Philosophy of Science: A Marginal or a Pervasive Field? A Reflection on the Past, Present and Future of the Department of Philosophy

Hub Zwart

> *We are surrounded and embraced by her: powerless to separate ourselves from her, and powerless to penetrate beyond her… She is ever shaping new forms: what is, has never yet been, everything is new, and yet nought but the old. We live in her midst but know her not. She is incessantly speaking to us, but betrays not her secret. We constantly act upon her, and yet have no power over her…*

These are the opening lines of the first issue of the journal Nature, published in 1869. They were written by Thomas Huxley, who had borrowed them from Goethe's famous fragment Die Natur (1783), who in his turn had probably borrowed them from his friend Christoph Tobler. This view of nature that Goethe expressed so eloquently in 1780 can be applied to contemporary technoscience, using the very same terms: we are surrounded by her, powerless to separate ourselves from her, we constantly act upon her, yet have no power over her, etc.…This is the theme of this chapter.

In it, I describe in a concise manner how the Department of Philosophy of the Science Faculty has evolved from 1957 up to the present, and how this evolution has always been intimately connected with and responsive to important developments in science and society. Indeed, the Department of Philosophy has evolved in a triangular landscape, as it were, consisting of three "poles" that closely interconnected with each, namely, science, nature and society, and the challenge of our department, as I see it, is to reflect critically upon the past, present and future of this evolving landscape. After analyzing the vicissitudes of the Department during the third quarter (the "Van Melsen epoch") and the fourth quarter of the twentieth century, I will focus on the present state of affairsand future prospects for philosophical reflection within the framework of the Faculty of Science.

The Van Melsen Epoch

The Department of Philosophy of the Faculty of Science was established in 1957 by Professor Andries van Melsen (1912-1994), chemist and philosopher (see fig. 1). Before taking up his position as chair of the department, he had already been Professor of Philosophy at Arts (Faculteit der Letteren). His most famous academic publications are *From Atomos to Atom: The History of the Concept Atom* (1949/1952) and *The Philosophy of Nature* (1953/1961), but he was a prolific author whose publications covered a broad range of subjects, such as science and philosophy, science and society, science and religion and science and nature (1962, 1964, 1969, 1977, 1983, 1993). His work was of high academic quality, but at the same time accessible and relevant for broader, non-academic audiences. He was not only a prominent scholar and teacher, but he also participated in various societal forums, committees and centres for reflection (such as the Katholiek Studie Centrum). He was intensely involved in debates that still dominate the agenda of contemporary philosophy, such as the role of technology in human existence, the relationship between science and religion and the concept of evolution. He was, in other words, a visible, committed and highly respected scholar of international renown. Colleagues and friends published a special volume devoted to his life's work, including a comprehensive bibliography (Van Melsen et al. 1985).

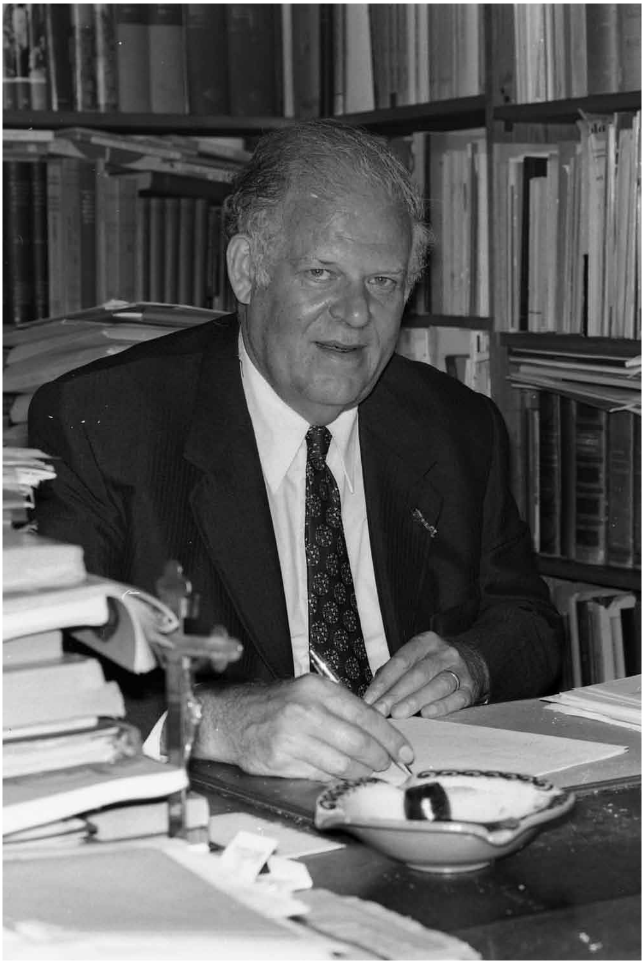

Figure 1: Andreas van Melsen in the 1960s (source: Faculty Photographic Departement)

In Van Melsen's time, the philosophy of science, like most of the sciences, was far from being "big." Although intellectual debates on science involved scholars from around the globe, these scholars primarily acted as individuals and their research was, as we now would call it, "researcher driven." The setting of their work was basically their private library. Van Melsen's image is closely associated with books, armchairs and cigars. I was granted an occasional visit to his impressive library, and many years after his death the scent of tobacco was still clearly noticeable, as was the brownish colour of the pages of his books. He lived at a time when it was still possible for an individual philosopher to personally own all of the books that really mattered. His successors in the department, such as Frans Soontiëns and Wil Derkse, were keen on keeping this style alive.

Van Melsen was not only the first full professor of philosophy at the Faculty of Science; he was also closely involved in setting up the Faculty as such. As Van Melsen explained time and again in the various books and essays he published on the relationship between philosophy and science, the basic objective of philosophy is to provide a kind of overarching view or synthesis, placing the insights produced by specific scientific research fields into their proper perspective, stressing the interrelatedness of their various contributions to developing a coherent and comprehensive view on human existence (1983). Over and above the specific insights into nature produced by scientific disciplines, philosophy addresses the mystery of the "being there" of nature as such (1993). Philosophy starts from the given that human beings from the very outset combine their will to know with a basic striving towards insight into good and evil and the purpose of scientific progress. Notably, he saw the integration of the claims of knowledge produced by the various branches of academic research as an important task of a *Catholic* university (Brabers 1998, p. 318). This model applied to the university as such, but to the Faculty of Science in particular. Notably, due to the emergence of positivism in the nineteenth century, science and faith had come to be seen as being at least potentially in conflict with one another (the so-called Galileo-complex). Although the neo-Thomistic tradition that still held sway over much of Catholic philosophical thinking during the 1950s had attempted to incorporate scientific insights into a predominantly religious world view, as Thomas Aquinas himself had propagated, the dynamics and pace of scientific discovery were such that the relationship between faith and science were, expressed in the most diplomatic manner, delicate. This said, most Catholic authors agreed that it would be disastrous if the Catholic University should fail to establish a Faculty of Science of its own, for this would leave the battlefield to others, as it were, when it came to conducting research and interpreting the meaning of the results thus generated, but also when it came to educating future generations of scientists and scientific professionals. In scientific fields, Catholic academics tended to see themselves as being underrepresented. Van Melsen agreed with the line of thought that there was no such thing as a "Catholic mathematics" or a "Catholic biology"; however, he did argue that it would be crucially important for a Catholic university to offer its students a possibility to systematically reflect on the various questions raised by upcoming scientific insights on human existence from a religiously informed perspective. Thus, although Van Melsen saw philosophy and science as being basically dissimilar in terms of both their methodology and the types of insights they produced, he argued that reflection should nonetheless constitute a *firmly integrated part* of the research and education conducted at the Faculty of Science (Brabers 1998, p. 347). A Catholic university could not afford to neglect either the blessings or the insights bestowed upon mankind by contemporary science and technology, nor could it ignore the potential challenges or conflicts with a religious worldview that were likely to emerge from these disciplines time and again, given the fact that, from the nineteenth century onwards, science had increasingly evolved from a materialistic and relativistic background, rather than from a religious one. Thus, it was of pivotal importance that a Catholic university should become engaged in science research through setting up a Faculty of Science of its own, but it was of no less importance that facilities for reflection, under sound philosophical guidance should be put in place as well, and in an integrated fashion.

As a consequence of this view, departments of philosophy were established in all of the faculties that were part of the Catholic University Nijmegen. Within the network, the Department of Philosophy established in the Faculty of Science was regarded as being of particular importance when it came to addressing and assessing the moral and cultural relevance of scientific insights from a religiously informed perspective. Thus, philosophical reflection became firmly institutionalized and, as it is called nowadays, “embedded.”

Van Melsen also emphasized that this should take the form of an interactive, two-sided process in the sense that Catholic philosophers should not only critically reflect on the doings of scientists from the point of view of philosophy and faith, but they should also be willing to expose and, if necessary, adapt their religiously inspired views to the insights generated by scientific research. This implied, among other things, that the traditional neo-Thomistic frame of reference should become much more open not only to new scientific findings, but also to new philosophical ideas, such as phenomenology and existentialism. This openness was in agreement, moreover, with similar attitudes that were evolving among philosophers of the Institute of Philosophy *(Hoger Instituut voor wijsbegeerte)* of Louvain, the oldest and most prominent institute for continental philosophy in the Dutch and Flemish speaking regions. This institute functioned as a role model or benchmark for Catholic philosophers in the Netherlands in general and for philosophers in Nijmegen in particular.

The Final Quarter of the Twentieth Century

In 1974 Van Melsen retired and was succeeded by Professor Guy Debrock (fig. 2), an expert on American pragmatism, notably the work of Charles S. Peirce (1839-1914). In addition to his studies on Peirce (Debrock 1992, Debrock & Hulswit 1994), Debrock primarily devoted himself to questioning some of the basic concepts of science, such as time, nature, meaning and causality. Meticulousness and precision were basic characteristics of his work. The Department of Philosophy set up its own book series, primarily devoted to publishing conference proceedings and volumes. Guy Debrock as well as other members of the Department of Philosophy contributed to this series, notably Paul Scheurer, who held a chair as Professor for Philosophy of the Physical Sciences from 1980 to 1987 (Debrock and Scheurer 1982, Scheurer and Debrock 1983, Debrock et al. 1983, Scheurer et al. 1985). Two important PhD theses were completed during this period, one on philosophical problems concerning the structure of physical time by Peter Kroes (1982), who later became Professor of Philosophy at the Delft University of Technology, and one on the semeiotics of causation by Menno Hulswit (1998), a prominent Peirce devotee and expert (1993, 1994, 2002).

Figure 2: Guy Debrock lecturing (source: Faculty Photographic Departement)

During the 1970s and 1980s, the focus of philosophical reflection shifted from the religious to the societal meaning and impact of science. The growing awareness of the relevance of science for society, and of society for science, resulted in the emergence of various “Science and Society” courses and gradually, although at first somewhat reluctantly perhaps, the Department of Philosophy became involved in this movement. It also focused on the history of science, resulting in publications on Newton (Scheurer and Debrock 1988) and Einstein (Debrock & Scheurer 1982), among others.

Over the years, however, the Department of Philosophy gradually declined in size and prominence, assuming the status of a service provider for reflection courses (Philosophy and Ethics, Science and Society, Science History) offered to students at the Bachelor level. This sidelining of the department was also reflected by the location of the department in the old massive concrete building: in the service wing, between the technicians and personnel management department. The

Science Faculty was then organized on a disciplinary basis. Therefore, courses of limited size (3 ECTS) were provided for Bachelor students in biology, physics, chemistry, mathematics and computer science. Special courses (Capita selecta) were also offered on selected themes, such as "evolution" or "brain and consciousness." (See fig. 3)

	Biology and environmental science	Physics	Chemistry	Mathematics	Computer science
Philosophy	Philosophy for biologists	Philosophy for physicists	Philosophy for chemists	Philosophy for mathematicians	
Science and society	Biology and society	Physics and society	Chemistry and society	Mathematics and society	Informatics and Society
History	History for biologists			History of mathematics	
Capita selecta					

Figure 3: "Reflection Courses" at the Faculty of Science

No formal research programme existed, and the Department was not involved in formal research evaluations. The academic staff consisted of one assistant professor for philosophy, one half-time assistant professor for Science and Society and History. The educational workload was substantial, and research was subservient to teaching. Important publications from the 1990s were a book on environmental philosophy and teleology by Frans Soontiëns (1993) and a volume on the greenhouse effect by Guy Debrock and Wim Thijssen (1992). The latter also published a history of the Faculty of Science (1985).

At the Turn of the Millennium

In 1999 Professor Debrock retired and in June 2000 Hub Zwart was appointed Professor of Philosophy and Chair of the department. His appointment coincided with the famous Press Conference that took place that same month across the pond, in Washington D.C., where (on June 26 2000) President Clinton, together with Francis Collins (Director of the Human Genome Project) and Craig Venter (his competitor, Director of the privately owned Celera company) announced that the massive effort to sequence the human genome was nearing its completion (Zwart 2008a). In retrospect, this concurrence, may perhaps appear as more than a mere coincidence.

In 2001, a new curriculum was developed in which a new profile for the Department of Philosophy (now re-baptized the Department of Philosophy and Science Studies) was defined. The curriculum indicated a shift from a more "fundamental" orientation (author studies, basic concepts) to a more "applied" and science-oriented approach. The life sciences (their cultural and societal significance in the past, present and future) became the primary object of research. The basic objective of the new curriculum was to make the work of the department more visible and relevant to the Faculty at large and to strengthen its academic performance and societal outreach. Environmental philosophy and animal philosophy became key domains. This resulted in three theses, an international volume (Zwart 2008b) and a series of scholarly and societal publications. The issues addressed in the theses – the vicissitudes of genetically modified mice as biotech pioneers (Ter Gast 2007), the meaning of biotechnology for human existence (Lemmens 2008) and the significance of concepts, such as integrity, for debates on genetic modification of research animals (De Vries 2009) – set the stage for the research agenda that was subsequently developed. The Chair of the Department joined a number of committees that focused on science policy, such as COGEM and the Netherlands Association of Animal Ethics Committees (as chair). On the international level, the EU–Canada exchange project Coastal Inquiries was hosted by the Department of Philosophy, with Hub Zwart acting as European lead. Within the framework of this project, European students did their Master theses on coastal environmental issues in Canada, and visiting Canadian students studied the emergence of "new nature" in coastal and wetland areas in the Netherlands. Together with Jozef Keulartz, Hub Zwart visited Derawan, a small island off the coast of Kalimantan, in order to study prospects for sustainable ecological coastal development.

In 2003, the Master track study Science Communication (C-variant) was established in accordance with the so-called "beta covenant." Educational tracks for the various scientific fields were to be extended from 4 to 5 years on the condition that new society-oriented Master track studies would be developed. The Faculty of Science decided to develop two new Master track studies, one for Science Management and one for Science Communication. It was also decided that the latter track would formally fall under the auspices of the Department of Philosophy. Together with Professor Cees van Woerkum (Wageningen University and Research Centre), a prominent expert on science communication studies, Hub Zwart became responsible for developing and implementing this new track, and in 2004 two assistant professors for science communication were appointed. The team currently consists of Dr. Riyan van den Born, Drs. Leen Dresen and, quite recently, Dr. Roald Verhoeff. With the retirement of tenured academic staff, two new assistant professors were appointed to the Department of Philosophy, namely, Dr. Martin Drenthen (philosophy) and Dr. Luca Consoli (science and society), as well as two part-time professors, one with a chair in "Sustainability and world views" (Professor Jozef Keulartz) and the other with a chair in the History of Science (Professor Christoph Lüthy). Thus, the Department of Philosophy made its first steps to expand from a mere service provider of limited size into a substantial research group.

In 2004, funding was acquired for setting up the Centre for Society and Genomics in the Department of Philosophy. Genomics exemplifies a number of changes that are currently taking place in the way in which scientific knowledge is produced, notably in the life sciences. The Human Genome Project (HGP) symbolizes the emergence of genomics as a new techno-scientific field (IHGSC 2001, 2004). With its dependence on evolving technologies for high-throughput biochemistry and bioinformatics, genomics represents the shift from a single gene-oriented approach ("gene hunting") to a whole genome approach (based on bioinformatics). It has resulted in a steady stream of ever-larger and more complex genomic data sets, thus transforming the study of virtually all forms of life. Genomics is seen as more than a new repertoire of tools. As a discipline, its aims are to provide a more comprehensive understanding of the functioning of organisms in both healthy and diseased states, and it has become "a central and cohesive discipline of biomedical research" (Collins et al 2003, p. 1). According to Collins (1999, 2003), Director of the Human Genome Project, genomics is not a particular branch of biology, nor is it a set of research tools for high-throughput analysis. Rather, it is a scientific field that is transforming the ways in which research in the life sciences is performed. Genomics has empowered researchers working in a variety of research fields with new research strategies that allow them to reframe and redefine some of the basic questions on living nature. As a "converging field," genomics brings together large numbers of researchers (critical mass) from various backgrounds, so that research is carried out on a much larger scale than in the past and with a more interdisciplinary approach. As an "enabling" field, it combines basic research with a plethora of applications. Initially, genomics focused on sequencing the genomes of model organisms *(Caenorhabditis elegans, Drosophila melanogaster, Arabidopsis thaliana, Homo sapiens)*, culminating in the HGP and, more recently, in the publication of genome sequences of the chimpanzee, the mammoth, the domesticated pig, the laboratory mouse and cultivated rice. These research endeavours have provided new insights on early human history and the coming-into-being of mankind. With the subsequent entry of genomics research into the post-sequencing phase, there has been a shift in focus from structural genomics (sequencing genomes) to functional genomics (understanding the relationships between genomes and the behaviour of living systems) and related areas, such as proteomics. The entire sequence of the human genome has become a database. As such, it is a starting point for new research endeavours, and genomics is now moving into new terrains that are of clear relevance to the Department of Philosophy, such as ecogenomics (genomics and sustainability), toxicogenomics (alternatives for research with animals), behavioural genomics (genomics and identity) and synthetic biology.

It was against the backdrop of this development that the Netherlands Genomics Initiative provided funding for a Centre for Society and Genomics (CSG) that would combine research into the societal dimensions and prospects of genomics with activities in the area of education and communication. Genomics provided a new approach for societal research, called ELSA genomics: studying the “ethical, legal and social aspects” of this novel field in an integrated and “embedded” manner. A development such as genomics evidently involves a number of challenges for academics active in social science and humanities research. Therefore, our research has to become interdisciplinary, anticipatory (forward looking) and interactive. This interaction, not only with scientists but also with social actors and policy-makers at various stages of the research, is an important element of this new style of working. Embedding in large-scale scientific research efforts and proximity to the daily activities in research facilities not only provides up-to-date information on what is actually happening in the laboratories, but also allows us to make our reflections and critical questions more relevant and precise. Thus, ELSA genomics involves “embedded” projects rather than “stand-alone” research. Prof. Dr. Hub Zwart became Director and Dr. Annemiek Nelis Deputy Director of CSG. Several staff members and researchers were appointed.

On January 2008, the CSG Next programme was launched, involving more than sixty research projects, 20% of which will be carried out within the organizational framework of the Department of Philosophy. The establishment of the CSG has not only enhanced our national and international prominence and visibility, but also implied involvement in new European projects (INES and ERASAGE). CSG is a Centre of international standing, with a high level of societal visibility and relevance. Our future plans are to use our networks and experiences to extrapolate our knowledge and approaches into other, “post-genomics” fields.

In 2005, the Institute for Science, Innovation and Society (ISIS) was established. This institute represents a collaborative effort between the Department of Philosophy and two other departments, namely, the Department for Sustainable Management of Resources (headed by Prof. Dr Toine Smits) and the Department of Innovation Studies, headed by Professor Ben Dankbaar. All three departments have developed Master track studies as well as substantial research programmes, combining mass with focus. The ISIS is one of the six research thematically oriented Institutes of the Faculty of Science that came to replace the discipline-oriented sub-faculties of the past (see fig. 4)

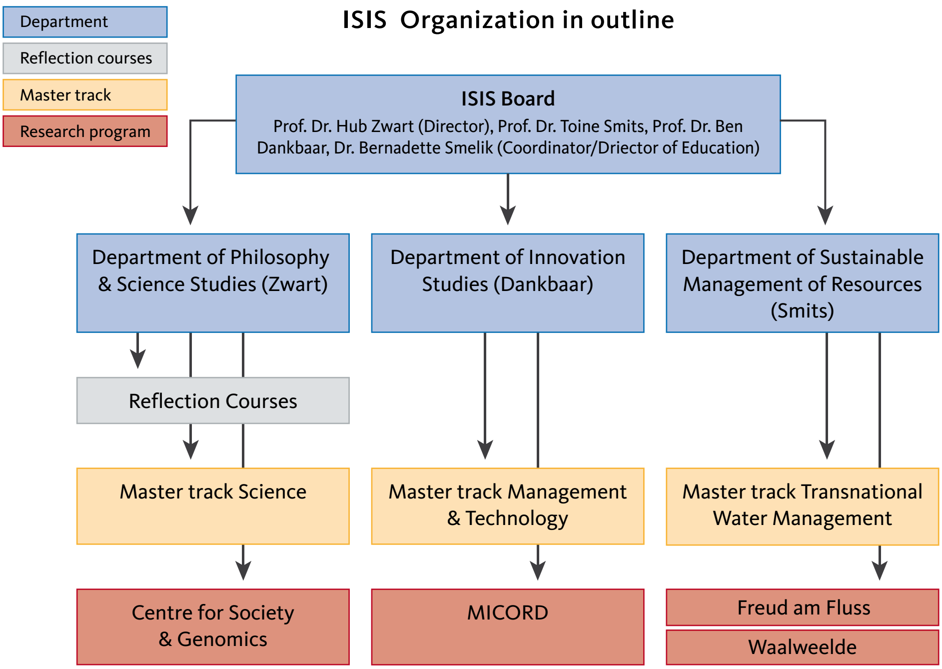

Figure 4: The Organization of ISIS

Once again, this development reflects a basic transition in contemporary science, from small-scale mono-disciplinary, researcher-driven research endeavours to large-scale, programmatic and thematic programmes. By taking an active part in this development, we managed to evolve from a small and marginal group into a substantial research entity that increasingly collaborates with other Institutes of Radboud University. The recent years can be characterized as a period of "tempestuous growth." In the coming years, over 30 academics will be employed in the ISIS (as compared to 3.0 fte in 2000), a tenfold expansion. New collaborations with other Institutes are already evolving. An important conclusion for the self-evaluation organized in 2008 was that for the years to come, consolidation is important. The challenge for the upcoming years will be to use this expansion not only for producing concrete results (in terms of academic publications, theses, societal impact, etc.), but also to transform both the Department of Philosophy and the ISIS into a solid organization that will remain a prominent player after 2012. We have to have everything "in place" when it comes to addressing emerging challenges. Firm embedding within the Faculty of Science will remain of pivotal importance. Not only our education, but also our research competence must become an integrated part of the activities of the Science Faculty (fig. 5).

Figure 5: The staff of ISIS in 2009

It is important to realize, however, that these developments (the vicissitudes of any philosophy of science department) actually *reflect* the vicissitudes of contemporary science as such. The increase of the scale of our research as well as the increased proximity of social science and humanities research to scientific research programmes is part of the scientific revolution that is taking place. We are not only studying this revolution, we are part of it; as such we are both the researcher and the "symptom."

The Present Revolution in Science

Indisputably, the sciences are currently experiencing a period of intense transformation, a tremendous increase in pace and scale: changes that are clearly reflected in the way in which the Faculty of Science and the Department of Philosophy have been repositioning themselves in recent years. This transformation is also reflected in the architecture of our new premises. In the old building, a kind of concrete labyrinth conveying a Stalingrad-like atmosphere, traditional disciplines tended to entrench themselves within their thick-walled concrete wings. In the new building, important concepts such as transparency, proximity, collaboration and communication have materialized. But how are we to characterize this change in a philosophical way?

To begin with, it has been claimed that we are currently experiencing a "third" scientific revolution, which began around the beginning of the twentieth century in physics (the quantum concept, the theory of relativity, the rise of quantum physics, etc.), gradually, during the course of the twentieth century, spread to other domains, more or less like an epidemic, first to cybernetics, then to computer sciences and ICT and, finally, from 1975 (the year of the "biotech revolution") onwards, to the life sciences. This is emphasized by the sideways movement (ever since Schrödinger in 1944 published his pioneer work and scientific best-seller *What is Life?*) of physicists (Delbrück, Wilkins, Franklin, Crick, Collins, etc.) towards biofields, a development that has had a significant impact on methodologies, technologies and the mind-sets of researchers in the life sciences. Important aspects of the transformations currently evolving are the remarkable increase in the pace and scale as well as the role of ICT.

The "century of the gene" is often depicted as a story-line building with three hallmarks/peaks: (1) the rediscovery of the work of Mendel in the spring of 1900; (2) the discovery of the structure of DNA by Watson and Crick half a century later (in 1953); (3) the final destination, as it were, in 2000 when the HGP was officially pronounced to be a major success. These three highlights represent three stages in the history of research into the elementary particles of life. But while Gregor Mendel was an isolated researcher, without a formal research position or research grant, and while the structure of DNA was uncovered by two scientists engrossed in an unofficial research quest, more or less as a sideline of their official research assignments, contemporary research is organized in the form of large-scale, multi-centre research endeavours that can involve hundreds of researchers and vast amounts of funding, bringing together experts from various fields and backgrounds. Indeed, whereas Mendel published a one-author article, and Watson and Crick's famous 1953 publication involved only two authors, the *Nature and Science* publications that announced the completion of the "working draft" version of the human genome (IHGSC 2001, Venter et al 2001) listed hundreds of "authors." This raises a question of a "Foucauldian type": What does it mean to be an author in the genomics era? (Foucault 1994). Or, more generally: What does it mean to be a scientist under contemporary conditions of pace and scale? To what extent is it still possible for individual researchers to represent themselves as autonomous, responsible, decision-making agents (Zwart 2008c)? Of course, the HGP is not the first example of a massive concerted action in the history of the life sciences, far from it, but this is not the issue. Rather, the issue is that the history and pre-history of genomics reflect the tendency of modern ("Faustian") science towards exponential growth. Quantitative measures, such as the number of researchers, author names, journals, journal articles, website hits or any other "performance indicator," all display this tendency towards doubling at regular intervals, as has been described by experts in "scientometry" (the quantitative study of science), beginning with De Solla Price (1963) in his classical study and continuing with his contemporary followers (Zwart 2001). Indeed, science is growing faster than either the population or the economy. and this permanent expansion of the size and costliness of science is inevitable when it comes to maintaining the current rate of progress (Rescher 1980). As De Solla Price already noted in his now famous one-liner: of all the scientists who have ever lived, more than 80% are still alive today.

Another important dimension is the role of ICT. The computer has emerged as the generic research instrument, comparable to the book in Alexandrian and scholastic scholarship. It has rapidly transformed virtually all research fields, not only in terms of contrivances for accurate measurement, data analysis and visualization, but also in terms of communication and globalization. It is an instrument that was originally designed as a powerful calculation machine and which was successfully transformed into a communication device (Licklider and Taylor 1968). Virtually all of today's scientific disciplines have dramatically changed – in terms of their basic methodology, their technology, even their epistemology – because of ICT. In the computer era, the key words are information and exchange. The computer assumed a somewhat ambiguous role in this process. On the one hand, the computer can be seen as the primal "product" or outcome of the scientific revolution. On the other hand, it has become a factor of transformation and acceleration in its own right, notably from the 1980s onwards, transforming virtually all research fields, especially those in the life sciences. Thus, the computer symbolizes the mutual pervasiveness of science and technology.

From a philosophical point of view, information is an intriguing phenomenon. Because it is immaterial, it can migrate quite easily through electronic channels of communication. It can be managed, analysed and manipulated in various ways. Information is multi-functional and can acquire relevance and meaning in various contexts. Genomics can be seen as a synthesis of genetics, molecular biology and ICT. Through the type of bioinformation provided by genomics research, the "informatization" of life is transforming a broadening array of research fields (Gaskell and Bauer 2006).

The philosopher Hegel claimed that the basic objective of philosophy must be to capture the present in thoughts *(...die eigene Zeit in Gedanken zu erfassen...)*. In this effort to understand the present, science and technology, and their impact on contemporary knowledge societies, obviously constitute a major target of reflection. Is it still possible, by way of a "Hegelian" effort, to capture the basic profile of contemporary sciences in a single term? In this contribution, I argue that a rather prominent feature of the contemporary sciences resides in their various forms of pervasiveness and on the extent to which they are effectively pervading and being pervaded by their scientific and social environments. This calls for a particular form of philosophical research, as exemplified by the activities of the Department of Philosophy and, more broadly, by the research style developed by the ISIS in the context of successfully establishing externally funded research programmes of substantial size and volume. It calls for an approach that is interdisciplinary and embedded and one that involves both conceptual and empirical forms of analysis in combination with input from the genres of imagination (novels, films, etc.). This type of research must be sensitive to what is happening in scientific fields (in interaction with societal and cultural trends), must build on a profound awareness of the dynamics and interrelatedness of scientific and societal change (the historical dimension), but must be predominantly anticipatory or forward looking in terms of its basic orientation.

Dimensions of Pervasiveness

Recently, the Faculty Board acknowledged in its "Strategic Plan" that pervasiveness is what characterizes the research activities conducted within our building. But what is meant by pervasiveness? First of all, science pervades nature and natural systems in various dimensions and directions. Building on highly advanced technologies for astronomical and astrophysical research, the sciences are pervading the immensities of the universe at large in unprecedented ways, revealing its evolution and its future, from its present state up to its most primal origins (the Big Bang). At the other end of the spectrum, in the context of research facilities such as CERN, science is also pervading the world of the extremely small. Relying on particle accelerators and detectors and other forms of high-tech equipment, the sciences are now pervading the micro- and nano-dimensions of elementary particles and the basic structures of biomaterials. Through genomics and bioinformation, the sciences are also pervading the world in a horizontal dimension, notably the bioworld of ecosystems and ecological networks, opting for a system-oriented rather than a reductionistic view, with special attention paid to the as yet largely unexplored role of micro-organisms on our "microbial planet" (notably through metagenomics). Indeed, a substantial part of our planet's biomass consists of micro-organisms, and human beings are now beginning to see themselves as "superorganisms," as containers of a plethora of microbial life forms rather than as discrete individuals. Yet, science is only beginning to pervade this terra incognita.

Finally, building on new molecular techniques (ranging from genomics to brain imaging), the sciences are pervading ourselves, our bodies as well as our minds, our cognitions, perceptions and emotions. Technosciences, such as ICT, genomics and nanoscience, are pervading many aspects of our personal and everyday life. They are becoming ubiquitous, embedded and highly adaptive.

The contemporary sciences pervade society and *are* pervaded by society in intimate ways. Science and science-based technologies permeate the way in which we communicate and interact with one another, thus significantly affecting social change. At the same time, social dynamics are having a profound impact on how research practices and research agendas are involving. Society is ever present in laboratories in various ways; this is evident through funding strategies (for example, through the increased attention paid to societal issues when it comes to assessing and selecting research proposals) and the institutionalization of ethical assessment (in the form of ethics committees and other forms of normative regulation) but also in the growing importance that universities, institutes and research groups are given to "valorization." The omnipresence of pervasive technosciences and scientific expertise is an outstanding feature of contemporary knowledge societies.

The contemporary sciences are also increasingly pervading *each other*. Traditional compartmentalizations in terms of disciplines are collapsing. Instead, research is evolving in the context of "emerging" and "converging" fields, where researchers from various backgrounds collaborate in the context of large-scale, thematically organized research programmes. This affects our own fields as well. Until recently, researchers from the social sciences and humanities (philosophy and history) tended to reflect on science from a certain ("critical") distance. Now, however, social science and humanities (SSH) research projects have become increasingly "embedded." As already mentioned above, the new research strategies are characterized by high levels of proximity to scientific research activities. Philosophers are becoming "embedded" experts, interacting and collaborating with science researchers within their own environment even during the very early stages of the research. It can no longer be argued that ethicists arrive on the scene "too late." They have taken ethical deliberation "upstream." Science and SSH research are becoming mutually pervasive.

Biomimesis

An important aspect of pervasiveness is the tendency of emerging technosciences to view themselves as much more "natural" than previous forms of human technology. Novel technosciences claim to be increasingly able not only to permeate and explore but also to mimic and imitate the technologies that nature herself has produced durint the course of billions of years of evolution. Ever since its introduction during the late 1990s, the concept of biomimesis (or biomimetics) has become quite popular among materials experts and synthetic biologists (Mann 1997, Bensaude-Vincent 2002) and has made its appearance in top journals, such as *Nature* (Ball 2001, Sanchez et al. 2005). According to Sanchez, biomimesis is "one of the most promising scientific and technological challenges of the coming years" (p. 285). But what is biomimesis?

Biomimesis is a strategy for inserting artificial (man-made) systems into natural systems in such a way that the artificial system becomes optimally embedded. The underlying concept is that natural systems and materials display a high degree of sophistication and adaptability and that nature, during the course of evolution, has generated a plethora of techniques (solutions to functional problems of living systems) that can be studied and imitated by contemporary technoscience. The ultimate goal is to reintegrate the technosphere into the biosphere (mutual pervasiveness of technology and nature). Whereas in the past the focus was on using technology to *improve* nature, nature's "pool of ideas" (Ball 2001) now increasingly becomes a source of innovation and improvement for molecular technology. A notable example is the wasteful systems of human production, which may ultimately be replaceable by the cyclical and sustainable economies characteristic of natural systems. Indeed, the idea of biomimesis is closely linked to that of sustainability. Although the concept as such has a long history in aesthetics and architecture, its present form was introduced by Warren McCulloch in 1962, and it became a key term among life scientists in the 1990s.

Whereas the concept of biomimesis emerged in scientific discourse, the idea as such has also been adopted in philosophical discourse. Peter Sloterdijk (see fig. 6) has argued, for example, that until recently we tended to see "nature" and "technology" as separate domains, and the latter as an adverse and intrusive force *(allotechnology)*. Newly emerging technologies, however, are increasingly biomimetical. Therefore, he refers to them as *homeotechnologies* – as nature-like, pervading natural systems in embedded ways, remodelling themselves after "natural technologies," making it increasingly difficult to distinguish technology from nature (Sloterdijk 1999).

Figure 6: The Director of ISIS, Hub Zwart (r), introducing the German philosopher Peter Sloterdijk (l) during the latter's visit to Nijmegen (27 April 2009).

In the past, the dominant view of the relationship between science and nature was a "Faustian" one in which science and technology were viewed by their respective protagonists as instruments for gaining mastery over nature. The Faustian will to know gradually turned towards understanding the basic forces and elementary building blocks of nature, as has been articulated by Goethe (1808/1910) in his famous lines in *Faust*, cited, for instance, in the novel *Elementary particles* by Michel Houellebecq (1998):

> *Dass ich erkenne, was die Welt*
> *Im Innersten zusammenhält (382-383)*

Yet, notwithstanding the Faustian intention to intimately explore the secrets of nature, the basic Faustian drive has always been to use this knowledge to go beyond nature, to transcend and improve nature. This is the Faustian ambition: creating artificial human life in the laboratory (the homunculus scene in Faust) and ultimately creating an artificial man-made landscape as a technological "paradise" (the polder scene in *Faust*).

This Faustian ideal also applies to biotechnology. Around 1900, biologist Jacques Loeb (1859-1924) already voiced the view that nature must be regarded as raw material to be modified and improved by bioengineers (Pauly 1987). Biology's core objective, Loeb said, is the improvement of nature. Why accept existing biological constraints as given? Why not use biological knowledge in order to improve life and – eventually – ourselves much more directly and effectively than we have done so far? Why not prolong the human life-span or opt for artificial instead of sexual reproduction? Indeed, the famous first chapter of Aldous Huxley's *Brave New World* (1932/1947), in which the "Central London Hatchery and Conditioning Centre" is described, consciously echoes Loeb's ideas. This first chapter describes how the chemical environments of embryos kept in vitro are systematically manipulated in order to adapt them to societal demands and actually contains references to Loeb's views.

Thus, the Faustian ambition has been to use our knowledge of the building blocks of nature to transcend natural limits and move human life into new, "postnatural" directions. This ambition also holds for the biotechnological revolution that emerged during the final decades of the twentieth century which enabled genes to be deleted or inserted and, thereby, the scientist to transcend natural borders and boundaries (such as between species) and produce new life forms. Thus, nature was the target, rather than the model, and the orientation of biotechnology was one-sided. The bioengineer was the active agent whose definitive aim was to modify nature. Through science and technology, landscapes could be cultivated and plants and animals could be modified and adapted to human interests, either through genetic modification or otherwise.

Yet, pervasive technosciences increasingly claim to entail a different vision of nature. It has become both an important objective and promise of pervasive science to facilitate the emergence of new generations of nature-friendly and environment-respecting technologies that may allow us to interact with nature in a much more sustainable, fine-tuned and sensitive manner. The basic idea is that by permeating natural systems more intimately than was ever possible before, technologies can now be designed that mimic and build on the "technologies" developed by nature herself, in a more refined fashion, allowing us to use the potentials and resources of nature (described as "Ali-Baba's cave of technology," Sanchez et al. 2005) in more intelligent and considerate ways.

Yet, of course, the new pervading technosciences may also be seen as pathways towards mastering and manipulating nature much more effectively than has ever been possible and that our age is even more Faustian than any previous century. An even more sophisticated will to power may, in a cunningly manner, have appropriated the rhetoric of biomimesis and sustainability. In addition to be possessed of a seismographic sensitivity for what is happening in contemporary research, contemporary philosophers of technology and science should also clearly hold on to their healthy, suspicious attitude toward all around them.

Still, the concept of biomimesis deserves to be taken seriously. In a much-cited review article, Viola Vogel (2002) addresses this development under the heading of "reverse engineering": the basic effort to reorient the innovation process, taking molecular nature as the model. Her focus is on proteins, which are described as nature's "workhorses." According to Vogel, a fine-grained understanding of the underlying design principles that allowed proteins to evolve and to fulfill a plethora of functions can provide researchers with new insights into how to enhance the performance of synthetic artificial systems with increased sophistication. For example, proteins can specifically recognize other biomolecules with a selectivity and affinity several orders of magnitude superior to their synthetic counterparts, which offers prospects for biomimetic biodetection. Proteins can also be used as switches in artificial systems or as micro-energy convertors or producers. A plethora of lessons can be learned from how nature solves the challenges of functional problems of living systems.

Thus, the concept of biomimesis (or homeotechnology, or reverse engineering) conveys the awareness that, while technology has been primarily used to modify nature, the rich sources of inspiration produced by almost 4 billion years of biological evolution have only begun to permeate technology and engineering. The biological world possesses countless examples of immense sophistication, starting with the cell with its thousands of chemical reactions that enable it to interact with its environment, carry out a broad variety of functions and reproduce, and extending to the complexity of organs and organisms. There is also a long list of natural "inventions," such as proteins, enzymes, DNA, membranes, fluids, sensory mechanisms, among others, that can become a model for human design.

In the course of history we have used natural systems in various manners: as biological materials (leather, wood, bone, etc.), as biological energy (pack animals) and as biological sensors (watchdogs, birds, etc.), to name a few. Micro-organisms have been used for fermentation and preservation. However, these applications have always been on the level of whole living organisms. The prospects for biomimesis that are currently opening up are directed towards the molecular level, towards the building blocks, such as proteins and biomaterials of living systems. As Ball (2001) argues, biomimetics has the potential to enrich many areas of technology, but the application of this field requires an intimate understanding of natural mechanisms at the molecular scale. The current prevailing view is that in the near future it will become possible to imitate characteristics of living materials, such as self-repair, self-assembly and recyclability. Indeed, the ultimate challenge in drawing inspiration from biological organisms is the creation of biomachines that can reproduce themselves.

The Future of Philosophy

Pervasive technosciences do not constitute "neutral" technologies. Rather, they are permeated by normative ideals and societal expectations. They intend to produce new generations of sustainable, nature-friendly and society-friendly applications, so that from now on science and technology may serve as the powers that solve rather than cause environmental and societal problems. Yet, these ideals cannot be taken for granted. Rather, the developments described above call for new and "permeating" forms of reflections and for embedded forums of deliberation that allow society a say in the development of research agendas, as is articulated by slogans such as "co-design" and "upstream innovation." Philosophy has two intimately related objectives in this respect. On the one hand, the objective is to empower both researchers and citizens, allowing them to address the (at times unprecedented) normative issues involved in pervasive science. On the other hand, it is the objective of philosophy to articulate a comprehensive assessment of the present, a conceptual backdrop as it were, that facilitates the assessment and "moral management" of more specific technological developments by researchers, policy experts and citizens.

It is a basic Hegelian insight that the subject and the object pole of the knowledge process tend to reflect and mirror one another. This means that, on the one hand, the "subject" (our views, categories and beliefs) will, to a considerable extent, determine how the world "out there" will present itself to us. Knowledge is always a dialogue, an interaction, a relationship, and experimental research basically comes down to playing a game of chess with nature. On the other hand, it means that the subject pole will be responsive to changes in the outside world as well and will, to a considerable extent, adapt itself to how the object pole (science) is evolving. To put it more concretely, the manner in which science studies in general and the philosophy of science in particular will evolve will, to a considerable extent, reflect the changes that are taking place in the (techno)sciences themselves. This means, for example, that philosophical research likewise becomes "big" – large-scale and programmatic, embedded in large-scale interdisciplinary research efforts – while the well-known distinction between "fundamental" and "applied" philosophy dissipates, as reflections on concrete innovations pose very basic questions, while the current developments of science pose significant challenges to philosophical ideas, notably on the more fundamental conceptual level. Stephen Toulmin (1982) once argued that "medicine saved the life of ethics," in the sense that, because of the plethora of moral dilemmas produced by contemporary biomedical sciences, ethics was transformed overnight from a dull and marginal academic subspecialty into a prominent arena of deliberation and research. I would argue that emerging technosciences are having a similar impact on the philosophy of science.

Ideally, we are not a marginal entity, a strange microbe "tolerated" somewhere and temporarily in the bowels of science. Rather, contemporary science is "pervaded" by bioethical, philosophical and societal issues and questions. It must be self-evident for the Faculty of Science that the societal dimension is an inherent part of science and that substantial research endeavours should explicitly explore and address this dimension in a professional and academic manner. In order to be equal to this task, however, we have to adapt ourselves in a responsive manner as well. Our research must become integrated in and responsive to the scientific research programs emerging in our scientific environment. This will allow us to make our research more timely and more relevant and will add focus and precision to our criticism. Kant argued that it is the task of philosophy to criticize (critically assess) the research that is being conducted within the other "Faculties." To a certain extent his view is still valid. The philosophy of science (and this includes science ethics of course) is a normative field that assesses – in a critical manner – the impact and prospects of research in terms of issues such as sustainability and responsibility, integrity of animals and democracy. However, in order to do this adequately and effectively, we have to become part of the very processes we study, to become immersed in the faculties whose work we critically assess. This approach will involve not only assessing the "condition" of the research endeavours we study, but also necessitate therapeutic interventions (or at least normative recommendations) as well.

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