NANOTECHNOLOGY AND MEDICINE IMPROVEMENT*

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DOI: 10.7813/2075-4124.2015/7-2/A.5

Received: 30 Sept, 2014
Accepted: 07 Jan, 2015

ABSTRACT

Nanotechnology has become an extraordinarily hopeful area in several human domains. Many scientific disciplines are developing their works in this area since the emergence of nanoscale, giving their contribution to the development of nanosciences. Many recent researches in areas as physical sciences, molecular engineering, biology, biotechnology and medicine for example are contributing for the investigation of biosystems at a nanoscale. Nanotechnology and nanobiosystems are becoming a privileged domain to reach an advanced level in the human development in many fields, as the examples of the biotechnology processes, the synthesis of new drugs and their delivery on a live body, the regenerative medicine and the new technologies in medicine (biotechnology and nanotechnology), body area networks for telemedicine (nanomedicine, nanoimaging, nanotechnological implants, in-body diagnostic systems, nanobiomedical wired devices, etc), or the application on the sustainability of the environment. Nanoscale may provide the tools to get improved conditions to investigate biosystems and to get advances with nanomaterials. These nanoscales, used in biosystems, contribute to enhance very innovative and promising results in medical area. Improvements in the telemedicine and on health are expectable with new systems operations and new nanotechniques. Many ethical problems and also legal and social implications are posed and the need for discussing this theme shows the importance of nanotechnology to the society and the consequences, both positive and negative, that the development of nanotechnology will have to mankind in the future.

Key words: Nanotechnology, nanomaterials, telemedicine, ethics

1. INTRODUCTION

"Small is beautiful"… "Small" is becoming smaller and smaller. This is true in a lot of domains and with great impact in our lives. Now, we are in nano scale. First mili (10^{-3}), then micro (10^{-6}) and now nano (10^{-9}). Briefly, pico (10^{-12}) and femto (10^{-15})

Nanotechnology (extremely small technology at the nanometre scale) involves multidisciplinary scientific knowledge and discusses matters related to the utilization of materials, mechanisms, devices and systems in a nanometer scale. Nowadays there are many fields in which nanotechnology is applied and it is expected that it can create an enormous field for innovations and take part in many fields of science developments. Particularly, it is expected that this kind of developments happen in various applications on the biomedical area, such as drug delivery, molecular imaging, biomarkers, biosensors (biomedical sensors wirelessly located on/in the human body; nano-biomedical data transmitter) and many other fields of application.

The first person to conceptualize nanotechnology was Richard P. Feynman, although he has not used this term in his speech to the American Physical Society on December 29, 1959, where he made the first comments on the subject. The word "nanotechnology" was first used by Professor Norio Taniguchi (1974) to define the fabrication of a scale of 1 nm. Nanotechnology is the potential ability to create things from the smallest element, using the techniques and tools that are being developed today to place every atom and molecule in place. The use of nanometer implies the existence of a system of molecular engineering, which will likely generate the subversion of the factory manufacturing model as it is known.

The idea that nanotechnology has just a technological impact by itself in human activities and many life dimensions as health must be analyzed, also considering the strong impact on the economic activities in which the technologies are applied. In biomedical area for example, the considerable impact on pharmaceutical and biomedical companies is quite visible.

Considering all the discussion involved, it is pertinent to consider that quite important ethical questions are raised in this field. This discussion is important to define some limits, taking into account the human and the technical limitations, for the indefinable context of the problem. In this perspective of the ethical discussion, human values must be highlighted. In nanotechnology area, particularly in the biomedical field, some questions are posed primarily on the impact on the human values and human condition, on the risks for human health derived from neglecting human behavior for example, and on the limits of science. The possible violation of the basic principles of natural life and individuals position concerning life limits, health and life, and its contextualization may be well understood in this discussion.

In this paper, some ideas are presented on nanotechnology, specifically about the concept and the reporting ideas involving nanotechnology. The discussion about the concepts is not the main objective of the present study. The main objective is to show the importance of this technology, some applications it has and the exposure to different limits and significant risks in several areas behind the enormous fields of opportunities and challenges. These risks may represent a problem but the challenges represent an open field to get significant progress.

* *A part of this material is developed in the chapter Filipe, J. A., Ferreira, M. A. M., Coelho, M. e Chavaglia, J. N. (2013), "Nanotechnology: Overpassing the limits of the human being. An ethical discussion applied to medical applications", in Silva, N. and Costa, G. J. M. (Ed.), "Ethical Dimensions in Bio-Nanotechnology - Present and Future Applications in Telemedicine", Hershey, USA: IGI Global.*

2. NANOTECHNOLOGY: A NEW ENHANCEMENT FOR SCIENCE AND APPLIANCES

In the 50s in the 20th century, the discovery of the double helix structure of the deoxyribonucleic acid (DNA) molecule brought new perspectives to medicine and new hopes to mankind. The revolutionary discovery of DNA allowed advances on new fields of science. Since then, research brought many other significant discoveries which limits are unknown.

The 20th century has transformed the face of Earth with so many and so great inventions, that were totally impossible before. From the innovations that permitted to fly using heavy aircrafts, permitted to use antibiotics for medical care, the arrival of electronics, or whatever many other discoveries that changed totally the life of humans. The existence got a sense completely different from before. The introduction of the computer and the advances in electronics with alternating current circuits have contributed to life at another level of existence. The radio, television, cars, telephone, airplane, computers and internet services were products that have become available to the current life.

As can be easily seen and perceived every day, science has been facing important advances in many fields in the last decades and recently great new advances have been made. Now a new history may be beginning in the current century. Technology at a nanoscale has arrived and a completely new world is now there, with significant and continuous discoveries.

Feynman, cited in Freitas (2005), proposed the use of machine tools to make smaller machine tools, these to be used in turn to make still smaller machine tools, and so on all the way down to the atomic level. Feynman was clearly aware of the potential medical applications of the new technology he was proposing.

These smaller machine tools would come to be transformed in nanomachine tools, nanodevices, and nanorobots, which could ultimately be used to develop a wide range of atomically precise microscopic instrumentation and manufacturing tools, that is, nanotechnology.

This new technology, nanotechnology, which is an expression that comes from the Greek word “nano” (“dwarf”, in English), is applied on a molecular level in engineering or manufacturing, for example.

The most common definition of nanotechnology is that of manipulation, observation and measurement at a scale of less than 100 nanometer (one nanometer is one billionth of a meter).

The term nanotechnology refers to several distinct classes of technology, each one of them has its own set of capabilities, potential applications and risks. The terms in this field that are specifically used for the different technologies may vary. However, it is important to be aware of the fundamental meaning of each one and the important distinctions between them.

Besides, nanotechnology is inherently multidisciplinary, depending on analytical techniques and methodologies of a set of disciplines including chemistry, physics, electrical engineering, material science and molecular biology, worked on the basis of many scientific fields in the area of lithography, nanomachines or nanorobots, for example.

Nanotechnology permits the modification of individual atoms and of molecules at a precise location, either chemically or physically and permits to develop devices which can scan and manipulate objects at near atomic scale (see Kubik et al, 2005). As nanotechnology deals with materials, devices, and their applications, in areas such as engineered materials, electronics, computers, sensors, actuators, and machines, at the nano length-scale, the advances brought an enormous impact on those areas. Medicine, engineering of materials or electronics are nowadays confronted with progress but also with an ethical discussion. Considering these nano-meter length scales, numerous disciplines and new technologies are going together to develop new processes and combinations.

Since the nineties of 20th century, the progresses were very relevant (see for example, Srivastava and Atluri, 2002). The discoveries of atomically precise materials are very significant, particularly the advances in medicine, manipulation on real materials, integrated systems, computers, agriculture or industry, in general, for example.

There are endless possibilities on these and other fields.

One of the developed fields in nanotechnologies is the area of nanorobotics, which involves devices as nanobots, nanoids, nanites, nanomachines or nanomites. These concepts have been used to describe this kind of devices, today much under research and development. Nanorobotics refers to the nanotechnology engineering discipline of designing and building nanorobots, with devices that are ranging in size from 0.1 to 10 micrometers and are constructed of nanoscale or molecular components.

The invention of nanorobot hardware architecture for medical defense should provide the basis for advanced ‘computational nanomechatronics: a pathway for control and manufacturing nanorobots’ (Cavalcanti, 2009).

In biological research, particularly in the area of molecular biology and working nucleid acid molecules, many achievements have been recently made. Moreover, many progresses have been made in the area of molecular biology applications. In this field, many techniques have been successfully implemented in many scientific fields, such as in the diagnostics area or in biology, biotechnology or medical science. For example, “the introduction of polymerase chain reaction (PCR) resulted in improving old and designing new laboratory devices for PCR amplification and analysis of amplified DNA fragments. In parallel to these efforts, the nature of DNA molecules and their construction have attracted many researchers. In addition, some studies concerning mimicking living systems, as well as developing and constructing artificial nanodevices, such as biomolecular sensors and artificial cells, have been conducted” (Kubik et al, 2005).

In this century, the development of ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) diagnostics are being made considering a large set of approaches using new techniques and technologies, many of them associated to DNA developments, being particularly supported by nanotechnology solutions, which have been already successfully introduced. These achievements take part in the fundamental development of many areas of diagnostics and science, including the health care, medicine or pharmaceutical industry (Kubik et al, 2005).

There are great scientific revolutions in human history and as seen before, nanotechnology is certainly one of them, which opens up unimaginable possibilities in various fields of human reality and in various fields for application in the industry.

3. MEDICINE AND NANOTECHNOLOGY

The nanotechnology is giving continuous steps towards new developments of research and applications. It will be expanded to many areas of life and sciences, particularly in medicine, where the diagnosis, drug deliveries’ systems in the body or the treatment of diseases are particularly important.

Applications of nanotechnology for treatment, diagnosis, monitoring, and control of biological systems have recently been referred to as "nanomedicine" by the Institutes of Health (see Moghimi et al, 2005).

The origin of the concept of nanomedicine is related to the idea that nanorobots and related machines could be designed, manufactured, and introduced into the human body to execute cellular repairs at the molecular level. Nowadays, nanomedicine has multiplied in many directions, understanding the idea that the ability to structure materials and devices at the molecular scale can bring enormous immediate benefits in the research and practice of medicine (see Freitas, 2005).

The use of instrumentation techniques inside the human body for 'medical nanorobotics for diabetes control', 'nanorobotics for brain aneurysm', 'nanorobots for treatment of patients with artery occlusion', 'nanorobots for laparoscopic cancer surgery', has been established and now only requires further industrial implementation and commercialization. Aspects such as integrating and using 'nanorobotic architecture for medical target identification' can effectively advance several medical issues, thus improving biomedical engineering. Upcoming and current available technologies should be used to achieve a fully functional 'medical nanorobot architecture based on nanobioelectronics' (Cavalcanti, 2009).

According to Moghimi et al (2005), the application of nanotechnology to medical activities, according to the idea inherent to the concept of nanomedicine, involves the identification of precise targets (cells and receptors) related to specific clinical conditions and the choice of the appropriate nanocarriers to achieve the required responses while minimizing the side effects. They say yet that "mononuclear phagocytes, dendritic cells, endothelial cells, and cancers (tumor cells, as well as tumor neovasculature) are key targets".

Moghimi et al (2005) also show how important are, nowadays, nanotechnology and nanoscience approaches to particle design and formulation. The authors highlight that they begin to expand the market for many drugs and are forming the basis for a highly profitable niche within the industry. Their article highlight rational approaches in design and surface engineering of nanoscale vehicles and entities for site-specific drug delivery and medical imaging after parenteral administration.

Among the very relevant fields of nanotechnology use one is the creation of artificial tissues, organs and cells (which are much investigated for the replacement of defective or incorrectly functioning cells and organs). The implantation of encapsulated cells is being studied for the treatment of diabetes, liver failure, kidney failure and for the use of encapsulated genetically engineered cells for gene therapy. Artificial cells uses are very relevant for drug delivery and other applications in biotechnology, chemical engineering and medicine (see Kubik et al, 2005). New researches are being directed to discover new techniques which may contribute for the artificial growth of organs and tissues on nanopatterned scaffolds, aiming to obtain internal tissues implants. The studies about the creation of nanostructures that can interact with and replace natural biological materials give many opportunities and hope for medical treatments.

Some of the medical areas in which nanomaterials have successful utilization are precisely the medical diagnosis, the proper and efficient delivery of pharmaceuticals or the development of artificial cells.

As seen, many advances in nanomedicine have been worked. Their use in valuable medical diagnostics or clinical therapeutics brings significant results. In Freitas (2005) many examples of applications are presented, for instance, single-virus detectors, tectodendrimers, nanoshells, fullerene-based pharmaceuticals, or immunoisolation, gated nanosieves.

Particularly, it is interesting to show the case of the advances on DNA sequencing and the consequent benefits. A ultrafast DNA sequencing has been made possible. Branton's team at Harvard University used an electric field to drive a variety of RNA and DNA polymers through the central nanopore of an a-hemolysin protein channel mounted in a lipid bilayer similar to the outer membrane of a living cell. Branton first showed that the nanopore could rapidly discriminate between pyrimidine and purine segments along a single RNA molecule and later demonstrated discrimination between DNA chains of similar length and composition differing only in base pair sequence (Freitas, 2005).

A colossal increase has been got recently in the understanding of the way basic biological processes happen at a molecular level (see for example the very particular case of the human genome sequence). The importance of these developments continues to grow very fast and so the focus on the essential molecular mechanisms underlying the normal functioning of cells, tissues and organisms themselves. Molecular medicine, by itself, exploits molecular and cellular biology advances to characterize how normal cellular processes fail or are subverted in disease. Nanotechnology has an important role in this matter.

According to Freitas, cited by Kubik (2005), there are three important molecular technologies: 1) Nanoscale-structured materials and devices are promising for advanced diagnostics and biosensors, targeted drug delivery and smart drugs, and immunoisolation therapies; 2) Biotechnology offers the benefits of molecular medicine via genomics, proteomics, and artificial engineered microbes; 3) Molecular machine systems and medical nanorobots will allow instant pathogen diagnosis and extermination, chromosome replacement and individual cell surgery *in vivo*, and the efficient augmentation and improvement of natural physiological function.

Operating in the human body, nanorobots can monitor levels of different compounds and store information in an internal memory. The use of nanodevices may permit to reduce the intrusiveness, increasing the patient comfort and to give a greater fidelity on results, once the target tissue can be examined in its active state in the actual host environment.

Nanorobots may be used to rapidly examine a given tissue location, surveying its biochemistry, biomechanics, and histometric characteristics in greater detail (see Kubik et al, 2005). If, or when this happen, this will help in better disease diagnosing.

In general, nanotechnology works the engineering of molecularly precise structures and molecular machines; and nanomedicine makes the application of nanotechnology to medicine, considering also the use of medical nanorobotics. Medical nanorobots can offer targeted treatments to individual organs, tissues, cells and even intracellular components. They can get involved in biological processes at the molecular level.

It is clear at this moment that nanotechnology will continue to offer very effective solutions in many medical areas. Nanomedicine may even give answers at the level of the control of human aging. This world is a completely new open world, with very large potentialities at diverse scales and dimensions, very particularly in the area of telemedicine. It is very interesting to understand that the extent of telemedicine and telehealth success will depend on how well the heath care system exploits the capabilities of advanced information technology. This technology can extend the reach of medical facilities and resources, promoting efficiency, productivity, accuracy in clinical decision making, coordination and integration (Ackerman et al, 2002).

4. NANOTECHNOLOGY AND ETHICS

Computers have brought the ability to type and made handwriting more and more superfluous. By its side, mobiles and their miniaturization brought the ability to generally communicate anywhere to anybody, making more and more useless the traditional phones. Nanotechnology, because of its negligible dimension of devices, will spread the use of devices that now are nuisance. For instance, the pacemaker that now is used like a “last resource”, maybe soon will be used in a much larger scale if it will be possible to design one at a nanoscale.

However ethical questions rise with the development of nanotechnology. What are the limits for this kind of progress? Until where we must go? What are the implications in a later phase of development of these technologies?

Global discussion has begun about this theme since the beginning of the discoveries about this subject. Legal, ethical and social implications are irreversible and the discussion is usually asked to be hard.

Vanessa Nurock, cited in Bensaude-Vincent (2010), questions the standard view of an ethics for nanotechnology. She argues that none of the current trends in the discipline of ethics would qualify for application to nanotechnology. Then considering that neurotechnology – a rapidly growing field at the intersection between nano and biotechnology – can affect moral capacities of the brain, she suggests that ethics itself may be affected by nanotechnology. And she leaves the question of a co-construction of ethics and bionanotechnology open to the debate.

Freitas (2005) says that the society should be “able to muster the collective financial and moral courage to allow such extraordinarily powerful medicine to be deployed for human betterment, with due regard to essential ethical considerations”.

In EU, there are some important concerns and discussion about the development of the integration of human beings and artificial (software/hardware) entities. A funded project in this area (ETHICBOTS) was created to promote and to coordinate a multidisciplinary group of researchers into artificial intelligence, robotics, anthropology, moral philosophy, philosophy of science, psychology, and cognitive science, with the common purpose of identifying and analyzing techno-ethical issues concerned precisely with the integration of human beings and artificial (software/hardware) entities.

Next generations, in the perspective of the utilization of nanomaterials, will have many benefits in all these chapters (health, economic, environmental, etc). By using this kind of advanced technology, with many more applications and much more friendly using, the conditions this technology offers will be very environmental friendly as well, as already seen.

In fact, there are irreversible and long-term impact consequences for future generations and for the environment. However, there are risks, as well. But in truth there are incredible potential advantages. And the discussion is around. The limits are, of course, evident and there has to be an achieved balance between the path found to the new dimension of knowledge and the contours the problem has. The rub of the question is exactly in what measure criticisms may have into account the potential of the technology.

So, despite the high feasibility for the economy and the environment, there are some considerations regarding the ethical, human dignity and moral limits on nanotechnology that should be taken into account.

It is interesting to go to the definition of human dignity and its relationship to moral made in the “opinion of the European Group on ethics in science and new technologies to the European Commission”, 2005, when discussing the ethical aspects of information and communication technologies (ICT) implants in the human body. The group makes allusion to the EU’s draft Treaty that Establishes a Constitution for Europe, stating that “human dignity is inviolable. It must be respected and protected” (Article II-61), and goes on to explain that “the dignity of the human person is not only a fundamental right in itself but constitutes the real basis of fundamental rights” (Declaration concerning the explanations relating to the Charter of Fundamental Rights). This group says yet that this explanation does not strictly define human dignity and that many writers have attempted to fill this gap. One such attempt suggests that human dignity is defined as follows: “the exalted moral status which every being of human origin uniquely possesses. Human dignity is a given reality, intrinsic to human substance, and not contingent upon any functional capacities which vary in degree. (…) The possession of human dignity carries certain immutable moral obligations. These include, concerning the treatment of all other human beings, the duty to preserve life, liberty, and the security of persons, and concerning animals and nature, responsibilities of stewardship.”

The introduction of new devices to go further above the natural capabilities of the human being brings lots of concerns to scientific community. Desires, challenges but also concerns are always present… What are the consequences? To human beings, to life itself, to health, to other living beings, to environment, to biodiversity, to progress, to the civilization as a whole...

5. CONCLUSION

The use of nanomaterials brought many benefits to mankind. Taking into account that nanotechnology is the ability to work at the atomic, molecular and supramolecular levels (on a scale of approximately 1 – 100 nm), the enormous possibilities to work nanomaterials can be easily understood. The creation and the use of these material structures, devices and systems with fundamentally new properties and functions result from their small structure, with applications in several areas, such as bioprocessing in industries; molecular medicine (considering physical, chemical, biological and medical techniques used to describe molecular structures and mechanisms, often referred as personalized medicine); analyzing the health effect of nanostructures in the environment; improving food and agricultural systems; or improving human performance at many fields, considering the different branches of science and the applications at many dimensions and scales.

Nanotechnology supplies the tools and the technology allowing that researches lead to the transformation of biological systems, as far as biology provides models and bio-assembled components to nanotechnology.

Nanoscales, used in biosystems, contribute to enhance very innovative and promising results in medical area. Improvements in the telemedicine and on health may be expected with new systems operation and new nanotechniques.

However, ethical as far as legal and social implications are posed. This discussion is as old as the issue is itself but the boundaries are very large, large enough to find out the difficulties on finding definitive answers to this discussion.

Ethical, legal and social implications in this context show the importance of nanotechnology to the society and the consequences that the development of nanotechnology will have to mankind in the future.

The irreversibility and long-term impact of these new developments enforce to have on mind that it is necessary to take into account also the rights of future generations and the planet (like Hans Jonas' "Principle of responsibility”).

The innovations are going fast and although the endemic crisis, economic but also social and politic, will bring some restrictions to the investments in the area of health and research in many countries, new developments in this area will prevail and many discoveries will be made. Innovations are growing and development is there, as much as the will to go faster in many domains of scientific investigation. The research on this subject gets new results everyday and new challenges have to be faced. Some work is going on this way and it is intended, after the conclusion of this paper, to analyze some data in order to study the impact of the crisis on nanotechnology and on applications to medicine and industry. The crisis may bring some restrictions, but challenges have to be faced and a new beginning is there. Ethics concerning nanodevices and the limits of human beings considering nanotechnology in general and applied to medicine also need a new research to be developed next. This debate of the limits of the human being regarding the application of nanotechnology may be also enlarged in order to have a study of the impact into telemedicine and e-health.

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