Big Expectations from Something Incredibly Small: An Introduction to Nanotechnology[1]

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In recent years, technology is moving full speed towards nanotechnology. The US National Nanotechnology Initiative (NNI) defines nanotechnology as the fundamental understanding of phenomena and materials at the nanoscale or the research and technology development at the molecular or macromolecular levels, in the length scale of approximately 1 to 100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.[2] Yet this definition, although widely used in scholarly publications, cannot be established as the standard definition of nanotechnology. The interpretations and meanings of this concept are multiple and diverse.

In 2000, the US government launched the National Nanotechnology Initiative, an interagency project designated to coordinate research amongst the various agencies seeking to fund research and development in nanotechnology.[3] Other countries followed suit. Mihail Roco, advisor on nanotechnology at the National Science Foundation, predicts that within ten years, the entire semiconductor industry and half of pharmaceutical industry will rely on nanotechnology.[4] Investment worldwide was estimated at $13 billion in 2006 and is expected

[1] The authors would like to thank Dr. Joachim Schummer, Professor of Karlsruhe University, Germany and editor-in-chief of *HYLE* (International Journal for Philosophy of Chemistry), for reading their manuscript and providing useful comments and suggestions to improve this paper. Yet, any lapses or oversights that may be inadvertently presented in this paper are solely theirs.

The work was done under the auspices of the Research Cluster for the Natural and Applied Sciences of the University of Santo Tomas.

[2] National Science and Technology Council (2000). *National Nanotechnology Initiative: The Initiative and its Implementation Plan*, Washington D.C. Visit http://www.nano.gov/html/res/nni2.pdf

[3] Ibid.

[4] Robin Fretwell Wilson. "Nanotechnology: the challenge of regulating known unknowns." Journal of Law, Medicine and Ethics. 34.4 (2006):704(10). Visit http://find.galegroup. com/gpas/start.do?prodId=IPS.

• *PHILIPPINIANA SACRA*, Vol. XLVII, No. 141 (May-August, 2012) pp. 565-580.

to reach $1 trillion by 2015.[5] Commercial products ranging from apparels, appliances, cosmetics, construction materials are currently available in the market. Nanotechnology figures prominently in the agenda of various interest groups like the government, industry, academe, science fiction novelists and transhumanists— a tell-tale sign that something big is expected from something incredibly small. Nanotechnology is expected to raise societal and ethical concerns which will affect peoples, cultures and institutions differently.

This paper aims to clarify the concept of nanotechnology through various definitions and sketch in broad outlines the societal implications of this new and emerging field.

Keywords: *nanotechnology, nanoscale, converging technologies, precaution, ethical decisions, science policy directions*

Nowadays, nanotechnology has become a buzzword and a universal concern. Scientists and engineers are pushing the frontiers of nanoscience and nanotechnology through new discoveries and innovations. Businessmen are excited about new markets and huge profits from nanotechnology products. Scholars in the academe publish discourses on the ethical, societal and legal aspects of nanotechnology. Meanwhile, various governments strategize policies to address the persistent problems of poverty, unemployment, food security, threat of terrorism, climate change, etc. The race for nano supremacy is on. First World countries study the prospects of higher investments to boost nanoresearch and development. Transhumanists became vitalized as nanotechnology offers the promise of immortality. Science fiction novelists depict nanotechnology as the harbinger of catastrophe beyond human imagination. The general public takes interest in issues beyond the hype and controversies as witnesses to the unfolding nanotechnology narrative.

What the researchers modestly aim to achieve in this paper is to clarify the concept of nanotechnology through a definitional approach and to sketch in broad outlines the societal and ethical implications of nanotechnology. Consequently, the next discussions will center on these two major themes.

A. What is Nanotechnology?

There has been a limited range of definitions and few historical accounts of nanotechnology in published journals. The US National Nanotechnology Initiative

[5] Ibid.

(NNI) definition of nanotechnology was the most often cited definition. As part of marketing tool, nanotechnology is dubbed as a transformative and enabling technology. As a demarketing strategy, it is presented as a harbinger of catastrophe. The lack of standard definition and the polarized views of nanostakeholders on nanotechnology demand a closer examination of the concept of nanotechnology and its broader societal and ethical implications.

A.1. The Locus of Nanotechnology in Technological Revolutions

Revolutionary technologies transformed the fabric of human society in ways we have never thought possible. Since the dawn of Industrial Age in the late 18th century, we have witnessed remarkable progress – the rise of the factory system and machine-based manufacturing, the improvement of transportation and communication systems, expansion of trade and commerce and the invention of machines. Prior to the industrial revolution, there was marked dependence on nature, human labor and beasts of burden such as horses and oxen.

The prospects of political and military supremacy ushered in the Atomic Age, following the detonation of the first atom bomb in Hiroshima in 1945. The atom bomb became the new symbol of power and domination and was proven to be the most potent explosive device capable of mass destruction. Aware of the incalculable dangers it posed to human existence, different countries all over the world agreed to sign a comprehensive test-ban treaty to prevent the nuclear menace. What remains of this age are nuclear power plants, which are still being used today as alternative power sources to oil, gas and coal.

In 1957, the first man-made satellite, Sputnik, orbited the earth. This marked the beginning of the Space Age. Man's triumph to conquer the universe became an obsession. On April 12, 1961, Soviet cosmonaut, Yuri Gagarin made history as the first person to fly in space. Meanwhile, the United States, through its Apollo missions had expressed its bid to lead space explorations. On July 20, 1969, the historic landing of Apollo 11 on the moon took place. Neil Armstrong, Michael Collins and Edwin Aldrin set foot on the moon, completed their mission and successfully returned to Earth. After the disintegration of the former Soviet Union in the 90s, NASA had lost its chief rival in space race.

The shift from analogue to digital technology paved the way for the coming of the Information Age. This also enabled the shift from phonograph records to CDs and MP3s, from typewriters to printers, mail to email, printed books to e-books, VHS to DVD. The greatest leap of this age was the successful launching of the worldwide web in 1992. Until the present, information technology continues to conquer new borders.

But the final frontier, it seems will not be the vastness of space, but the ultra miniscule realm of atoms.[6] Raymond Kurzweil predicted that the Nanotechnology Age is expected to begin between 2025 and 2050.[7] This prediction may come sooner than expected. Scientists and engineers are now working on the atomic and molecular level with the aim of precision and control. With the manipulation of the building blocks of matter, nothing is rendered impossible.

A.2. Definitions of Nanotechnology

The span of centuries from the Industrial Age in the 18th century to the Information Age of the 20th century demonstrates the unparalleled feat in the history of human civilization. Our prospects for a better, brighter world have led us to set our sights into the brave new world of nanotechnology. The old cliché "bigger is better" no longer carries an appeal. The search for smaller, lighter, faster, cheaper and more versatile products became the new standard.

Nanotechnology started as a vision which had been associated with the 1959 talk of Richard Feynman entitled "There's Plenty of Room at the Bottom." In his paper, he made two bold predictions, which found their fulfillment in nanotechnology. First is the actual manipulation of individual atoms and second, the idea of machines making smaller machines.[8] He excited his audience by opening up the possibility of extreme miniaturization like putting all information contained in all books of the Library of Congress, British Museum and the National Library of France on the head of a pin.

Nanotechnology is a relatively new term in our vocabulary. A cursory reading of the enormous corpus of literature on nanotechnology would reveal that there is no standard definition of nanotechnology. The United Nations Educational Scientific and Cultural Organization (UNESCO) asserts that definitions of nanotechnology around the world vary depending on national strengths.[9] China, Japan and Korea

[6] *The Nanoage*, no date, accessed at http://www.thenanoage.com/ on July 23, 2010.

[7] Ibid.

[8] The first prophecy of Feynman, which talks of the possibility of manipulating individual atoms and molecules, was fulfilled by the invention of the Scanning Tunneling Microscope (STM), which has the capacity not only of visualizing the atoms but by moving them at the same time. The second prophecy relates to the functional efficiencies of machines which are capable of making machines that are in turn capable of producing even smaller machines, and so on.

[9] UNESCO Report. "The Ethics and Politics of Nanotechnology" 2006, Paris. Accessed at http://unesco.org/images/0014/001459/1445951e.pdf on July 9, 2010.

focus on materials especially electronics while researchers in Africa and Latin America emphasize the materials in the context of medicine and environmental science. In this section, the researchers will endeavor to present various definitional approaches[10] in order to clarify the concept of nanotechnology.

As a conventional way of expressing the meaning of a word, nominal definitions are commonly used. This can be done by giving the etymology or the synonym of the term.

Etymology

The term nanotechnology is composed of the prefix *nannos* which literally means "dwarf" and the root word technology, which is derived the Greek word *technē* which refers to the knowledge of doing or making. According to Agazzi, it refers to the efficient action that knows the reasons for its efficiency and is based upon them.[11] Nano as a unit measure means one billionth. One nanometer is 1/1,000,000,000 of meter.

Synonym

Molecular technology is another term for nanotechnology, a concept popularized by nanotechnology visionary, Eric Drexler. According to him, "The new technology will handle individual atoms and molecules with control and precision; call it *molecular technology*."[12] In the *Engines of Creation*, he enunciates the idea that we can use the terms "nanotechnology" and "molecular technology" interchangeably to describe the new style of technology.[13]

Real Definition

More commonly, real definitions are used in two ways- first, by identifying the genus and specific difference of the thing and second, by giving its objective features. For Schummer, the real definition of nanotechnology refers to a list of specific research topics, which vary from country to country and over time, typically include scanning

[10] The following sources contain illuminating discussions on definitions: Patrick Hurley's *A Concise Introduction to Logic*, 10th edition, (CA: Thomson Wadsworth, 2008); Irving Copi's *Introduction to Logic*, (New York: Macmillan Publishing, Co.,1986); and Manuel Piñon's *Fundamental Logic*, (Manila:UST Press, 1973).

[11] Craig Dilworth , ed. Evandro Agazzi. *Right, Wrong and Science The Ethical Dimensions of the Techno-Scientific Enterprise*, (Amsterdam: Rodopi, 2004), 57.

[12] Eric Drexler. *Engines of Creation: The Coming Era of Nanotechnology*. (New York: Avon Books, 1986), p.4

[13] Ibid., 5.

probe microscopy, nanoparticle research, nanostructured materials, polymers and composites, ultra-thin coating, heterogeneous catalysis, supramolecular chemistry, molecular electronics, molecular modeling, lithography for chip production, semiconductor research and quantum dots, quantum computing, MEMS, liquid crystals, light-emitting diodes (LEDs), solar cells, fuel cells chemical sensors, targeted drug delivery, molecular biotechnology, genetic engineering, neurophysiology, tissue engineering, and so on.[14]

Other Relevant Definitions

Metaphorical definitions

Metaphorical definitions give us allied meaning of terms as opposed to its literal meaning. These definitions are rather poetical expressions of a term. Using this definition, nanotechnology is perceived as a "coordinated movement, a choreographed dance among atoms and molecules to achieve a desired effect."[15] For Sargent, it means that nanotechnology is not a single set of scientific theories or applications. Clearly, the "dance metaphor" speaks of the convergence of disciplines in nanotechnology. Physics, chemistry, biology, as it were, are engaged in a dance, artistically executing choreographed steps in wonderful synergy to the beat of an irresistible tune. In making the language of chemistry accessible to non-chemists, Sargent resorts to useful analogies like atoms as letters, molecules as words, supramolecular entities as sentences and chapters.

Drexler also appealed to this definition when he made allusions to nanotechnology as the ultimate tool that will provide the engines of construction, engines of abundance, engines of healing and ultimately, engines of destruction. As engines of construction, nanomachines as assemblers "will let us place atoms in almost any reasonable arrangement, they will let us build almost anything that the laws of nature allow to exist."[16] Furthermore, he adds, "they will let us build almost anything we can design-including more assemblers."[17] This in fact is the essence of the Drexlerian ambition of molecular machines or the ultimate machinery that is capable of producing all the physical goods that we do not have or those that we lack. As engines of abundance, these nanomachines "will transform technology

[14] Joachim Schummer. *The Impact of Nanotechnologies on Developing Countries*, http://www.joachimschummer.net/papers/2007_Nano-Developing-Countries_Althoff-et-al.pdf, accessed on July 23, 2010.

[15] Ted Sargent, *The Dance of Molecules: How Nanotechnology is Changing our Lives*. (New York: Thunder's Mouth Press, 2006), Prologue.

[16] Drexler, 14.

[17] Ibid.

and the economy at their roots, opening a new world of possibilities".[18] Following our earlier thesis, molecular machines will not only provide for man's needs but sustain them without limits. His assemblers will produce products for human needs from common materials, without labor and smoke-emitting factories. As engines of healing, among other things Drexler speculates on the probability of cell repair machines, which is analogous to car repair. He explains: "To repair a car, a mechanic first reaches the faulty assembly, and identifies and removes the bad parts, and finally rebuilds and replaces them. Cell repair will involve the same basic tasks- tasks that living systems already prove possible."[19] Finally, as engines of destruction, Drexler cautions his readers against the threats posed by replicating assemblers and thinking machines. The threat from uncontrolled replicators[20] which have the propensity to obliterate life came to be known as the "gray goo problem."[21] The term engine is used as metaphor for power, dynamism, force or control.

As Efficient Cause

The efficient cause is defined as the cause from which motion first flows forth. It may refer to the principal or an instrumental efficient cause. Nanoscale manufacturing or nanofabrication involves two approaches- the bottom up and top-down fabrication. These terms were applied to nanotechnology by the Foresight Institute in 1989 in order to distinguish between conventional manufacturing and molecular manufacturing. Molecular manufacturing is characterized by the bottom up approach as opposed to conventional manufacturing which is considered as a top-down approach. In the bottom-up approach, products and materials are created atom by atom using nanoscale factories while the top-down approach uses natural and man-made substances that are then joined and constructed using a process specific to the product. [22] The bottom-up process is similar to building a structure using LEGO; wherein the pieces are put together and assembled to create desired assemblies. The starting point is the individual pieces or building blocks and end point is a more complex product. The advantage of this approach is its flexibility. One can build almost anything with it given the adroitness and skills of manipulating the building blocks. The top down approach is quite analogous to the art of sculpture wherein the artist gets a block of marble and forms his masterpiece out the material by carving

[18] Ibid., 63.

[19] Ibid, 104.

[20] In discussion of evolution, a replicator is an entity (such as a gene, meme or the contents of a computer memory disk) which can get itself copied, including any changes it may have undergone. See *Engines of Creation*, 288.

[21] Ibid., 172.

[22] UNESCO Report. *The Ethics and Politics of Nanotechnology*. Published in 2006, Paris. Retrieved from http://unesdoc.unesco.org/images/0014/001459/1445951e.pdf.

the marble into a desired nanostructure or form. In the process, the material is scaled down and unwanted components are removed.

Teleological Definition

Nanotechnology may be defined in terms of its goals. The goals of any technology, for that matter, are expressed in terms of promises, opportunities or gains one could expect from it. Hence, it is directed to the future. Aside from the values of improving past technologies, expressed in comparative degrees like smaller, faster, cheaper, more efficient, more versatile and more durable products, nanotechnology's goals as Schummer pointed out, are translated into visions. These visions of the future of nanotechnology are expressed in different formulations like "shaping the world atom by atom," "the next industrial revolution," the next Renaissance," "convergence of technologies"—nanotechnology, biotechnology, information technology and cognitive science.

Stipulative Definition

The term nanotechnology was first introduced by Professor Norio Taniguchi (1912-1999) formerly of Tokyo Science University, in 1974 at the International Conference on Production Engineering in Tokyo. Taniguchi used the word to describe ultra fine machining – the processing of a material to nano scale precision – work that he started in 1940 by studying the mechanisms of machining hard and brittle materials such as quartz crystals, silicon and alumina ceramics, primarily by ultrasonic machining.[23]

US National Nanotechnology Initiative (NNI) Definition[24]

Based on the US NNI Definition, nanotechnology involves:

- research and technology development at the atomic, molecular or macromolecular levels,
- the length scale of approximately 1 to 100 nm range,
- provide a fundamental understanding of phenomena and materials at the nanoscale,

[23] J. Corbet, et al *Nanotechnology: International Developments and Emerging Products,* Accessed at http:wwwsciencedirect.com/science on July 7, 2010.

[24] National Science and Technology Council (2000). *National Nanotechnology Initiative: The Initiative and its Implementation Plan,* Washington D.C. Visit http://www.nano.gov/html/res/nni2.pdf.

- create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.

Definition by Royal Society and Royal Academy of Engineering[25]

According to the definition proposed by the Royal Society and Royal Academy of Engineering, since nanotechnology encompasses such a wide range of tools, techniques and potential applications, they have found it more appropriate to use the term nanotechnologies. "Nanotechnologies are the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometre scale to distinguish it from nanoscience which is the study and manipulation of nanoscale particles."

Asia-Pacific Economic Cooperation (APEC) Definition[26]

Based on the definition proposed by APEC, nanotechnologies are regarded "as materials and systems whose structures and components exhibit novel and significantly improved physical, chemical and biological properties, phenomena and processes due to their nanoscale size. The goal of nanotechnology is to exploit these properties by gaining control of structures and devices at atomic, molecular and supramolecular levels and to learn to efficiently manufacture and use these devices."

A.3. The Nanoscale: Big is small and size definitely matters

The basic calculus underlying nanotechnology is size advantage. As a unit of measure, a nanometer is a billionth of a meter, thus, rendering it imperceptible to the naked eye. They can only be studied using advanced microscopy. The size factor makes nano particles so unique that they exhibit properties that are not found in their bulk counterparts. Nanoparticles have increased chemical reactivity due to their surface area per unit volume. By shrinking the size of the particle, the magnetic, optical and electrical properties of things are changed and quantum effects are enhanced. Fig. 1 presents how things are different at the nanoscale due to increased surface area.

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[25] *Nanoscience and nanotechnologies: opportunities and uncertainties*, The Royal Society, July 2004, The Royal Society & The Royal Academy of Engineering http://www.nanotec.org.uk/report/Nano%20report%202004%20fin.pdf, accessed July 9, 2010.

[26] *Nanotechnology: The Technology for the 21st Century*, APEC, January 2002, http://newapectf.nstda.or.th/web/publications/4.pdf, accessed on July 12, 2010.

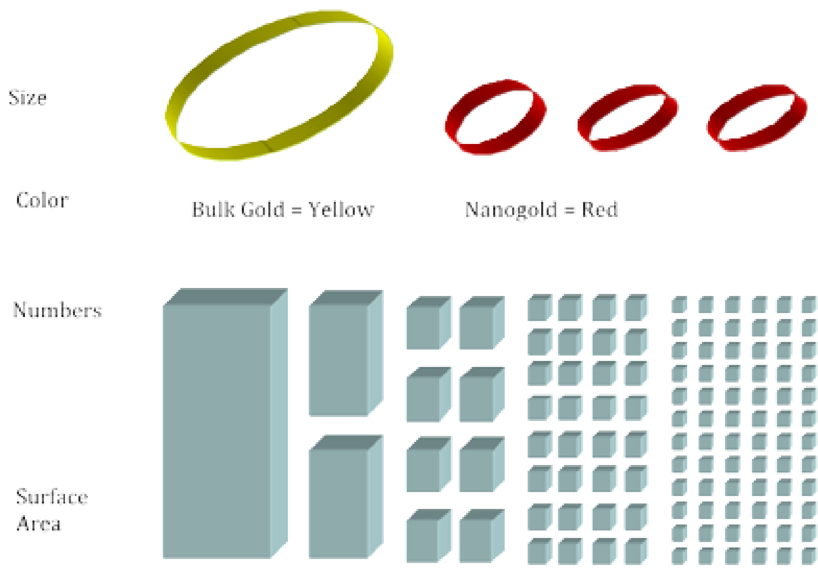

Figure 1. Properties of gold and other elements are different at the nanoscale

Source: *Nanotechnology Demystified*

The exciting discoveries in physics and chemistry will find useful applications in other research areas such as electronics, molecular biology, genetic engineering, environmental studies, medicine and other health sciences and will consequently raise confounding societal and ethical issues that will create broad spheres of impact that are interdependent. A concern brewing in one sphere like nanotoxicity cannot be localized in the environmental sphere alone. It usually creates ripples in other domains health and medical, economic, legal and geopolitical spheres. The table below shows that the societal implications of nanotechnology create broad spheres of impact that overlap with other areas.

Table 1. Spheres of Impact and Categories of Concern

Environmental and Safety Sphere	Health and Medical Sphere	Economic Sphere	Legal Sphere	Geopolitical Sphere
	Human enhancement Life extension	Public/private ownership	Liability	Nano-divide
		Business/University partnership and conflict of interest	Business/University partnership and conflict of interest	
	Cost and access	Cost and access		Cost and access

	Genetic discrimination	Genetic discrimination	Genetic discrimination	
		Intellectual property patents	Intellectual property patents	Intellectual property patents
		Economic "arms" race	Economic "arms" race	Economic "arms" race
Funding priorities	Funding priorities	Funding priorities		Funding priorities
Military applications	Military applications	Military applications		Military applications
Workforce preparation	Workforce preparation	Workforce preparation		Workforce preparation
	Privacy	Privacy	Privacy	Privacy
Technology transfer	Technology transfer	Technology transfer	Technology transfer	Technology transfer
Toxic Waste	Toxic Waste	Toxic Waste	Toxic Waste	Toxic Waste
Non-biodegradability	Non-biodegradability	Non-biodegradability	Non-biodegradability	Non-biodegradability
Nanotoxicity	Nanotoxicity	Nanotoxicity	Nanotoxicity	Nanotoxicity
Nanocarcinogens	Nanocarcinogens	Nanocarcinogens	Nanocarcinogens	Nanocarcinogens
Worker safety	Worker safety	Worker safety	Worker safety	Worker safety
Definitions and standards	Definitions and standards	Definitions and standards	Definitions and standards	Definitions and standards
Nano-regulation	Nano-regulation	Nano-regulation	Nano-regulation	Nano-regulation
Public awareness and acceptance	Public awareness and acceptance	Public awareness and acceptance	Public awareness and acceptance	Public awareness and acceptance

Source: *Nanotechnology, Ethics and Society*

B. Societal and Ethical Implications of Nanotechnology

B.1. Expected Benefits from Nano

Nanotechnology promises to solve our energy problems through more efficient fuel cells, reduce contaminants in water through effective sensors and filtration systems. In agriculture, it is expected to increase crop yield through effective pest and disease control systems and sensor networks for crops and livestock similar to that of radio frequency identification (RFID) chips or devices.

Nanotechnology is likewise poised to break new grounds in the field of medicine through targeted drug delivery system and tailored therapies. This means that drugs will be delivered at the precise time and location where they are needed and at the right amounts. Nanoparticles such as quantum dots and nanoshells are used as biomarkers for image enhancement. The new approach in medicine will be preventive, predictive, participatory and personalized. Nanomedicine will redefine the concept of pathology and normality.

In the US, the Institute for Soldier Nanotechnologies under MIT undertakes unconventional projects focused on enhancing the survivability of soldiers. The US NNI recognized the crucial role of nanotechnology in defense applications which include (1) dominance in information through advanced nanoelectronics, (2) more sophisticated virtual reality systems for effective training, (3) enhanced automation and robotics, and (4) improvements in nuclear, biological and chemical sensing and casualty care.

Life has become more convenient these days through commercially available "smart products" like stain-resistant pants, scratch-proof paints, washing machines and air purifiers containing silver nano, highly improved tennis balls and rackets and other sports utilities, cosmetics and beauty products with nanocomponents.

B.2. Nano Fears

While the perception of optimism over nanotechnology predominates, the climate of fear and suspicion over the potential deleterious impacts of nanotechnology to health and the environment also surfaces. Nanoparticles have the potential to cross the blood-brain barrier and might cause undesirable reactions to our immune system. While safety and risk assessment of nanoparticles have not been completed, commercial products were already made available in the market. There is uncertainty regarding the long term effects of nanoparticles in the environment. Some studies suggest technology assessment and life cycle analysis to address the sustainability issue, environmental, health and security concerns. The reports made by the International Risk Governance Council (IRGC) and the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) suggest that there exists knowledge gaps regarding the nature of nanoparticles and emphasize the need for an international framework with which to address risk at the global level. The further miniaturization of devices which may be implanted or worn as accessory will pose a threat to our privacy.

B.3. Learning from Biotechnology

The apparent exuberance in nanotechnology was tempered by the growing interest of the public in nanotechnology discourse. Civil society discourses on nanotechnology were sentiments reinvented and revived from similar controversies bred by previous technologies like nuclear power, stem cell and genetically modified organisms. These civil society actors come from different sectors of the society —

genetic technology watchdogs, environmental and anti-globalist activists, social justice advocates, feminists and disability rights campaigners. Among these protest groups are the ETC Group, Earth First, Corporate Watch, New Luddites and New Chartists. The ETC engages with policy and decision issues. Both ETC and Earth First are radical campaign and action networks that previously mobilized over agricultural GM. The New Luddites argued that the threats from perceived risks issuing from nanotechnology are a sufficient reason for it to be banned. The New Chartists were primarily interested in patenting issues in relation to Converging Technologies. The phrase "convergent technologies" refers to the synergistic combination of four major "NBIC"(Nano-Bio-Info-Cogno) provinces of science and technology, each of which is currently progressing at a rapid rate: (a) nanoscience and nanotechnology; (b) biotechnology and biomedicine, including genetic engineering; (c) information technology, including advanced computing and communications; (d) cognitive science, including cognitive neuroscience.[27]

The public's heightened concern over broader societal and ethical issues may be due, to a large extent, to the strings of controversies generated by biotechnology, particularly those surrounding genetically modified organisms and GM foods. Issues of safety, choice vs. autonomy, confidence in the regulatory system and playing God argument were raised and consequently yielded negative reactions from the public. To avoid another backlash, lessons have to be learned from these experiences. Participatory upstream management will facilitate public acceptance instead of suspicion and indignation.

B.4. Precaution: Road to Responsible Nano

As in any emerging technology, nanotechnology is bogged down by the unknown. Technological developments suffer from what David Collingridge referred to as control dilemma. The negative consequences of technology will be difficult to predict in its initial stage of development. It will emerge from its latent state when it is already deeply entrenched in the society and there is little that can be done to reverse the undesirable situation. In the light of uncertainty, risks and complexity involved

[27] Mihail C. Roco and William Sims Bainbridge, eds. *Converging Technologies for Improving Human Performance- Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, NSF/DOC-sponsored report, ed by, National Science Foundation June 2002, Arlington, Virginia, .11, Accessed at http:www.wtec.org/Converging Technologies/ReportNBIC_reportpdf, on July 9, 2010.

The report talks about the grand vision of unifying sciences and converging technologies to "initiate a new renaissance" with the claim that: "Convergence of diverse technologies is based on *material unity at the nanoscale and on technology integration from that scale.* Revolutionary advances at the interfaces between previously separate fields of science and technology are ready to create key *transforming tools* for NBIC technologies." Ibid.

in nanotechnology development, which is the best way to proceed? Hans Jonas, a German philosopher, articulates that the gap between our ability to foretell and the power to act creates a moral problem that requires self-policing our great capacities for action. Precaution is both an ethical responsibility and a moral imperative. According to the World Commission on the Ethics in Scientific Knowledge and Technology (COMEST), "when human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm." The COMEST defines morally acceptable harm as "harm to humans or environment that is threatening to human life or health, or serious and effectively irreversible, or inequitable to present or future generations, or imposed without adequately considering the human rights of those who are affected.

Conclusion

Nanotechnology is a fledging and evolving concept that has been defined and interpreted in a number of ways. The lack of standard definition will bear a significant impact in framing ethical debates in nanotechnology. Our discussions on the definition of nanotechnology provide us the following insights: First, there is no absolute and standard definition of nanotechnology. To begin with, not everybody agrees on the term nanotechnology used as a singular term because it is not limited to the use of just one application but rather to diverse technologies. The Royal Society and Royal Academy of Engineering find it appropriate to use "nanotechnologies." Second, based on a teleological approach, the meaning of nanotechnology will be diverse and disparate relative to the objectives, strength and capacities a nation would like to develop. In a sense, it is used as a forecasting tool to envisage the future. Finally, the various definitions reveal the gap between fact and fiction, hype and reality, what is and what should be.

Varied interest groups perceive nanotechnology either as an opportunity or a threat. While it is true that nanotechnology has the potential to build, it likewise has the potential to destroy. Nanotechnology is unfolding and we have not heard the last words yet. The level of public engagement and the ethical choices of nanostakeholders will define the landscape of nanotechnology. Whatever science policy choices we make today will have an enormous impact on our future.■

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