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Pervasive Science: Challenges of contemporary technosciences for governance and self-management

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Abstract

According to Hegel, the basic assignment of philosophy is to capture the present in thoughts. When it comes to understanding *our* present, an assessment of the technosciences and their impact on our view on nature, society and ourselves must be of key importance. A prominent feature of contemporary technosciences resides in their pervasiveness: the extent to which they pervade nature, society and human bodies, even on a molecular level, as well as each other. On the one hand, the 20th century is the era of the elementary particles, of identifying the elementary subatomic and molecular building blocks of matter and life. On the other hand, it is the era of complexity, of evolving systems. In both directions, our understanding of ourselves is challenged and deepened by technoscientific explorations. Increasingly, moreover, our technologies tend to become nature-like. This allows us to embed them more adequately in natural systems, but it also opens up unprecedented opportunities for modifying natural systems, including human bodies. How are we to address the bioethical and biopolitical prospects and concerns implied in these developments?

1. Introduction: Assessing the present and exploring the future: the basic assignment of philosophy

Das was ist zu begreifen, ist die Aufgabe der Philosophie ...

[Sie ist] ihre Zeit in Gedanken erfasst (Georg Wilhelm Friedrich Hegel)

According to Hegel, the basic “assignment” of philosophy is to assess the present, to capture it in thoughts. When it comes to understanding *our* present (i.e. the contemporary world), science and technology, including their impact on contemporary knowledge societies, must evidently constitute a major target of reflection. Is it still possible, by way of a “Hegelian” effort, to capture the basic profile of the contemporary sciences in a single term? Such an effort would constitute a starting point for a systematic exploration of the future, while such an exploration in its turn would provide us with input on how to address the bioethical and biopolitical challenges of the present. In the first section, I will outline the idea that a rather prominent feature of the contemporary technosciences resides in their pervasiveness, the extent to which they are effectively pervading, and being pervaded by, each other, as well as by their scientific and social environments in various ways. They not only deepen and broaden our understanding of the world and of ourselves (section 2), but also produce new “biomimetic” technologies that allow us to interact with natural systems, both “internally” (inside our bodies) and “externally” (outside our

bodies), in more intimate and effective ways, opening up prospects for modification that are as fascinating as they are uncanny.

2. Pervasive science

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 and written by Thomas Huxley. Actually, these lines were borrowed from Goethe's famous fragment *Die Natur*. The basic idea of this paper is that what Goethe has written so eloquently about nature can now be written about the contemporary technosciences using the very same terms: we are surrounded by them, powerless to separate ourselves from them, we constantly act upon them, yet have no power over them.

Thus, I take pervasiveness to be a key feature of the emerging technosciences. They pervade natural systems in various dimensions, from the immensities of the galaxy down to the nanoworld of elementary particles and the basic molecular structures of biomaterials and living systems. Moreover, technosciences are pervading the bioworlds of ecosystems and ecological networks, opening up unexplored realms of microbial life. But they also pervade us: our bodies and minds. Building on techniques ranging from genomics to brain imaging, they are analysing the dynamics of cognitive and emotional functions in a much more detailed way than ever before. Technosciences (ICT, genomics, nanoscience) are permeating everyday life, becoming ubiquitous, embedded and highly adaptive.

Technosciences also pervade *each other*. Disciplinary compartmentalisations give way to emerging supra-disciplinary fields, involving experts from a broad range of disciplines in large-scale research programmes. Traditional distinctions (science vs. technology, fundamental vs. applied research, nature vs. technology, subject vs. object) are increasingly difficult to uphold. Finally, emerging technosciences pervade and *are pervaded* by society in far-reaching ways. They permeate the ways in which we communicate and interact with one another, significantly affecting social change in knowledge societies. At the same time, societal dynamics have a profound impact on the ways in which research is organised and research agendas evolve. Pervasiveness inspires both fascination and concern.

Although the societal import of pervasiveness will eventually present itself in terms of concrete and acute bioethical issues, the assessment of these issues must build on a thorough analysis of the manner in which new scientific insights and approaches actually "inform" society, notably by affecting the way we see ourselves, i.e. the way in which we assess our contemporary being-in-the-world. This is done in two directions: firstly by deepening (on the molecular level) the molecular and genetic basis of our functioning as human beings; and secondly, by broadening (on the ecological level) our self-awareness of

our embedding within complex and dynamical external networks. Thus, novel scientific approaches significantly influence the manner in which we assess our own functioning. Rather than expanding our knowledge of ourselves as human beings in an *anthropocentric* fashion, in isolation from the rest of the biosphere, our functioning is now explored and assessed against the backdrop of the internal and external networks that allow us to exist and are affected by our policies and behaviours, as individuals and as societies. Self-knowledge as such is not the end-point of our desire to know. On the contrary, as has been articulated by Nietzsche, Foucault and others, the will to know (ourselves) is inspired by a will to transform, to control and to improve (ourselves). In terms of our ecological functioning, new scientific insights may provide opportunities for more sustainable forms of interaction and co-development, but also for strengthening our technological sway of nature in more sophisticated and effective ways. In terms of physical and cognitive functioning, new scientific insights may provide opportunities for performance enhancement. Yet, in order to realize these opportunities, natural systems (including our own bodies) will be permeated by our probing and our modifications, and this process is bound to entail a plethora of (often unprecedented) bioethical quandaries. Although on the *conceptual* level the distinction between “Self” versus “nature” and between *understanding* nature (or ourselves) and *manipulating* nature (or ourselves) may be clear, in actual practice, in the context of emerging technosciences, these processes are often implicated in one another, so that manipulation enables us to further our understanding, while a refined and sensitive understanding may allow us to manipulate natural systems or human bodies in more effective ways. How should we assess these newly emerging avenues and opportunities for modification and self-modification? Before addressing the quandaries involved in bioethical and biopolitical terms, a thorough analysis of the type of knowledge involved is called for.

Regardless of whether this analysis is directed towards the micro-level of molecular functioning or towards the macro-level of ecological functioning, in both cases our will to know is inspired by the idea that novel technosciences may allow us to develop new generations of nature-like (bio-mimetic) technologies that may enable us to interact more directly and intimately with natural systems and processes, including ourselves. This is a perspective provokes both fascination and unease. In the next sections, two core aspects of pervasiveness will be explored more thoroughly. On the one hand the relationship between pervasiveness and the Self (pervasive Self-understanding) – or rather: the blurring of the boundaries between technology and the Self- – and on the other hand the relationship between pervasiveness and nature – or rather: the blurring of the boundaries between pervasive technologies and natural systems, represented by the emerging possibilities for biomimesis and biomimetic interventions.

Scientific research takes place in the context of a triangular relationship involving three “poles” that mutually imply and affect one another, namely the pole of *knowledge* or *science* (the technosciences), the pole of *nature* (natural systems) and finally the *human pole*, the pole of the Self (of individuals, communities and societies). None of these poles can be meaningfully studied in isolation from the others. Nonetheless, in the context of philosophical research activities, the focus of attention may temporarily shift from science, to nature, to Self and vice versa.

3. Pervasiveness and self-knowledge

*“Know then thyself, presume not God to scan,
The proper study of mankind is man”
(Alexander Pope, Essay on Man)ⁱⁱ*

Having identified pervasiveness as a key feature of contemporary research activities, the “second step” in the argument begins from the observation that the ultimate target of the pervasive research under study apparently resides in understanding, improving and managing human life itself. Thus, the outcomes of pervasive research are bound to significantly affect the ways in which we come to see, and subsequently to develop and manage ourselves. It is indeed astonishing that, regardless of the disciplinary backgrounds of the research communities involved – (bio)physics, (bio)chemistry, (bio)informatics, the molecular life sciences, etc. – they eventually are bound to contribute to the converging ambition of elucidating the functioning of ourselves as human beings. This is not to suggest that contemporary technosciences are *anthropocentric* in their basic orientation; rather the contrary is true. Paradoxically, although pervasive research entails important messages for self-understanding, it eventually undermines rather than strengthens an anthropocentric understanding of ourselves. Through pervasive research we deepen and broaden our self-understanding in the sense that we become increasingly aware of the entanglement of our functioning within the webs and networks of life on all levels. In order to understand ourselves, pervasiveness allows and incites us to focus on understanding our relatedness with other species as well as with a broad variety of natural systems.

This “gathering” of research communities around the analysis of human life itself, is the outcome of a longer history. Whereas the first half of the 20th century is generally regarded as the Golden Age of modern physics, resulting in groundbreaking “applications” such as nuclear energy and the atomic bomb, most of which involved major and unprecedented ethical and biopolitical challenges, during the second half of the 20th century, the focus of the scientific revolution that began in 1900 (with the introduction of the quantum-concept, the mutation-concept, the rediscovery of Mendel, etc.) shifted towards the biofields, notably affecting the research practices that centred on elucidating human functioning. It is indeed astonishing that disciplines such as physics, chemistry, informatics etc. gradually shifted their focus of attention and by and large transformed themselves into biophysics, biochemistry, bioinformatics and the like. An important signal for this migration trend was the publication in 1944 by the prominent physicist Erwin Schrödinger of the scientific best-seller, *What is life?*, in which he urged physicists to turn attention to the elementary particles of life. The book coincided with the Manhattan Project and greatly influenced a whole cohort of physicists (Delbrück, Wilkins, Franklin, Crick, Collins, etc.) in migrating towards biofields – a development that has had a significant impact on methodologies, technologies and mind-sets of life-science researchers. The discovery of the structure of DNA in 1953 by a biologist and a physicist, building on physical and chemical technologies and methods such as crystallography and

molecular model-building, symbolised this trend. And physics brought with it the use of large equipment and, eventually, of big science. Indeed, an important aspect of the transformations currently evolving in research are the remarkable increase of pace and scale as well as the role of high-tech equipment, notably ICT. Eventually, these variously evolving disciplines will begin to address some of the unexplored domains of human life, notably on the molecular and ecological level, such as our “internal” and “external” (genetic, molecular, neural, ecological, etc.) networks, thereby significantly challenging and affecting the way we look upon ourselves.

Elsewhere (2007) I have outlined how genomics has fuelled and revived fundamental debates concerning our ambition to know ourselves. (Bio)physics, (bio)chemistry, (bio)informatics and a plethora of other emerging research practices increasingly focus on elucidating human behaviour and human functioning on all levels (genetic, physiological, cognitive, behavioural) and in various dimensions. Firstly, by focusing on the extremely small, the study of life “from molecule to man”. Thus, the analysis of our internal networks and pathways has become a converging field involving a broad range of experts from various scientific backgrounds (ranging from mathematics and physics up to the human sciences and humanities). Secondly, contemporary research practices are deepening our understanding of our embeddedness in socio-cultural and symbolical networks that greatly affect our cognitive functioning. Human intelligence is not only a result of our having a well-developed brain, but also the fact that our cultural and symbolical environment *facilitates* intelligent behaviour. In other words, our intelligence is the outcome of a complex interaction between our neural networks on the one hand and our symbolical systems and networks (verbal communication, writing, mathematics, politics, ethics, etc.) on the other. Thirdly, we have become increasingly aware of our intimate entanglement in broader networks and webs of life in various ways (the analysis of our external biological networks). We increasingly see ourselves as elements in ecological networks whose “health” and functioning is greatly dependent on our decisions, policies and behaviour. Moreover, we increasingly see ourselves as “super-organisms”, as containers hosting a plethora of microbial life forms, on whose “labour” the greater part of our metabolism depends. Finally, we increasingly see ourselves as the outcome of a history that must be interpreted as a narrative of evolving ecological networks rather than as a single-species (anthropocentric) story (Jones 2001). Our history is basically a multi-species history, a co-evolution of human beings and various other species whose vicissitudes are intimately intertwined with ours, a story of interactions between human communities, domesticated animals, cultivated plants and modified environments. In other words, our understanding of ourselves is both deepened (on the molecular level) and broadened (on the socio-cultural level) and widened (on the ecological level). This increased Self-awareness opens up new challenges and possibilities for self-management (bioethics) and governance (biopolitics).

Self-knowledge is not an end in itself, in terms of the cognitive insights it provides, but also a precondition for managing and even improving ourselves: our functioning as well as our societal and ecological embedding. And pervasive research furthers this process not only by enriching our understanding, but simultaneously by providing new tools and technologies that may allow us to *use* these insights for governance (biopolitics) and self-management (empowerment). Notably, pervasiveness gives

rise to a plethora of bio-mimetic technologies that can *in theory* be applied to manage and improve, in a “nature friendly” manner, both our own physiological, senso-motorial and cognitive functioning as well as the functioning of the ecosystems we inhabit.

4. Biomimesis as a key aspect of pervasiveness

Gardeners now use DNA kits... People are making genetically modified roses all over the world... The technology is everywhere... Michael Crichton Next

An important characteristic of emerging technosciences, and an important aspect of their pervasiveness, is their tendency to see themselves as much more “natural” (more adaptive to nature) 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 nature herself has produced in the course of billions of years of evolution. Ever since its introduction during the late 1990’s, the concept of biomimesis (or biomimetics) has become popular in a number of research fields, such as material science (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, for instance, biomimesis is “one of the most promising scientific and technological challenges of the coming years” (p. 285). But what exactly is biomimesis?

Biomimesis refers to the objective of reinserting artificial (man-made) systems in natural systems in such a way that the artificial system becomes optimally embedded. The idea is that natural systems and materials display a high degree of sophistication and adaptability and that nature, in 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” now increasingly becomes a source of innovation and improvement for molecular technology (Ball 2001). Notably, the wasteful systems of human production might be replaced by the more 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 – in its present form it was introduced by Warren McCulloch in 1962 – it became a key term among life scientists only from the 1990s onwards.

In the past, a “Faustian” view of the relationship between science and nature was regarded as dominant. Science and technology were seen by their protagonists as instruments for gaining mastery over nature. The Faustian will to know gradually forced its way down to the basic and elementary building blocks of nature, as was articulated by Goethe in his famous lines from *Faust*, cited, for instance, in the novel *Elementary particles* by Michel Houellebecq (1998): *Dass ich erkenne, was die Welt / Im Innersten zusammenhält*. Yet, notwithstanding the Faustian desire to intimately explore the secrets of nature, the basic Faustian drive has always been to use this knowledge in order to go *beyond* nature, to transcend and

improve nature. This is the basic Faustian ambition: from creating artificial human life in the laboratory (the homunculus scene in *Faust*) up to creating an artificial manmade landscape as a technological “paradise” (the polder scene in *Faust*).

This Faustian ideal also applies to “classical” biotechnology. Around 1900, biologist Jacques Loeb (1859-1924) voiced the idea 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*, describing the “Central London Hatchery and Conditioning Centre” consciously echoes Loeb’s ideas. The 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 concerning the building blocks of nature in order to transcend natural limits and to move human life into new, “postnatural”, directions. This is also the case in relation to the biotechnological revolution that emerged during the final decades of the twentieth century. Genes could now be deleted or inserted in order to transcend natural borders and boundaries (such as between species) and to produce new life forms. Thus, nature was the target, rather than the model, and the orientation of biotechnology was trans-natural. The bioengineer was the active agent who actively aimed at modifying nature. Through science and technology, landscapes could be cultivated and plants and animals could be adapted to human interests, either through genetic modification or otherwise.

Newly emerging pervasive technosciences, however, increasingly claim to incorporate a different vision of nature. It has become 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 ever 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 more effectively than ever before; our age is arguably becoming more Faustian than any previous century. An even more sophisticated will to power may, in a cunning manner, have appropriated the rhetoric of biomimesis and sustainability. Thus, in addition to a seismographic sensitivity for what is happening in contemporary research, contemporary philosophers of technology and science should maintain a healthy attitude of suspicion.

Nonetheless, 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: nature's "workhorses". According to Vogel, a fine-grained understanding of the underlying design principles that allowed proteins to evolve and to fulfil 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 challenge of functional problems of living systems.

Thus, the idea of biomimesis (or homeotechnology, or reverse engineering) conveys the awareness that, while, thus far, 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. Biology supplies examples of immense sophistication, starting with the cell with its thousands of chemical reactions that enable it to interact, 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", like proteins, enzymes, DNA, membranes, fluids, sensory mechanisms, 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), as biological sensors (watchdogs, birds etc.), and of course as micro-organisms in the context of fermentation and preservation. The prospects for biomimesis that are currently opening up are directed towards the molecular level, towards the building blocks, the proteins and biomaterials of living systems. As Ball (2001) argues, biomimetics has the potential to enrich many areas of technology, but requires an intimate understanding of natural mechanisms at the molecular scale. The idea 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.

5. Pervasive applications: philosophical reflections

The basic profile of pervasive science is as yet highly ambiguous. On the one hand, novel developments seem to offer ample opportunities for the development of sustainable and nature-friendly technologies, for example through "ecogenomics" (the use of molecular and genomics technologies for improving our understanding of the functioning of ecosystems). On the other hand, these same developments may allow us to strengthen our technological sway over nature (both inside and outside human bodies) by increasingly allowing us to interact and intervene with natural systems in intimate and tailored ways. A similar ambiguity emerges when we consider the bioethical and biopolitical implications of pervasiveness.

On the bioethical level, it initially seems to favour empowerment by opening up new possibilities for self-management, creating new opportunities for developing what Michel Foucault has called “practices of the Self”. We may begin to influence our molecular, physiological and cognitive systems more effectively than ever before. At the same time, it is clear that these developments offer new possibilities for biopolitics, that is: for top-down initiatives directed at the management of populations. For example, new technologies may permeate the bodies of psychiatric patients, top athletes or Alzheimer patients in order to restore or improve their functioning, through biomaterials or genetically modified viruses designed to produce neurotransmitters or other “natural” substances whenever our bodies are insufficiently able to do so. Such technologies may enhance the opportunities for individuals to manage their own condition, but may also open up avenues for manipulation by various institutions.

By remodelling their genomes (“synthetic biology”), viruses can be used for producing biomaterials. By adding gene segments to plant viruses, self-replicating, biomimetic enzymes can be generated, for instance for producing cellular energy (ATP), hormones (testosterone), enzymes (insulin) or muscle tissue inside human bodies. Viruses can be used as synthetic platforms for producing self-replicating compounds or for self-assembling enzymes and catalytic products that stimulate various cellular processes (Comellas-Aragones et al 2007). Enzymes encapsulated in a virus can be used for biodetection inside human bodies or for setting up self-assembling systems for producing composite materials such as bone tissue (Kinsella & Ivanisevic 2007). Thus, “nature’s own approach” (self-assembly) is used to produce a broad variety of biomolecules (Carette et al 2007). In laboratories, synthetic biology has already begun to pervade our bodies. In addition to therapeutic applications, other options come into view as well, notably in the context of special professions such as soldiers of the future, who may well be equipped with biosensors (miniaturised biomimetic sensing devices) or self-replicating systems for wound healing or intracellular production of biomolecules that increase strength, endurance and resistance to stress or disease. A report published by the National Research Council (2001) highlights how “pervasive” this research is becoming. Yet, beyond these “avant-garde” applications, more every-day, ubiquitous, or life-world applications, involves therapeutic applications and prevention, are coming into view as well.

Since the original demonstration in 1999 that measured electrical activity generated by neurons can be employed to control devices such as computers or prostheses, research on Brain-computer-interaction (BCI) has evolved at a stunning pace (Lebedev 2006; Birbaumer 2006). Applications focus on restoration of limb mobility in severely handicapped (paralysed) individuals through invasive and semi-invasive micro-recording devices. The focus is on revalidation (recovery of normal functioning), notably in the context of reduced mobility by providing subjects with feed back signals derived from their own brain activity, deciphering intentions through measuring the electrical activity of massive neuronal populations (Scott 2006). In the future, researchers envision that they will be fully implanting recording systems that wirelessly transmit multiple streams of electric signals derived from neurons.

Although the present context of application is mainly therapeutic, there are no obstacles, technologically speaking, to using these same techniques for enhancement in healthy individuals, thus pervading the realm of normal functioning, notably in situations where natural functioning seems unable

to deal with the increasing complexities of emerging devices. A classical example is the fighter jet pilot. These pilots find themselves increasingly challenged by the swiftness and complexity of aircraft mobility. Some of the “deficiencies” of human behaviour (such as misguided impulsive responses) may not be amendable by training or by external equipment. Biomimetic electrodes may then be implanted as life-saving devices to overrule and counteract the pilot’s “inadequate intentions”. Again, our focus will be on more everyday scenarios involving techniques that may be employed for signalling and counteracting stress, depression and ADHD or other behavioural issues.

A bottleneck is the development of fully implantable biocompatible devices for recording electrophysiological activity by brain-derived signals. It is precisely here that some of the trends outlined in this paper may converge. The primary objective would then be to develop electrodes that become increasingly indistinguishable from their neural environments, produced from viral genomes to which particular gene segments are added for the production of biomaterials through self-assembly. Thus, both trajectories eventually converge in a boundary zone where biomaterials facilitate “performance enhancement”, giving rise to “Science-fiction like scenarios”.ⁱⁱⁱ

Big international companies such as IBM are developing futuristic playgrounds where pervasive technologies permeate everyday environments, connecting a plethora of novel devices in an apparently seamless computing environment. Pervasive computing is the technology that tries to make this possible. Islands of technologies are gradually converging into a comprehensive technological environment. In the near future, computing will no longer be an activity that is conducted behind desktops. Rather, an omnipresent network of devices is expected to facilitate all functions of life. The basic question once again is whether this will enhance empowerment (self-management) or rather discipline and control (embedding human individuals as “elements” in digital networks). Human-computer interaction (HCI) is a research field involving issues of design, evaluation, adoption, and actual use of new information technologies. Emerging digital environments may come to include devices for diagnostic and prevention, thus enabling individuals (belonging to patient groups, risks groups, special professions, etc.) to monitor their health and condition, thereby providing tools for Self-management, but it may also allow Big Brother to monitor our behaviour more effectively than ever before. At a certain point, with the help of biomaterials (bioelectrodes, bioimplants, etc.) these technologies may begin to enter the bodies, blurring the boundaries between technology and Self.

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ⁱ Hegel (1821/1970), p. 26

ⁱⁱ Cited at the Press Conference (June 26 2000) announcing the impending completing of the human genome sequencing effort (Zwart 2008).

ⁱⁱⁱ *Onderzoeksinstituut Neurowetenschappen* (notitie), p. 15.