap between developing and developed countries since it is not a zero-sum game (We may have to be careful not to let the increased degree of satisfaction on both sides of the conflict gloss over existing problems). It is also likely that multinational firms that are successful in nanotech R&D will create and expand employment in developing countries. Just as the inventions by Thomas Edison, many countries can benefit from inventions, especially after the property rights expire. At least, the benefits of medical agents can still be widely enjoyed within 25 years when the patent expires. Nonetheless, insurmountable problems remain concerning the relation between patenting and public health, even after the Doha Declaration (2001), which verifies the importance of the TRIPS Agreement (the Agreement on Trade-Related Aspects of Intellectual Property Rights) being implemented and interpreted "in a manner supportive of… public health."[11]

The potential issues that can influence a particular industry allow no cause for optimism. The public aspect of pharmaceutical firms should be taken into consideration. It is also essential that the government assist them in making ethically sound decisions.

CONCLUSION

In this paper, I have briefly introduced several important characteristics of the historical and current circumstances of nanotech research and development, in Japan in particular, in order to discuss how ethical issues of nanotechnology should be addressed or how the ethics of nanotechnology should be constructed to fit the situation. I discussed several important aspects of nanotech R&D and its ethical issues, namely continuity (including interdisciplinarity), uniqueness, international dimension and political intervention. Citing the example of the pharmaceutical industry, I discussed the potential impacts of nanotechnology on

8. They do not necessarily contradict each other. For example, well-prepared regulations alleviate the fear of researchers.
9. Reportedly, civil groups in India are criticizing the enormous investment in Tata Motors Limited, known for the low-priced car nano. They argue that the governmental financial aid is unfair in benefiting only the wealthiest (*The Big Issue Japan*, Vol. 126 p. 12).
10. Kagaku Kogyo Nippo Sha p. 1149.
11. "Declaration on the TRIPS agreement and public health" available at the WTO website http://www.wto.org/english/theWTO_e/minist_e/min01_e/mindecl_trips_e.htm [Accessed 20 Feb, 2009].

the industry and maintained that the uniqueness of the ethical issues of nanotechnology as a whole should be recognized. Due to the lack of attention from domestic ethicists on the ethical issues of nanotech R&D, I argued for the significance of international cooperation in the form of mutual reference to or replication of domestic guidelines and regulations to ensure the comprehensiveness of regulatory measures. ■

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