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THE EVALUATION OF SOCIAL, ETHICAL AND LEGAL ASPECTS OF HUMAN ENHANCEMENT IN BIONANOTECHNOLOGY

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Dr.'s Maryam and Leila Ahmadi map some of the main topography of the profound, controversial and far reaching ethical, social and legal issues in the field of human enhancement in bionanotechnology. They identify some of the key issues raised, provide concerns and recommend proactive considerations and detailed solutions to these issues.

Keywords: Human enhancement, bionanotechnology, ethical, social, legal aspects.

I. INTRODUCTION

Humans have always tried to improve themselves through "natural methods" such as physical exercise, diet, meditation, education and training (and later on cosmetic surgery and Lasik eye corrections). However, with ongoing work to unravel the mysteries of our minds and bodies, coupled with the art and science of emerging technologies, we are near the start of the Human Enhancement Revolution. Technology will be a big game changer. While previously technological progress has improved the tools we work with, from the printing press to the steam engine to computers, in the future, technology will change ourselves, our bodies and, possibly, even our minds[1].

> "Now we are not limited to 'natural' methods to enhance ourselves or to merely wield tools such as a hammer or binoculars or a calculator. We are beginning to incorporate technology within our very bodies, which may hold moral significance that we need to consider. These technologies

[1] Berger, M. (2 Sept 2009). Nanotechnology's role in the ethics debate on human enhancement. *Nanowerk Spotlight*. Retrieved from *http://www.nanowerk.com/spotlight/spotid=12433.php.*

> promise great benefits for humanity – such as increased productivity and creativity, longer lives, more serenity, stronger bodies and minds, and more – though there is a question whether these things translate into happier lives, which many see as the point of it all"[2,3].

In general, Human enhancement refers to any attempt to temporarily or permanently overcome the current limitations of the human body through natural or artificial means. The term is sometimes applied to the use of technological means to select or alter human characteristics and capacities, whether or not the alteration results in characteristics and capacities, which lie beyond the existing human range. Here, the test is whether the technology is used for non-therapeutic purposes. Some bioethicists restrict the term to the non-therapeutic application of specific technologies — neuro-, cyber-, gene-, and nano-technologies — to human biology[4,5].

Therefore, Enhancement is understood as interventions, which aim at an improvement of human abilities and performance beyond "normal" levels - also in an excessive and undesired manner[6].

Defining "human enhancement" is a challenging task and no consensus on a common definition has been reached so far. Basically, there are four main approaches that are commonly used to define this concept[7].

***i)* the implicit approach,** which considers the result of some given technological interventions on human beings as a human enhancement, without providing nor addressing any explicit reasons to do so[8,9];

ii) **the therapy-enhancement distinction approach,** according to which interventions aiming at healing or improving health enter into the 'treatment' category, while

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[2] Persaud, R. (2006). Does smarter mean happier? *Better humans? The politics of human enhancement and life extension*. Demos: London.

[3] *President's Council on Bioethics*. (2003). Government Printing Office: Washington, DC.

[4] Hughes, J. (2004). Human Enhancement on the Agenda. *IEET*. Retrieved from http://ieet.org/index.php/IEET/more/hughes20041101

[5] Moore, P. (14 Apr 2008). *Enhancing Me: The Hope and the Hype of Human Enhancement*, John Wiley & Sons Ltd: Australia.

[6] Friele, M. Fulford, KWM. (2004). Intervening in Psychic Capacities. *Poiesis and Praxis, 2* (4): 257-257. Springer-Verlag.

[7] Menuz, V., Hurlimann, T. and Godard, B. (2013). Is Human Enhancement also a Personal Matter? *Journals of Science and Engineering Ethics*: Illinois Institute of Technology.

[8] ter Meulen, R. (2010). Dignity, posthumanism and the community of values. *American Journal of Bioethics* 10: 69-70. Taylor & Francis Group: Kentucky.

[9] Sadler, J.Z. (2010). Dignity, arete and hubris in the transhumanist debate. *American Journal of Bioethics,* 10: 67-68. Taylor & Francis Group: Kentucky.

contrary, all interventions that do not have such purposes would be human enhancements[10, 11];

iii) **the improvement of general abilities approach,** according to which human enhancement is the result of the application of emerging technologies to individuals so as to improve their body, mind or any ability beyond the "species-typical normal functioning" of a human being[12, 13]; and

iv) **the increase of individual well-being approach,** which considers that "any change in the biology or psychology of a person which increases the chances of leading a good life" is a human enhancement[14, 15].

These different approaches have several limitations. They rely on concepts such as "normality", "health", "species-typical normal functioning" and "human standard capacities", whose definitions are both controversial and challenging. Moreover, they tend to overlook the complexity and variability of the contexts in which the use of emerging technologies and human enhancement may occur. We suggest that in order to grasp such a complexity, a comprehensive definition of human enhancement cannot but focus on personal and subjective perceptions and the factors that may influence them. In other words, we propose an approach that emphasizes the outcome of a given intervention such as perceived by the individual that underwent it, on one side, and, on the other side, the many factors that may influence individual decisions to consider (or not) – for oneself – the results of a given intervention as a human enhancement (e.g., political and social norms, rules, values, environmental factors, passive coercion, unconscious goals, and/or statistically defined attributes, considered within a given society in a given historical period of time). For more details about this approach, please consult (Menuz, et al., 2011).

In general, advances in human enhancement in this potentially powerful technology raise a host of ethical, legal, and social questions that healthcare providers and scientists will need to consider if significant modifications or enhancements of the

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[10] Allhoff, F., Lin, P., Moor, J. and Weckert, J. (2009). Ethics of Human Enhancement: 25 Questions & Answers. *Studies in Ethics, Law, and Technology* 4: 4.
[11] Missa, J.N., and Perbal, L. (2009). *Enhancement: éthique et philosophie de la médecined'amélioration*. Vrin: Paris.
[12] C. Coenen, M. Schuijff, M.Smits, P. Klaassen, L.Hennen, M. Rader, and G.Wolbring. (2009). Human Enhancement: study. S.A.T.O. Assessment, ed. (Brussel, European Parliament).
[13] Chadwick, R. (2008). Therapy, enhancement and improvement. *Medical Enhancement and Posthumanity***,** pp. 25-37. Springer: Netherlands.
[14] Savulescu, J. (2006). Justice, fairness and enhancement. *Annals of the New York Academy of Sciences*, 1093: 321-38.
[15] de Melo-Martin, I. (2010). Defending human enhancement technologies: unveiling normativity. *Journal of Medical Ethics.* 36, pp.483-487.

human body and its systems became possible, beyond what might be seen as medical purposes. These questions and concerns include definitions, appropriate applications, dual use, potential risks, regulations, and access. Some of these questions are:

- What our technological future will be like?
- Will the quality of our lives improve with increased technology or not?

We can at least collectively affect our futures by choosing which technologies to have and which not to have and by choosing how technologies that we pursue will be used. The question really is: How well will we choose? The emergence of a wide variety of bionanotechnology should give us a sense of urgency in thinking about how we approach this technology and enhancements ethically. “Which kinds should we develop and keep? And, how should we utilize those that we do keep?” “[I]t is not satisfactory to do ethics as usual.” “Better ethical thinking in terms of being better informed and better ethical action in terms of being more proactive is required.”[16] The main goal is to generate new insights into the role of legal, ethical and social expertise in national policy-making on bionanoscience and technology, coherent with international and other NGO projects.

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We strongly believe that flexible and proportionate regulatory measures informed by scientific evidence are beneficial to everybody; the public, consumers and employees are protected from harm while industry is able to participate in developing standards and preparing guidance to ensure a level playing field and reduced risk of liability.

II. Converging Technologies for Improving Human Performance

Human enhancement technologies (HET) are techniques that can be used not simply for treating illness and disability, but also for enhancing human characteristics and

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[16] Moor, J. H. (2005). Why we need better ethics for emerging technologies. *Journal on Ethics for Emerging Technologies,* 7:111–119. DOI: 10.1007/s10676-006-0008-0. Retrieved from http://crown.ucsc.edu/academics/pdf-docs/moor-article.pdf.

capacities[17]. In some circles, the expression "human enhancement technologies" is synonymous with emerging technologies or converging technologies[18]. In other circles, the expression "human enhancement" is roughly synonymous with human genetic engineering[19,20]. It is used most often to refer to the general application of the convergence of nanotechnology, biotechnology, information technology and cognitive science (NBIC) to improve human performance (Roco et al., 2004).

Since the 1990s, several academics (such as some of the fellows of the Institute for Ethics and Emerging Technologies)[21] have risen to become cogent advocates of the case for human enhancement while other academics (such as the members of President Bush's Council on Bioethics (President's Council on Bioethics, 2003) have become its most outspoken critics [22].

Converging Technologies for Improving Human Performance is a 2002 report commissioned by the U.S. National Science Foundation and Department of Commerce. The report contains descriptions and commentaries on the state of the science and technology of the combined fields of nanotechnology, biotechnology, information technology and cognitive science (NBIC) by major contributors to these fields. Potential uses of these technologies in improving health and overcoming disability are discussed in the report, as well as ongoing work on planned applications of human enhancement technologies in the military and in rationalization of the human-machine interface in industrial settings (Roco et al.).

Implants and prosthetics may in the future also be used for enhancement. Currently, implants and prosthetics are only used for medical applications. Pacemakers have been on the market since the 1950s. Bionanotechnology may be applied to improve them in biocompatible or drug-eluting coatings and in smaller electrodes or improved batteries. Cochlear implants also exist, and may be improved with bionanotechnology.

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[17] Enhancement Technologies Group. (1998). *Writings by group participants*. Retrieved 02 Feb 2007. Retrieved from http://www.ucl.ac.uk/~ucbtdag/bioethics/writings/index.html#Bibliography.

[18] Roco, M.C., Bainbridge, W.S. (2004). Converging Technologies for Improving Human Performance. Springer: Netherlands. Retrieved from http://www.wtec.org/ConvergingTechnologies/Report/NBIC_report.pdf

[19] Agar, N. (2004). *Liberal Eugenics: In Defence of Human Enhancement*. Oxford: Blackwell.

[20] Parens, E. (2000). *Enhancing Human Traits: Ethical and Social Implications*. Georgetown University Press: District of Columbia.

[21] Bailey, R. (2006). The Right to Human Enhancement: And also uplifting animals and the rapture of the nerds. *Reason.com*. Retrieved from https://reason.com/archives/2006/06/02/the-right-to-human-enhancement.

[22] Report of the President's Council on Bioethics (October 3003). Beyond Therapy: Biotechnology and the Pursuit of Happiness. Washington, D.C. Retrieved from https://repository.library.georgetown.edu/bitstream/handle/10822/559341/beyond_therapy_final_webcorrected.pdf?sequence=1&isAllowed=y.

Retina implants depend on nanostructured electrodes for connecting a chip to the optical nerve. These chips have been in the clinical test phase for some years, but they will not enter the market anytime soon. They enable vision in a broader spectrum than just the visible light. Patients see also in Infrared. This is considered an enhancement of which the pros and cons are currently being debated. However, this Infrared vision can't be switched off; closing one's eyes does not shut out the Infrared light. As a result, the patient can't sleep anymore[23].

In the reality of today Infrared vision is no more than an undesirable side effect of a medical device intended for assisting disabled people. Neuro-implants include deep brain stimulation for Parkinson's and depression. Some of these implants are already in use. Prosthetic limbs integrated into the nervous system are also being developed including a "nanohand" in a European Union (EU) funded project.

Brain-machine interfaces are applied in experiments in apes and humans, mainly for medical applications. In the long term, enhancement applications are foreseen.

> "Understanding of the mind and brain will enable the creation of a new species of intelligent machine systems that can generate economic wealth on a scale hitherto unimaginable. Within a half-century, intelligent machine might create the wealth needed to provide food, clothing, shelter, education, medical care, a clean environment, and physical and financial security for the entire world population. Intelligent machines may eventually generate the production capacity to support universal prosperity and financial security for all human beings. Thus, the engineering of the mind is much more than the pursuit of scientific curiosity. It is more even than a monumental technological challenge. It is an opportunity to eradicate poverty and usher in the golden age for all humankind."[24] (Roco et al.)

III. Bionanotechnology

Through millions of years, plants and animals have developed amazing ways to produce materials with extreme and unique characteristics. Consider the strength and elasticity of a spider's web or the variety of colors of many butterflies and insects. By studying naturally occurring materials on the nanometer scale, we can obtain the inspiration and knowledge to create new materials with completely unique characteristics. In bionanotechnology many secrets of nature will be revealed, and you

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[23] Hughes, J. (2004). *Citizen Cyborg: Why Democratic Societies Must Respond to the Redesigned Human of the Future*. Westview Press: Massachusetts.
[24] Malsch, I. (2012). *Ethics and Nanotechnology; Responsible development of nanotechnology at global level in the 21st century*. Lambert Academic Publishers: Deutschland.

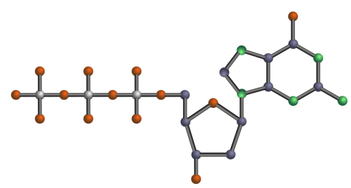
will learn how to take advantage of this insight in the production of new materials[25].

The impact and importance of nanotechnology continues to grow, and nanomedicine and biotechnology have become areas of increased development. Biomedical engineers who work with biological processes and structures must have a deeply rooted understanding of the role of bionanotechnology, a rapidly evolving sector of the nanotechnology field[26].

Nanotechnology has great promise in biology and medicine. This includes new approaches to fundamental studies, improved methods for detection of protein or nucleic acid-based biomarkers of disease, and new ways to administer drugs or vaccines or enhancing their effects. The tools of nanotechnology provide new insights into mechanisms of normal biological functions and diseases. Novel nanotechnology-based imaging methods reveal structural and functional information at progressively higher levels of resolution, both in cells and in organisms. Molecular components of biological systems on their own can be often viewed as nanoscale machines with functions that have been tuned through evolution and with design principles often based on self-assembly and self-organization phenomena. These biological nanomachines can be incorporated into micro- and nanofabricated devices, a merger that yields novel structures and functionalities[27].

In general, medical research is now focusing increasingly on the micro and nano scale. Concepts such as lab-on-a-chip (microarrays) are now being used the world over to facilitate ultra-sophisticated tests while taking a negligible amount of biological material from the patient. Nanostructures such as quantum dots and dendrimers have started finding extensive applications in curing cancer, and the silver nanoparticle is considered a prime candidate for fighting viruses such as AIDS. Each of these advances has needed manipulation at the nanoscale.

Credit: DNA Double Helix
openclipart.org



Credit: DNA Molecule
openclipart.org

An increasing amount of attention is being paid to development and manipulation of biomaterial at the nano-level, because that is the way nature works. Nature uses miniscule building blocks such as DNA to build huge structures such as the human body.

[25] Farber, D. (August 2002). What utopia can technology deliver? *ZDNet*. Retrieved from http://www.zdnet.com/news/what-utopia-can-technology-deliver/296365

[26] Norwegian University of Science and Technology Specialisation. Master's Degree Programme, 5 years. Bionanotechnology. Retrieved from http://www.ntnu.edu/studies/mbiot5.

[27] Reisner, D.E. (25 August 2011). *Bionanotechnology: Global Prospects*. CRC Press 1st edition: Kentucky.

Hence, medical research is now tending toward the view that to correct seemingly incurable defects, a thorough understanding of bionanostructures such as DNA is imperative. The study and manipulation of structures at the nanoscale and their use in medical applications is known as Bionanotechnology. Bionanotechnology – the functional integration of nanofabricated structures and biological molecules – is an important area within nanotechnology, with applications such as molecular machines, biosensors, and self-assembled nanostructures (note: 'bionanotechnology' does not refer to genetic modification etc., which is part of programs such as Biotechnology or Biomedical Engineering)[28].

Bionanotechnology has become an exciting field of research and an area of technology development, especially since the length scale nanotechnology can access more and more coincides with the length scale of basic biological structures and fundamental biological components. Bionanotechnology is a branch of nanotechnology, which uses biological starting materials, utilizes biological design or fabrication principles or is applied in medicine or biotechnology[29].

Bionanotechnology is the key integrative technology of the 21st Century and aims to use the knowledge, gathered from the natural construction of cellular systems, for the advancement of science and engineering. Investigating the topology and communication processes of cell parts can lead to invention of novel biological devices with exciting applications. Though microscale to nanoscale research offers an excellent space for the development of futuristic technologies, a number of challenges must be overcome.

Bionanotechnology also deals with the knowledge of how biological molecules, such as proteins, polysaccharides and DNA, can be integrated with man-made materials to provide new types of sensors and products. This is a fast moving and exciting field with applications in, for example, medical diagnostics (Reisner, 2011).

Bionanotechnology is studying new materials and technologies that solve biological and medical problems at the nanoscale. Examples of bionanotechnology research include artificial bone, biosensors and detection, imaging of biological samples on the nanoscale, nanotoxicity and biocompatible polymers[30]. Applications of bionanotechnology are extremely widespread. Bionanotechnology promises to recreate biological mechanisms and pathways in a form that is useful in other ways.

NA nanotechnology is one important example of bionanotechnology. The utilization of the inherent properties of nucleic acids like DNA to create useful materials

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[28] Chase, P.B., Hong, S., et al (2012). Bionanotechnology and Nanomedicine. *Journal of Biomedicine and Biotechnology*.

[29] Green, N. MSc Bionanotechnology Programme. Retrieved from http://www.southampton.ac.uk/postgraduate/pgstudy/programmes/ecs/msc_bionanotechnology.html.

[30] Bionanotechnology, http://www.ntnu.edu/physics/bionano.

is a promising area of modern research[31]. Another important area of research involves taking advantage of membrane properties to generate synthetic membranes. Protein folding studies provide a third important avenue of research, but one that has been largely inhibited by our inability to predict protein folding with a sufficiently high degree of accuracy. Given the myriad of uses that biological systems have for proteins, though, research into understanding protein folding is of high importance and could prove fruitful for bionanotechnology in the future. This field relies on a variety of research methods, including experimental tools (e.g. imaging, characterization via AFM/optical tweezers etc., x-ray diffraction based tools, synthesis via self-assembly, characterization of self-assembly (using e.g. dual polarization interferometry, recombinant DNA methods, etc.), theory (e.g. statistical mechanics, nanomechanics, etc.), as well as computational approaches (bottom-up multi-scale simulation, supercomputing).

Bionanotechnology holds great promise for revolutionizing the field of medicine. Cells naturally interact with their surroundings and with one another via exquisitely complex nanoscale structures. Nanomedicine and bionanotechnology provide the means to improve present techniques for characterizing the nanoscale structure and function of cells, and to mimic those structures by designing artificial biomaterials through molecular synthesis and nanoscale self-assembly (Bio-nanotechnology, Nanoscience and Nanotechnology).

Researchers are working to create novel materials to deliver therapeutic drugs more effectively, diagnose disease much earlier, and even to repair damage to the human body as a result of injury or disease. These materials can be composed of a wide range matter, from functionalized gold or silica nanoparticles to biocompatible polymers and synthetic bioactive peptides and proteins. The common thread is that these materials are designed to organize into functional units with characteristic dimensions on the nanoscale, and this nanoscale structure is integral to their function.

Advances in imaging materials at the nanoscale provide insight into the interaction of cells with biomolecules. Identifying biomimetic strategies could lead to the creation of specialized materials that foster biological self-repair of the human body. Institute researchers seek to use these new capabilities to produce novel, biocompatible implants. Based on newly developed constructs with synthetic components and arrays of cells, it may soon be possible to repair tissues (e.g., skin, muscle, cartilage, ligaments, tendons, nerves, and bone) with implants composed of biocompatible coatings that the body will accept and integrate within the physiological medium. This is in stark contrast with the largely inert, metallic and polymeric materials currently used in biomedical implants, which generally lack any structural design on the nanoscale.

Another goal is to apply bionanotechnology to cancer diagnostics and therapeutics. Researchers are working to develop bionanotechnology platforms for ultimate application in the clinic. They are working on the development of new assays

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[31] Bio-nanotechnology, Nanoscience and Nanotechnology, http://www3.imperial.ac.uk/nanoscienceandnanotechnology/research/bionanotechnology.

that will increase the accuracy of diagnosis by orders of magnitude, new imaging techniques, and methods for targeted delivery of chemotherapeutic agents[32].

IV. Definition of Bionanotechnology

At the present time, there is no consensus definition of bionanotechnology. To take advantage of the enthusiasm of funding agencies, a number of old (and important) areas, such as colloid science, molecular biology, and implantable materials surface science, have been relabeled "nanotechnology." In fact, all of these fields, coupled with biological systems, should be included in bionanotechnology. In general, the idea of bionanotechnology is the engineering of interfaces between molecules or materials and biological systems.

Looking ahead, the key areas for commercialization will be bringing engineered systems into biological contact and biological function. The version of bionanotechnology popularized in the media has been largely oversold. The general idea, which was popular twenty years ago as the "magic-bullet" theory of biotechnology and has been adopted as the bionanotechnology target, can be described as the "dump truck" model of technology. In this conception, the technology components consist of a targeting moiety, either biological or nanotechnological, and one or more cargoes, which are envisioned as small machines capable of specific destructive or corrective action. In reality, designing targeting molecules that are selective for diseased tissues and capable of delivering cargoes larger than a typical antibody has proven extraordinarily difficult, and molecular targeting of nanoscale devices greater than 5 nm outside the vascular space may prove to be prohibitively difficult. However, with no guiding principles for the effective biological direction of non-biological molecules, this is still an open question[33].

V. Bionanotechnology and Humane Enhancement

A tendency within bionanotechnology for biomedical applications is the blurring of the borderline between humans and technical artifacts. There is a certain overlap with the issue of enhancement, but also poses specific questions. The use of technical artifacts or interventions for restoring or substituting impaired functions of the human body is an integral part of human culture, as exemplified by glasses for impaired vision, limb prostheses, dental implants, pacemakers and organ transplants. Against this background, the use of nanotechnologies in biomedical applications pose the question whether such applications bring about a new quality in the foreseeable time which might push the – culturally defined – borderline between humans and technical artifacts further, and if so, whether this borderline has a moral status and should therefore be fix to a certain extent, or whether it may or should be subject to change? The latter poses the question how far-

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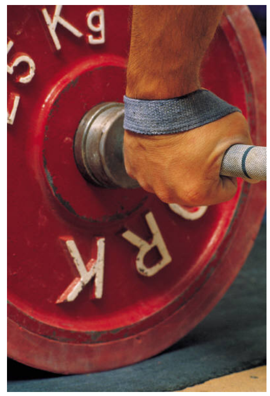
[32] Nanobiotechnology. (n.d.). Wikipedia. Retrieved from https://en.wikipedia.org/wiki/Nanobiotechnology.

[33] International Institute for Nanotechnology (IIN), Nanomedicine/BioNanotechnology. Northwestern University. Retrieved from http://www.iinano.org/content/Research/Research_nanobio.htm.

reaching these changes and interventions may go[34].

Nanotechnology research being conducted in the bio-medicine field has resulted in self-organizing scaffolds that opened the field for new generations of tissue engineering and biomimetic materials, it is expected that soon it may be viable to produce organ replacements. These artificial organs are not mere prosthetics, as they are not of a mechanical nature but rather made of living matter and are an identical copy (without eventual pathologies) to the organ they are going to replace.



Images Credit: Clipart

In general, enhancement of our cognitive, physical, perceptual or psychological capacities through technology is ubiquitous. Education technologies, computational devices, nutritional supplements, steroids, pharmaceuticals, communication systems and optical lenses are each a type of human enhancement technology. While it is far from clear to what extent the nanosciences and nanotechnologies as enabling technosciences may contribute to human enhancement, it is obvious that "bionanotechnology" as such has been the major, and still is an important, for the discourse on human enhancement (with contributions on neurotics catching up recently). Reasons for this might be (a) the broad interdisciplinary character of the field, (b) its relevance with regard to materials, (c) the strong visionary roots and shaping of the political discourse on nanotechnology, and finally, (d) the advent of the debate on converging technologies within the discourse on nanotechnology.

Enhancement is not at all new or specific to nanotechnologies. Examples can be found in (for e.g.), use of growth hormones in pediatrics, plastic and cosmetic surgery, doping in sports, or genetic engineering[35] and it is also discussed in neuroscience for

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[34] Bruchez, M.P. (Winter 2006). Commercialization and Future Developments in Bionanotechnology. Papers from the 12th U.S. Frontiers of Engineering, 36:4.

[35] Hüsing, B., Gaisser, S. (Mar 2006). Nanobiotechnology in the medical sector - Drivers for development and possible impacts. Report for WP3: Potential socio-economic impacts of medicinal nanobiotechnology applications. Retrieved from http://www.isi.fraunhofer.de/isi-wAssets/docs/t/de/publikationen/ISI_Nanobiomedicine_WP3_revised-290320061.pdf

cognitive, motor and sensory enhancement[36,37,38,39,40]. Nevertheless, nanotechnologies, especially in their convergence with biotechnology and ICT, are often seen as powerful potential enablers to perform such interventions into a broad variety of motor, sensory and cognitive functions with unprecedented precision. The benefits are obvious and tremendous as bionanotechnology may solve problems associated with the transplant of organs such as the lack of donated organs and compatibility/rejection issues. Tissue engineering can be defined as 'the use of cells and their molecules in artificial constructs that compensate for lost or impaired body functions'[41].

The technology works by creating scaffolds made of porous biomaterials, which mimic the cellular environment, which then are seeded with cells and allowed to grow there. The grown tissue construct is then implanted into the body of the patient where it replaces the diseased tissues and the scaffold degrades. The most relevant advantage brought by nanotechnology to tissue engineering is that the new properties of nanomaterials make the cell interaction and other cellular functions more efficient when compared with traditional materials. Nanophase materials (with grain sizes less than 100 nm) can be used to enhance tissue regeneration and to improve cell adhesion, cell spread and migration. Studies have observed the ability of these novel materials to replicate the characteristics and simulate the functions of several body tissues, and nanophase coatings have been used on the surface of biomaterials to improve their biocompatibility and bioactivity. The use of polymers in tissue engineering is also quite promising since several studies have shown that they show increased biodegradability and pending the natural tissue regeneration process polymers degrade in vivo by hydrolysis into non-toxic products which enter into normal metabolic pathways and are naturally excreted from the body as carbon dioxide and water[42].

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[36] Fuchs, M. et al. (2002). drze Sachstandsbericht 1: Enhancement - Die ethische Diskussion über biomedizinische Verbesserungen des Menschen.
Bonn: German reference center for ethics in life sciences (drze).

[37] Kennedy, D. (2 Apr 2004). Just Treat, or Enhance? *Science*. University of Milan: Italy, 304 (5667), p. 17. Retrieved from
http://www.sciencemag.org/content/304/5667/17.full.pdf.

[38] McGuire, G.Q., McGee, E.N. (1999). *Implantable brain chips? Time for debate*. Hastings Center Report, 29: 7–13.

[39] Wolpe, P.R. (2002). Treatment, enhancement and the ethics of neurotherapeutics. *Journal of Brain and Cognition.* Reed/Elsevier, 50 (3):387-395.

[40] Chatterjee, A. (28 Sept 2004). Cosmetic Neurology, The Controversy Over Enhancing Movement, Mentation and Mood. *Neurology* 28;63(6):968-74.

[41] Hüsing, B., Bührlen, B., and Nusser, M. (2004). Tissue-engineered products: Potential future socio-economic impacts of a new European regulatory framework. Unpublished report for IPTS, Karlsruhe: Fraunhofer Institute for Systems and Innovation Research.

[42] European Technology Platform. (2006). Nanomedicine, Nanotechnology for Health, Strategic Research Agenda, quoted in Nanomedicine report. Retrieved from
http://www.etp-nanomedicine.eu/public/press-documents/publications/etpn-publications/strategic-research-agenda

Bionanotechnology can also be used to encourage the growth and influence the differentiation of stem cells. Advances in this area such as the development of new methods for nanopatterning surfaces has allowed the study of ordered, reproducible nanotopography thus opening the field for future production in vitro or in vivo of human tissue (European Technology Platform, 2006). Bionanotechnology give us cybernetic body parts, nanomedical devices that patrol the body for cancerous outbreaks, or implanted nanochip to enhance brain functions. An interesting topic raised is the question if, analogous to the 'digital divide' – those who do not have adequate access to information and communications technology (ICT) are disadvantaged relative to those who do. While this divide reflects, by and large, the existing divide between haves and have-nots, ICT exaggerates that divide – there is a risk of an 'enhancement divide': the gap between those who can access and benefit from nanotechnology and those without[43].

Examples of therapeutic applications include the restoration of sight or hearing. According to the RS-RAE Report[44] applications that are closest to being developed for market are improved cochlear implants and retinal implants, designed to improve and/or restore hearing and vision, respectively. In contrast, augmentation applications refer to scenarios of human enhancement to 'super-human levels'[45]. Some examples of augmentation include enhanced memory, long-range vision, infrared night vision, cognitive multi-tasking, and on-demand strength augmentation[46]. Canton estimated that augmentation would appear within 'the next 5-8 years' (Canton, 2004).

The other area of human enhancement involves designed evolution, which refers to those human enhancements 'that we might choose to make in vitro, prior to conception and after birth, involving the human genome that as individuals and as a society we have ethically and scientifically chosen' (Canton). Examples in this area include human clones, bones that repair through self-assembly and 'intracellular disease scavengers that search and destroy on demand' (Canton).

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[43] Berger, M. (Sep 2009). Nanotechnology's role in the ethics debate on human enhancement. *Nanowerk Spotlight*. Retrieved from http://ethics.calpoly.edu/NSF_report.pdf.

[44] Royal Society and Royal Academy of Engineering Nanoscience and Nanotechnologies (2004). Opportunities and Uncertainties. Latimer Trend Ltd, Plymouth, UK. Retrieved from https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2004/9693.pdf.

[45] Canton, J. (2004). Designing the Future: NBIC Technologies and Human Performance Enhancement. *Annals New York Academy of Sciences*, 1013: 186-198**.**

[46] Bruce, D. (Dec 2007). Human Enhancement? Ethical Reflections on Emerging Nanobio-technologies. Report on an Expert Working Group on Converging Technologies for Human Functional Enhancement. NanoBio-RAISE EC FP6 *Science and Society Co-ordination Action***.**

VI. ANTHROPOLOGY - WHAT IS THE NATURE OF THE HUMAN BEING?

The critical issue in human enhancement is what a human being is. Are we a machine, a bag of genes, a spiritual and bodily being, a conscious mind, a set of capacities restrained by natural form… etc.? Note that in the context of nanotechnologies there may be a conflict between holistic and functional views. Traditional presuppositions assume that there are moral or societal bounds or limits that should modulate what may be technically feasible in intervening in the human condition. If so, what are these and how are they to be identified? These are challenged by the transhumanist assumption that we are independent and should rise above any current limitations. A common thread in a number of authors is to assume that human beings as we know them today are inadequate, when compared with the functional improvements they imagine. Thus we may ask whether humans should be restricted to what they have always been or are we free to expand ourselves boundlessly? Questions are raised by very uncertain future prospects engineering the human germ line, are already faced in chemical alterations, sports science and cosmetic surgery. There are serious issues at the human-machine interface and the human-communications interface, if we are once able to have our human capacities significantly influenced by the logic of the machine. The nature of the human being touches on a number of extremely large questions, of which some may be summarized:

Human-machine interface – for example, should we develop devices that might promote direct brain-machine interactions, or apply external or internal controls of the body or the brain; should we incorporate computer chips in the skin; what is our human responsibility if we have a neurotransplant?

Credit: Anders Sandberg, Brain Computer Interface, Creative Commons
https://commons.wikimedia.org/wiki/File:Brain-Computer_Interface_(BCI)_-_FET09_Prague.jpg

Body-mind-brain issues - What is the relationship between one's identity and one's body?

Disability and Super-ability - What prosthetics should and should not be allowed? To the disabled alone or to the able-bodied to give them super-abilities?

Medical/non-medical interface - Should technologies devised and permitted in a strict medical context then be applied without limit to non-medical interventions? e.g. in repairing or altering sensory organs, like extending sight into the infrared for better night vision when driving.

Ageing - If ageing is something which humans will never overcome, should humans always continue to seek to extend our lives?

Equity and justice - if we change humans, who is it for? Should we promote technologies, which will knowingly favor only a few?

What is it that makes life worth living? Beyond a certain basic point of physical survival and necessity, are the things that matter most to humans not the functional things but the relational, the aesthetic, the creative and so on? Would these factors be upheld by nanobiotechnology or threatened by it?

Are the biggest human problems less about our physical limitations than our moral, relational, and spiritual failings?[47]

VII. Enhancement and the Social Dimension

As mentioned above, enhancement of human capabilities has played a significant role in bionanotechnologies visions, is envisioned for military applications and also conjures long-term visions of technologically enhanced man-machine hybrids ("cyborgs"). Human enhancement is prominently advocated by transhumanists and extropians. These are sociocultural groups that advocate "the moral right for those who so wish to use technology to extend their mental and physical (including reproductive) capacities and to improve their control over their own lives. [They] seek personal growth beyond [their] current biological limitations" and aim at "redesigning the human condition, including such parameters as the inevitability of aging, limitations on human and artificial intellects, psychology, suffering, and our confinement to the planet earth". Apart from these utopian and far-reaching visions, a latent social demand for enhancement of certain human functions (e. g. cognitive performance, alertness, mood, endurance) is not unlikely.

Against this background, ethical deliberations and social debates are required whether there is a difference between helping someone whose capacities are below average to reach the average, and helping someone already above average to reach a still higher level of functioning (Friele et al. 2004). However, many of the concerns that have been raised by commentators are not necessarily new. Indeed, debates between ethicists, social scientists, theologians and religious groups, regulators and transhumanists about human enhancement are well established. The particular dimensions of the debate with regards to human enhancement and bionanotechnology are explored below.

How do we balance the rights and duties of the individual, and his/her flourishing, with the wider flourishing of the society to which they belong, and the role of that society in a global context? In this wider context, who decides what is regarded as 'better', or what ranks an enhancement? More generally, how do our plural societies handle the widely different normative assumptions about being human? On the other side genetic manipulation is becoming increasingly possible and more and more accurate. In theory in the future human beings could be 'repaired', 'improved' or have their natural capabilities

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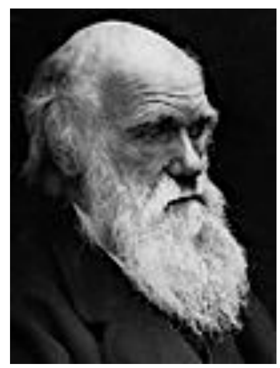
[47] Nordberg, A. (Autumn 2009). *Nanotechnology Patents in Europe: Patentability Exclusions and Exceptions*. Master´s Thesis: Stockholm University.

'enhanced' in vitro raising several obvious ethical questions[48].

Just as we ought to try to anticipate challenges posed by bionanotechnology to current regulatory systems before they materialize, we should try to anticipate challenges to social and ethical norms grounded in obtaining conceptions of the human person and situation. This is not merely because a technological onslaught may be coming and we should begin preparing ourselves. It is also because appreciating the possibilities for how some bionanotechnologies might alter us and our relationships would seem a crucial part of making informed and discriminating judgments regarding whether to support particular types of bionanotechnology or lines of bionanoscience research. Although a bionanotechnological revolution may be inevitable, its particular shape and trajectory are not. Still less defined are any social or ethical transformations that might result. Even if it is true, as many claim, that the rate of technological progress is exponential, it does not follow that social change also proceeds at that pace. Indeed, there is no way to measure social change in a way that makes such a claim intelligible. Moreover, not all social change engendered by technological progress is properly considered social progress. For these reasons, social progress is neither fully determined nor well measured by technological progress[49].

One of the implications of previous revolutions in science, particularly the Darwinian revolution, is that human flourishing must be understood naturalistically. To flourish as a human being is to flourish as a particular kind of living, sentient, social, rational animal. For human beings, the constituents of flourishing are (something like) longevity, health, reproduction, pleasure and the avoidance of pain, well-functioning social groups and healthy relationships, autonomy, knowledge, and meaningfulness, realized in an endorsable form by endorsable means.


Charles Darwin, 1869
Credit: Public Domain

Are any of the facts about us that inform what counts as a flourishing human life so understood going to be altered by bionanotechnology? Probably. Nanomedicine, for example, promises to allow us to avoid and eliminate some diseases, recover from some previously terminal injuries, and slow bodily and cognitive deterioration. If it delivers on this promise, then what can reasonably be considered a long, healthy life might be different in thirty years than it is now. Bionanotechnology also has the potential to enable novel forms of realizing several of the other constituents of human flourishing.

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48 Sandler, R. (2008). Nanotechnology and Human Flourishing: Toward a Framework for Assessing Radical Human Enhancements. *Philosophy and Medicine*. Springer International: Switzerland.
49 Gaskell, G. et al. (May 2006). Europeans and Biotechnology in 2005: Patterns and Trends. *Eurobarometer 64.3*, a report to the European Commission's Directorate-General for Research.

Bionanotechnology might make possible new forms of sociability; they might enable new ways of reproducing ourselves; and they might make possible new sources of pleasure and new ways of avoiding pain. Therefore, advances in bionanotechnology might require that we rethink what counts as a long, healthy, socially rich, pleasurable, meaningful human life.

This sort of rethinking is familiar. Current conceptions of what counts as health and longevity in industrialized nations differ from what could have been reasonably maintained two-hundred years ago, and in just the last decade information technologies and the internet have enabled novel forms of sociability that have implications for what can reasonably be considered well-functioning social groups and relationships. So the impacts of bionanotechnology on human flourishing, while potentially profound in many ways, are nevertheless similar to those of previous technologies. Most bionanotechnologies are routine bionanotechnologies in this respect: They are intended to improve on what we already have in historically familiar sorts of ways, although their cumulative effect might be to significantly alter what can reasonably be maintained as realizing the constituents of human flourishing.

Could bionanotechnology go further? Is it possible that bionanotechnology will enable altering the constituents of human flourishing, not just what can be considered endorsable realizations of them? Many bionanotechnologists believe so. For example, there is a research program underway, funded in part by the United States National Science Foundation and drawing participation from members of the mainstream scientific community, called nanotechnology, biotechnology, information technology, and cognitive science (NBIC) convergence. Its aim is to explore the possibilities for humans and society at the intersection of these technologies, and the expectation is that "converging technologies integrated from the nanoscale would achieve tremendous improvements in human abilities, and enhance social achievement" (Roco).

A major argument made against human enhancement is that it is inherently socially divisive. Unless some utopian future society could be realized, the strong likelihood is that a few might be greatly advantaged but the majority would not have access. Who would be the losers as well as the winners in any development? If the potential for individual human enhancement is indeed as far-reaching as the claims, which its proponents make, this is an extremely serious problem.

Being realistic, there seems little hope of the greatly trumpeted benefits being available to all but a very few rich or otherwise fortunate people. To dismiss this concern on the grounds that new technologies have always been economically or socially divisive would seem a wholly inadequate response to the realities.

"Not long ago, the less-advantaged within developed societies could listen to the radio, go to the free public library, and read inexpensive newspapers. As information and communication increasingly moved to the Internet, their access to both information and communication decreased relative to that by the more-advantaged."[50] Thus, a central general concern is equality and fairness. It is likely that access to enhancing interventions will not be equal, so that certain segments of the population will be favored over others, thus leading to a further widening of socio-economic divide. It is feared by some that bionanotechnology will also sharpen and widen divisions both within societies and between nations: a bionano-divide will be created.

Whether or not this happens depends partly on how bionanotechnology develops. This does not rule out the possibility that enhancement could be used by individuals to compensate for existing inequalities, and to narrow the socioeconomic gap.

In this case, it has to be asked whether enhancement on the level of the individual should be the preferred means, or whether other means (e. g. changing social conditions) are ethically more acceptable in order to diminish socioeconomic disparities. In this context, the issue of accomplice arises: it is a controversial issue to which extent the interests of the affected individual should be followed by provision of enhancement – even if this perpetuates unfair and discriminating tendencies, or whether the individual's wishes should be denied due to these reasons. In this context, it is also argued that some forms of enhancement are not only chosen in order to achieve a competitive advantage, but for the sake of non-competitive, intrinsic benefits. If enhancement were rejected in order to avoid socioeconomic inequalities, the achievement of intrinsic benefits would also be ruled out.

If applications of bionanotechnology "are primarily in enhancing existing materials, cosmetics, electronics and medicine and if these are relatively inexpensive, then there may be no increase in inequalities. However, if they are expensive and particularly useful and desirable, then they probably will." (Berger, 2014)

> "This in itself does not show that there is a problem, of course. There is a problem only if the created inequalities are unfair and therefore morally wrong. A thought-provoking question is raised: Will we need to rethink ethics itself? To a large extent, our ethics depends on the kinds of creatures that we are. Philosophers traditionally have based ethical theories on assumptions about human nature. With enhancements we may become relevantly different creatures and therefore need to re-think our basic ethical positions. For example, will we be as sympathetic toward other humans that differ substantially from us in their nature? We may need to do ethics differently. Converging technologies – for example, nanotechnology, bionanotechnology, neurotechnology, genetics and information technology – will almost certainly enable some dramatic enhancements, at least in the medium term." (Berger)

[50] Berger, M. (25 Feb 14). New approach to chip design could yield light speed computing. *Nanowerk Spotlight*. Retrieved from http://www.nanowerk.com/spotlight/spotid=12433.php.

Another question relates to what values are driving the research and development of converging technologies in the different spheres, academic, industrial and military. To what extent are these values of elite, which are not shared with the population at large? Military and commercial dimensions may be especially problematic for some, because the driving values of these contexts might diminish other important value considerations. Eurobarometer surveys report that most European citizens are not aware of much that is being researched in this area?[51]

Another potential social impact of nanotechnology given considerable attention in the literature from commentators including ethicists, involves speculation about the possibilities of convergence of nanotechnology with other technologies (such as biotechnology) in ways that might lead to applications for 'radical human enhancement', raising 'profound ethical questions' (Friele et al.) about 'the types of creatures that we ought (or want) to be'[52].

According to the EU Commission Recommendation on a code of conduct for responsible nanosciences and nanotechnologies research 'The N&N research organisations should not undertake research aiming for non-therapeutic enhancement of human beings leading to addiction or solely for the illicit enhancement of the performance of the human body[53].'

The expression 'illicit enhancement' is unclear and appears to point in the direction of a general law prohibiting technologies that enhance human performance, but such general prohibition does not exist otherwise all aesthetic/cosmetic surgery would not be legally possible.

The intention of the legislator might be to refer to the use of illegal substances or proceedings in sports activities commonly known as 'doping'. The expression 'leading to addiction' is also overly vague, substances or proceedings that have an addictive effect are here considered unethical but the recommendation does not provide a definition or a scale for this addictive effect (Nordberg, 2009).

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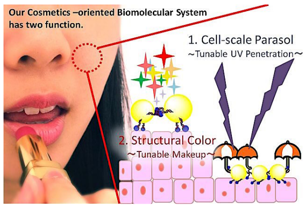
[51] Sandler, R. (Jan 2009). *Nanotechnology: The Social and Ethical Issues*. Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies**.** Retrieved from www.nanotechproject.org/process/assets/files/7060/nano_pen16_final.pdf.

[52] European Commission. (2008). A code of conduct for responsible nanosciences and nanotechnologies research & Council conclusions on responsible nanosciences and nanotechnologies research. 424 final. Paragraph 4.1.16, Annex to the EU Commission Recommendation, Brussels. Retrieved from http://ec.europa.eu/research/science-society/document_library/pdf_06/nanocode- apr09_en.pdf.

[53] Harris, J. (2007). *Enhancing Evolution: The Ethical Case for Making Better People*. Princeton University Press: New Jersey**.**



Credit: Taku Ueki, Creative Commons

Credit: DHA Pills, Public Domain

Credit: Kliek, Creative Commons

It is likely that the Commission had in mind products like cosmetics, food supplements and probiotic foods for human consumption. In any case these expressions can be interpreted in the sense that those illicit activities mentioned are mentioned as an example of what might be considered human enhancement and therefore by its nature unethical.

Radical human enhancement leads to broader philosophical questions such as how far is the concept of human being defined by its biological identity, and whether evolutionary manipulation in human DNA will change the concept of humanity. Such interrogations have important legal consequences in light of the debate surrounding the legal concept of person and its boundaries.

There are also familiar range of general social issues of technology including accountability and control. Who controls what is done, and how far should both academic and commercial sector be subject to public ethical scrutiny for what it funds? There need to be procedures and regulations to govern the risks. How precautionary should these be over uncertainties and 'unknown unknowns'? What would constitute adequate knowledge to proceed in any given case? If things go wrong with enhancements, whose responsibility is it?

One must also consider the ethics of foregoing potential benefits. Harris cites a moral duty to enhance if we have it within our power to do so[54].

One difficulty is predicting whether an enhancement would actually be socially beneficial. The social impact of bionanotechnology has proved notoriously difficult to foresight. Science fiction has explored some of the deep-seated fears of what might happen if enhancement technologies became as invasive and pervasive as might occur. Would it lead to more conformity or more diversity? How far would social pressure force the issue on people who would have chosen to avoid something but now feel they would risk being 'left behind'?[55]

VIII. Ethical aspects of Human Enhancement

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[54] Bruce, D. (Dec 2007). Human Enhancement? Ethical Reflections on Emerging Nanobio-technologies. Report on an Expert Working Group on Converging Technologies for Human Functional Enhancement. NanoBio-RAISE EC FP6 *Science and Society Co-ordination Action***.**

[55] UN General Assembly. (Dec 1948). The United Nations Universal Declaration of Human Rights, adopted by the General Assembly. Retrieved from http://www.un.org/en/documents/udhr/.

Ethical rules can and are often coded into regulatory instruments establishing rules of conduct for certain activities ranging from politics and international relations to professions and commercial activities. A few examples relevant to bionanotechnology are the UN charter of human rights[56], The UN Millennium Declaration[57], The European Convention for Human Rights[58], The Charter of Fundamental Rights of the EU[59], the Treaty of Lisbon[60] and the EU Commission Recommendation on a code of conduct for responsible nanosciences and nanotechnologies research (European Commission, 2008).

The ethical dilemma comes from the fact that such advances may not only create inventions to repair and replace damaged human organs and functions to their natural capabilities but also technological innovations that may in fact go beyond therapy and either intentionally or as a side effect may attempt to 'improve' nature augmenting human skills, competencies and performance levels and even introducing new abilities, e.g. telepathy or telekinetic.

If the ethical debate is already complex when referring to legally competent adults, expected developments brought by nanotechnology in the field of biotechnology theoretically may allow in the near future to repair, improve, enhance or introduce new abilities in early stages of human life and even to change future generations.

Human enhancement issues arise from bionanotechnology's potential to transform aspects of the human situation and not merely, as with form of life issues, modify some parameters. This might be accomplished by significantly altering the kind of creatures that we are, reconstituting our relationship to the natural environment, creating self-aware and autonomous artificial intelligences (i.e., artifactual persons) or developing robust alternative environments (e.g., virtual worlds that are as rich, immersive and socially complex as the

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[56] UN General Assembly. (Dec 1948). The United Nations Universal Declaration of Human Rights, adopted by the General Assembly. Retrieved from http://www.un.org/en/documents/udhr/.

[57] Council of Europe. (Nov 1950). European Declaration of Human Rights. Retrieved from http://www.echr.coe.int/Documents/Convention_ENG.pdf.

[58] Charter of Fundamental Rights of the European Union. (Dec 2000). Implementing Regulations to the European Patent Convention 2000 as adopted by decision of the Administrative Council of 7 December 2006. *Official Journal of the European Communities*. Retrieved from http://www.europarl.europa.eu/charter/pdf/text_en.pdf.

[59] (13 Dec 2007). Treaty amending the Treaty on European Union and the Treaty establishing the European Community, signed at Lisbon. *Official Journal of the European Union*. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:C:2007:306:TOC.

[60] Cabrera, L. (2009). Nanotechnology: Changing the Disability Paradigm. *International Journal of Disability, Community & Rehabilitation,* Vol 8, No. 2. Retrieved from http://www.ijdcr.ca/VOL08_02/articles/cabrera.shtml.

physical world).

In such cases, novel ethical terrain would be introduced or some prominent aspect of our ethical landscape would need to be reconfigured or reconceived—e.g., what it means to be human (human nature), personal identity (psychological and metaphysical), the moral status of (some) artifacts, what constitutes embodiment and emplacement and the constituents of our flourishing (e.g., what is valuable or meaningful in life).

Examples of the types of technological accomplishment that would give rise to human enhancement issues, should they be realized, include genetic, pharmacological or biomachine enhancements of our physical, cognitive and psychological capabilities (or the introduction of novel capabilities) significantly beyond the range attainable by technologically unassisted people; direct integration of human and machine intelligences; artificial intelligences that pass the Turing test; and nano assemblers or nanobots that would enable rapid molecular manufacture of macro-scale objects. These would also raise substantial social context issues (e.g., access to technology), form of life issues (e.g., effects on democratic institutions), technoculture issues (e.g., disaffection with our biological selves) and contested moral issues (e.g., the appropriateness of transcending biological "limits")[61].

Ethicists, social scientists, theologians and different religious groups have long been expressing concerns that include debates on whether we are or will soon be facing eugenic trends in society, leading to concerns over social and labour market discrimination of individuals who do not wish or are not able to access enhancement (Cabrera, 2009), and to our society's ability to accept and integrate those who were born different from the established patterns of 'normality' and still do not wish to change themselves[62].

Technological and scientific progress has provided mankind with tools to oppose nature, but emerging technologies such as bionanotechnologies introduced the possibility to control and change natural occurring phenomena. Mankind is about to claim control over its biological identity, and while some consider that escaping from natures' determinism is the ultimate freedom, other voice concerns over what is perceived has an anthropologic trend of replacing faith in a divine principle by unquestioned faith in technology[63].

The formation of Eugenic and hedonistic trends in society, combined with an absolute faith in technology and a lack of widely accepted ethical principles and the absence of comprehensive public ethical debate concerning the use and access to emerging technologies have been observed and are also important part of this issue.

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[61] Van Calster, G. (Sep 2006). Regulating Nanotechnology in the European Union, *Nanotechnology Law & Business*; Vol 3 Iss 3, 356-372.

[62] Lucas, R. (1996). *Comentario Interdisciplinar a la Evangelium Vitae*. Madrid**.** Bento XVI. (2009). *Carta Encíclica Caritas in Veritate*. ed. Paulinas: Lisboa**.**

[63] EGE (The European Group on Ethics in Science and New Technologies). (2007) Opinion on the ethical aspects of nanomedicine. Opinion N° 21**.** Retrieved from http://ec.europa.eu/european_ group_ethics/activities/docs/opinion_21_nano_en.pdf.

The discussion of the ethical issues as well as the formulation of governance recommendations is framed by the idea that this technology will be developed sooner or later and will thus become a concrete and urgent issue needing to be faced.

Many cultures still struggle to regulate the health care system for the purpose of making people well and this should provide caution to those who consider there to be a simple route towards an effective regulation of human enhancements. When establishing ethical guidelines, it is crucial to clarify the perspective from which the question is being asked, in order to understand the breadth of the ethical concern invoked by human enhancements and the scope of answers. If the matter is of personal morality alone, then it will not be necessary or ethical appropriate to involve professionals within such choices. In turn, a matter that concerns society at large should take precedence over individual morality.

At all levels, it is crucial to establish some general principles that govern ethical conduct of human enhancement. These should involve widespread, independent consultation and investment into research principles. Equally, one may derive some minimal conditions of ethical practice that are informed by other forms of medical intervention, such as the promotion of autonomy, concern about justice and welfare and so on. Finally, perhaps the most pressing issue is the degree to which the use of human enhancements requires a global response, rather than just domestic policy. While such work has become from research leadership in a number of countries around the world, there is still much more to achieve before either a clear sense of the global implications of human enhancement has been achieved, as well as a reasonable strategy has been formulated.

IX. Legal aspects: The European Group on Ethics in Science and New Technologies

The European Group on Ethics in Science and New Technologies (EGE) is an EU commission entity responsible for conducting studies and releasing opinions concerning general ethical aspects of new technologies. The Group is a neutral, independent, pluralist and multidisciplinary body, composed of fifteen experts appointed by the Commission for their expertise and personal qualities.

The task of the Group is to examine ethical questions arising from science and new technologies and on this basis to issue Opinions to the European Commission in connection with the preparation and implementation of Community legislation or policies.

"In order to face the ethical issues that are arising with the rapid advances in science and technology, the Members represent a broader range of professional competences in different disciples such as, inter alia, biology and genetics, medicine, pharmacology, agricultural sciences, ICT, law, ethics, philosophy, and theology"[64].

The EU Commission and the EGE have both sent signs of opposing research that can lead to human enhancement technologies, even if simultaneously recognizing that in practice it may be often difficult to dissociate therapeutic from enhancement and

[64] EGE (European Group on Ethics in Science and New Technologies). (2005). Ethical aspects of ICT implants in the human body. Opinion N° 20. Retrieved from http://ec.europa.eu/european _group_ethics/publications/docs/avis20compl_en.pdf.

simultaneously stressing the strategic relevance of nanotechnology research. The EU commission recommendation on a code of conduct for nanotechnology states unequivocally that 'N&N research funding bodies should not fund research in areas which could involve the violation of fundamental rights or fundamental ethical principles.'(European Commission)

Exemplifying that 'research organisations should not undertake research aiming for non-therapeutic enhancement of human beings leading to addiction or solely for the illicit enhancement of the performance of the human body.' (European Commission)

In addition, the document also emphasizes the need for due respect for precaution (European Commission). The European Group on Ethics in Science and New Technologies (EGE) has also studied the issue of human enhancement in the context of the discourse on nanosciences and nanotechnologies. In their Opinion No. 21 on nanomedicine (EGE 2007), the group argued that the border between medical and non-medical applications is not entirely clear, but that it is possible to give examples clearly illustrating both cases (EGE). The prospects of more and more human enhancement interventions would raise questions not only for the state but also for the individual. The group asked how we can preserve the plurality of life styles and avoid the transformation of the medical system into a mere service system for whatever desire individuals may have. Moreover, the EGE argued that maintaining the distinction between medical and non-medical uses is important with respect to European research funding policies, because non-medical research funding of nanomedicine may not be advocated as easily as research funding within the medical sphere. The Group proposed that HET should not be given priority. In the view of the group, health care concerns must be met first. However, in another, earlier Opinion by the EGE, the group discussed the topic of human enhancement in detail, including some of its very visionary aspects. We refer here to Opinion No. 20 on ICT implants (EGE 2005) and the related documents[65].

Nanotechnology based technologies such as miniaturization of Intelligence and Communication Technologies (IT) and Radio Frequency Identification tags have open the real possibility of applying electronic tags capable of receiving and relaying a considerable amount of information. Nanotags will be easily applied /embodied into a wide variety of material or even to implant in to the human body. Such technology could be extremely useful and used in unlimited beneficial contexts; however it is equally true that it raises ethical issues such as respect for the privacy of individuals, the dignity of human beings and informed consent and accountability for abuses.

The EGE has also addressed the issue, recommending that enhancing nanotechnology implants, medical proceedings and pharmaceuticals should be banned.

[65] Plant Genetic Systems. (1995). T-356/93. *Official Journal of the European Patent Office*, 545.

Regarding implants, the EGE general opinion is that 'non-medical applications of ICT implants are a potential threat to human dignity and democratic society.'(Plant Genetic Systems, 1995)

The EGE has recognized that there is a conflict of values between limiting the freedom of citizens, i.e. freedom to use surveillance devises eventually in a beneficial/consensual context, and promoting the safety and right to privacy of others. However the overall opinion of the EGE is that Information and communication technologies implants, such as nanotags and other described earlier, are a threat to human dignity.

The EGE has stated that: 'ICT implants for surveillance in particular threaten human dignity. They could be used by state authorities, individuals and groups to increase their power over others. The implants could be used to locate people (and also to retrieve other kinds of information about them). This might be justified for security reasons (early release for prisoners) or for safety reasons (location of vulnerable children). However, the EGE insists that such surveillance applications of ICT implants may only be permitted if the legislator considers that there is an urgent and justified necessity in a democratic society (Article 8 of the Human Rights Convention) and there are no less intrusive methods[66].'

Access to ICT implants for enhancement should be used only:

• To bring children or adults into the "normal" range for the population, if they so wish and give their informed consent, or
• To improve health prospects (e.g. to enhance the immune system to be resistant to HIV). As for health purposes, access to ICT implants for these purposes should be based on need rather than on economic resources or social position.

The EGE stressed that the following possibilities should be banned:

• ICT implants used as a basis for cyber-racism;
• ICT implants used for changing the identity, memory, self-perception and perception of others;
• ICT implants used to enhance capabilities in order to dominate others; and
• ICT implants used for coercion towards others who do not use such devices.

In the view of the group, there must be a broad social and political debate as to what kind of applications should be accepted and legally approved, particularly concerning surveillance and enhancement. A precautionary approach is recommended by the EGE. The member states and their national ethics councils (or corresponding

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[66] Berloznik, R., Casert, et al, (2006). Study by the European Technology Assessment Group: Brussels. *STOA (European Parliament Scientific and Technological Options Assessment)*; 183, IP/A/STOA/SC/2005-183. Retrieved from http://www.europarl.europa.eu/stoa/publications/studies/stoa183_en.pdf.

institutions) would have a responsibility to create conditions for education and constructive, well-informed debates in this area.

This opinion is not exempted of criticism and can even be considered discriminatory in itself since one hand it imposes one concept of normality and an intolerable intromission of the State in its citizen's private sphere that denies personal freedom of choice regarding one's own body, considering that there is little conceptual difference between the 'old' technologies that allow to change the human body (devises, chemical products and surgery proceedings that allows us to change appearance, functions) and the new technologies that will do the same in a more efficient and potentially painless manner. Further it can be objected that there is a considerable inconsistency between the ethical considerations and intended objectives lay down in this EGE opinion and the nature and predictable political effects of the proposed legal solution.

There are different currents of opinion, but there is a large consensus as to the need to increase research in the ethical, legal and social aspects of nanotechnology, with particular emphasis on interdisciplinary projects that bring together expertise from the relevant natural fields of science and combine it with different perspectives from philosophers and social scientists such as sociologists, anthropologists and jurists[67].

The EGE has also stated that the concept of human dignity encompasses the freedom to decide to use enhancement technology, considering that 'Provided that ICT devices are implanted in accordance with the principles outlined in this Opinion, there is no need to declare these implants. They could and should remain unrecognizable to an external observer. The right to privacy includes the right to have an ICT implant.'(Plant Genetic Systems)

The EGE points out that 'It is clear that this field needs regulation. …[A]ny regulations need to be based on the following principles: dignity, human rights, equity, autonomy and the derived principles, precautionary, data minimization, purpose specification, proportionality and relevance.'(Plant Genetic Systems)

Referring to the limits imposed on the freedom to use one's own body by provisions under which it is prohibited to turn one's body, its parts or products into sources of profit (Article 3 of the Charter of Fundamental Rights; Article 21 of the Convention on Human Rights and Biomedicine; Article 4 of UNESCO's Universal Declaration), the EGE, for example, raised the question whether an extensive construction of the principles of non-commodification and non-instrumentalisation might lead one to conclude that implanting ICT for purposes that are, broadly speaking, for personal profit or advantage (e.g. to get into a disco under preferential conditions) should not be permitted.

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[67] Bonazzi, M. (2006). Reconstructing Man? The Power of converging technologies. European Commission DG RTD _ Dir. Industrial Technologies. Brussels**:** Belgium. Retrieved from http://cordis.europa.eu/wire/index.cfm?fuseaction=article.Detail&rcn=11117.

Credit: Public Domain

The EGE, even if compared to the U.S. President's Council on Bioethics (PCB), contributed to the widening of philosophical perspectives on human enhancement. Moreover, it analyzed a field that only played a marginal role in the work of the PCB, which centered its study on the biotechnologies and biosciences, including the use of "neuro-ceuticals" and longevity research. It is notable that the EGE made rather surprisingly specific recommendations concerning as till highly visionary field of R&D. Consequently, the objective of its Opinion was primarily to raise awareness and questions concerning the ethical dilemmas created by a range of ICT implants in this rapidly expanding field. In the view of the EGE, ethical awareness and analysis must take place now in order to ensure they have an appropriate and timely impact on the various technological applications. Nevertheless, where the group deemed it necessary, the Opinion also proposed clear ethical boundaries, legal principles and several concrete steps that should be taken by responsible regulators in Europe. The EGE opined that efforts should be made to ensure that ICT implants are not used to create a two-class society or to increase the gap between the industrialized countries and the rest of the world[68].

X. EU Activities

The EU reacted to the new debate on human enhancement (which focuses on second-stage and non-genetic enhancements), transhumanist perspectives and actors, largely in the course of activities on nanotechnology and the closely related discourse on "converging technologies".

Even some EU officials raise the subject of the highly visionary or radical aspects of HET. One example of this is a short article by a member of staff of DG Research on an EU website in which he listed a number of EU-funded projects on CT[69].

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[68] Ach, J., Lüttenberg, B. (2008). (eds.) *Nanobiotechnology, Nanomedicine and Human Enhancement*. Münster: Berlin.

[69] Office of Technology Assessment at the German Parliament (TAB) (2008). Konvergierende Technologien und Wissenschaften. Der Stand der Debatte und politischen Aktivitätenzu Converging Technologies, Background Paper 16 (author: Coenen, C.). Retrieved from

Political discussions and activities on nanotechnology and nanoconvergence often center on the topic of human enhancement (Office of Technology Assessment, 2008).

One aim of these projects is to develop new devices with which to compensate for disabilities and impairments, but the author also discusses these as technologies for a possible "reconstruction of man".

Apparently, most of the relevant EU activities that have explicitly dealt with the topic of human enhancement have taken place in the context of activities on the ethical and social aspects of nanosciences and –technologies[70].

During the discussions about the question of how converging nanosciences and nanotechnologies might transform society, the perspective of human enhancement and its pitfalls were mentioned several times, and it was repeatedly argued that Europe needs an alternative social vision of the future prospects of nanosciences and CT. In line with the U.S. and international ethico-political discourse, nanotechnology and CT have thus become the focus of debate on human enhancement in the EU, too. This was also reflected in official EU statements:

- As early as in 2006, the European Parliament (EP) emphasized the need to respect high ethical principles and welcomed the planned reviews of issues such as non-therapeutic human enhancement and links between nanosciences and nanotechnologies and individual privacy[71]. The EP expected the reviews to be public and to include a thorough analysis of nanomedicine.

- In 2008, following a public consultation which even included the proposal to ban a wide range of HET, the European Commission proposed a code of conduct for responsible nanosciences and nanotechnologies research, in which it is stated under the title "Prohibition, restrictions or limitations" that "nanosciences and nanotechnologies research organisations should not undertake research aiming for non-therapeutic enhancement of human beings leading to addiction or solely for the illicit enhancement of the performance of the human body"(Harris, 2007).

Several ongoing or recently completed EU-funded projects on nanotechnology or CT have included research on ethical and social aspects of human enhancement in their work. Much of this research was informed and inspired by the work of the above-mentioned high-level expert group on converging technologies[72].

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http://www.tab.fzk.de/en/projekt/zusammenfassung/hp16.htm.

[70] European Parliament. (2006). Nanoscience and Nanotechnology. European Parliament resolution on nanosciences and nanotechnologies: an action plan for Europe 2005-2009 P6_TA(2006)0392 (2006/2004(INI).

[71] EU HLEG FNTW (EU High Level Expert Group "Foresighting the New Technology Wave). (2004). Converging Technologies – Shaping the Future of European Societies", (Alfred Nordmann, Rapporteur). Retrieved from http://ec.europa.eu/research/conferences/2004/ntw/pdf/final_report_en.pdf.

[72] Andler, D. et.al. (May 2008). Converging Technologies and their Impact on the Social Sciences and Humanities. (Final report of the CONTECS project). Retrieved from

Most of the activities stick, for example, to the group's critical stance towards an "engineering of the mind" and towards the post humanist and other techno-futurist overtones of the NBIC initiative in the United States. One can mention here, for example, the FP6 projects

(i) CONTECS which included analyses of ethical aspects of human enhancement and the ideological framing of the debate on human enhancement;
(ii) DEEPEN which also looked at the possible use of emerging nanotechnologies to enhance human bodily and cognitive capacities;
(iii) KNOWLEDGE NBIC which analyses converging technologies, including HET and the discourse on them, with a view on broader tendencies in science and society;
(iv) NANOBIORAISE in which also philosophical and other core questions with regard to human enhancement were discussed;
(v) NANOLOGUE which aimed at fostering the social dialogue about nanotechnology and, for this purpose, also analyzed key documents of the debate on CT and human enhancement;
(vi) ETHICSCHOOL which organized two summer schools in 2008 on the ethics of nanotechnology and CT and also produced an e-learning module on these issues; and
(vii) NANO2LIFE, a European Network of Excellence on nanobiotechnology, which looked at CT with a special view to its ethical aspects and to the topic of neurodegenerative diseases, and which also joined forces with the project NANOBIORAISE to discuss topics such as second-stage HET.

Moreover, the issue of human enhancement, including its more visionary aspects, also played a role in a STOA project on converging technologies (STOA, 2006), and will most probably also be a topic in FP7 projects such as "The Nanomed Round Table" (Harris). It is obviously beyond the scope of the present overview to summarize the results of all these projects. We will however, within the following, point out some interesting findings and approaches to the topic with regard to three of these projects.

In its analysis of the visions and the state of the art in converging technologies, the CONTECS project[73] came to the conclusion that visions and the state of the art in R&D are considerably distant from each other and that the gap is especially wide with regard to human enhancement and HET in the fields of neuroenhancement, physical enhancement, and biomedicine. However, according to the authors, one reason for this finding might be that in these fields there are more disciplines, methods and approaches

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http://www.contecs.fraunhofer.de/images/files/contecs_report_complete.pdf.
[73] Fuller, S. (2008). Research trajectories and institutional settings of new converging technologies (CIT6 No. 028334 KNOWLEDGE NBIC, Specific Support Action CIT6, Deliverable 1). Retrieved from http://www.converging-technologies.org/docs/Knowledge%20NBIC%20D1.pdf.

to be combined than in other fields and therefore a greater need for and more challenges to interdisciplinary R&D.

The final report of the CONTECS project also analysed how the topic of human enhancement and certain non-therapeutic HET were promoted by the NBIC initiative and other actors in the U.S. and how this relates to transhumanism, including its above-mentioned historical forerunners. The authors hold that the debate about human enhancement raises several important matters, which include:

(i) Issues around what it means to be human, human dignity, human nature, deference for nature and human diversity;
(ii) Challenges to established concepts of personhood and personal identity;
(iii) The questions of (self-) determination and free will; and
(iv) Issues such as work ethics, aspiration, effort, and authenticity.

The authors argue that more attention should be paid to issues that are largely neglected in the debates so far, such as:

(i) More realistic or ethically urgent uses of HET (e.g. drugs, deep brain stimulation, or future mandatory enhancements for soldiers and other groups); and
(ii) Artistic, lifestyle and identity-political forms or visions of enhancement and modification (e.g. in architecture, media art, science fiction, and queer politics).

If certain second-stage HET would really become available, policy makers would have to think about quality criteria for devices and implants, and devise approval procedures for the use in therapy, rehabilitation or for lifestyle/recreational use. Also, as a result of access to such technologies, new divides within and between societies may emerge. This can be anticipated in advance and accordingly, international agreements could be made. In the project KNOWLEDGE NBIC, the topic of human enhancement is also discussed not only pertaining to certain technologies and the differences between the U.S. and EU initiatives on converging technologies, but as relevant from a broader historical and social perspective. In the first output of the project[74] argues that the CT agenda, in Europe as well as in the U.S, takes up a new notion of regarding human beings as means for the production of benefits (i.e. human capital for a nation's economy or society). The author holds that, financial matters aside, the main obstacles to making advances in CT may be more ethical than technical, because potential HET will probably develop faster than public willingness to test and use them. The extreme prospects of genetic and neural re-engineering – both in terms of risks and benefits –would indeed revisit the classic questions of social engineering (Bonazzi, 2006).

[74] Glenn, L.M., Boyce, J.S. (2008). Nanotechnology: Considering the Complex Ethical, Legal, and Societal Issues with the Parameters of Human Performance**.** *Nanoethics*; 2:265–275.

XI. STRATEGIES AND RECOMMENDATIONS

As bionanotechnology continues to progress, the importance of a continued discussion and the monitoring and legal, ethical and social interpretation of the potential impacts of human enhancement are critical. Progress in bionanotechnology is being made around the world and breakthroughs in human enhancement are expected to follow suit. Science and engineering as well as social activities are expected to change, regardless of whether there are policies to guide or promote such changes. To influence and accelerate changes in the most beneficial directions, it is not enough to wait patiently while scientists and engineers do their traditional work. Rather, the full advantages of bionanotechnology developments may be achieved by making special efforts to break down barriers between fields and to develop the new intellectual and physical resources that are needed. To address the potential legal, ethical and social issues threatening to slow down these advances, several strategies and recommendations would be useful and appropriate. Thus, the article identified the following general strategies for achieving convergence:

1) Activities must be enhanced that accelerate bionanotechnology developments for improving human enhancement, including focused research, and design; increasing synergy from the nanoscale; developing interfaces among sciences and technologies; and taking a holistic approach to monitor the resultant social evolution. The aim is to offer individuals and groups an increased range of attractive choices while preserving fundamental values such as privacy, safety, and moral responsibility. A research and development program for exploring the long-term potential is needed (Roco et al.);

2) Experimentation with innovative ideas is needed to focus and motivate needed bionanotechnology developments. For example, there could be a high-visibility annual event, comparable to the sports Olympics, between information technology interface systems that would compete in terms of speed, accuracy, and other measurements of enhanced human enhancement. Professional societies could set performance targets and establish criteria for measuring progress toward them (Roco et al.);

3) Education and training at all levels should use bionanotechnology as well as prepare people to take advantage of it. Interdisciplinary education programs, especially in graduate school, can create a new generation of scientists and engineers who are comfortable working across fields and collaborating with colleagues from a variety of specialties. Essential to this effort is the integration of research and education that combines theoretical training with experience gained in the laboratory, industry, and world of application. A number of comparable graduate education projects need to be launched at the intersections of crucial fields to build a scientific community that will achieve the bionanotechnology that can greatly improve human capabilities (Roco et al.);

4) A proactive approach including continuing dialog —since bionanotechnology is a highly interdisciplinary area, and collaboration among all those involved in the cross disciplinary field of human enhancement in bionanotechnology, scientists, ethicists, lawmakers, economists, futurists, as well members of the public would be needed to account for the complicated issues, positive and negative, arising from bionanotechnology;

5) Establish a comprehensive definition or classification schemata of bionanotechnology in a way that is suitable for scientific, regulatory, and policy purposes;

6) Have stakeholders (e.g., researchers, industry, and physicians) and lawyers, lawmakers, economists and ethicists meet to establish principles, guidelines, and recommendations[75];

7) Come to terms that our creations can have unintended or unforeseen consequences and consider who will decide issues of regulation and liability. Among considerations, should there be international oversight or national government oversight or will individual jurisdictions be called upon to enact statutes or decide on a case-by-case basis?

8) Continue explorations and discussions of the Property –Personhood Continuum, issues of personal identity, and consider whether current law is sufficient or will new laws be needed? The possibility of legal reform and the creation of specialized "science courts," where the judges will have ongoing education and training to recognize and deal with these new legal issues and categories that arise from emerging technologies (Berloznik et al. (2006). Legal institutions must try to avoid getting blinded by the hype and inappropriately sweeping in—and perhaps over-regulating—of both the novel and the mundane applications of this still relatively young technology[76]. As bionanotechnology progresses, and both humans and nonhumans receive therapeutic benefits and enhancements, or alterations, it will be up to the policymakers, courts, and legal profession to delineate and configure legal, social and ethical guidelines for regulation and privacy and will serve as an framework for future advances in bionanotechnology and human enhancement, as well as to determine individual culpability and responsibility (Noah, 2006);

9) Concentrated multidisciplinary research thrusts could achieve crucially important results. Among the most promising of such proposed endeavors are the Human Cognome Project to understand the nature of the human mind, the development of a "Communicator" system to optimize human teams and organizations, and the drive to enhance human physiology and physical performance. Such efforts

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[75] Noah, L. (2006). Managing biotechnology's revolution: has guarded enthusiasm become benign neglect? *Virginia Journal of Law and Technology, Vol 11 No* 4.
[76] Editor's note. (May-Jun 2002). Brain work: The neuroscience newsletter. *Neuroethics*: Mapping the field: Vol. 12 No. 3, p. 1.

probably require the establishment of networks of research centers dedicated to each goal, funded by coalitions of government agencies and operated by consortia of universities and corporations (Roco et al.);

10) It should be prepared key organizations and social activities for the envisioned changes made possible by bionanotechnology and enhancement technologies. This requires establishing long-term goals for major organizations and modeling them to be most effective in the new setting. Major concerns are expressed about the potential of enhancement technologies for social divisiveness or injustice. These include who or what controls what is done; how far both academic and commercial sector should be subject to public ethical scrutiny for what it funds; who and what regulates its safety; how precautionary should we be over uncertainties and 'unknown unknowns'; what would be adequate knowledge to proceed in any given case; who are the losers as well as the winners in any given development; and how do our plural societies handle the different normative assumptions about being human;

11) We urge that in the consideration of potential technologies for human enhancement that feasibility is considered as a pre-requisite to ethical and social reflections;

12) There needs to be effective government/social oversight with some system of accountability, entailing checks and balances or regulation, with regard to any adaptation for human enhancement of techniques developed and justified in medical and other contexts;

13) Guidelines or criteria should be established about what would constitute the sort of enhancement technology for which social approval is a prerequisite, over and above personal choice;

14) There needs to be a wider social discussion about the potential role of cognitive enhancement using drugs. We wish to avoid seeing in fields like education, job skills and business the phenomenon observed in some sports of an essentially runaway development for the sake of competitive advantage, which results merely in changing the playing field to a different level, and which locks the competitors in to the technologies. People should have the opportunity to become literate about these areas of technology, and so begin to develop the critical tools by which societies will need to assess whichever of these technologies do eventually come close to fruition (UN General Assembly, 1948);

15) Flourishing communities of bionanotechnology scientists and engineers will need a variety of multiuser, multiuse research and information facilities. Among these will be data infrastructure archives, that employ advanced digital technology to serve a wide range of clients, including government agencies, industrial designers, and university lab oratories. Other in dispensable facilities would include regional nanoscience centers, shared brain scan resources, and engineering simulation supercomputers. Science is only as good as its instrumentation, and

information is an essential tool of engineering, so cutting-edge infrastructure must be created in each area where we desire rapid progress (Roco et al.);

16) Integration of the sciences will require establishment of a shared culture that spans across existing fields. Interdisciplinary journals, periodic new conferences, and formal partnerships between professional organizations must be established. A new technical language will need to be developed for communicating the unprecedented scientific and engineering challenges based in the mathematics of complex systems, the physics of structures at the nanoscale, and the hierarchical logic of intelligence (Roco et al.);

17) We must find ways to address ethical, legal, and moral concerns, throughout the process of research, development, and deployment of bionanotechnology. This will require new mechanisms to ensure representation of the public interest in all major bionanotechnology projects, to incorporate ethical and social-scientific education in the training of scientists and engineers, and to ensure that policy makers are thoroughly aware of the scientific and engineering implications of the issues they face. Examples are the moral and ethical issues involved in applying new brain-related scientific findings[77]. Should we make our own ethical decisions or "are there things we'd rather not know" (Cass, 2012); and

18) To live in harmony with nature, we must understand natural processes and be prepared to protect or harness them as required for human welfare. Bionanotechnology may be the best hope for the preservation of the natural environment; because it integrates humanity with nature across the widest range of endeavors, based on systematic knowledge for wise stewardship of the planet (Roco et al.).

It is necessary to accelerate developments in medical technology and healthcare in order to obtain maximum benefit from bionanotechnology, including molecular medicine and nano-engineered medication delivery systems, assistive devices to alleviate mental and emotional disabilities, rapid sensing and preventive measures to block the spread of infectious and environmental diseases, continuous detection and correction of abnormal individual health indications, and integration of genetic therapy and genome-aware treatment into daily medical practice. To accomplish this, research laboratories, pharmaceutical companies, hospitals and health maintenance organizations, and medical schools will need to expand greatly their institutional partnerships and technical scope (Roco et al.).

XII. Conclusion

The long-term goal of nanotechnology is to be able to fully manipulate molecular and atomic structures. If we define nanotechnology as the application of materials and

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[77] Cass, T. (8 Nov 2012). *Bionanotechnology - Combining Nanotechnology with Biology*. Institute of Biomedical Engineering. Imperial College: London. Retrieved from http://www.azonano.com/article.aspx?ArticleID=2502.

devices with characteristic (i.e. property determining) length scales between 1 and 100nm to the development of new products and processes; then bionanotechnology is its interface with biological systems.

Biology too has many examples of materials and structures that share a common length scale with nanotechnology, however it is the requirement for application that distinguishes bionanotechnology from biophysics or structural biology or virology. This is the same distinction that separates biotechnology from molecular and cell biology or physics from electronics and chemical engineering from chemistry.

Recognizing that nanotechnology and biology share common length scales at this level we can see how the combination of the two creates the opportunity to produce and apply novel hybrid structures, materials and devices that exploit the distinctive features of both. Exploitation spans the use of nanomaterials as tools in fundamental biological research, the development of novel approaches to diagnose and treat disease as well as new ways to generate energy or clean up the environment. The emerging science of bionanotechnology refers to the harnessing of the vast diversity of self-assembling building blocks and processes for the assembly of nano-scaled structures for the manufacture of highly functional nanomaterials. The link between biology and nanotechnology is also seen in processes common to both domains such as self-assembly of the importance of kinetic rather than thermodynamic control in creating and maintaining structures. There are also significant differences between the two realms, perhaps most significantly the observation that many biological structures have only marginal stability at ambient temperatures with respect to non-functional states. This can have important implications for building hybrid bionano constructs and it is in the design and fabrication of such "hard-soft" interfaces that bionanotechnology's distinctive flavor lies[78].

Since humans are made of the same basic building blocks as the natural world, bionanotechnology will probably enable the ability to change human tissues and cells at the molecular level. We are at the beginning of bionanotechnology. Science and technology is expanding at a rapid pace, and the future looks bright for increasing human mental and physical capabilities, particularly for vulnerable groups. This will open doors in medicine thought impossible, and it will enable us to extend the length and quality of human life. It will also open the door to “enhancements” of the body — better IQ, appearance, and capabilities. These enhancements will undoubtedly benefit many, but they also bring up important moral, social, ethical, and legal questions that human society has not yet had to face.

Bionanotechnology would likely allow for an enormous array of human enhancements and medical treatments. In the long run, bionanotechnology would enable us to analyze and repair any physical ailment in the body. This would mean that bionanotechnology would be able to repair someone who is damaged or diseased back to

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[78] Heller, J., Peterson, C. (N/A). Human Enhancement and Nanotechnology. A Foresight Nanotech Institute Policy Issues Brief. Retrieved from http://www.foresight.org/policy/brief2.html.

full health; an aged body and brain could be restored to a youthful state. The ultimate result could be the end of pain, disease, and aging. These innovations would be relatively uncontroversial, since they are simply extensions of modern medicine[79].

For example, in bionanosensors we can see how biomolecules and nanomaterials can be combined to mutual advantage and produce devices with applications in clinical, environmental and bioprocess monitoring. The enhancement of bionanosensors compared to conventional biosensors arises from the fact that many nanomaterials have optical, electronic or magnetic properties that were unanticipated from knowledge of the bulk (macroscopic) material, largely as a consequence of the greater proportion of atoms in the former being at or near the surface.

Fabrication of particles, wires, pores, films or more complex structures with enhanced optical, electronic, magnetic or mechanical characteristics produce a new family of base sensors that lack only the molecular specificity necessary to use them in complex backgrounds. Of course, it is such molecular recognition specificity that is the hallmark of biomolecules and the interface between the two is what provides bionanosensors with their analytical power.

In general, bionanotechnology is a new interdisciplinary R&D field that integrates engineering, physical sciences, molecular engineering, biology, biochemistry and biotechnology through the development of physical and biological devices/processes using nano-fabrication techniques to generate nano-sized building blocks and materials with specific functions and new properties. It involves the development of biologically based procedures, the use of biological components and systems, the design of biocompatible objects and systems and the use of nanotechnology to support biotechnological processes.

Bionanotechnology is the utilization of pseudobiological molecules and processes/procedures to achieve technological including nanotechnological goals.Bionanotechnology has established itself as a very fertile research field as the paradigm-shifting science and technology that lead to innovative multifunctional nanostructured devices and nanobiosystems for biological and chemical analysis, energy, novel materials and renewable resources. Bionanotechnology have the potential to make significant impact in a wide range of fields and applications[80].

For example, there are nanomaterials that are designed to perform a specific function when added to a biological system. In many cases the particles that we create have multi-functional capabilities that can include the ability to be tracked within the body, deliver a specific compound at a controlled rate, be targeted to a particular location, or to remotely kill cells once the particles have reached their destination. Specific functionalities that can be engineered into the particles include fluorescence, magnetic properties, light scattering, and drug delivery. In many cases, biomolecules (e.g.

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[79] Adelaide University Bionanotechnology Laboratory: Water Energy and Materials (BioNanoTech). Retrieved from http://www.adelaide.edu.au/bio-nano-tech/.

[80] Baldwin, R. (Jan 2006). Bionanotechnology. *NanoComposix*. Retrieved from http://nanocomposix.com/technology/bionanotechnology.

antibodies, oligonucleotides, peptides, or Fab fragments) are bound to the particle surface to direct the particle to a specific location. Long circulation times are obtained by protecting the particles with a stealth layer that allows the nanoparticle to avoid the body's scavenging mechanisms[81].

Advances in the bionanotechnology research have provided a new set of research tools, materials, structures, and systems for biological and medical research and applications. These nanotechnologies include the application of fluorescent quantum dots for optical imaging, the design of metallic nanoparticle surfaces for ultrasensitive biomolecular fingerprinting, and the use of nanostructures as hyperthermia agents for cancer therapy. Unlike conventional technologies, unique properties can be incorporated into nanometer-size particles, structures, and systems simply by changing their size, shape, and composition. Because of the tunable properties, biologists and clinicians could custom-design a material for a specific research need[82].

However, it is not clear what advances will be made in this field of science, and it is not clear how the culture will change in light of those advances.

In some respects this means that despite the fact that there is considerable conflict in relation to this field, both opponents and proponents of human enhancement share a concern about the need to approach the use of such technologies with caution. There is widespread agreement about the need for a more rigorous and open debate about the use of such technologies for human enhancement purposes. They appear open to the possibility of further regulation in this area. There is no doubt that human enhancement pose risks. They pose risks of adverse effects, and they can be used for immoral purposes. Regulations are in order. The potential for benefit as well as harm, along with our current profound ignorance, counsels in favor of taking small regulatory steps rather than sweeping prohibitions based on human rights.

In a related sense, the need to give detailed consideration to the full range of potential ethical, legal and social implications is generally agreed upon by prominent contributors to this area. There is less agreement, however, on whether there may be a possible regulatory role in this area.

In many cases, the regulations should take the form of national statutes. This is especially true when the distinction between therapy and enhancement is at issue. Individual nations have the ability to craft statutes that reflect the subtlety of current local conditions. It should be noted that commentaries on regulation are also dependent upon the jurisdiction within which the commentator is working. Such regulations can be passed, amended or repealed as the changing situation warrants. Treating human rights in this way would weaken them by reducing them to the status of mere regulations. In other

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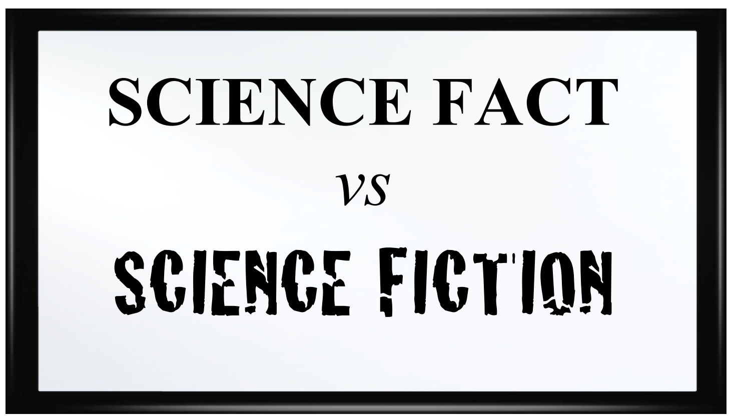
81 Chan, W.C. (Jan 2006). Bionanotechnology progress and advances. *Official Journal of the American Society for Bone and Marrow Transplantation*, 12 (1 Suppl 1): 87-91.

82 Gunderson, M. (May 2008). Enhancing Human Rights: How the Use of Human Rights Treaties to Prohibit Genetic Engineering Weakens Human Rights, *Journal of Evolution and Technology*; Vol. 18 Iss. 1, pp. 27-34. Retrieved from http://jetpress.org/v18/gunderson1.html.

cases, international treaties may be appropriate. This is especially true in cases where science has not progressed to the point where bionanotechnology can be carried out with reasonable safety. But, the treaties should not be stated in terms of human rights. Rather they should be treaties that can be amended as needed and formed on the basis of compromise without the heavy hand of human rights[83].

Enhancements should be the subject of decision-making at a social level, in the first instance. The implications are too serious to be treated just as matters of personal preference, for example, in the unintended social engineering that could result from individual use of chemical cognitive performance enhancers.

Hype is the enemy of deliberative technology assessment and governance. In many developed countries, bionano-hype has generated uncritical attitudes, blind support of any research that bears the bionano label, and the public's exaggerated hopes and fears, which draw on science fiction rather than actual R&D projects. If developing countries copy the bionano-hype, an additional danger is that 'bionanotechnology' will become a symbol of modernism and thus that the assessment of bionanotechnology will turn into a symbolic debate on modernism versus traditionalism.



Therefore all countries are advised to take measures to avoid or to reduce bionano-hype. Public education needs to address this issue by explaining the diversity of bionanotechnology and by pointing out the difference between actual R&D projects and science fiction. A proactive strategy for contributing to public understanding and public awareness should include, first of all, correct information on the state -of-the art, on trends and intentions, on programme visions and measures, etc. Such a strategy would also take into account the experiences of earlier public debates and of the (only partial) public acceptance of, for instance, biotechnology, genetic engineering, genetically modified organisms, and stem cell research. Mistakes were made; evaluations should be commissioned. In addition, mandatory ethics components should be integrated in bionanoengineering and bionanoscience education to provide students with ethical skills that allow them to analyze assess and communicate the ethical and social dimensions of bionanotechnology.

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83 Schummer, J. (2007). Identifying Ethical Issues of Nanotechnologies. Henk ten Have (ed.), *Nanotechnology: Science, Ethics and Politics*. UNESCO Publishing: Paris, 79-98.

Because technologies increasingly shape society and determine the way we live, the entire process of projecting, supporting, guiding and regulating technologies – that is, technology governance – has become a critical part of politics. Societies need to adjust to this development. Rather than letting experts or administrators make the crucial decisions, technology governance needs a stronger basis, including citizen participation, from the earliest step on, in identifying social needs and possible technological solutions. Democratizing technology governance is the best way to ensure that emerging technologies are developed in accordance with the ethical standards of a society[84].

It seems that if any conclusion can be drawn from the article, it is that we need to be sensible about human enhancement if it is to have value in society's future. Scientists should collaborate with policy-makers, philosophers and the public to engage in a dialogue about the ethical consequences of enhancement technologies in order to reach the maximum benefit with minimal damage (Healey, 2012).

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