The human centred approach to bionanotechnology - ethical considerations

By Gonçalo Jorge Morais da Costa, Nuno Miguel Araújo da Silva and Nuno Sotero Alves da Silva

Abstract
The primary challenge to promulgating a more human-centred approach to managing and accounting for innovation is: can we encourage innovation that adds net social value? At the same time, can we deter - or at least not encourage - innovation that serves malicious ends, or that poses grave threats to humanity? Therefore, the aim of this paper is to obtain answers concerning bionanotechnology as a research field, but which are their applications? What sort of ethical and moral dilemmas encompasses? And, does the level of such dilemmas is a sum of biotechnology and nanotechnology, or imposes new challenges?

Introduction
Innovation traditionally was viewed as a linear process: from basic research value to technology development and on to test/evaluation, demonstration, deployment, commercialization, and ultimately, market penetration. And perhaps, if successful, market saturation, obsolescence, and finally replacement. Human (and social) factors- needs, desires, demands, behaviour - were considered either not at all or intuitively, anecdotally, coincidentally, mechanically, and often reactively. Innovation was driven, first, by hard science, engineering, and production, with marketing and sales trailing behind like army camp followers.
The key challenge to disseminate a more human-centred approach should manage and account for innovation net social value. That is, whose benefits clearly outweigh its costs?; at the same time, can we dissuade innovation that serves malicious ends or that poses grave threats to mankind? In that sense, such challenge is clearly bounded to the field of bionanotechnology. But, how can we define bionanotechnology? As we will demonstrate, such concept is still an ongoing debate, and for that we need to address two levels of arguing:

- what is biotechnology? Which are its applications? What ethical and moral dilemmas arise?
- what is nanotechnology? Which are its applications? What ethical and moral dilemmas arise?

Biotechnology can be broadly defined as using organisms or their products for commercial purposes. It has been used into food, crops or domestic animals; but, recent developments in molecular biology have given biotechnology a new meaning, a new prominence, and a new potential. It is (modern) biotechnology that has captured the attention of the public, and of course encompasses a great deal of ethical and moral dilemmas, as the ones related to healthcare.
Nanotechnology is the creation of functional materials, devices, and systems through control of matter on the nanometer length scale, the exploitation of novel properties and phenomena developed at that scale. Through out literature it is possible to find several examples of nanotechnology applications: giant magneto resistance in nanocrystalline materials, nanolayers with selective optical barriers, etc. (IMM, 2003). Concerning the possible and moral dilemmas of such technology it is usual that philosophers, ethicists and many scientists

frequently speak as such objects will exist in the very near future, but in fact they already exist which clearly creates a policy vacuum.
Only after the previous analysis is possible to acknowledge the objective of our paper: how can we define bionanotechnology as a research field? Which are its purposes? What kind of ethical and moral dilemmas occur? And, does the rank of such dilemmas correspond to a sum that elapses from biotechnology and nanotechnology, or imposes new challenges?

Development

Biotechnology and its applications

Contrary to its name, biotechnology is not a single technology. Rather it is a group of technologies that share two common characteristics: working with living cells and their molecules; and, having a wide range of practice uses that can improve our lives. In spite of such claim, we will plead that biotechnology is unique amongst the three major technologies for the twenty-first century - information technology, materials science, and biotechnology - because is a sustainable technology based on renewable biological resources. Such natural resources include animals, plants, yeasts, and microorganisms and having formed mankind’s nascent food and beverage industry for several millennia.
So, biotechnology can be broadly defined as “using organisms or their products for commercial purposes” (NAL, 2008). But recent developments in molecular biology have given to biotechnology a new meaning, a new prominence, and a new potential. It is this (modern) biotechnology that has captured the attention of the public, which has a dramatic effect on the world economy and society.
Historically, the modern era of scientific biotechnology commenced with the elucidation of the DNA structure by Watson and Crick in 1953, and the subsequent development of the tools to cleave and resplice genetic material in the early 1970s. Not surprisingly, therefore, the term biotechnology is generally considered synonymous with gene splicing and other forms of genetic engineering.
However, in the future, the most significant breakthroughs in human medicine will result from mapping and understanding the human genome. With less than five per cent of all human genes identified, it has become increasingly clear that each new gene discovery proffers new drugs for the diagnosis, treatment, and prevention of human disease (OECD, 2002). These advances will enable biotechnologists not only to measure disease potential and expand the applications for genomic diagnostics, but also to devise fundamental new therapeutic approaches. Products and medical applications of modern biotechnology include: artificial blood vessels from collagen tubes coated with a layer of the anticoagulant heparin (Dyck et al., 1999; Huynh et al., 1999); and, gene therapy (altering DNA within cells in an organism to treat or cure a disease) is developing therapies to treat diseases such as cystic fibrosis, AIDS and cancer (BIO, 2005).
Genomics and genetic engineering are also playing a substantial role in the development of agricultural biotechnology. The early goals in the development of transgenic livestock were the increase of the meat and the production characteristics of food animals. However, long research and development timelines associated to low projected profit margins, especially in developed nations where food is relatively inexpensive; have shifted priorities to the production of protein pharmaceuticals and nutraceuticals in the milk of transgenic animals (Lowe, 1999). And, similar initiatives using genetic manipulation are aimed at making crops more productive by reducing their dependence on pesticides, fertilizers and irrigation, or by increasing their resistance to plant diseases (Lowe, 1999).
Plus, marine organisms are also capable of producing a variety of polymers, adhesives, and compounds for cosmetics and food preparation. Bioactive natural products are found in organisms that reside in areas which stretch from easily accessible intertidal zones to depths

in excess of 1000 meters. Collaborations between marine chemists, molecular pharmacologists, and cell biologists have yielded an impressive library of potentially use (NAL, 2008). However there are still many catalysts still to be discovered, which will have to exhibit improved performance, stability, turnover numbers, specificity, and product yields. Biotechnology is also playing a role in clean manufacturing. Nevertheless, various types of chemical manufacturing, metal plating, wood preserving, and petroleum refining industries currently generate hazardous wastes, comprising volatile organics, chlorinated and petroleum hydrocarbons, solvents, and heavy metals. Bioremediation with microbial consortia is being investigated as a means of cleaning up hazardous sites. Methods include in situ and ex situ treatment of contaminated soil, groundwater, industrial wastewater, sludge's, soil slurries, marine oil spills, and vapour-phase effluvia.

Finally, biotechnology is being currently used in DNA fingerprinting (process of cross matching two strands of DNA) namely into the following fields (BIO, 2005):

- criminal investigations- DNA from samples of hair, bodily fluids or skin at a crime scene as a way to confirm suspects is enhancing rapidly;
- polymerase chain reaction (PCR)- process that entails into a more quick and accurate way of identify the presence of infections such as AIDS, Lyme disease and Chlamydia;
- paternity determination- through DNA it is possible to confirm if a child's DNA pattern is inherited, half from the mother and half from the father;
- human fossils- to determine how closely related fossil samples are from different geographic locations and geologic areas. The results shed light on the history of human evolution and the manner in which human ancestors settled different parts of the world.

The ethical dimensions of biotechnology

The ethical issues created by biotechnology are vast and growing. Our present moral systems work mightily to reconcile the new world order into their established patterns of accepted behaviour. The ethics of biotechnology raises immensely complex issues; the biotechnology of ethics raises even more intractable ones. Our current scientific advances promise to allow us to engineer the most basic of our life processes: the dissemination in our environment of genetically modified organisms (GMO); the genetic modifications and their use in food; the applications of research in human genetics.

The publication of the first experimental protocols of the technique of genetic engineering in 1973 (on micro-organisms) raised the fear into researchers: many biologists considered it was a high risk activity, and therefore restrictive measures were taken. The GMOs had to be confined and prevented from disseminating in the environment. They could modify the "balance of nature" and subsequently the foreign DNA could alter the metabolic activity in an unpredictable and undesirable way, producing unsuspected and irreparable damage to environment and mankind. In fact, science fiction literature was already starting the debate by presetting GMOs with the ability to destroy the reserve of raw materials, enhancing the lack of confidence concerning such organisms.

With new progress in scientific knowledge and experimental techniques, it occurred to scientists not to confine the GMOs in bioreactors, but to let these organisms grow freely in the soil in order to improve: the environment through micro-organisms with the ability to clean chemically contaminated soils (bioremediation); and, the performance of vegetal culture. However, such decisions entail into a discussion regarding the relationships between these GMOs and other organisms (including human beings). Won't the modified characteristics be transferred to other organisms, creating non intentional and, may be, damageable effects (OECD, 2005)? Our knowledge about the interactions between the microbial populations in an ecosystem is fragmentary, especially on the exchange of genetic material, but precise studies are going on (BIO, 2005). No negative effects of the release of GMOs (micro-organisms) have been reported until now; however studies are being conducted (BIO, 2005). The problem is to know if they can be set up with objectivity. The question remains open: can this problem be treated with objectivity, similar to debate regarding nuclear power? Biotechnology may soon provide us with the ultimate ability to “design” our individual moral senses and biologically “grow” implanted ethical codes of behaviour within the human being. The more commanding focus will be on the genetics of ethics, rather than on the ethics of genetics.

Therefore, we need to recognize the extraordinary uniqueness of current life forms and how highly special and precious they remain. To the extent, modern science threatens the delicate symbiosis between our ethical and legal norms and our biological evolution. New, daily scientific advances leave a moral order ill-equipped to respond. Ethical choices are the result of deeply ingrained predispositions and a lifetime of cultural adaptation. When faced with new situations, we tend to respond slowly, viewing any significant departure from the moral status quo as a threat. The law also inherently moves slowly, proceeding through careful analysis and studied reflection. Legal precedent and a hierarchical judicial system lend additional brakes to an already sluggish, orthodox order.

With such intrinsic conservatism, it should come as no surprise that we are today continuing to struggle, both ethically and legally, with technological breakthroughs that are decades old. Contraception and abortion are, at their core, denials of our biological selves (Singer, 1981; Dawkins, 1989; Thiele, 1999) and, thus we continue to be uncomfortable with the ramifications inherent in the utilization of the technology. Contraception is still vigorously debated in many societies, through technology that is now antiquated.

Currently, biotechnology among many other things is enabling us to begin prenatal testing for fetal genetic conditions and to begin artificial manipulation of an unborn’s genotype. The intractable social, moral, and legal issues posed by only these two technological advances illustrate the potential impact of biotechnology in our society (Kevles, 1993; 1995). When is such testing viable and to whom should it be made available? Which genetic disorders or diseases will allow (require?) state regulated abortions or invasive procedures? How are the rights of a “good-gene” child to be weighed against maternal health and reproductive freedom? Who should bear the economic costs of raising a child conceived with certain knowledge of the genotype-disorder? Is there a duty for individuals to test in vitro so they may reject embryos that pose significant health costs over the embryo’s lifetime? What is a “bad” gene trait and how do we decide which embryos are “good” (Burgess, 2001)? What will happen at an ethnical level: will nations be characterized by homogeneous ethnic groups, encompassing therefore synonymous cultures (Brunger and Bassett, 1998)? Of greater concern is the short shrift paid to concerns about biopiracy in isolated communities (Burgess, 2001).

Moreover, all these dilemmas entail into an important discussion regarding biotechnology patents: it is possible for a company or a country owns our genetic evolution, instead of mankind itself? In fact, there is a substantial debate in public forums and academic circles about whether patenting is morally and ethically acceptable (see for example: McGee, 1998; Caplan, 1998; Merz and Cho, 1998; Caulfield and Gold, 2000; Gold, 2000). Regarding such matter, we will assume the vision underline by Caulfield and Gold (2000), which entails into the absence of patents regarding the human genome.

Clearly, all the previous questions remind us the importance of undertaking a critical reflection concerning the role of industry into biotechnology, as Rahul Dhanda (2002) in this well-written book, “Guiding Icarus: Merging Bioethics with Corporate Interests” explores. Dhanda makes it clear at the outset that he is an industry insider, working for Interleukin

Genetics, and so his perspective is explicitly pro-science and pro-industry. Therefore, he is not naive about the many pitfalls of industry or the social responsibility that it bears. Even if you disagree, as we do, with some elements of Dhanda's position regarding the following issues:

- the critical importance of comprehensive informed consent procedures- such procedures are not only hints at the real problems with how informed consent is used (as a paper to sign rather than as an ongoing process), which undermines its protective utility;
- the insufficient attention to whether DNA donors- such people are likely to understand what they are consenting to;
- the DNA databases- as it occurs in any database, DNA databases can also produce errors and be violated, which means a blind faith in them will lead people to discount the possibility that their personal DNA information can be wrong;
- the DNA patents- it should not be allowed to any company to patent the human genome, in spite of the valid economical argument concerning the costs of research.

He is still convincing about the need to integrate bioethics as a corporate value within the biotechnology industry. In conclusion, such questions guarantee many decades of ethical and legal wrangling. We are living beings designed to forward our biological selves; when technology changes the landscape too quickly, we tend to become confused and resist what are often perceived as threats to our self-identity. Technological interference with, or enhancement of, natural processes is, simply, something that frustrates us. And while we are attempting to resolve the momentous issues raised, technology speeds ahead leaving a perplexed and somewhat paralyzed society in its wake.

Nanotechnology and its applications

Nanotechnology emerged as an important research area in the 1980s. From the beginning, nanotechnology has been observed to be an enabling, horizontal, and cross-sectoral technology (Franks, 1987). It is projected to revolutionize several industrial sectors by providing valuable technological innovations, but before define such research field it is important to address the etymology of the concept “nano”. The Greek word *nanos* (dwarf) is the origin of nano; meaning that a nanometer is one billionth of a meter, or roughly 75,000 times smaller than the width of a human hair. Therefore, approximately three to six atoms can fit inside of a nanometer (nm), depending on the atom.

When Drexler coined the word nanotechnology in the 1980s, he was discussing about building machines on the scale of molecules, a few nanometers wide-motors, robot arms, and even whole computers, far smaller than a cell (Drexler, 1986). Drexler spent the next ten years describing and analyzing these incredible devices, and responding to accusations of science fiction. Meanwhile, mundane technology was developing the ability to build simple structures on a molecular scale. As nanotechnology became an accepted concept, the meaning of the word shifted to encompass the simpler kinds of nanometer-scale technology, as described in another book of Drexler (1991), called the “Unbounding the Future”. In fact, the importance of Drexler into the research field is also recognized through the foundation of the Foresight Institute, which is a nonprofit organization dedicated to the responsible development of nanotechnology (FI, 2000). However, this theoretical capability was envisioned in 1959 by the renowned physicist Richard Feynman in his lecture, “There’s Plenty of Room at the Bottom”, concerning miniaturization down to the atomic scale.

Applications of nanotechnology extend to several fields, following four generations of nanotechnology development (Roco, 1998; Roco, 2001; Roco, 2001a; Roco, 2001b; Roco, 2002; Roco, 2003):

The present era, as Roco illustrates it, concerns passive nanostructures, materials designed to perform one task. The second phase, started around 2005, and introduced active nanostructures for multitasking. The third generation is expected to begin emerging around 2010 and will feature nanosystems with thousands of interacting components. After that, a few years later it will arise the first integrated nanosystems, similar to a mammalian cell with hierarchical systems within systems, are expected to be developed.
For instance, examples of nanotechnology generations in biomedical and biotechnology are: targeted drug delivery, gene therapy, and nanomedicine (biomechatronic human prostheses for locomotion, manipulation, vision, sensing, and other functions, such as: artificial limbs, artificial internal organs, artificial senses, human augmentation) (Davis, 1997; West and Halas, 2000; Bogunia-Kubik and Sugisaka, 2002). This field has important connection with neuroscience, to develop neural interfaces and sensory motor coordination systems for the integration of these bionics devices to human body/brain. In the field of computing it is possible to acknowledge: nano-computers and defect tolerant computer architectures (Heath, et. al., 1998). In the field of microelectronics we have the following examples: the replacement of silicon with carbon nanotubes in a transistor (McEuen, 1998); miniaturization of electronic devices (Sohn, 1998); and, DNA-based computing (Seeman, 1998). These advances have taken place with parallel advances in methodologies and instrumentation such as scanning tunnelling microscopy (Quate, 1991).
Finally an important question arises: why is the length scale of nanotechnology so important? According to the LANL (2008), there are five reasons: the wavelike properties of electrons inside matter are influenced by variations on the nanometer scale. By patterning matter on the nanometer length scale, it is possible to vary fundamental properties of materials without changing their chemical composition; the systematic organization of matter on the nanometer length scale is a key feature of biological systems; nanoscale components have very high surface areas, making them ideal for use in composite materials, reacting systems, drug delivery, and energy storage; the finite size of material entities, as compared to the molecular scale, determine an increase of the relative importance of surface tension and local electromagnetic effects, making nanostructured materials harder and less brittle; the interaction wavelength scales of various external wave phenomena become comparable to the material entity size, making materials suitable for various opto-electronic applications.

The ethical dimensions of nanotechnology

With such awesome potential dangers inherent in nanotechnology, we must seriously examine its potential consequences. Granted, nanotechnology may never become as powerful and prolific as envisioned by its evangelists, but as with any potential, near-horizon technology, we should go through the exercise of formulating solutions to potential ethical issues before the technology is irreversibly adopted by society. We must examine the ethics of developing nanotechnology and create policies that will aid in its development so as to eliminate or at least minimize its damaging effects on society (Sweeney, Seal and Vaidyanathan, 2003). However, the ethical implications of nanotechnology are simultaneously unpredictable and predictable.
In his novel The Nanotech Chronicles, Michael Flynn (1991) presents his view on the gradual development of future nanotechnology and its social implications through out six nano-science fiction stories, which can provide us some interesting directions regarding such matter. However, we tend to disregard that the ethical perception concerning biotechnology can be a good starting point for the ethical implications of nanotechnology, as suggested by Weil (2001), or Wolfson (2003). Moreover, the principles that Richard Severson (1997) outlines in his book, “The Principles of Information Ethics”, to guide IT ethical decisions are also insufficient to this analysis. In our opinion, the ethical analysis concerning

nanotechnology should engage the implications link between: individual level; professional level; and, societal level.
Nanotechnology as a tremendous impact on individual identity because the ethical concept of life revolves around nanotechnology in accordance to Venneri (2001, 234): “nanotechnology encompasses the attributes of self-generation, reproduction, self-assembly, self-repair and natural adaptation”, and clearly these are all attributes we ascribe to living things. The other, fantastic aspect of how the concept of life might change with nanotechnology regards the promises of nanomedicine. Nanotechnology may be able to repair or reproduce tissue, diagnose disease (e.g. cancer) at a very early stage, dispense drugs at the cellular level, and even reverse disease. Therefore, our concept of the human life span may be revolutionized as a result; people may live longer by techniques considered by many to be artificial. Some will wonder if nanotechnologists are “playing God” by tinkering so directly with nature. Others will wonder to what extent humanity and nanomachinery will blend; if we are downloaded into our technology, what are the chances that we will thereafter be ourselves or even human (Joy, 2000; Weckert, 2001)?
Plus, future nanotechnology-enabled, implanted or swallowed diagnostic tools will make possible the collection of an enormous amount of individual cellular/subcellular level surveillance data of the human body, which is remotely transmitted to a medical database server to be analyzed and monitored by diagnostic software. When such technologies become possible, a key ethical question arises: can the health information infrastructure handle, collect, process, and analyze real-time on-going health data? Moreover, ensuring privacy and confidentiality in such a system would be of utmost importance; a system without adequate safeguards presents serious ethical problems.
From the above it is clear that an in-depth ethical analysis is necessary having in consideration the human dignity through the following requirements (UNESCO, 2006)

- non-instrumentalisation- the ethical requirement of not using individuals merely as a means but always as an end of their own;
- privacy- the ethical principle of not invading a person’s right to privacy;
- non-discrimination- people deserve equal treatment, unless there are reasons that justify difference in treatment. It is a widely accepted principle and in this context it primarily relates to the distribution of health care resources;
- informed consent- the ethical principle that patients are not exposed to treatment or research without their free and informed consent;
- equity- the ethical principle that everybody should have fair access to the benefits under consideration;
- the precautionary principle- this principle entails the moral duty of continuous risk assessment with regard to the not fully foreseeable impact of new technologies as in the case of ICT implants in the human body.

At a professional level nanotechnology can raise the following issues to its practitioners (Flynn, 1991): the dimensions of intended and unintended social consequences of technological innovation, including attempts to fix unintended consequences by technological implementation, and cultural conservatism; understand the limits of social foresight and of planning technology-induced social changes; the different kinds of interests and values that professionals are confronted and the need for responsible decisions; risk analysis and the social relativity of risk perception; standard excuses from moral responsibility.
Finally, at a societal level we may refer that nanotechnology embraces potential dangerous for the environment. In 2002, researchers reported to the Environmental Protection Agency (EPA) that nanoparticles have appeared in the livers of research animals and that there is a potential for nanoparticles to piggyback on bacteria and enter the food chain. There is no

regulatory body that is tracking nanomaterials, so we could be releasing an undetectable toxin into the biosphere (Rupley, 2002). However, the ethical dilemmas are far more complex that the environmental issues.

An essential feature that sets nanostructures apart from other artefacts is size. They are from 1 to 100 nanometers, from one- to 100-billionths of a meter, significantly less than the 50,000 nanometers of a human hair. Obviously, they cannot be perceived by the naked eye (Ratner and Ratner, 2003: 6), and can thus be produced and deployed without ever being observed by any human being. The kinds of ethical issues this unobservability creates can be illustrated by noting three problems: privacy; intrusion; disclosure and appropriation. These problems are external to nanotechnology. They arise through what are predictably the ordinary uses made of nanostructures or as a consequence of there being nanostructures at all.

Concerning privacy, we could simply add nano-sensing devices to the paint or a composition floor to turn a ‘safe’ room into a recording and transmitting studio. Alternatively, such devices could be put into our bodies without our being the wiser. The average citizen would be at the complete mercy of anyone familiar with nano-sensing. Their detection would require what we can presume to be special highly sophisticated equipment (Robison, 1994: 1-2).

We are also helpless to preclude disclosure, the second privacy tort. The standard sort of example is someone’s passing on a secret. The secret is disclosed. We all keep some information to ourselves. This is, among other things, one way of distinguishing between friends, acquaintances and strangers. We tell friends things about ourselves that would be inappropriate to tell our acquaintances (although that would be one way of beginning to turn an acquaintance into a friend). Telling such things to strangers would mark us as addled, if not crazy. Control over information about our personal lives allows us to keep, among other things, control over who we are: publicly, and privately. Nanosensors would allow a stranger to know everything about us that we would want to control, from private conversations with one’s spouse or lover to intimate details about one’s body temperature and state of health. A stranger could well know far more about us than we can know about ourselves (Robison, 2004).

That someone knows as much or more about us as we do permits the last relevant privacy tort, namely appropriation. That occurs when someone takes another’s identity. Such theft will become that much easier as information about us is relayed to a stranger who will pick up all those conversations we think are private, and use that information to appropriate our identity (Robison, 2004).

In each case- intrusion, disclosure and appropriation- our privacy is invaded, and of course such invasion can obviously also be harmful, which is enhance by nanotechnology.

Bionanotechnology and its applications

After the debate concerning biotechnology and nanotechnology, how can we define bionanotechnology as a research field? 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 relabelled nanotechnology. In fact, all of these fields coupled with biological systems, should be included in bionanotechnology. Therefore, the idea of bionanotechnology embraces the engineering of interfaces between molecules or materials and biological systems, which clearly encompasses a wider, or a blurred definition. Even acknowledging the following definitions the quandary holds: “bionanotechnology claims that it is a multi-disciplinary area that sits at the interface between engineering and the biological and physical sciences” (BBSRC, 2007: 1); while the OECD defines it as “an area that covers the interface between physics, biology, chemistry and the engineering sciences”

(OECD, 2005:4); or, “bionanotechnology represents the convergence of nanotechnology and biotechnology, yielding materials and products that use biological molecules in their construction or are designed to affect biological systems”(NCBC, 2007: 3). Some examples of bionanotechnology applications include: engineering biomolecules for non-biological use, such as DNA-based computer circuits using nanotechnology tools; medical diagnostic devices and medical imaging to study biology combining nanomaterials with biological systems for outcomes such as targeted drug therapies.

However, despite the political rhetoric and normative discourses that claim the prospective of such technology, due to immeasurable institutional inflexibility (insecure career paths, unfair evaluation, need of longer training), the truth is that the conventional wisdom concerning its benefits is not supported by systematic evidence and remains poorly understood (Weingart and Stehr, 2000; Bruce et al., 2004; Schild and Sorlin, 2005). Although since the 1990s there has been an outstanding output of new empirical studies to add to the more plentiful conceptual and normative approaches adopted in the past, where a worrying lack of consensus about how to measure cross-disciplinarity arise (Bordons, Morillo and Gómes, 2004). Another crucial aspect that still needs to be evaluated is the costs and risks of failure regarding its ethical and moral dilemmas.

Conclusion

Through out this paper we have acknowledged the arguments that allow us to reveal the answers regarding biotechnology and nanotechnology. Plus, we were able to respond to the primary research question: how can we recognize bionanotechnology as a research field? However, the literature review process seems to disregard the answers regarding its ethical and moral dimensions. Such reality induces us to argue through our personal opinion concerning such matter: bionanotechnology encompasses not only the ethical dilemmas that prevail in each one of the research fields, biotechnology and nanotechnology, but enhanced such dilemmas.

The key reason for our argument is simple, and probably debatable; however, in order to justify our argument we present two valid assumptions: bionanotechnology as a research field is still an unknown variable, as well as it is boundaries. In fact, even the scientific community disagrees about the concept itself - as demonstrated above; and, the ethical and moral dilemmas that biotechnology and nanotechnology engage are still under debate, and may be considered blurred or fuzzy. Therefore, the ethical and moral dilemmas of bionanotechnology can be considered as a Pandora box.

In conclusion, a research field that elapses from an ongoing definition, and whose ethical and moral dilemmas is a composite of the previous ones, clearly enhances the existent ethical quandaries.

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